Science and Salmon Recovery

Robert T. Lackey

Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon 97331

Citation: Lackey, Robert T. 2017. Science and salmon recovery. pp. 69-94. In: *New Strategies for Wicked Problems: Science and Solutions in the 21st Century,* Edward P. Weber, Denise H. Lach, and Brent S. Steel, editors, Oregon State University Press, Corvallis, Oregon, 223 pp.

Email: Robert.Lackey@oregonstate.edu
Phone: (541) 737-0569
Web: http://fw.oregonstate.edu/users/robert-lackey

Chapter 3

Science and Salmon Recovery

ROBERT T. LACKEY

Efforts to restore declining wild salmon runs in California, Oregon, Washington, and Idaho have evolved into a "salmon recovery industry" with multiple local, state, and federal government bureaucracies and the associated contractors. Overall, the recovery industry employs thousands of scientists and other technical experts. Over many years and after hundreds of millions of dollars spent for scientific research, US Pacific Coast salmon are arguably the most studied group of fishes in the world. The vast bureaucracy and massive quantity of science have, however, failed to reverse the long-term decline of wild salmon.

The wickedness of the salmon recovery problem is easy to see along the West Coast of the United States. The scale of the problem is massive, involving hundreds of tributaries and watersheds in the Columbia River Basin of the Pacific and Inland Northwest (259,000 square miles; the size of France), more than thirty coastal rivers and watersheds, and ocean habitat that, given the migratory patterns of Pacific salmon, often extend hundreds of miles farther from the mouths of their home rivers. The scale means that complexity is endemic; the problem of salmon recovery cuts across international, national (e.g., Canada, tribal governments), state, and local boundaries, and involves values of great importance to the economy, Native American culture, recreational interests, food systems, and environmental protection. The nature, and tremendous size, of human settlements across this territory—millions of people, sizable industrial plants and processes, hydroelectric dams, and the general demands placed by human consumption and waste on waterways critical to fish survival—means that significant efforts to save salmon are likely to have profound effects on the region's established social, political, and economic patterns of living and working. Added up, these characteristics remind us that successful wild salmon recovery is not something that can be solved once and for all; instead, it has been, and will continue to be, relentless in character.

In fact, successful wild salmon recovery, if it ever occurs, rests squarely in the realm of the political process. Despite well over a century of failure to recover wild salmon, however, many in the salmon recovery industry insist that science continue to play a privileged, even dominant, role in helping decipher and decide key elements of this highly contested, wicked policy problem. The preference for science appears to be supported by both traditionally Democratic and traditionally Republican constituencies; in short, policy advocates from all parts of the political spectrum usually champion science as a critical or determining factor in policy decisions. But as this chapter makes clear, science is but one player in the larger, extremely complex drama of recovery, and to date it has not provided much in the way of successful sustained fish recovery across the region.

This chapter starts with a discussion of the policy context for salmon recovery, the paradox of apparent abundance existing simultaneously with salmon population declines, and the complexity added by the Endangered Species Act to an already wicked problem. A brief review of the difficulties associated with salmon recovery goals and objectives follows, before the analysis turns to a set of six lessons learned that illustrate how the wicked salmon recovery problem is most likely to stay wicked at the macro scale in the years to come. The conclusion brings us full circle by reminding us that it is not technical inadequacies that preclude successful recovery strategies from being implemented; rather, it is the unpleasant social and economic costs and consequences arising from implementation that feed into a politics in which the deck is stacked against the adoption of such strategies.

POLICY CONTEXT

The striking decline of salmon runs in California, Oregon, Washington, and Idaho has been typical of those that have occurred elsewhere. In other regions of the world where salmon were once plentiful, increasing human numbers, their activities, and consequent alteration of the landscape have coincided with decreasing salmon abundance. Thus, what *has* happened—and *is* happening—to wild salmon in California, Oregon, Washington, and Idaho is the latest example of a pattern that has played out numerous times in other regions of the world for salmon (Lackey et al. 2006a) and other fish species (Limburg and Waldman 2009; Limburg et al. 2011).

Prior to the 1800s, large spawning migrations (runs) of Atlantic salmon were found in many coastal rivers of western Europe and eastern North America (Montgomery 2003; National Research Council 2004). By the middle to late 1800s, many of those runs were drastically reduced, concurrent with human population increase and economic development (Limburg and Waldman 2009). Overall, salmon runs continue to be much reduced on both sides of the Atlantic Ocean. The largest remaining Atlantic salmon runs, although diminished by historical standards, occur in eastern Canada, Iceland, Ireland, Scotland, and the northern rivers of Norway, Finland, and Russia, locations with relatively few people and limited human impact on the aquatic environment. Nevertheless, Atlantic salmon are readily available in the retail market because commercial aquaculture provides an ample and consistent supply.

As with Atlantic salmon, Pacific salmon (Chinook, coho, sockeye, chum, pink, and steelhead) were historically abundant across a large region (Augerot 2005). Nevertheless, Pacific salmon, found on both sides of the North Pacific, have also declined substantially from historical levels, especially in the southern portion of their distribution, although not as dramatically as Atlantic salmon (Nehlsen 1997). Hatchery production has been used to maintain most runs in southern portions of the range (e.g., Japan, Korea, California, Oregon, and Washington). Today, in California, Oregon, Washington, and Idaho, runs that are sufficiently large to support commercial, recreational, and tribal fishing almost always comprise mainly hatchery-produced salmon. Runs of wild salmon in the northern portions of the range (e.g., Russian Far East, Alaska, Yukon, and northern British Columbia) are in better condition, though large hatchery programs exist in these regions as well (Nehlsen 1997). There are indications that salmon numbers are increasing in Arctic habitats, presumably caused by an overall warming trend (Nielsen et al. 2013).

The discoveries of gold in California (1848) and elsewhere later resulted in substantial adverse effects on many salmon runs (Lackey et al. 2006c). Efforts to protect and restore salmon populations in California, Oregon, Washington, and Idaho began in the early 1850s, and such efforts have been technically challenging, socially contentious, and politically painful (National Research Council 2012). Overall, past recovery efforts for wild salmon (in contrast to salmon bred and raised in hatcheries) have been largely unsuccessful (National Research Council 1996, 2012). Over many decades, thousands of scientists have been involved with salmon recovery efforts, but prospects for recovery of wild salmon remain elusive (Scarce 2000; National Research Council 2012). Of the nearly 1,400 distinct Pacific salmon populations that occurred prior to 1848 in California, Oregon, Washington, and Idaho, an estimated 29 percent have been extirpated (Gustafson et al. 2007). The remaining populations of wild salmon are greatly reduced, with almost all at less than 5 percent of their historical levels (Schoonmaker et al. 2003). Twenty-eight evolutionarily significant units (i.e., a group of salmon populations considered to be a "species" for purposes of regulatory protection) are formally listed as either threatened or endangered as defined by the Endangered Species Act (ESA).

Salmon recovery efforts are costly, though deciding which specific expenses should be deemed recovery costs is complicated and the subject of debate. Just within the Columbia River Basin, for example, salmon recovery costs have totaled approximately $10 billion since 1978 (Northwest Power and Conservation Council 2013), though part of this estimate reflects lost electricity sales (i.e., "forgone revenue") when the hydropower system curbed generation to meet constraints imposed by salmon recovery requirements (e.g., passing water downstream, but bypassing turbines that harm salmon).

As a public policy case study, wild salmon recovery in California, Oregon, Washington, and Idaho is characterized by many apparent conundrums:

- For well over a century, both scientists and the public have recognized the dramatic decline of wild salmon runs, but consensus remains elusive on a regional recovery policy that would actually work.
- At least several billion dollars has been spent to restore wild salmon, but their overall, long-term downward trajectory continues.
- Many populations of wild salmon are listed as "threatened" or "endangered," yet wild salmon are available seasonally in grocery stores—and farm-raised fresh salmon are sold year around.
- The various species of salmon are among the most thoroughly studied fishes in the world, but the failure of recovery efforts is often attributed to a lack of scientific information (Naiman et al. 2012).
- Thousands of scientists and other technological experts are employed to facilitate the recovery of wild salmon, but, over the long term, salmon populations have rarely responded positively to these recovery efforts (Lackey et al. 2006c).

- The Endangered Species Act, arguably the most powerful US environmental law, has been extensively used by some policy advocates to impose federal authority by listing various salmon species as either threatened or endangered; however, this approach has been insufficient to achieve salmon recovery (Lackey 2001b).
- The overarching goal of the ESA is to protect at-risk species and the habitat on which they depend, but this law, counterintuitively, may impede recovery of wild salmon in watersheds where the chances of recovery are greatest (Lach et al. 2006).
- To offset the effects on salmon runs of certain dams constructed for hydropower, irrigation, and other purposes, federal, state, and tribal governments are required to operate salmon hatchery programs to supplement runs to sustain fishing, but these programs may actually *weaken* wild salmon runs (Lichatowich 1999).
- Federal and state agencies are mandated with protecting and restoring wild salmon runs, but they are also tasked with promoting harvest (i.e., fishing), which can work, by definition, against recovery.

In sum, the salmon recovery issue is a classic example of the difficulties of effectively addressing wicked problems. Scientists engaged in salmon recovery issues tend to depict the policy debate as a scientific or ecological challenge, and the "solutions" they offer are usually focused on aspects of salmon ecology (Naiman et al. 2012). Even though there is an extensive scientific literature about salmon (Quinn 2005; Lackey et al. 2006a), experience thus far suggests that the future of wild salmon will largely be determined almost entirely by factors outside the scope of science (Williams et al. 1999; Montgomery 2003; Lackey et al. 2006b). More specifically, to effect a long-term reversal of the downward trajectory of wild salmon, a broad, interdependent, and complex suite of important public policy questions must be considered and effectively dealt with to successfully recover wild salmon to significant, sustainable levels:

- *Hydroelectric energy.* How costly and reliable does society want energy to be, given that wild salmon ultimately are affected by providing the relatively cheap, carbon-free, and reliable energy produced by hydropower?

- *Land use.* Where will people be able to live, how much living space will they be permitted, what activities will they be able to do on their own land, and what personal choices will they have in deciding how land is used?
- *Property rights.* Will the acceptable use of private land be altered, and who or what institutions will decide what constitutes acceptable use?
- *Food cost and choice.* Will food continue to be subsidized by taxpayers (e.g., publicly funded irrigation, crop subsidies), or will the price of food be determined solely by a free market?
- *Economic opportunities.* How will high-paying jobs be created and sustained for present and subsequent generations?
- *Individual freedoms.* Which, if any, personal rights or behavioral choices will be compromised or sacrificed if society is genuinely committed to restoring wild salmon?
- *Evolving priorities.* Is society willing to continue substituting hatchery-produced salmon for wild salmon, and, if so, will the ESA permit this?
- *Political realities.* Will society support modifying the ESA such that salmon recovery expenditures can be shifted to those watersheds offering the best chance of success?
- *Cultural legacies.* Which individuals and groups, if any, will be granted the right to fish, and who or what institutions will decide?
- *Indian treaties.* Will treaties between the United States and various tribes—guaranteeing Native American fishing rights and comanagement (with US states) of salmon stocks, and negotiated more than 150 years ago—be modified to reflect today's dramatically different biological, economic, and demographic realities?
- *Population policy.* —What, if anything, will society do to influence or control the level of the human population in California, Oregon, Washington, and Idaho, or indeed the United States as a whole?
- *Ecological realties.* Given likely future conditions (i.e., an apparently warming climate), what wild salmon recovery goals are biologically realistic?
- *Budgetary realities.* Will the fact that the annual cost of sustaining hatchery and wild salmon runs in California, Oregon, Washington, and Idaho exceeds the overall commercial market value of the harvest eventually mean that such a level of budgetary expenditure will become less politically viable?

These are all key policy questions germane to the public debate over wild salmon recovery policy, and they highlight how scientific information, while at some level relevant and necessary, is clearly not at the crux of the policy debate. In short, scientists can provide useful technical insight and ecological reality checks to help the public and decision-makers answer these policy questions, but science is only one input among many (Policansky 1998; Scarce 2000; National Research Council 2012).

THE PARADOX OF ABUNDANCE AND DECLINE

The question of whether wild salmon will continue to exist in the western United States is not new (Lichatowich 1999; Montgomery 2003). In California, Oregon, Washington, and Idaho, the decline started in earnest with the California gold rush. By the 1850s, excessive harvest and the impacts of mining activities on spawning and rearing habitat were decimating salmon in streams surrounding California's Central Valley. In response, by the 1870s, the federal government had begun what would eventually become a massive hatchery program in an unsuccessful attempt to reverse the decline (Taylor 1999). A similar salmon scenario followed gold discoveries in other locations. By the late 1800s, supplemental salmon stocking from hatcheries was widespread from California to Washington.

Even the massive Columbia River salmon runs had been greatly reduced by the end of the nineteenth century, largely because of minimally regulated fishing and loss of habitat caused by nominally regulated land practices such as mining, farming, ranching, and logging (National Research Council 1996; Lackey et al. 2006c). In 1894, the head of the agency that preceded NOAA Fisheries proclaimed to Congress that the Columbia's runs were in very poor condition and declining. Prior to 1933, the year the first main-stem dam on the Columbia was completed, the total Columbia salmon run had been reduced to one-fifth or less of the pre-1850 level. One can argue that the most severe Columbia River salmon decline took place in the nineteenth century—not the twentieth or twenty-first centuries—though that is not to suggest that the latter two centuries have been favorable ones for salmon.

In California, Oregon, Washington, and Idaho, supplemental stocking of juvenile salmon spawned and raised in hatcheries has long been used to sustain salmon runs at levels sufficient to support fishing (Taylor 1999). The majority of salmon runs in these states that currently support fishing are now of hatchery origin (Schoonmaker et al. 2003). Advocates for restoring wild salmon runs often assert that salmon originating from hatcheries are an imperfect substitute for naturally produced (wild) salmon (Williams et al. 1999). Further, many analysts have concluded that large-scale hatchery programs have actually hindered the recovery of wild salmon, because the relatively large numbers of hatchery-produced fish enable policy makers to allow salmon fishing to continue (Lichatowich 2013). Whether it is done in the open ocean, coastal waters, or river environments, fishing for salmon when a run is dominated by hatchery-origin fish will inevitably lead to the capture and death of some wild fish, even though fishing regulations may require the release of captured wild salmon. Other opponents of hatcheries argue that the straying or intentional dispersal of hatchery fish to different streams over many decades has resulted in a massive mixing (and weakening) of the native gene pool (Taylor 1999). Hatchery-origin salmon do interact ecologically with wild salmon and, depending on the desired management goal, the effect can be viewed as either positive or negative (Pearsons 2008). Given the current relatively low abundance of wild salmon, the absence of supplemental stocking from hatcheries would mean that salmon fishing would not currently be viable in California, Oregon, Washington, and Idaho, at least for the next few decades.

As indicated earlier, the salmon issue is full of paradoxes. For example, no biological species of Pacific salmon (Chinook, coho, sockeye, chum, pink, or steelhead) is currently in danger of extinction, but many distinct, locally adapted populations (also called runs or stocks) have been extirpated, and hundreds more are at risk (Gustafson et al. 2007). North American stocks that spawn in the "north" (northern British Columbia, Yukon, and Alaska) are generally doing well (with exceptions), but most wild stocks that spawn in the "south" (California, Oregon, Washington, and Idaho) are not (Augerot 2005).

The decline in wild salmon runs was caused by a well-known but poorly quantified combination of factors, including unsustainable harvests from earlier commercial, recreational, and subsistence fishing; blockage of upriver habitat by dams built for electricity generation, flood control, and irrigation, as well as for many other purposes; loss of spawning and rearing habitat from various mining, farming, ranching, and forestry practices; unfavorable ocean or other climatic conditions; reduced stream flow caused by diversions of water for agricultural, municipal, or commercial needs; hatchery production to supplement diminished salmon runs or to produce salmon for the retail market; predation by marine mammals, birds, and other fish species;

competition, especially with exotic fish species; diseases and parasites; and many others (Knudsen et al. 2000; National Research Council 1996, 2004, 2012).

Salmon experts continue to study and debate what proportion of the decline in wild salmon is attributable to which factor (Quinn 2005; Naiman et al. 2012). Having participated in many multi-organizational salmon science and policy meetings over the past several decades, I have observed that many affected organizations have developed, or funded the development of, sophisticated assessments of salmon populations that usually end up—probably not surprisingly—supporting their organization's favored policy preference. All the major organizations that participate in the salmon policy recovery disputes employ, or at least have access to, scientists. No one, not even the most astute salmon scientist, knows for sure the relative importance of the various factors that caused the decline of wild salmon, and therefore scientific debate is to be expected. Debate over scientific issues, however, often reflects clashing ethical attitudes, personal beliefs, and policy preferences (Policansky 1998; Scarce 2000).

There is also the incongruity of *apparent* high salmon abundance with simultaneous concern about extinction. Try explaining to the average shopper that salmon are at risk of extinction when fresh salmon are available year-round at the local grocery store. Most wild salmon sold in California, Oregon, Washington, and Idaho now come from Alaska and northern British Columbia. Salmon are still relatively abundant in these northern locations because of comparatively unaltered spawning and rearing habitat, reasonably restrictive regulations to control harvest, and favorable ocean conditions (Lackey et al. 2006c). Also, large quantities of "farm-raised" salmon are available year-round from many sources (e.g., British Columbia, Norway, Scotland, Chile, and New Zealand).

Yet, while the various Pacific salmon species are impressively resilient, the few recovery successes for *wild* salmon have been in locations where salmon spawning and rearing habitat was in comparatively good condition, migratory blockages from dams or other obstructions were not present or were minimal, and harvest occurred at levels that assured that sufficient numbers of adults reached the spawning grounds. The sockeye salmon runs of the Fraser River, British Columbia, are the best documented long-term example of at least partial recovery after decimation. In this case, the cause was the substantial 1914 Hell's Gate rockslide that hindered salmon migration (Roos 1991). Sockeye salmon runs recovered appreciably after fish passage was improved, stringent harvest controls were implemented, and other vigorous management actions were taken.

The resilience of salmon was also illustrated when a landslide (about five hundred years ago) blocked the Columbia River just east of Portland, and salmon were thus prevented from reaching upriver streams to spawn (O'Connor 2004). After the slide was breached naturally, salmon eventually reestablished themselves in streams above the blockage. Such blockages of the Columbia River and its tributaries almost certainly occurred at various other times over the past several thousand years.

In both the Fraser River and Columbia River blockages, freshwater salmon habitat was in excellent condition above the obstruction. Presently, however, there are few locations in California, Oregon, Washington, or Idaho where high-quality spawning and rearing habitats are intact (pre-1850 condition) and accessible to salmon. Today, river and stream blockages in California, Oregon, Washington, and Idaho have left 44 percent of this original spawning and rearing habitat inaccessible to returning salmon (McClure et al. 2008).

THE ENDANGERED SPECIES ACT: ADDING COMPLEXITY TO AN ALREADY WICKED PROBLEM

For many reasons and for more than a century, salmon recovery has been a wicked policy problem. And particularly since the early 1990s, the Endangered Species Act (ESA) has greatly added to the inherent complexity, because it has become the major policy driver (Lackey 2001b; Lichatowich 2013). ESA places science in the policy driver's seat and does not, in practice, allow equal consideration of competing policy priorities. Advocates of salmon recovery have used the ESA successfully to force many changes in salmon policy, but these successes have also resulted in a number of policy paradoxes. For example, threatened or endangered salmon are the only ESA-listed animals for which government routinely licenses large numbers of people (i.e., fishermen) to harvest them. Further, if society's paramount salmon concern was with the depleted condition of wild salmon runs in California, Oregon, Washington, and Idaho, government agencies could simply close salmon fishing, cease supplementing runs with hatchery releases, and wait to see if wild salmon runs rebounded. Recreational, commercial, and Native American fishermen would object for obvious reasons, but most people would not be affected by a ban on fishing or stocking hatchery-origin salmon. Furthermore, farm-raised salmon (from British Columbia, Chile, Scotland, and Norway) and wild salmon (harvested in British Columbia and Alaska) would remain abundant and could continue to supply the retail market—and taxpayers would save hundreds of millions of dollars by closing the hatchery system and eliminating the subsidies currently needed to maintain existing salmon runs.

In addition to the ESA goal of restoring wild salmon, there is the broadly supported goal of sustaining recreational, commercial, and Native American fishing using fish hatcheries. Other support for continued hatchery operations comes from governmental organizations. State and tribal fish and wildlife agencies usually operate salmon hatcheries with funds provided by the Bonneville Power Administration, US Bureau of Reclamation, US Army Corps of Engineers, an assortment of private and public power companies, and the sale of fishing licenses. The loss of these funds and jobs would be bureaucratically traumatic to the recipient state agencies.

Ultimately, listing wild salmon as endangered or threatened as defined by the ESA means that all stakeholders, not just fishermen, are affected. As mandated by court decisions, efforts to protect or restore wild salmon often conflict with a suite of other individual and societal priorities (Policansky 1998). For example, two of the most visible contemporary examples of such conflict are the ongoing debate over how to balance Columbia River electricity generation with salmon survival, and the contentious lawsuits over how to divide up scarce Klamath River Basin water (in southern Oregon and Northern California) among threatened salmon, endangered suckers, migratory waterfowl, treaty Native American tribes, farmers, and a host of other demands.

I have often heard colleagues involved in ESA salmon conflicts, usually in informal settings, characterize the ESA as a naïve piece of legislation in search of a credible public policy goal. The ESA's consultation requirements, aimed at avoiding actions that could jeopardize the continued existence of protected salmon runs, apply only to "federal actions," but arguably some of the most important actions affecting at-risk species occur in the private sector, and these are usually beyond the scope of the ESA.

Supporters of the act, on the other hand, maintain that the ESA is forcing society to make the necessary, though painful, sacrifices for the future well-being of society or, perhaps, even society's very survival. What would be the status of wild salmon in California, Oregon, Washington, and Idaho had the ESA not been invoked? They assert that while the ESA may not be perfect, it is needed more than ever, as declines in salmon populations clearly attest. Although there may be references to the economic value of salmon fishing, salmon for some segments of society is a cultural icon. To other policy advocates, salmon may be a surrogate for the overall "health" of the natural environment. To yet other advocates, the fundamental policy debate is whether humans have a moral duty to save wild salmon from extinction.

THE DIFFICULTIES ASSOCIATED WITH RECOVERY GOALS AND OBJECTIVES

Presupposing, abstractly at least, that society regards "saving" or "recovering" wild salmon populations as a worthwhile endeavor, substantial tension exists over what the *unambiguous* and *specific* recovery goal ought to be (Lackey 2003). For example, should the policy goal be simply to save from extinction a biological *species*, an evolutionarily significant unit, or an individual salmon run? Such a policy objective (e.g., saving a species, evolutionarily significant unit, or run) can be achieved by conserving relatively low numbers of wild salmon (i.e., museum or remnant runs), but such numbers would be insufficient to sustain fishing. Conversely, from a treaty rights perspective, advocates argue that the appropriate salmon recovery goal must be at a population level sufficiently robust to permit sustainable tribal fishing. Or, from the perspective of recreational and commercial fishermen, maintaining salmon runs at the sufficiently high levels required to sustain their harvests should be the overarching goal, but achieving this goal requires heavy reliance on supplemental stocking from hatcheries. Perhaps even more contentious, who decides which goal is appropriate?

Beyond any ESA requirements, a much more challenging recovery objective is to increase runs of wild salmon to levels that would sustainably support fishing. Restoring wild salmon runs across their entire range to levels prior to 1850, or anything close to those levels, is not realistic. Almost certainly this objective is not achievable with wild salmon unless human impacts are reduced to pre-1850 levels. More fundamentally, will some advocacy groups continue to demand that salmon runs comprise entirely wild fish to achieve whatever level of recovery is demanded? If recovery success is constrained to wild fish, the project becomes much more challenging; it would be especially difficult to produce enough wild fish to support significant recreational, commercial, and tribal fishing. If hatchery fish are used to sustain large salmon runs and salmon fishing is permitted, there will continue to be adverse effects on the relatively small portion of that run that is wild-origin salmon, but what level of adverse effect on wild salmon is acceptable to society? Given the substantial societal and monetary costs to restore wild salmon, perhaps much of the public would continue to opt for using hatcheries to sustain salmon runs, in spite of the adverse effects on wild salmon. Thus, there is no inherently *best* approach to recovery, but rather a suite of alternatives, with "best" as largely a function of which vision of the recovery objective one accepts.

No one is bent on eradicating salmon. Further, scientists usually have a pretty solid assessment of the major causes of the long-term declines in salmon populations, even if the relative importance of the causes is open to debate (National Research Council 1996, 2012). Rather than acting on sinister motives or lack of knowledge, society makes choices by choosing between *desirable* but *conflicting* policy alternatives. For every recovery option, there are trade-offs: benefits come with costs. Thus, achieving the goal of restoring wild salmon engenders some of the features of a zero-sum game (Lackey 2006).

SALMON POLICY: LESSONS LEARNED

Given the complicated policy and ecological context of this natural resource case study, coupled with my personal observations while participating over many years in the bureaucratic process, what are the lessons learned? Whether these should be called lessons learned, frustrating truths, or candid realities, I propose that collectively they will circumscribe the future of wild salmon in California, Oregon, Washington, and Idaho. In different ways, each lesson highlights the inadequacies of using the traditional approach to science for resolving, or even coping with, the long-term decline of wild salmon populations. In every case, the policy dynamic suggests a need for innovative problem-solving methodologies that go beyond science and factor in social, institutional, economic, and political realities.

Lesson 1: Efforts to recover wild salmon will continue to struggle because of conflicting policy priorities and the constraints of the ESA's approach to species protection.

Beginning with the early listings of threatened or endangered populations of salmon two decades ago, the ESA has been a powerful tool in the hands of salmon recovery advocates. Lawsuits have forced the allocation of billions of dollars for salmon recovery, as well as untold additional billions in private costs (Williams et al. 1999; Lichatowich 2013). Some advocates press the claim that such expenditures are justified because the bureaucracy is responding to society's wishes. Conversely, others argue that such expenditures are largely a waste of money and, worse, society has never been asked to choose between wild salmon and other competing public policy priorities.

Once a species is deemed at risk of extinction, then the full force of ESA comes into play. In California, Oregon, Washington, and Idaho, many wild salmon runs are at risk because of varied and collective actions of the human population. Wild salmon runs in the worst condition are almost always in rivers and streams least likely to ever again support significant wild runs. There are, however, rivers and streams in relatively better condition (from a salmon perspective), but salmon runs in these environments are not at-risk and therefore receive little of the benefit of ESA-mandated expenditures. Some advocates argue that recovery resources ought to be spent on watersheds with the greatest chance of sustaining wild salmon, not in watersheds where success is very unlikely. Critics lambast this approach as a form of wild salmon triage. It is highly doubtful that ESA has the flexibility to permit writing off certain rivers and streams (for wild salmon) and moving the recovery dollars to places where achieving success would be much easier. For example, what if the billions of dollars spent on restoring wild salmon to the California Central Valley and the Columbia River had been spent on restoring salmon to the coastal watersheds of northern California, Oregon, and Washington?

After watching such recovery debates play out for decades, and in spite of the social turmoil caused by ESA, it looks to me like society has already made a choice relative to the future of "wild" salmon in California, Oregon, Washington, and Idaho. Salmon runs are now generally less than 5 percent of the 1850 levels, most of the current runs in these four states are of hatchery origin, and society is not willing to alter lifestyles to reverse the long-term decline. ESA will not greatly alter the long-term trajectory for wild salmon. To be fair, however, no one knows what would have happened to wild salmon had the money *not* been spent, although it is likely that they would be worse off and, very likely, in some cases, extirpated.

My interactions with senior government bureaucrats suggest they generally recognize most of the scientific and policy facts and realities surrounding wild salmon recovery. I have found that politicians also generally recognize the facts and realities, at least in private. Those in leadership roles with nongovernmental advocacy organizations recognize them. Most definitely, knowledgeable salmon technocrats (including scientists) recognize the facts and realities. In short, the overarching essential "facts of the case" are rarely in dispute, but the probability of success of a specific recovery effort often is in dispute.

As required by ESA and other laws and policies, hundreds of millions, if not billions, of dollars continue to be spent to recover wild salmon (Lichatowich 2013). Such funding distorts the behavior of individuals and organizations. Bureaucratic, professional, and personal conflicts of interest, both real and perceived, abound. Because agencies are obtaining large amounts of funding to try to reverse the decline, they are not likely to point out publicly the obvious inadequacies of current recovery plans. Because many scientists obtain significant research funding to work on interesting scientific questions, they are not likely to point out the obvious defects in recovery plans. Because advocates from nongovernmental organizations (and their lawyers) are well funded from membership fees and taxpayer-reimbursed costs for their lawsuits, they are not likely to point out the obvious. Because politicians use the argument that they are *already* allocating billions to recover salmon runs, additional unpopular decisions do not have to be made, so they too are not likely to point out the obvious flaws in salmon recovery strategies.

Lesson 2: Current institutional and political dynamics limit our ability to deal effectively with salmon recovery.

Over my career and involvement with salmon recovery, one fascinating and revealing aspect has been a recurring recommendation, even a plea, from some colleagues to "lighten up" and be more optimistic and positive in assessing the future of wild salmon (Lackey 2001a). Many scientists tend to urge their "realist" colleagues to abandon blunt assessments and forthright honesty in favor of offering a more encouraging tone of optimism for salmon recovery. For example, a common sentiment is illustrated by a reviewer's comment on a journal manuscript: "You have to give those of us trying to restore wild salmon some hope of success."

In contrast, some colleagues, especially veterans of the unending political conflict over salmon policy, have confessed their regret over the "optimistic" approach that they had taken during their careers in fisheries, and they now endorse the "tell it like it is" tactic. They feel that they had given false hope about the effectiveness of hatcheries and the ability of their agencies to manage mixed stock fishing. Many professional fisheries scientists acknowledge that they have been pressured by employers, funding organizations, and colleagues to "spin" fisheries science and policy realism to accentuate optimism. Sometimes the pressure on scientists to cheerlead is obvious; other times it is subtle. For example, consider the coercion of scientists by other scientists (often through nongovernmental professional societies) to avoid highlighting the importance of US population policy on sustaining natural resources (Hurlbert 2013).

These problems are compounded by other institutional and political dynamics. Many salmon scientists take professional refuge in the reality that senior managers or policy bureaucrats select and define the policy or science question to be addressed, thus constraining research. Consequently, the resulting scientific information and assessments are often scientifically rigorous, but so narrowly focused that the information is only marginally relevant to decision-makers. Rarely are fisheries scientists encouraged to provide "big picture" assessments of the future of salmon. Whether inadvertent or not, such constrained information often misleads the public into endorsing false expectations of the likelihood of the recovery of wild salmon (Lackey 2001a; Hurlbert 2011).

The problem with such optimism is that it does not convey what is happening with wild salmon, and it allows the public, elected officials, and fisheries managers to escape the torment of confronting species triage. No salmon expert ever seriously argues that you can have wild salmon everywhere they once were, but few are willing to be explicit about identifying those locations where the cost is high and chance of success is low (Lackey 2001a). The pressure to present an optimistic picture of the future also means that the public will be less likely to understand the difficult trade-offs required for effective salmon recovery. As well, the lack of accurate information about the long-term prospects of success increases the probability that public spending on ineffective recovery policies will continue rather than funding other, perhaps more important, policy priorities.

It is not only fisheries scientists, managers, and analysts who avoid explicitly conveying unpleasant facts or trade-offs to the public. Such an inclination exists on the part of elected and appointed officials. The 160-year track record of salmon policy makers in California, Oregon, Washington, and Idaho has demonstrated an unceasing propensity on the part of elected and appointed officials to slip into the behavior of "domesticating" the policy issue. By this, I mean the practice of taking difficult, divisive policy issues (i.e., salmon recovery) off the political table until a solution emerges or the problem disappears by solving itself (e.g., the species is extirpated or a political consensus emerges on a recovery strategy) (Lach et al. 2006). Relative to salmon recovery, the most common indicators of "domestication" are funding more research or scientific reviews, holding more workshops and venues to get stakeholders involved through collaboration, forming more planning teams to assess policy options, and tweaking current regulations or policies. Starting in the 1850s with the first efforts by politicians to reverse the decline of wild salmon in the California Central Valley, policy domestication through generous funding of such activities has provided the public with the illusion of progress in salmon recovery (Lichatowich 1999; Montgomery 2003).

And yet, for scientists at least, it has been easy to find comfort in debating the scientific nuances of hatchery genetics, evolutionarily significant units, dam breaching, fishing regulations, predatory bird and marine mammal control, habitat restoration, and atmospheric and oceanic climate trends. This focus on scientific details, often couched in optimistic rhetoric, can unintentionally mislead the public about the realities of the situation (Hurlbert 2011).

To appreciate the evolution of the current political circumstance, note that political actions to *domesticate* salmon recovery are easier than political actions that will *reverse* wild salmon decline. Thus, few elected or appointed officials explicitly propose ways to change political realities about recovery of wild salmon. Instead, they suggest permutations of existing policy options (e.g., revise the ESA, protect more or different salmon habitats, modify hatchery practices to reduce adverse effects on wild runs, change K–12 education to stress the importance of wild salmon, or somehow transform attitudes through public awareness).

Lesson 3: Market incentives and the rules of commerce tend to work against increasing wild salmon numbers.

The ongoing drive for competitive advantage and near-term, low-cost production in a globalized economy will continue to affect adversely wild salmon runs in California, Oregon, Washington, and Idaho (Lackey 2005; Lichatowich 2013). This is because noneconomic values, such as preserving at-risk wild salmon runs as required by ESA, tend not to get weighted very heavily in decision-making (Lichatowich 2013).

The tendency of market forces to put downward pressure on wild salmon runs is not inherently good or bad, but is a function of producers seeking the materials, labor, and location that give them a comparative cost advantage. For example, electronics are generally obtained from wherever they can be assembled at least cost. Automobile assembly plants typically end up wherever manufacturers can produce cars most inexpensively. Wheat is mostly produced where it can be grown most productively and consistently. Wood also tends to be produced where trees can be grown and harvested most efficiently and milled at the lowest price. Moreover, taxpayer subsidies and government regulations are often used to encourage certain behaviors and choices deemed socially important (e.g., renewable energy) or to discourage others (e.g., coal-fired power plants). And while there is considerable political rhetoric to modify the current rules of commercial (e.g., "fair") trade, it is not clear what such modifications would be, much less how they would affect salmon recovery (Lackey 2005).

The point here is that markets and costs matter greatly in developing an effective salmon recovery program. The requirements of large-scale salmon recovery (and the changes in economic practices that such a program would entail) will necessarily raise costs for individual consumers. How much more are people willing to pay for food, electricity, or transportation produced in ways that will not degrade salmon habitat? In short, as with all policy choices, there are winners and losers.

Lesson 4: Competition for critical natural resources, especially for water, will continue to increase and will work against recovering wild salmon.

Salmon need clean, cold water in abundant amounts to thrive and prosper, but this simple reality is often overlooked in policy analysis and forecasting. Many watersheds in California, Oregon, Washington, and Idaho suffer from human-induced water shortages, but unless the competition for scarce water explodes into open political conflict, most people are oblivious to the magnitude of the challenges. Even with media stories about impending water scarcity, most written in a doom-and-gloom style, our insatiable demand for fresh water shows little sign of easing. In such a setting, how will advocates for wild salmon fare relative to advocates for competing priorities such as water for domestic use, irrigation, manufacturing, generating electricity, and a host of other needs?

Without new problem-solving methodologies, the continuing water war in the Klamath Basin, along the California-Oregon border, gives us an indication of what many think is the probable future throughout California and the Pacific Northwest states. A decade ago, national newspapers described Klamath Basin farmers defying law enforcement agents and illegally opening locked valves and releasing water to irrigate their fields. Television news showed Klamath River choked with dying salmon caused by low water flows, poor water quality, and diseases.

Considering competition for water over a millennial time frame, it is likely that Earth's climate is returning to something closer to the Medieval Warm Period (years 900 to 1400). This was a period of mega-droughts that lasted for many decades, perhaps longer than a century (Ingram and Malamud-Roam 2013). Coupled with reduced snow and rain caused by a generally warmer climate, how will wild salmon recovery programs stack up against competing demands for scarce water?

Lesson 5: Dramatic increases in the human population of the Pacific Northwest will work against wild salmon recovery.

Assuming that there are not major changes in immigration/population policy in the United States, the most probable scenario for the human population trajectory through this century for places like California, Oregon, Washington, and Idaho is substantially upward (Lackey et al. 2006d). Any serious discussion about the future of wild salmon therefore must consider human population and the increasing demands placed on natural resources, as well as the impacts on land (National Research Council 1996; Hurlbert 2013).

The latest demographic forecasts show a slowing of the world population (currently 7.2 billion) growth rate through this century, with a leveling off toward 2100 (United Nations 2013). Yes, a leveling off is predicted, but at 10.9 billion people. But, especially for regions like the Pacific Northwest and the United States generally, there is a different story; it is largely one of past, current, and future immigration. Currently, Washington, Oregon, Idaho, and British Columbia are home to fifteen million humans. In the absence of policy changes, and assuming a range of likely human reproductive rates and migration to the Pacific Northwest from elsewhere in Canada and the United States, by 2100 this region's human population will not be its present fifteen million, but rather will be somewhere between fifty and one hundred million, a potential quadrupling, or more, of the region's population by the end of this century.

Consider those fifty to one hundred million people in the Pacific Northwest in 2100, and their demands for public and private infrastructure, whether for housing, schools, sewage treatment plants, industrial sites, roads, parking lots, airports, restaurants, stores, electricity, drinking water, pipelines, golf courses, and on and on. The consumer demand will be immense.

Visualize the western region of the state of Washington and southwestern corner of British Columbia in 2100, with its metropolis of Seattle-Vancouver, or "Seavan." Seavan is formed as smaller, discrete cities grow together and, by 2100, stretches from Olympia (Washington) in the south, along Puget Sound northward through the once stand-alone cities of Tacoma and Seattle, and on to Vancouver (British Columbia), east to Hope at the head of the Fraser Valley, and west to cover the southern half of Vancouver Island. Rather than the six million people of the early 2000s, Seavan in 2100 rivals present-day Mexico City or Tokyo, with thirty million inhabitants. Think of it as the New York City to Boston corridor, transplanted to the Pacific Northwest.

At the same time, it is not simply the number of people that causes problems for wild salmon, but it is also their individual and collective ecological footprint and the fact that humans and salmon tend to use the lower elevations of watersheds. Protected public lands (e.g., national parks, wilderness areas, and national forests) are often at higher elevation, and streams in these locations usually provide little habitat for wild salmon.

Lesson 6: Individual and collective lifestyle preferences are important, and substantial changes must take place in these preferences if long-term downward trends in wild salmon abundance are to be reversed.

For most fisheries scientists and others involved with salmon recovery, it is easy to assume that wild salmon are near the top of the public's concerns. It seems that everyone supports salmon, and especially wild salmon. But the fact is that salmon recovery is only one of many priorities that individuals, when not forced to make a choice, profess to rank highly. When forced to make a choice, salmon recovery drops substantially in importance compared with other priorities.

Consider the following brief history as an example of where wild salmon rank as a societal priority. In 1980, the Northwest Power and Conservation Act elevated the importance of salmon runs within the Columbia River Basin by acknowledging the important role dams played in the decline of salmon. This legislation forced dam operators to balance the public interest of reducing the impacts of hydropower on salmon against the public interest in sustaining affordable, reliable electricity supply. Further, in 1991, the first Columbia River salmon "evolutionarily significant unit" was listed under the terms of the ESA. Starting with this first 1991 ESA listing, followed by many others, it would appear that wild salmon had won out over electricity as a societal priority.

However, despite the new and formal Columbia River policies favoring salmon, crises serve as reminders of real-world priorities when the needs of salmon are pitted against other important societal wants. In 2001, two decades after passage of the Northwest Power and Conservation Act and only a decade after the first salmon listing, ongoing electrical blackouts and brownouts in California prompted the US Bonneville Power Administration to declare a power emergency, abandon previously agreed-upon interagency salmon recovery commitments, and generate electricity at maximum capacity using water reserved to help salmon migrate. In short, electricity for air conditioners and refrigerators won out over both wild and hatchery-bred salmon. Perhaps even more instructive, there was scant public opposition. There were minimal legal challenges. There were no elected officials publicly pleading to save the water to help salmon. Nor were any environmental groups blanketing the Internet with calls to mobilize in defense of salmon. Even among wild salmon advocates, the silence was nearly complete.

The lesson here is that many people will support "saving wild salmon" so long as *their* individual lifestyles are not greatly affected. For well over a century, there have been many of these societal trade-offs, and the choices made reflect the *relative* low priority of recovering wild salmon vis-à-vis other societal values and policy goals.

CONCLUSION

Based on my experiences with salmon recovery programs, among the scientific community there remains a common delusion that wild salmon in California, Oregon, Washington, and Idaho *could* be greatly increased concurrent with the present upward trajectory of the region's human population coupled with most individuals' apparent unwillingness to reduce substantially their consumption of resources and standard of living. Few salmon advocates argue publicly that society *must* make these substantial and contentious changes to recover wild salmon. Further, the implicit public optimism of salmon scientists and technocrats about restoring wild salmon tends to perpetuate this avoidance of reality.

Strategies exist that could successfully restore wild salmon to California, Oregon, Washington, and Idaho, but each requires major and politically divisive choices (Lackey et al. 2006). It is not technical inadequacies that preclude such recovery strategies from being implemented. Rather, it is the unpleasant resulting consequences arising from implementation. The economic and societal costs of implementing a wild salmon recovery strategy that has a good chance of restoring wild salmon runs to significant, sustainable levels in California, Oregon, Washington, and Idaho would be extremely high. Based on the experience of the past 160 years or more, it appears unlikely that society collectively is willing to bear such costs except in an ad hoc, case-by-case fashion that, when all is said and done, is unlikely to make a major difference in overall salmon recovery numbers in the Pacific Northwest. Examples here include the 1992 congressional approval for the removal of two dams on the pristine Elwha River on the Olympic Peninsula in Washington State, and the private, collaborative agreement to remove four dams on the Klamath River in southern Oregon and northern California in 2016.

What is not clear at this time is whether these two cases are harbingers of the future or exceptions to the general rule that politics and economics, and the other factors noted in this chapter, often stand in the way of substantial, effective, widespread salmon recovery. It is significant that these midsize dams have been, and are being, breached in order to restore historical, natural seasonal water flows of benefit to the fish. Combined with the explosion of small-scale, watershed-based collaborative management efforts (see chapter 9) across the US West designed to restore ecological functions, including conditions supportive of salmon, steelhead, and bull trout restoration, there is some hope, albeit one might argue that it is at the margins of the overall wicked problem. This less sanguine view finds at least some support in the fact that one of the Elwha River dams (Elwha Dam) was not removed until 2011, almost twenty years after congressional approval, that the second Elwha dam (Glines Canyon) was not removed until 2014, and that the Klamath River dam removal agreement came only after sixteen years of a highly contentious process and failure to gain congressional approval. Yet even at this glacial pace of change, an optimistic person might imagine a world a hundred years hence and find that such small, limited steps toward recovery have resulted in the removal of another fifty to a hundred small to medium dams, and perhaps even a few of the larger dams in the Columbia River system.

Nonetheless, to succeed over the larger region of the Pacific Northwest, a wild salmon recovery strategy must change the trajectory of the major policy drivers, or that strategy will fail even if dams are successfully removed from the system. If society continues to spend billions of dollars only in quick-fix efforts to restore wild salmon runs, then in most cases these efforts will be only marginally successful. The same holds true for the possible solutions presented in the second half of this volume. For while the application of one, or several, of these problem-solving changes might well address adequately salmon recovery in some watersheds in the Pacific Northwest region, such efforts are unlikely to improve the region-wide status of wild salmon except at the margins *unless they are tied strategically to a larger, basin-wide plan capable of making the difficult trade-offs described herein.*

In the opinion of this author, the billions spent on salmon recovery might be considered "guilt money"—modern-day indulgences—a tax society and individuals willingly bear to alleviate their collective and individual remorse. It is money spent on activities not likely to achieve recovery of wild salmon, but it helps people feel better as they continue the behaviors and choices that preclude the recovery of wild salmon. It also sustains a job program for scientists and other technocrats by funding the salmon recovery industry.

References

Augerot, Xanthippe. 2005. *Atlas of Pacific Salmon.* Berkeley: University of California Press.

Gustafson, Richard G., Robin S. Waples, James M. Myers, Laurie A. Weitkamp, Gregory J. Bryant, Orlay W. Johnson, and Jeffrey J. Hard. 2007. "Pacific Salmon Extinctions: Quantifying Lost and Remaining Diversity." *Conservation Biology* 21 (4): 1009–1020.

Hurlbert, Stuart H. 2011. "Pacific Salmon, Immigration, and Censors: Unreliability of the Cowed Technocrat." *Social Contract* 21 (3): 42–46.

———. 2013. "Critical Need for Modification of U.S. Population Policy." *Conservation Biology* 27 (4): 887–889.

Ingram, B. Lynn, and Frances Malamud-Roam. 2013. *The West without Water: What Past Floods, Droughts, and Other Climatic Clues Tell Us about Tomorrow.* Berkeley: University of California Press.

Knudsen, E. Eric, Cleveland R. Steward, Donald D. MacDonald, Jack E. Williams, and Dudley W. Reiser, eds. 2000. *Sustainable Fisheries Management: Pacific Salmon.* Boca Raton, FL: Lewis Publishers.

Lach, Denise H., Sally L. Duncan, and Robert T. Lackey. 2006. "Can We Get There from Here? Salmon in the 21st Century." In *Salmon 2100: The Future of Wild Pacific Salmon*, edited by Robert T. Lackey, Denise H. Lach, and Sally L. Duncan, 597–617. Bethesda, MD: American Fisheries Society.

Lackey, Robert T. 2001a. "Defending Reality." *Fisheries* 26 (6): 26–27.

———. 2001b. "Pacific Salmon and the Endangered Species Act: Troublesome Questions." *Renewable Resources Journal* 19 (2): 6–9.

———. 2003. "Setting Goals and Objectives in Managing for Healthy Ecosystems." In *Managing for Healthy Ecosystems*, edited by David J. Rapport, William L. Lasley, Dennis E. Rolston, N. Ole Nielsen, Calvin O. Qualset, and Ardeshir B. Damania, 165–166. Boca Raton, FL: Lewis Publishers.

———. 2005. "Economic Growth and Salmon Recovery: An Irreconcilable Conflict?" *Fisheries* 30 (3): 30–32.

———. 2006. "Axioms of Ecological Policy." *Fisheries* 31 (6): 286–290.

Lackey, Robert T., Denise H. Lach, and Sally L. Duncan, eds. 2006a. *Salmon 2100: The Future of Wild Pacific Salmon*. Bethesda, MD: American Fisheries Society.

———. 2006b. "The Challenge of Restoring Wild Salmon." In *Salmon 2100: The Future of Wild Pacific Salmon*, edited by Robert T. Lackey, Denise H. Lach, and Sally L. Duncan, 1–11. Bethesda, MD: American Fisheries Society.

———. 2006c. "Wild Salmon in Western North America: The Historical and Policy Context." In *Salmon 2100: The Future of Wild Pacific Salmon*, edited by Robert T. Lackey, Denise H. Lach, and Sally L. Duncan, 13–55. Bethesda, MD: American Fisheries Society.

———. 2006d. "Wild Salmon in Western North America: Forecasting the Most Likely Status in 2100." In *Salmon 2100: The Future of Wild Pacific Salmon*, edited by Robert T. Lackey, Denise H. Lach, and Sally L. Duncan, 57–70. Bethesda, MD: American Fisheries Society.

Lichatowich, James A. 1999. *Salmon without Rivers: A History of the Pacific Salmon Crisis*. Washington, DC: Island Press.

———. 2013. *Salmon, People, and Place: A Biologist's Search for Salmon Recovery.* Corvallis: Oregon State University Press.

Limburg, Karin E., and John R. Waldman. 2009. "Dramatic Declines in North Atlantic Diadromous Fishes." *BioScience* 59 (11): 955–965.

Limburg, Karin E., Robert M. Hughes, Donald C. Jackson, and Brian Czech. 2011. "Human Population Increase, Economic Growth, and Fish Conservation: Collision Course or Savvy Stewardship?" *Fisheries* 36 (1): 27–34.

McClure, Michelle M., Stephanie M. Carlson, Timothy J. Beechie, George R. Pess, Jeffrey C. Jorgensen, Susan M. Sogard, Sonia E. Sultan, et al. 2008. "Evolutionary Consequences of Habitat Loss for Pacific Anadromous Salmonids." *Evolutionary Applications* 1 (2): 300–318.

Montgomery, David R. 2003. *King of Fish: The Thousand-Year Run of Salmon.* Boulder, CO: Westview Press.

Naiman, Robert J., J. Richard Alldredge, David A. Beauchamp, Peter A. Bisson, James Congleton, Charles J. Henny, Nancy Huntly, et al. 2012. "Developing a Broader Scientific Foundation for River Restoration: Columbia River Food Webs." *Proceedings of the National Academy of Sciences* 109 (52): 21201–21207.

National Research Council. 1996. *Upstream: Salmon and Society in the Pacific Northwest.* Washington, DC: National Academies Press.

———. 2004. *Atlantic Salmon in Maine.* Washington, DC: National Academies Press.

———. 2012. *Sustainable Water and Environmental Management in the California Bay-Delta.* Washington, DC: National Academies Press.

Nehlsen, Willa. 1997. "Pacific Salmon Status and Trends—A Coastwide Perspective." In *Pacific Salmon and Their Ecosystems,* edited by Deanna J. Stouder, Peter A. Bisson, and Robert J. Naiman, 41–50. New York: Chapman and Hall.

Nielsen, Jennifer L., Gregory T. Ruggerone, and Christian E. Zimmerman. 2013. "Adaptive Strategies and Life Cycle Characteristics in a Warming Climate: Salmon in the Arctic?" *Environmental Biology of Fishes* 96 (10-11): 1187–1226.

Northwest Power and Conservation Council. 2013. *2012 Columbia River Basin Fish and Wildlife Program Costs Report.* Portland, OR: Northwest Power and Conservation Council, Document 2013-04.

O'Connor, Jim E. 2004. "The Evolving Landscape of the Columbia River Gorge: Lewis and Clark and Cataclysms of the Columbia." *Oregon Historical Quarterly* 105 (3): 390–421.

Pearsons, Todd N. 2008. "Misconception, Reality, and Uncertainty about Ecological Interactions and Risks between Hatchery and Wild Salmonids." *Fisheries* 33 (6): 278–290.

Policansky, David. 1998. "Science and Decision Making for Water Resources." *Ecological Applications* 8 (3): 610–618.

Quinn, Thomas P. 2005. *The Behavior and Ecology of Pacific Salmon and Trout.* Bethesda, MD: American Fisheries Society.

Roos, John F. 1991. *Restoring Fraser River Salmon: A History of the International Pacific Salmon Fisheries Commission, 1937–1985.* Vancouver: Pacific Salmon Commission.

Scarce, Rik. 2000. *Fishy Business: Salmon, Biology, and the Social Construction of Nature.* Philadelphia, PA: Temple University Press.

Schoonmaker, Peter K., Ted Gresh, Jim Lichatowich, and Hans D. Radtke. 2003. "Past and Present Pacific Salmon Abundance: Bioregional Estimates for Key Life History Stages." In *Nutrients in Salmonid Ecosystems: Sustaining*

Production and Biodiversity, edited by John G. Stockner, 33–40. Bethesda, MD: American Fisheries Society.

Taylor, Joseph E. 1999. *Making Salmon: An Environmental History of the Northwest Fisheries Crisis*. Seattle: University of Washington Press.

United Nations. 2013. *World Population Prospects: The 2012 Revision, Key Findings, and Advance Tables*. Department of Economic and Social Affairs, Population Division, Working Paper No. ESA/P/WP.227.

Williams, Richard N., Peter A. Bisson, Daniel L. Bottom, Lyle D. Calvin, Charles C. Coutant, Michael W. Erho Jr., Christopher A. Frissell, et al. 1999. "Scientific Issues in the Restoration of Salmonid Fishes in the Columbia River." *Fisheries* 24 (3): 10–19.

About the Author:

Dr. Bob Lackey is professor of fisheries science at Oregon State University. In 2008 he retired after 27 years with the Environmental Protection Agency's national research laboratory in Corvallis where he served as Deputy Director, Associate Director for Science, and in other senior leadership positions. Since his very first fisheries and wildlife job mucking out raceways in a California trout hatchery, he has worked on an assortment of environmental and natural resource issues from various positions in government and academia. His professional assignments involved diverse and politically contentious issues, but mostly he has operated at the interface between science and policy. He has published over 100 articles in scientific journals and is a fellow of the American Fisheries Society and the American Institute of Fishery Research Biologists. Dr. Lackey has long been an educator, having taught at five North American universities and currently teaches a graduate course in ecological policy at Oregon State University. Canadian by birth, he is now a U.S.-Canadian dual-citizen living in Corvallis, Oregon.