Salmon 2100:

The Future of Wild Pacific Salmon

Robert T. Lackey, Denise H. Lach, and Sally L. Duncan

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Salmon 2100: The Future of Wild Pacific Salmon

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Nestled amongst the gravel, hundreds of tiny red-orange eggs thrive on the life-giving oxygen fed to them by the swirling action of the crystalline stream.

For the Sockeye salmon and, indeed, all five species of salmon found on the Northwest Coast, it is the stream where their life journey will begin.

For a good number it is also where their journey will end.

Andy Everson, Artist

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Preface

The impetus for the Salmon 2100 Project can be traced to a downtown hotel restaurant table in a West Coast city several years ago. Around this table, a group of veteran fisheries scientists, policy analysts, and salmon bureaucrats mulled over a conference they had all attended that day.

The conference was not unusual. It was like so many others, and for many of us, these professional meetings tend to blur together. As has become typical in California, Oregon, Washington, Idaho, and southern British Columbia, a group of salmon experts had been assembled to discuss policy and management options that might help restore wild salmon while minimizing the impacts on competing societal interests.

The atmosphere surrounding this conference, typical of nearly all salmon meetings, was a mixture of policy complexity and scientific uncertainty, overlaid with an informal, public veneer of optimism. As always, the unspoken premise was "if the experts could just solve the *scientific* challenges, or if we could just get sufficient money to do more of what we are *already* doing, salmon runs could and would be brought back to significant and sustainable levels." Perhaps not back to mid-1800 levels, we would all surmise, but surely returned to a healthy state that would support fairly heavy fishing by commercial, recreational, and Indian interests.

In contrast to the public conference during the day, the tone around the table in the evening was decidedly different. Yes, everyone agreed, salmon recovery *was* technically complex and scientific uncertainties certainly *do* abound, but the limitations to wild salmon recovery were not primarily scientific, even though most of the day's discussion had focused on scientific topics. Instead, they recognized that *dramatic policy changes* must be implemented if the long-term downward trend in wild salmon abundance was to be reversed in California, Oregon, Washington, Idaho, and southern British Columbia (hereafter referred to as the Pacific Northwest and California). Amidst all the discussion of scientific and technical matters, such policy changes simply were not on the table.

And so once again, nothing presented or discussed had convinced these fisheries scientists and policy analysts that the rather grim trend would be reversed by relying on current policies. Yes, most scientists agreed that there would be decades of "good" ocean conditions where salmon runs would do *somewhat* better (as the early part of the 21st Century has already demonstrated), but over the long term, the trajectory was downward, unless there were major policy changes.

Many of the people involved in the conference were the same ones sitting around the table, but the tenor of the two discussions was as different as night and day. It was almost as if two parallel worlds existed, one of a fairly positive, optimistic perspective about the future of wild salmon, the other a highly skeptical, pessimistic assessment of any of the recovery strategies under consideration.

Why the dichotomy? Is there some kind of "conspiracy of optimism" that has overtaken the scientific process? Are fisheries biologists, salmon policy analysts, and salmon advocates creating or contributing to it? If the technical experts are truly pessimistic, somehow that judgment is not being communicated and understood by decision makers and others responsible for implementing salmon policy. Confusing the issue for this region, perhaps, is the fact that the majority of the salmon caught here are hatchery fish, thus rendering the wretched status of *wild* salmon essentially invisible.

Whatever the reason, there had been a dramatic difference between what the experts privately voiced in the evening and what the public and decision makers had apparently understood from their earlier professional and public presentations.

Given the dichotomy between public and private understanding, the overarching goal of the Salmon 2100 Project is to evaluate critically the potential policy options needed to protect and restore wild salmon runs from mid-British Columbia southward. Because the chasm between ecological reality and salmon recovery appears to be immense, both delusional optimism and baseless pessimism are banished from the project. Instead, we have asked our authors to identify and describe practical policy options that could successfully sustain significant runs of wild salmon if adopted.

To identify those policy options, we enlisted more than two dozen salmon scientists, salmon policy analysts, and salmon advocates. They range from hardcore technical scientists to aggressive champions of particular salmon recovery policies, thus representing a spectrum from quasi-institutional to highly individual opinions. Writing styles vary from scholarly to popular, from somber to lively. We are fully aware that among the authors are people who do not agree with each other, to put it mildly, and several who frankly do not concede each others' right to an opinion. Nonetheless, all their views enrich the current debate, whether we agree with them or not.

Everyone who participated in the project recognizes that restoring wild salmon to the Pacific Northwest and California is a daunting challenge. Since the discovery of gold in California in 1848, salmon runs have dramatically declined across the region due to water pollution; loss of spawning, rearing, and riparian habitat from a multitude of human actions; a history of overfishing; dam construction and operation; water withdrawal for irrigation and industrial cooling; competition with hatchery-produced salmon; competition with various nonindigenous fish species; predation by marine mammals and birds; and climatic and oceanic shifts. Sustaining significant runs of wild salmon through 2100 remains an elusive goal even after numerous efforts that have cost a lot and caused significant social dislocation. It appears that more aggressive recovery strategies must be implemented if wild salmon are to survive in significant numbers through the century.

The project neither rejects nor advocates any particular policy or class of policies. The prescriptions offered by the participants are universally candid, sometimes uncomfortably radical, and occasionally sobering. Nearly all conclude that major, sometimes wholesale modification of core societal values and preferences will have to occur if significant, sustainable populations of wild salmon are to be present in the region by 2100. All have been asked to offer specific direction for those changes.

We want this book to play a challenging role that is some mixture of court jester, Greek chorus, cage rattler, and straw man to decision makers, elected and appointed officials, and others who have various mandates and directives to address the decline of wild salmon runs in the Pacific Northwest and California.

Ultimately, it is the general public that must become engaged in salmon policy debates if intelligent, informed decisions are to be made. Therefore, we offer this book also to the general public in a quest to illuminate starkly what would have to change if wild salmon recovery efforts are to have a reasonable likelihood of success.

Furthermore, we do not think our policy prescriptions are only relevant to this region: the same basic policy and science questions exist for restoring wild salmon in eastern North America, Europe, and the Asian Far East.

Robert T. Lackey
Denise H. Lach
Sally L. Duncan

Corvallis, Oregon
June 2005

Contributors

Kenneth I. Ashley

Dr. Ken Ashley is a limnologist, fisheries biologist, and environmental engineer. He obtained his academic training at the University of British Columbia (B.Sc. in zoology; M.Sc. in zoology; M.A.Sc. and Ph.D. in civil engineering), worked at the BC Fisheries Research Section office on the UBC campus for 28 years and is an adjunct professor of biology at the University of Idaho-Moscow and an adjunct professor of environmental engineering at the University of British Columbia. His first assignment in 1979 was to design equipment to prevent winterkill in small, naturally eutrophic interior lakes, and for the past 20 years, he has been conducting whole-lake and whole-river nutrient addition experiments. He has dealt with a wide variety of limnological and fisheries management issues, specializing in the effects of hydroelectric development, forest harvesting, and overfishing on coastal and interior salmonid populations. His recent professional emphasis included providing technically defensible scientific advice to a variety of fisheries-hydro compensation and habitat restoration programs and developing new methods for oxygenating lakes. After completing his Salmon 2100 chapter, he resigned from his government position to start a new career with the Greater Vancouver Regional District as a senior biologist/environmental engineer.

Xanthippe Augerot

Dr. Xan Augerot is the director of science programs at the Wild Salmon Center and the codirector of the State of the Salmon Consortium, based in Portland, Oregon. She coordinates the Wild Salmon Center's research and monitoring activities across the North Pacific, working closely with its river-based conservation programs. Augerot has many years of experience working with fellow salmon conservationists from Russia, Japan, Canada, and the United States, both as a doctoral student and then as the conservation director for the Wild Salmon Center. As codirector of the State of the Salmon Consortium, she oversees a multidisciplinary team whose mission is to support a knowledge network across the countries of the North Pacific Rim that will develop and share range-wide salmon status and trend assessments and contribute to efforts to sustain salmon biodiversity in perpetuity. Launched jointly by the Wild Salmon Center and Ecotrust in 2003, the consortium blends science, policy, and communications designed to create a common language for monitoring and conserving salmon around the North Pacific. Augerot was the lead author on the new *Atlas of Pacific Salmon*, copublished with the University of California Press.

Larry L. Bailey

Larry Bailey is an author and farmer from Tonasket, Washington, who has been involved in community-level economic development and environmental initiatives for more than two decades. He has published three novels about rural life and is a partner in Rural Resource Associates Ltd., a consulting company that specializes in assisting landowners, small communities, and nonprofits with community economic and environmental issues in Washington State and British Columbia. Bailey became involved in salmon recovery as the founder of the Upper Columbia Regional Fisheries Enhancement Group, one of 14 legislated and funded community-based salmon recovery organizations in Washington State.

David A. Bella

Dr. David Bella is professor emeritus at Oregon State University. He received his B.S. in civil engineering from Virginia Military Institute (1961) and his M.S. (1965) and Ph.D. (1967) in environmental engineering at New York University. Beginning in the 1960s, his research on aquatic ecosystems integrated computer simulations with field and laboratory studies. He has since been involved in a wide range of assessment research, including pollution in lakes, rivers, and estuaries; nuclear waste disposal; destruction of chemical weapons; global climate change; space-based weapons; and the decline of salmon in the U.S. Pacific Northwest. Over the years, his research has shifted from engineered solutions to the study of "real problems": this includes whole human systems—the organizations we work in, the presumptions we hold, and the ways we (mis)frame problems.

Gustavo A. Bisbal

Dr. Gustavo Bisbal is manager of the Columbia River Basin and Water Developments Branch at the Oregon Office of the U.S. Fish and Wildlife Service in Portland. He is an adjunct professor in biology at Portland State University. For more than 20 years, he has provided scientific and policy assistance to diverse domestic and international agencies concerned with complex natural resource management issues in marine and freshwater ecosystems. Between 1994 and 2002, as senior science and policy analyst with the Northwest Power and Conservation Council, he was responsible for the integration of scientific information into policy decisions to protect and restore fish and wildlife resources affected by hydropower operations in the Columbia River basin. Prior to this, he served in the National Oceanic and Atmospheric Administration and in Argentina's Federal Fisheries Agency in several resource management issues involving large marine ecosystems.

Michelle L. Boshard

Michelle Boshard has an interdisciplinary science degree and is a trained facilitator with extensive experience in all aspects of nonprofit management at local, provincial, national, and international levels. She has coordinated numerous community stewardship initiatives, projects, and programs in topical arenas such as lakes, watersheds, wetlands, fisheries, and agriculture. Boshard is a partner in Rural Resource Associates Ltd., where she helps landowners work with all levels of government in British Columbia and Washington State. Prior to this, she was the stewardship coordinator for the Okanagan Similkameen Boundary region of British Columbia, a position funded by the Department of Fisheries and Oceans. Boshard currently manages a riparian demonstration project designed to provide economic as well as habitat improvement.

Ernest L. Brannon

Dr. Ernest Brannon received his Ph.D. from the College of Fisheries, University of Washington, in 1973. He worked for the International Pacific Salmon Fisheries Commission from 1953 to 1973, finishing as the chief research biologist. He then became a faculty member in the College of Fisheries, University of Washington, as a professor in fisheries with emphasis in salmon life history and culture until 1989, when he joined the faculty as a professor of fish and wildlife with the College of Natural Resources, University of Idaho, and director of its Aquaculture Research Institute. He became a professor emeritus in 2001 and presently holds the position of distinguished research professor in the Center for Salmonid and Freshwater Species at Risk, in the Aquaculture Research Institute.

James L. Buchal

James Buchal is a graduate of Harvard, the Yale Law School, and the Yale School of Management and has practiced law for more than 20 years, including more than a dozen years of involvement in cases concerning salmon policy in the Pacific Northwest. He is the author of *The Great Salmon Hoax: An Eyewitness Account of the Collapse of Science and Law and the Triumph of Politics in Salmon Recovery* and frequently writes on the subject of natural resource management.

Russell A. Butkus

Dr. Russell Butkus is associate professor of theology at the University of Portland in Portland, Oregon. He is also the associate director of the environmental studies program and is responsible for the B.A. track in environmental ethics and policy. He received his B.A. in religion from St. Lawrence University and his M.Ed. and Ph.D. from Boston College. His long-standing interest is in religious and theological education for social justice. He works within the methodological framework of political theology and the theologies of liberation. His research and teaching interests are in the field of environmental theology and ethics. He has recently served as a theological consultant for *The Columbia River Watershed: Caring for Creation and the Common Good* (2001), an international pastoral letter by the Roman Catholic Bishops of the Pacific Northwest. He is the coeditor (with Carol Dempsey, O.P., Ph.D.) and a contributor to the published volume by Liturgical Press titled *All Creation is Groaning, An Interdisciplinary Vision for Life in a Sacred Universe* (1999).

Carl Jeff Cederholm

Jeff Cederholm has a 33-year career working on behalf of wild salmon. He completed thesis research on the effects of channelization on salmon in Big Beef Creek. From 1972 to 1981 he worked for the University of Washington's Fisheries Research Institute, on the effects of logging on salmon in the Olympic Peninsula. He continued this research when he moved to the Washington State Department of Natural Resources in 1981. Over the years, Cederholm's work has focused extensively on the complexities of logging impacts on stream systems, the role of marine-derived nutrients for all animals within a watershed, and practical methods of stream enhancement. Some of his principal contributions have been in educating the public about the importance of wild salmon preservation. He also played a major role in the establishment of the Kennedy Creek "educational" watershed, near Olympia, Washington, which attracts hundreds of school children and other visitors each year.

Jeff Curtis

Jeff Curtis is the Pacific salmon director for Trout Unlimited, covering Washington, Oregon, Alaska, Idaho, and California. As former executive director of WaterWatch of Oregon, he has long been involved with water allocation issues in Oregon and the northwest. Before joining WaterWatch, he was director of intergovernmental affairs for the Oregon Department of Fish and Wildlife and, from 1987 to 1990, worked for the Columbia River Inter-Tribal Fish Commission. He served as counsel to the Subcommittee on Fisheries and Wildlife Conservation and the Environment of the House Merchant Marine and Fisheries Committee in the 1980s. A native of Baton Rouge, Louisiana, he graduated from Spring Hill College in Mobile and received his J.D. from Louisiana State Law School. From 1967 to 1970, he was a Peace Corps volunteer in Iran.

Jeffrey J. Dose

Jeffrey Dose is the Senior Fish/Aquatic Biologist for the Umpqua National Forest, which is headquartered in Roseburg, Oregon, a position he has held since 1987. He grew up in the western Oregon towns of Coos Bay and Eugene, graduated from Oregon State University with a degree in fisheries science in 1977, and to date, he has over 27 years of experience as a professional fish biologist. He has spent the past 24 years working in the Umpqua River Basin with two Federal land management agencies. His focus area has been habitat management and ecosystem restoration, specifically the effects of land use practices on salmon habitat and aquatic ecosystems. Among other professional contributions, he assisted the *Federal Ecosystem Management Assessment Team* (FEMAT) in developing the Northwest Forest Plan in 1993. In addition to numerous agency awards and commendations, Mr. Dose is a past recipient of the Oregon Chapter AFS Award of Merit.

Eric G. Doyle

Eric Doyle is a fisheries biologist and interdisciplinary environmental specialist with eight years experience in science and policy issues related to marine and freshwater fisheries habitat. His professional interests and experience derive from graduate research on the costs and benefits of ESA-related habitat protection and restoration measures for Pacific salmon, and watershed assessment and restoration planning. He has worked with local, State, Tribal and Federal governmental agencies on fish habitat issues and associated permitting requirements, and has field experience in freshwater salmonid habitat surveys, biological surveys in marine intertidal, open water, and benthic environments, marine fisheries management, and intertidal biological monitoring. Mr. Doyle also has extensive experience in the application of GIS data and technologies to watershed assessment and management.

Sally L. Duncan

Dr. Sally Duncan has spent the last 25 years writing, thinking, and talking about the communication gaps between scientists and non-scientists, and the application gaps between science findings and the need for solutions to real problems. Her B.A. in history from the Australian National University, her M.A.I.S. in journalism, history and broadcasting from Oregon State University, and her Ph.D. in environmental sciences from Oregon State University, along with several decades of contract writing in natural resources, have all provided her with opportunities to contemplate how science, technology, and the many layers of society interact, and how with the best of intentions, and the "best available science," society often comes up with less than stellar results. Research interests include the diffusion of GIS technology in natural resource management, the development of new and local knowledge communities in understanding natural resources, and the meaning of biodiversity conservation to regular people.

Peter Galbreath

Dr. Peter Galbreath works as a Fisheries Scientist in the Fish Science Department of the Columbia River Inter-Tribal Fish Commission (CRITFC), Portland, Oregon, with expertise in the areas of genetics, reproduction and artificial propagation. His work at CRITFC involves research and monitoring of salmon/steelhead restoration efforts in the Columbia Basin, with particular emphasis on assessment of hatchery supplementation projects designed to rebuild natural populations. Prior to coming to CRITFC, he served for nine years as Director of the Mountain Aquaculture Research Center at Western Carolina University, Cullowhee, North Carolina, where he was involved in research on population genetics of native brook trout, and on aspects of trout reproduction. Before that, he worked for over ten years with the FAO, USAID and Peace Corps as a specialist in extension and training in aquaculture development projects in western and central Africa. He acquired his Ph.D. in zoology (fish genetics) at Washington State University in 1994, and an MS in fisheries and allied aquacultures at Auburn University in 1978.

Gordon F. Hartman

Dr. Gordon Hartman obtained his Ph.D. from the University of British Columbia in 1964, in behavior and ecology of juvenile salmonids. Originally out of the logging camps and sawmills of central British Columbia, Dr. Hartman has 53 years of experience in and across several fields of biological work. These include research in salmonid biology, administration as Fish and Wildlife Regional Director (Kootenays), later as Director of Wildlife (Yukon), and university teaching at Guelph in The Netherlands, Addis Ababa in Ethiopia, and Malaspina, British Columbia. Activities include three years in Africa working on fish-related programs. This experience in many parts of the world, and in the related fields of research, teaching and management, has caused Dr. Hartman to see and consider the future of fisheries resources in a broad perspective of time-related social and ecological elements. These include the dramatic changes that he has seen on the land during a 78-year lifespan, the poverty and land abuse seen in the "developing" world, and the endless push for expansion in industry, agriculture, and urbanization here at home. They also include the strong global-level signals about forests, water and climate change that came back during the four-year preparation of the book, *Fishes & Forestry: Worldwide Interactions and Management*, coauthored by Tom Northcote.

David T. Hoopes

Dr. David Hoopes has been professionally involved in the fields of environmental education, research and resource management for over 40 years. Both as a Federal fisheries biologist in Alaska and the environmental coordinator for a national engineering consulting firm, he has worked on a wide range of natural resource issues. For the last five years he coordinated the local branch of Washington's state-wide salmon recovery program. He has also served as an adjunct faculty member at four colleges and universities where he taught a number of courses in the environmental studies program and has authored more than 30 scientific papers and technical articles. He is a registered fisheries scientist, certified by the Board of Professional Certification of the American Fisheries Society and a Fellow of the American Institute of Fishery Research Biologists.

E. Eric Knudsen

Dr. Eric Knudsen earned his B.S. degree from the University of Massachusetts and his M.S. and Ph.D. degrees in fisheries science from Louisiana State University. He has 31 years of experience in fisheries science and management; 23 of those years have been focused on Pacific salmonids. During his Federal career in the Pacific Northwest and Alaska, he was involved with salmonid population ecology, habitat interactions, population management, and discerning the strengths and weaknesses of salmon monitoring and assessment techniques. He is now "retired" and engaged in private consulting, with an emphasis on evaluating salmon science and population status and trends. He is a past president of the Western Division, American Fisheries Society, and actively promotes advancements in salmon science to support improved management for sustainable, robust fisheries.

Steven A. Kolmes

Dr. Steven Kolmes occupies the Rev. John Molter, C.S.C., Chair in Science at the University of Portland. He is Director of the University's Environmental Studies Program, which he founded. His research interests are in the areas of salmon recovery planning, water contamination issues, sublethal pesticide effects, and in joint scientific-theological/ethical analysis of the assumptions and arguments underlying salmon recovery planning and other environmental issues. Prior to his present appointment, he carried out research and taught at Hobart and William Smith Colleges, Simon Fraser University, the University of Utrecht, and University College, Cardiff.

Denise H. Lach

Dr. Denise Lach is an Associate Professor of Sociology at Oregon State University and past Co-Director of the Center for Water and Environmental Sustainability. She is most curious about how science and scientific information is used - and not used - in organizations to solve problems, rationalize choices, and delay decisions. Currently, she is conducting research on how managers use scientific information to make natural resource decisions, how watershed councils use collaborative processes to make changes at local scales, and how to elicit civic involvement around environmental issues. Her research has been published in both academic and professional journals (e.g., *Law and Society Review*, *Climatic Change*, *Impact Assessment and Project Appraisal*) and presented at conferences around the world.

Robert T. Lackey

Dr. Robert Lackey, Senior Fisheries Biologist at the U.S. Environmental Protection Agency's research laboratory in Corvallis, Oregon, is also Courtesy Professor of Fisheries Science and Adjunct Professor of Political Science at Oregon State University. Since his first fisheries job 40 years ago mucking out raceways in a Sierra Nevada trout hatchery, he has dealt with a range of natural resource issues from positions in government and academia. His current professional focus is providing policy-relevant science to help inform ongoing salmon policy discussions. Dr. Lackey is a Certified Fisheries Scientist and a Fellow in the American Institute of Fishery Research Biologists.

John H. Lombard

John Lombard, Senior Policy Analyst at Steward and Associates, an environmental consulting firm, is the author of *Saving Puget Sound: A Conservation Strategy for the 21st Century*, to be published by the American Fisheries Society in Fall 2006 (see www.saving pugetsound.com/home.htm). The book expands on the arguments in his chapter, applying them in detail to conservation challenges in the Puget Sound region. From 1996 to 2000, he was the Seattle region's Watershed Coordinator for the Greater Lake Washington watershed, home to 1.4 million people, and including by far the most densely populated part of Washington State. He currently advises local governments, environmental groups and other clients on issues related to salmon recovery, the Endangered Species Act and land use regulations.

Kaitlin L. Lovell

Kaitlin Lovell is Trout Unlimited's Salmon Policy Coordinator, leading the legal and policy programs on Endangered Species Act protections for wild Pacific salmon and steelhead, which include hatchery reform, recovery planning, and the role of science in salmon policy. Prior to joining Trout Unlimited, she served as Assistant University Counsel at Cornell University in New York where she focused on environmental and real estate law. She has a J.D. from Cornell Law School and a B.S. in environmental science from Bucknell University. Kaitlin's prior scientific research includes food web dynamics in the lakes of upstate New York, acid mine drainage impacts to algal species diversity in Pennsylvania, and impacts to near-shore species diversity from fishing and Atlantic salmon farming practices in the North Sea.

Donald D. MacDonald

Donald MacDonald is the principal of MacDonald Environmental Sciences Ltd., an environmental consulting firm that specializes in environmental assessment and ecosystem-based management. He is also the Canadian Director of the Sustainable Fisheries Foundation, a non-profit, charitable organization whose focus is the development and implementation of a sustainable fisheries strategy for west coast salmon and steelhead populations. Over the past 25 years, he has published more than 250 journal articles, book chapters, and technical reports on a wide variety of topics related to aquatic resource management, natural resource damage assessment, ecological risk assessment, water quality assessment, sediment quality assessment, and ecosystem management. He is a Certified Fisheries Scientist, a Registered Professional Biologist, and a member of numerous professional societies.

James T. Martin

Jim Martin retired after 30 years with the Oregon Department of Fish and Wildlife, during which he spent six years as Chief of Fisheries and three years as Salmon Advisor to Governor John Kitzhaber. He led the team that developed the Oregon Plan for Salmon and Watersheds, a state conservation plan to address Endangered Species and Clean Water issues in Oregon. He now works as Conservation Director for the Berkley Conservation Institute, a branch of Pure Fishing, which is one of the largest fishing tackle companies in the world and is an industry leader in conservation advocacy. With a B.S. in wildlife and a Masters in fisheries from Oregon State University, he also holds a courtesy appointment there, teaching Natural Resource Problem Solving in the Department of Fisheries and Wildlife. He is a board member for the National Wildlife Federation, The Theodore Roosevelt Conservation Partnership and the Oregon Wildlife Heritage Foundation. In 2005, he was inducted into the National Freshwater Fishing Hall of Fame in Hayward, Wisconsin.

John H. (Hal) Michael, Jr.

Hal Michael is a Fish Biologist with Washington Department of Fish and Wildlife in Olympia, Washington. Since his first position on an anadromous salmonid research project 30 years ago, he has been involved in research, front-line salmon management, a range of environmental and regulatory issues involved in the operation of fish hatcheries, and is now back into local area fish management. His current interest is on developing an understanding of the role that spawning salmon, and the nutrients they deliver, play in Pacific Northwest ecosystems. He is a Fellow in the American Institute of Fishery Research Biologists.

Jay W. Nicholas

Jay Nicholas has had nearly 30 years of professional experience with hatchery and native salmon in Oregon. He earned a Masters in fisheries biology at Oregon State University in 1977, and began his fisheries career with the Oregon Department of Fish and Wildlife researching wild and hatchery Chinook salmon in coastal rivers. In addition to a lifelong love of fish and fishing, his work experience has focused on life histories of wild trout, Chinook, and coho salmon; interactions of hatchery and wild salmon; historic trends of salmon populations and management in the Pacific Northwest; and developing salmon conservation plans in collaboration with scientists, government, and stakeholders. In 1995 he became the team leader and principal writer/editor of the *Oregon Plan for Salmon and Watersheds*, which he continues to support. He wrote and illustrated a children's book that describes the spirit of the Oregon Plan, and donated all proceeds to the Oregon Youth Conservation Corps. He is currently working with a team of Oregon Department of Fish and Wildlife managers and scientists developing recovery plans for salmon and steelhead that are candidates for listing under the ESA.

Thomas G. Northcote

Tom Northcote grew up on a farm in the lower Fraser River Valley and early became interested in pursuing a career in freshwater fishes and limnology, largely as a result of sport fishing in the innumerable small streams, sloughs, and lakes in the region, many now almost obliterated by rapid human population growth and "development." His professional degrees are from the University of British Columbia, Vancouver, along with postgraduate work at Cambridge focused on environmental and genetic controls in the behavior of salmonid movements and migrations. He was in charge of the British Columbia Fisheries Research Division at UBC from 1957 to 1972. Also at UBC, he taught limnology courses in the Zoology Department from 1958 to 1991, and started fisheries-forestry courses in the Forest Sciences Department in 1972, which he carried on until retirement in 1992. He has worked on freshwater fish ecology and limnology in Peru, Brazil, Scandinavia, and New Zealand, and still maintains strong research connections in those countries.

Edwin P. (Phil) Pister

Phil Pister spent 38 years as a fishery biologist with the California Department of Fish and Game. He studied wildlife conservation and zoology under A. Starker Leopold at the University of California (Berkeley) and has spent virtually his entire career supervising aquatic management and research within an area encompassing approximately a thousand waters of the eastern Sierra/desert regions of California. He founded and serves as Executive Secretary of the Desert Fishes Council and is involved in desert ecosystem preservation throughout the American Southwest and adjoining areas of Mexico. He holds special interest in the fields of conservation biology and environmental ethics and has served on the Board of Governors of the American Society of Ichthyologists and Herpetologists and Society for Conservation Biology. He has lectured at 80 universities in North America and the United Kingdom, and has authored 79 published papers and book chapters.

Guido R. Rahr III

Guido Rahr is the President and CEO of the Wild Salmon Center, an international conservation organization dedicated to protecting wild salmon, trout, and char, and their habitats along the Pacific Rim. His undergraduate degree is from the University of Oregon and he has a Masters of Environmental Studies from Yale University. He has worked in the environmental field since 1985, and has developed conservation programs for Conservation International, the Rainforest Alliance, the United Nations Development Program, and Oregon Trout (where his work won the President's Award from the American Fisheries Society). He has been an advocate of salmon refuges since 1994 when he read a copy of Livingstone Stone's speech delivered at the 1892 annual meeting of the American Fisheries Society that called for the creation of parks for wild salmon. Since then he has authored or co-authored papers on fish refuges and he and his colleagues at the Wild Salmon Center have launched fish refuge programs in the United States and Russia. This work resulted in an effort to establish the world's first whole basin salmon refuge (500,000 acres) on the Kol River. Home to all Pacific salmon species, the Kol is located on the Kamchatka Peninsula, in the Russian Far East.

William E. Rees

Dr. William Rees received his Ph.D. in population ecology from the University of Toronto and has taught at the University of British Columbia's School of Community and Regional Planning (SCARP) since 1969, where he was Director from 1994 to 1999. His teaching and research focus is on the public policy and planning implications of global environmental trends and the necessary ecological conditions for sustainable socioeconomic development. He is perhaps best known for inventing 'ecological footprint analysis,' and his book on the concept, *Our Ecological Footprint* was published in 1996 (now available in English, Chinese, French, German, Hungarian, Italian, Japanese, Latvian and Spanish.) He is a founding member and recent past-President of the Canadian Society for Ecological Economics, and a co-investigator in the 'Global Integrity Project,' aimed at defining the ecological and political requirements for biodiversity preservation. In 1997, UBC awarded William Rees a Senior Killam Research Prize in acknowledgment of his research achievements and in 2000 The Vancouver Sun recognized him as one of British Columbia's top "public intellectuals."

Brent S. Steel

Dr. Brent S. Steel is Professor of Political Science, Director of the Master of Public Policy Program, and Director of the Program for Governmental Research and Education at Oregon State University. He is also affiliated with the Environmental Science, Water Resources, and Marine Resource Management graduate programs at OSU. His current research concerns the role of science and scientists in the environmental policy process both in the United States and in the former Soviet Union. He is on the advisory boards for Project Vote Smart, the Oregon League of Cities, and the OSU Rural Studies Program. He is also on the editorial board for the journal *Sustainability: Science, Practice & Policy.*

Cleveland R. Steward

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Benjamin B. Stout

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We think we want to save wild salmon. We say we want to save wild salmon. We can even provide a list of excellent reasons for doing it. But can we muster the will? *We do still have choices about policy options, but is our desire to save wild salmon likely to be buried by the desire of so many people to live in a beautiful area, or the desire to fish however much we want, or the desire for more goods and services?*

Introduction: The Challenge of Restoring Wild Salmon

Robert T. Lackey, Denise H. Lach, and Sally L. Duncan

Introduction

Restoring runs of wild salmon is a widely professed goal for the region of western North America encompassing southern British Columbia, Washington, Idaho, Oregon, and California. Some people accord wild salmon mythological status, and thus, their calls for protection take on the tone of religious fervor. Substantial support for wild salmon recovery also comes from those who fish for salmon. Others fold the saving of wild salmon into broader environmental concerns.

But whatever the motivation to protect and recover wild salmon, it is *unlikely to happen* if current trajectories in human population and development continue. The implications of science findings in both biology and economics have yet to be adequately explained. And dramatic changes in salmon recovery trends would have to occur if the restoration undertaken to date were to have any measurable chance of success. For all the talk of sustainability, society has yet to make the painfully difficult choices required to achieve it.

"But whatever the motivation to protect and recover wild salmon, it is *unlikely to happen* if current trajectories in human population and development continue."

At best, we can say what is likely. Through the 21st century, appreciable year-to-year variation in the size of wild salmon runs probably will occur. In addition, short-term trends will continue to be confusing because of decadal fluctuations caused by cyclic climatic and oceanic changes. Most stocks of wild salmon in the region, however, likely will remain at their current low levels or continue to decline despite costly restoration efforts. Based on historical patterns, another cyclic climatic and oceanic change likely will occur early in the 21st century, extend for several decades, and stimulate modest increases in the size of wild salmon runs. However, the long-term trend is likely to remain downward (Hare et al. 1999).

The uncertainty of current predictions is obvious, but the most likely outcomes are not in doubt,

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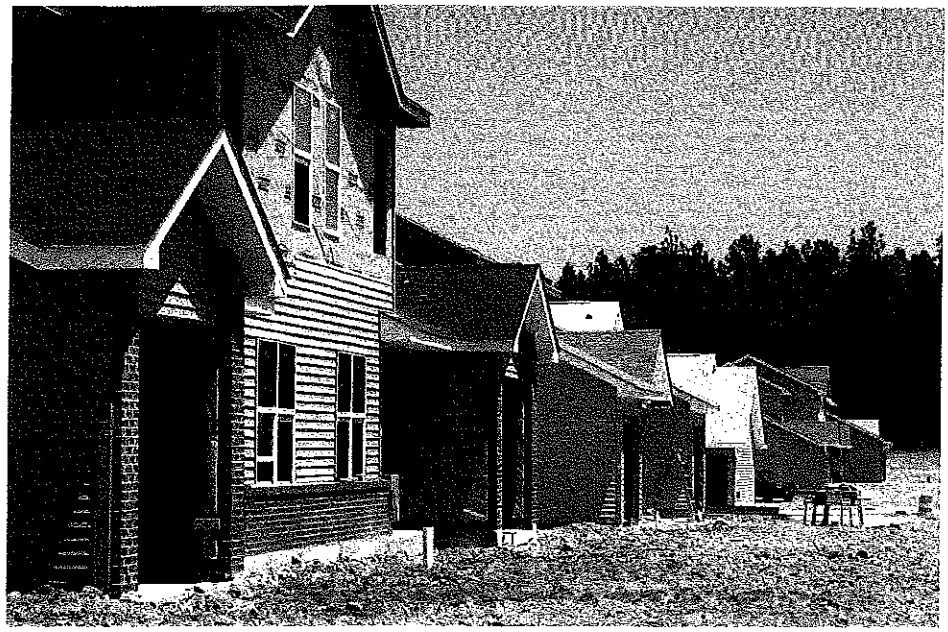

Figure 1. Building houses converts high value salmon habitat into areas suitable for family living, but unsuitable for salmon. (Source: U.S. Army Corps of Engineers.)

particularly as the cumulative effects of outside forces interact and affect wild salmon, their habitat, and their human neighbors.

The Salmon 2100 project focuses on policy and science questions about wild salmon. We define wild salmon as those produced by natural spawning in natural or minimally altered fish habitat from parents that were spawned and reared in similar habitat. Defining exactly what a wild salmon is can be challenging and involves a blend of scientific information and implied policy preferences (I. I. Courter, Oregon State University, and R. T. Lackey, unpublished). A fuller treatment is provided in Chapter 2.

It is debatable whether feasible policy options for restoring wild salmon exist in the overlap between what is ecologically possible and what is desired by society. For most individuals, the choices are difficult, unpleasant, and preferably avoided. Considerations in the salmon policy debate include, How expensive will energy be? Where will people be able to live? How will use of private and public property be prescribed, and proscribed? Will people be allowed to harvest salmon at all, and if so, which individuals and groups will be granted the right to fish? Will human food, transportation, and energy continue to be subsidized? Will society be able to provide high paying jobs for the next generation? What personal freedoms will be sacrificed to restore wild salmon? Should society control western North America's rate of human population growth, which is driven almost entirely by immigration from outside the United States and Canada, plus some from elsewhere in the United States and Canada?

The answers to these and other questions will be primary determinants of the future of wild salmon runs. Scientists can obtain the necessary data and help evaluate the consequences of different policy options, but the wild salmon problem will remain an issue of societal choice (Smith and Steel 1997; Lackey 1999; Mills 2000).

Figure 2. New housing developments are cropping up over Pacific Northwest and California regions at astonishing rates. Many areas are experiencing population growth rates at levels comparable to some Third World countries. (Source: U.S. Army Corps of Engineers.)

Although few people appear to be happy with the present situation and a strong majority publicly professes support for maintaining wild salmon, there is little indication that society, or more correctly, its policy makers, is inclined to confront the root agents of decline (Black 1995). It may appear that political institutions are unable to act, but in fact, decisions are made daily by institutions *and individuals* on the relative importance of maintaining or restoring wild salmon. Wild salmon decline is related both to people's individual life styles and also to the overall number of people. Thus, it is likely that society will continue to chase the illusion that wild salmon runs can be restored without massive changes in the number, lifestyle, and philosophy of the human occupants of the western United States and Canada.

> "What is it *really* going to take to have wild salmon populations in significant, sustainable numbers through 2100?"

The latter statement, with its concept of an illusion, forms the premise of this publication. The challenge we invited authors to address was encapsulated in a single question: what is it *really* going to take to have wild salmon populations in significant, sustainable numbers through 2100? The only assumption required in addressing this question was that human population pressure would increase, as discussed in Chapter 3. Few disagree with this assumption.

In western North America, the most vocal public concern about salmon policy is driven by the decline of wild salmon (Smith and Steel 1997; Lichatowich 1999). The precise 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

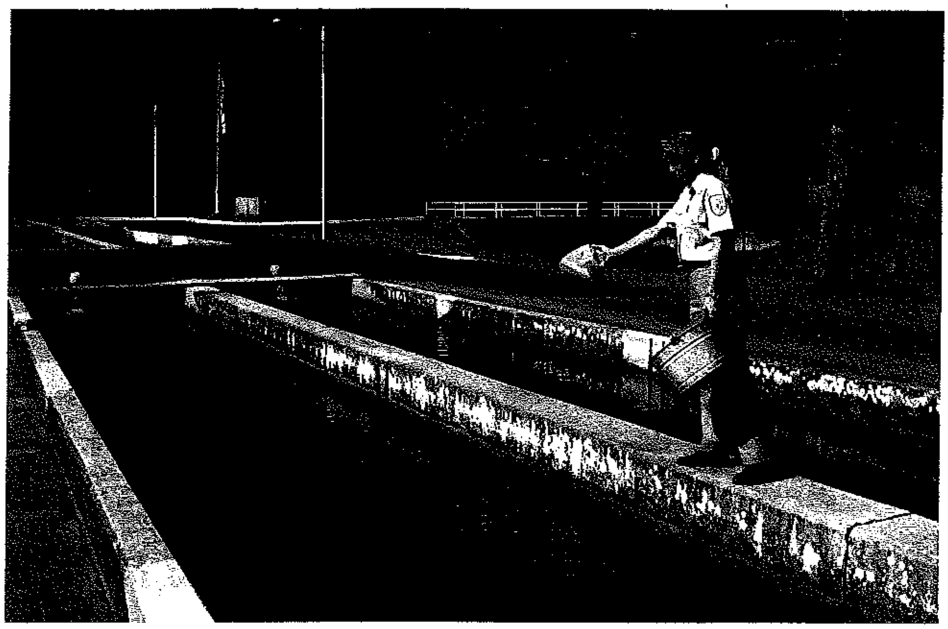

Figure 3. Some individuals view hatcheries as an integral part of keeping salmon fishing viable. Others, however, see large ecological problems for wild fish and would like to see them shut down. (Source: U.S. Fish and Wildlife Service.)

food or recreational resource because farm-raised (from many sources) and imported wild salmon (mainly from Alaska) are readily available for retail sale, and supplemental stocking could maintain at least some runs in perpetuity, albeit at high economic and ecological cost (Michael 1999).

Many people view salmon as a cultural symbol, an indicator of the region's quality of life (Lang 1996; National Research Council 1996). Those who advocate preservation of wild salmon do not necessarily always choose salmon restoration over competing priorities (e.g., flood control, inexpensive electricity, personal mobility), but maintaining or restoring wild salmon runs may be a central public policy objective for them (Smith et al. 1998).

The most important driver determining the ecological future of the region is the size, character, and distribution of the region's human population (Northcote 1996; Hartman et al. 2000), which is growing at a rate comparable to that in some rapidly growing Third World countries. From post-Ice Age waves of aboriginal immigrants from the North 10 millennia ago to the influx of North Americans (and Europeans) from the East during the past two centuries to the influx from Central and South America and Asia after the Second World War, western North America has been transformed in a few thousand years from a relatively sparsely populated region to one of the most urbanized in North America with more than 90% of the population residing in urban communities (2000 U.S. Census). Although the birth rate of residents has apparently slowed, the influx of people

"Many people view salmon as a cultural symbol, an indicator of the region's quality of life."

continues unabated, at least in part because of the strong attraction of unspoiled nature images such as the salmon represents. The human population surely will continue to grow, and the region probably will become even more urbanized (Hartman et al. 2000).

Restoration—Options and Illusions

Restoration connotes assorted expectations among salmon technocrats, decision officials, and policy advocacy groups (Hyatt and Riddell 2000). At one extreme, restoration may mean nothing less than rebuilding all wild salmon runs to levels that existed prior to 1850 (e.g., runs sufficiently large to support intense, but sustainable, fishing by commercial, recreational, and Indian fishermen). To others, wild salmon restoration efforts would be considered successful if a more modest goal were achieved: maintaining stocks at levels where extinction was unlikely (e.g., endangered species recovery). Still others envision successful restoration as permitting sustainable commercial, recreational, and Indian fishing, with the preservation of individual stocks being relevant but not essential. Some people, arguing that most of salmon spawning and freshwater rearing habitat is altered beyond rehabilitation, condone a significant, even dominant, role for hatcheries to maintain runs at levels high enough to support harvest levels as high as those in the past. By contrast, some see no role for salmon hatcheries in wild salmon restoration except for the possible temporary and last ditch role of keeping a stock from disappearing. Some individuals and groups are willing to eliminate immediately all fishing for salmon, close all salmon hatcheries, and breach major dams. Conversely, others would be willing to forego some or all of the remaining wild salmon runs if the cost of their maintenance became too onerous.

Because there is so little agreement on what constitutes successful wild salmon restoration, it is impor-

Figure 4. Many aquatic environments have been drastically altered in ways that do not favor salmon. Creation of dams provides cheap electricity, but also has created difficult migratory barriers for salmon. (Source: U.S. Army Corps of Engineers.)

Figure 5. Agriculture is a significant source of habitat alteration that puts downward pressure on salmon numbers. (Source: Adina Crisan.)

tant to define expressly how success should (or will) be determined when a particular restoration strategy is proposed. Even among the organizations that champion wild salmon restoration, there is a jumble of divergent, often contradictory, goals for restoration. At the poles are groups that view restoration as returning both commercial and recreational fishing to past, high levels and, at the opposite end, others who view restoration largely as a biological or genetic diversity concern and would close all fishing immediately. The following publicly stated restoration goals and objectives are examples extracted from documents developed by government agencies, Indian groups, and private organizations during the last few years:

> ... halt declines... and rebuild populations... to a level that will support commercial and sport harvest... . [U.S. government hydroelectric organization]

> The opportunity to catch and keep salmon in reasonable numbers for sport fishermen is the general goal of salmon fisheries management... hatchery raised fish can be substituted in any instance where natural reproduction cannot be sustained. [Recreational fishing advocacy organization]

> Our goal is to restore wild salmon and steelhead populations to harvestable, self-sustaining levels... hatcheries may be used for various purposes including to provide fisheries and in attempts to preserve or restore naturally reproducing populations. [State government fisheries agency]

> ... to ensure the long-term viability of Pacific salmon populations in natural surroundings and the maintenance of fish habitat for all life stages for the sustainable benefit of the people.... [Canadian government fisheries agency]

Salmon restoration should ultimately aim toward the production of wild adult salmon runs comparable in size to historic numbers... anything short of production of large harvestable runs makes little economic sense. [Commercial fishing advocacy organization]

... abundant harvestable wild salmon and steelhead populations in our rivers and streams, region-wide. [Environmentalist and preservationist advocacy organization]

... there is a fundamental conflict between the goal of recovering endangered wild salmon and the goal of providing fish for commercial harvest through hatchery operations... ensure that policymakers are aware of the costs associated with efforts to recover salmon.... Federal, state, and tribal fishery agencies tend to be insensitive to the significant cost of the measures they propose.... [Organization representing interests of industries that are major users of electricity]

... recovery, which is defined as abundant, self-sustaining populations that are sufficient to support the treaty-based fishery rights of Columbia Basin tribes. [Scientists in a letter sent to the President of the United States]

Restore anadromous fishes to historical abundance in perpetuity. [Organization advocating the interests of certain Indian tribes]

Many of the region's environments have been permanently altered in ways that do not favor wild salmon. The Columbia basin, for example, is now dominated by a series of main-stem and tributary reservoirs. Land use in much of the watershed has also changed in ways that no longer favor salmon (Bisson et al. 1997; Michael 1999). As dramatic as the environmental changes are, some fishes, especially exotics, are thriving (e.g., walleye, American shad *Alosa sapidissima*, smallmouth bass *Lepomis dolomieu*, northern pike *Esox lucius*, and brook trout *Salvelinus fontinalis*). These exotic species are well adapted to the new environment. It would be difficult—some argue impossible—to recreate the region's habitats that once existed and

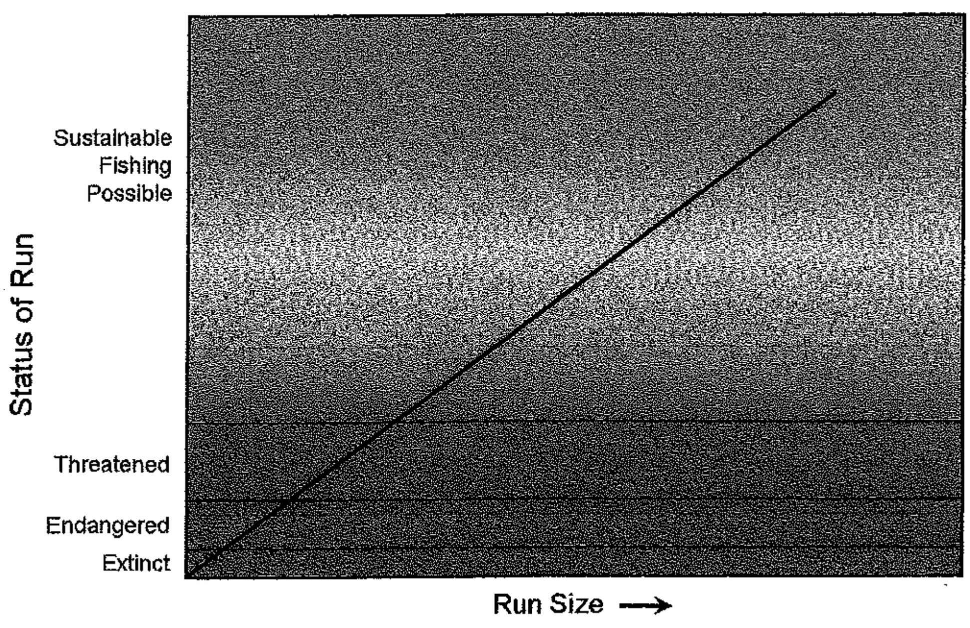

Figure 6. Meeting Endangered Species Act and Species at Risk Act requirements is a modest policy objective because it is usually insufficient for maintaining sustainable fishing. (Source: Robert T. Lackey.)

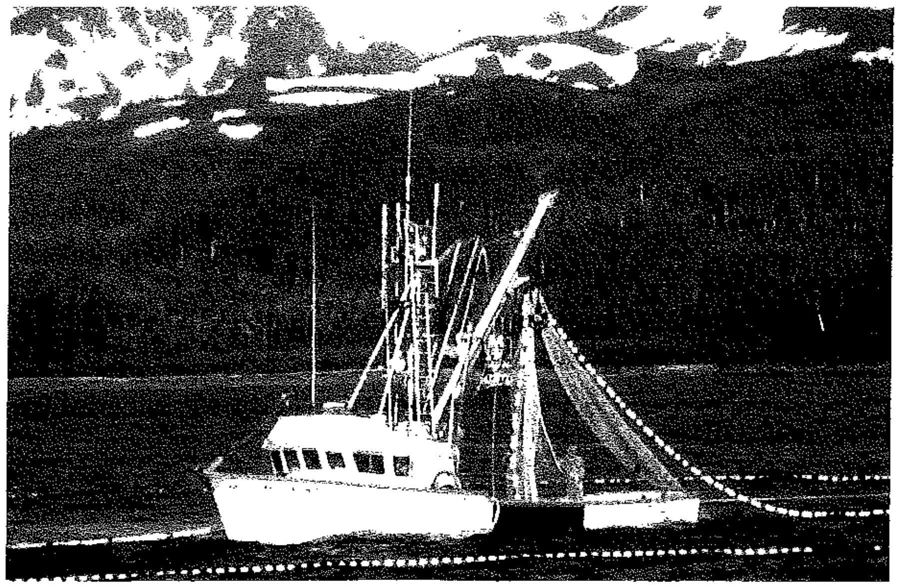

Figure 7. Both commercial and sport fishing may need to be further controlled in managing wild salmon. Competing alternatives include stopping all fishing immediately versus using supplemental stocking for hatcheries to maintain commercial and sport fishing at high levels. (Source: National Oceanic & Atmospheric Administration [top photo] and U.S. Fish and Wildlife Service [bottom photo].)

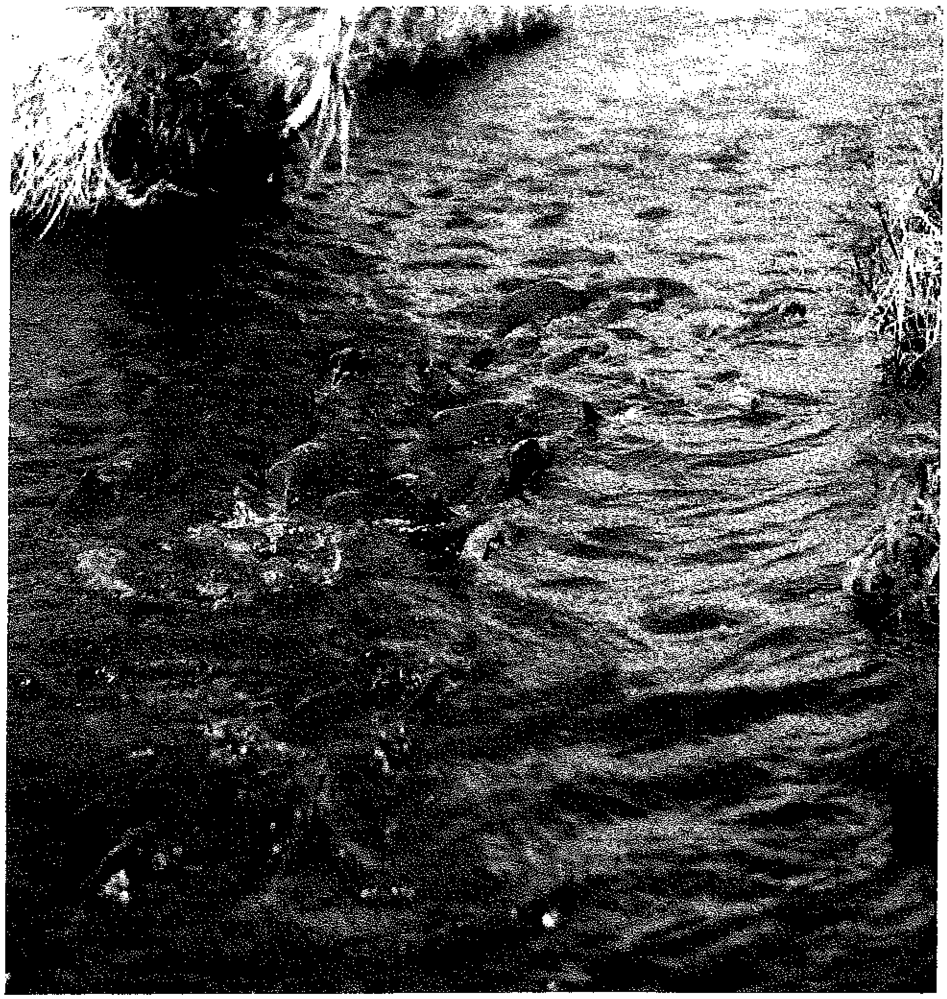

Figure 8. At the core of any salmon policy is the question of whether there are feasible policy options available, given society's other priorities. (Source: Robert T. Lackey.)

were ideal for wild salmon. A simpler, cheaper policy option would be to manage for those fishes, typically exotics, best suited to current habitat. Such an approach, while relatively easy and cheap to accomplish, would be an explicit decision to terminate many stocks of wild salmon.

There have been serious efforts to systematically prioritize wild salmon stocks to allocate society's efforts to restore runs (Allendorf et al. 1997; Wu et al. 2000). A similar option, creating salmon sanctuaries, is to preserve stocks in watersheds, such as those surrounding coastal rivers, where some reasonably healthy wild stocks still exist and thus the chances of restoration are greater (Rahr et al. 1998; Michael 1999). Also, some stocks (e.g., Chinook salmon *Oncorhynchus tshawytscha* using Hanford Reach on the main stem of the Columbia River) are better adapted to the highly altered environment of the region because they spawn at times of the year when water flows are more natural and in locations relatively less altered. Others argue that perhaps we should stop focusing on stocks and accept that no *species* of salmon is in danger of extinction.

This acceptance of the inevitable is countered as merely admitting defeat in the face of difficult, expensive, and divisive policy choices.

People of the United States and Canada now devote considerable resources toward earnest, and often futile, attempts to restore wild salmon stocks (Independent Scientific Group 1999). Will society conclude that maintaining wild salmon in ecologically suboptimal environments of the region carries economic costs that are too high? More fundamentally, will society question and reverse, as some suggest, the economic expansionist ideology that has long been the hallmark of western society (Lichatowich 1999; Salonius 1999)? Michael (1999), in one of the few cases of someone trying to answer such questions, concluded that "... society has already decided that anadromous salmonids in the Pacific Northwest will exist in low numbers and less diversity than historically."

"We take no position on any policy, nor do we even assert that society ought to do what is required to restore and sustain wild salmon."

Current and past attempts to cope with the inexorable increase in human population of the region (primarily land use planning and zoning) have met with limited success from an ecological perspective (Northcote 1996; Kline and Alig 1999). Even strict land-use laws, such as those passed in Oregon, are regularly challenged in the courts and through democratic means. An example is a 2004 voter-approved Oregon initiative that potentially overturns some aspects of Oregon's long-established land-use planning laws. Even when strict land-use laws or policies are in place, they often merely accommodate growth rather than control it. Growth management, including the various permutations of land-use zoning, balanced growth, sustainable growth, smart growth, or environmentally sensitive growth have merely attempted to adjust to human population growth in the least disruptive way. As long as people insist on an ever higher standard of living, it is a delusion to expect that wild salmon runs can be maintained, much less restored, alongside a doubling, tripling, or more of the region's human population (Hartman et al. 2000). Most people would assuredly find the prerequisite changes in policies on human population growth rate and associated economic reorientation to be draconian; there is little evidence of the willingness of most people even to consider such choices.

The essays which follow provide a spectrum of policy choices on how significant runs of wild salmon might be sustained in this region through 2100. We take no position on any policy, nor do we even assert that society ought to do what is required to restore and sustain wild salmon. These are choices that society at large must make with a clear understanding of the various policy options. It is our hope that this book will provoke a rigorous and honest analysis of the science and policy surrounding society's professed but possibly delusional goal of sustaining wild Pacific salmon in western North America.

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The decline of wild salmon began in earnest in the middle of the 19th century, and debate still rages 150 years later over whether they can be restored and to what extent. Salmon restoration questions are complex, ambiguous, and polarized and marked by extreme opinions held by multiple groups. Is there an important difference between wild and hatchery fish? Does our endangered species legislation work? What is the rightful role of a salmon technocrat?

Wild Salmon in Western North America: The Historical and Policy Context

Robert T. Lackey, Denise H. Lach, and Sally L. Duncan

Introduction

The future of wild salmon in western North America remains uncertain. Opinion polls consistently demonstrate widespread support for salmon, but the long-term decline in wild salmon abundance from southern British Columbia southward apparently continues. Short-term (several decades) improvements have been common since the decline began following discovery of gold in California in 1848, but overall, the trend has been downward.

Policy perspectives about salmon restoration are bounded by extremes. There are those who profess to be willing to bear any burden to protect and restore the remaining runs. Others assert that Pacific salmon are abundant worldwide and no species of salmon is in danger of extinction. Wild runs in California, Oregon, Washington, Idaho, and southern British Columbia are toward the end of their southern distribution, aquatic habitats have been changed dramatically, and now, runs can be most efficiently maintained by supplemental stocking from hatcheries. Occupying a middle ground between the policy extremes, others acknowledge that salmon restoration may be an important policy priority to some in western North America, but it is only one of *many* competing, important policy priorities from which society must make some difficult choices. Still others question the soundness of expending substantial public resources to restore wild salmon because such efforts, they argue, have little chance of accomplishing their purpose.

In the scientific arena opinions are similarly diverse. Some credible scientists argue that restoration of wild runs is not only technically feasible, but is possible without significant disruptions to the functioning of individuals or society. Other scientists remain skeptical about the viability of wild salmon and recommend that *if* society wishes to maintain salmon, it must require technocratic intervention, such as hatcheries or spawning channels.

The question of whether wild salmon will continue to exist in western North America is not a new one. The decline began in earnest with the discovery of gold in California and the gold rush that followed the next year. By the 1850s, excessive harvest and the impacts of mining activities were decimating salmon in

The views and opinions presented in this chapter are those of the authors and do not necessarily represent those of any organization.

Figure 1. Starting with the discovery of gold in California in 1848, mining spread to many areas of western North America, as in this historic photo. Salmon runs were decimated by the effects of these early mining operations and never recovered. (Source: www.historichwy49.com,)

streams surrounding the California Central Valley. By the 1880s, the Columbia River salmon runs were also in serious decline. In 1894, the head of the predecessor agency to the National Marine Fisheries Service proclaimed to Congress that the Columbia's runs were much reduced and still declining. By 1933, the year the first main-stem dam on the Columbia was completed, the total Columbia salmon run had already been reduced to a fifth or less of the pre-1850 level. One can argue that the most severe salmon decline took place in the 19th century—not the 20th century—though that is not to imply that the 20th century was a favorable one for salmon.

The decline of wild stocks was caused by a well-known but poorly understood combination of factors, including unfavorable ocean or climatic conditions; excessive commercial, recreational, and subsistence fishing; various farming and ranching practices; dams built for electricity generation, flood control, irrigation, and many other purposes; water diversions for agricultural, municipal, or commercial requirements; pollutants of many types; hatchery production used to supplement diminished runs or produce salmon for the retail market; degraded spawning and rearing habitat; predation by marine mammals, birds, and other fish species; competition, especially with exotic fish species; diseases and parasites; and many others (Augerot 2005).

The future can be considered according to many time frames. A few years or a decade is appealing in the political arena but is biologically unrealistic because the subtle, but crucial, effects on salmon populations of ocean and climate cycles and various human-derived causes are impossible to assess over such short time frames. Also, salmon life cycles range from 2 to 8 years and a decade is time enough for only one or a few generations to respond to a policy action. Conversely, forecasts several centuries ahead, while biologically appealing, are not credible because technological change and evolving societal priorities are highly uncertain. We argue that 2100 is a good compromise, a balance between scientific tractability and political relevance. We recognize that to some, it may be too distant to be credible; to others, it may not be sufficiently distant to comprehend the long-term consequences of salmon recovery policy.

Besides causing discomfort by forecasting a century ahead, serious discussions about the long-range future of salmon in western North America raise troublesome realities. There are realities that force us to accept that we cannot have it all. Other realities expose our personal battles between emotion and intellect. Still other realities force us to acknowledge mutually exclusive policy alternatives. Collectively, these are questions few of us relish. Nevertheless, they must be addressed head on if policy options to restore wild salmon are to be rigorously assessed.

“Virtually no one is happy with the current situation; yet, few in the general public recognize the connections between individual and societal choices and the current and future status of salmon.”

The Policy Conundrum

In the southern half of the range of western North American salmon (California, Oregon, Washington, Idaho, and southern British Columbia), salmon runs have declined markedly from the levels of the mid-1800s (Netboy 1980; Nehlsen et al. 1991; Cone and Ridlington 1996; National Research Council 1996; Lackey 1999a; Lichatowich 1999; Knudsen et al. 2000; Augerot 2005). Despite many costly efforts to protect and restore wild salmon, the total number of wild salmon in the region continues to decline over the long term (Huntington et al. 1996; Lichatowich 1999).

Virtually no one is happy with the current situation; yet, few in the general public recognize the connections between individual and societal choices and the current and future status of salmon. Thus, there is a policy conundrum: salmon ostensibly enjoy universal public support, but society collectively has been unwilling to arrest their decline, much less restore depleted runs (McGinnis 1994, 1995).

As a public policy issue, salmon restoration symbolizes a class of contentious, socially wrenching challenges that are becoming increasingly common in western North America as demands increase on limited ecological resources (Lackey 1997, 1999a). These issues share numerous characteristics: (1) *complexity*—there are innumerable options and trade-offs that can be presented to officials and the public (Taylor 1999); (2) *polarization*—these issues tend to be divisive because they represent a clash between competing values; (3) *winners and losers*—some individuals and groups will benefit from each policy choice and others will be harmed, and many of the trade-offs are well known; (4) *delayed consequences*—there is no immediate fix, and the benefits, if any, of painful concessions will often not be evident for decades; (5) *decision distortion*—these are not the kinds of policy problems that democratic institutions address smoothly because it is easy for advocates to appeal to strongly held values; (6) *national versus regional* *conflict*—the priorities of society at a national (or international) level often differ substantially from those of the local or regional society; and (7) *ambiguous role for science*—science is important but usually not pivotal in evaluating policy options because the selection by society of a policy option is inherently driven by values and preferences (including political judgments). Further constraining the role of scientific information is widespread public skepticism over its veracity, because much of it is tendered by government agencies, industries, and myriad interest groups, each having a vested interest in the outcome of the debate and often promulgating "science" that supports its policy position (Scarce 2000).

As is typical in contentious ecological policy issues, various fisheries scientists promulgate legitimate, but often different, interpretations of the same set of data. Also, the dominant scientific view often changes over time (e.g., the consensus among scientists several decades ago was to remove trees and woody debris from streams to allow unimpeded access for adults during migration; now, the consensus is to place or return woody debris into streams to provide habitat for juvenile salmon). Such scientific controversies confuse policy discussions and create skepticism on the part of the public and policy makers.

For those who place high value on maintaining runs of wild salmon, it is easy to conclude that conflicting societal priorities and technical limitations preclude a rational, positive resolution (Lang 1996). Regardless, choices are being made—even the no action option is a policy choice. From some political perspectives, society's policy choices may not be the correct or desirable ones, but the selected choices should definitely be good ones, with good choices defined as the desires or preferences of the majority being implemented and, preferably, with no *unanticipated* consequences.

Even fundamental policy and science issues such as the question of what is a wild salmon are controversial (Brannon et al. 2004; I. I. Courter, Oregon Department of Fish and Wildlife, and R. T. Lackey, U.S. Environmental Protection Agency, unpublished). There are several dramatically different definitions that lead to very different policy perspectives. Plainly, a wild salmon is one produced by natural spawning in fish habitat (e.g., streams, lakes, or estuaries) from parents that were spawned and reared in fish habitat. Conversely, a hatchery salmon is one produced by artificial (i.e., human-assisted) spawning, which is usually accomplished in a hatchery. At the extremes, the difference between wild and hatchery is clear, but how are fish that use artificial spawning channels classified? What about first generation offspring from one or both parents of hatchery origin? How are the *additional* salmon produced by lake fertilization classified? What about salmon stocks, which, over many generations, have been able to adapt and survive in highly altered aquatic environments? In this chapter, we use the term wild salmon arbitrarily to include those individuals produced from natural spawning in natural or minimally altered habitat. Others consider salmon produced by wild parents spawning in spawning channels (constructed by humans) to be wild.

“As is typical in contentious ecological policy issues, various fisheries scientists promulgate legitimate, but often different, interpretations of the same set of data. Also, the dominant scientific view often changes over time.”

Technocrats continue to vigorously debate what proportion of the decline is attributable to which specific factor. Many affected agencies, organizations, and entities have developed, or funded the development of, sophisticated assessments or computer models of salmon populations that usually end up—probably not surprisingly—supporting their organization's favored policy position.

The most strident voices include a range of affected groups such as inland barge operators, marine

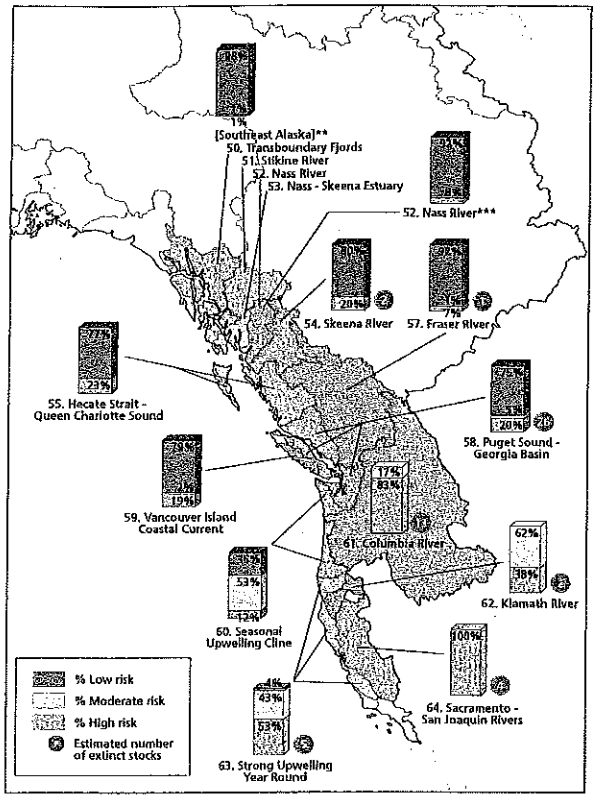

Figure 2. Many runs of wild salmon in California, Oregon, Washington, Idaho, and southern British Columbia are either extinct or at risk of going extinct. (Source: The Wild Salmon Center.)

shipping interests, highway users, industries that are dependent on high volumes of electricity, cattlemen's and farmers' associations, logging interests, recreational, commercial, Indian fishermen, and a spectrum of environmental advocacy organizations. In fact, 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, but we all make educated guesses.

We also have the recent incongruity of salmon abundance and concern about extinction. Two examples illustrate this point. First, in 1995, more *wild* Pacific salmon (summed over all regions) were harvested than in any other year in history. In such a situation, commercial fishermen typically assert that there is a salmon glut, hence the relatively low prices that they are able to command. Second, in the first few years of the 21st century, the *total* Columbia River salmon run, which are mostly hatchery fish, has been among the highest since at least 1938, the year the first federal main-stem Columbia dam was completed.

There are explanations that attempt to untangle the seeming paradox of salmon abundance concurrent with concern about extinction (Nielsen 2004). Most of the wild fish now come from Alaska and northern

British Columbia. They are abundant, but this plenty is due predominantly to favorable ocean conditions, spawning and rearing habitat in a relatively unaltered state, and vigorous regulations to control harvest. Also, large quantities of competitively priced farm-raised salmon are available year-round from many sources (e.g., Washington, British Colombia, Norway, Scotland, Chile, Australia, and New Zealand). And the recent "record" runs in the Columbia are but a shadow of their 1850 level of 10–15 million, as well as being predominantly fish of hatchery origin. Although there are explanations, for many there continues to be the seeming contradiction of salmon abundance occurring simultaneously with cries to confront risks of extinction.

The U.S. Endangered Species Act (ESA) and Canadian Species at Risk Act (SARA) are no less free of paradox and intellectual intrigue. Threatened or endangered salmon are the only listed animals for which governments routinely provide large numbers of licenses to kill. If society's concern about loss of salmon stocks in western North America is as great as many people assert, why don't we simply close fishing and hatcheries completely until salmon runs rebound? Recreational, commercial, and Indian fishermen would assuredly object, but most people would not be affected by a ban on fishing or supplementing runs with hatchery fish. Farm-raised salmon 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 salmon runs.

Ultimately, listing wild salmon as endangered or threatened as defined by the ESA or SARA means that everyone, not just fishermen, is affected. Efforts required to restore wild salmon run headlong into many other individual and societal priorities. Two of the most obvious and visible recent examples are the periodic electricity shortages and decisions over how to balance Columbia River electricity generation versus salmon survival and the contentious law suits over how to divide up scarce Klamath basin water supplies among farmers, refuge managers, threatened salmon, endangered suckers, and threatened bald eagles.

Do we need to bring some annoying reality to this discussion? Even though some predict a dramatic slowing of world population growth by the end of this century (Lutz et al. 2001), the human population of western North America continues to grow at an annual rate comparable to that of some Third World countries. For example, applying middle-of-the-road (from our perspective) annual growth rates of the current human population in Oregon, Washington, Idaho, and British Columbia (currently 15 million in total), there will be a population of 60–80 million people by 2100. Given such a probable human population level in the Pacific Northwest and the fact that California already is highly populated, you may ask whether society is being delusional about the chances of the ESA, SARA, or anything else doing much to save wild salmon.

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In western North America, we now expend considerable public and private resources in a frantic attempt to save salmon stocks that are down to a few individuals. Have we reached a point where society soon will conclude that sufficient resources already have been spent in an abortive bid to save *all* wild salmon stocks? Or are we at the stage of recognizing that society wishes to maintain salmon in the southern part of their North American range (mid-British Columbia southward) but prefers to do it using hatcheries and other technofixes that, although costly and not certain to succeed, will avoid the major social dislocation of restoring wild fish? Alternatively, will society accept the creation of salmon refuges, analogous to national parks, which preserve runs of a few stocks in a fully wild state? Or will society demand that protection and restoration of wild salmon trumps all other societal priorities, regardless of individual and collective costs?

“Pacific salmon are one of the most studied groups of fishes in the world. The vast scientific knowledge available is a reflection of the economic, recreational, and cultural importance of salmon.”

Salmon Biology

Pacific salmon are one of the most studied groups of fishes in the world (Scarce 2000; Quinn 2005). The vast scientific knowledge available is a reflection of the economic, recreational, and cultural importance of salmon. Many gaps and uncertainties remain, however, in our understanding of the biology of Pacific salmon.

There are seven species of what are classically labeled "true" Pacific salmon (Groot and Margolis 1991; Quinn 2005). All are found on the Asian side of the Pacific Ocean, but only five (Chinook salmon *Oncorhynchus tshawytscha*, coho salmon *O. kisutch*, sockeye salmon *O. nerka*, chum salmon *O. keta*, and pink salmon *O. gorbuscha*) are found on the North American side (Lichatowich 1999). There are also two species of sea-running trout (rainbow trout *O. mykiss* or steelhead (anadromous rainbow trout) and cutthroat trout *O. clarkii*) that have similar life histories and are usually lumped in the genus *Oncorhynchus* with the five North American true salmon and treated as Pacific salmon. A major difference between true salmon and sea-running trout is that true salmon nearly always die shortly after spawning, but many sea running trout do not (Pearcy 1992). Because anadromous trout and salmon in western North America have similar life cycles, are members of the genus *Oncorhynchus*, and are collectively part of the salmon restoration policy debate, we will group all seven as *Pacific salmon* (Chinook, coho, sockeye, chum, pink, steelhead, and sea-run cutthroat; Table 1). Several species of Pacific salmon have been introduced elsewhere (e.g., the North American Great Lakes, New Zealand, Chile, Argentina, and Norway) and have established prosperous populations; these are not considered here. Also not considered here are other

Table 1. Pacific salmon types.

Common names	Scientific names
Chinook salmon, king salmon, tyee salmon, spring salmon	*O. tshawytscha*
Coho salmon, silver salmon	*O. kisutch*
Sockeye salmon, red salmon, blueback salmon	*O. nerka*
Chum salmon, dog salmon, calico salmon	*O. keta*
Pink salmon, humpback salmon	*O. gorbuscha*
Rainbow trout, steelhead	*O. mykiss*
Coastal cutthroat trout, sea run cutthroat trout	*O. clarkii*

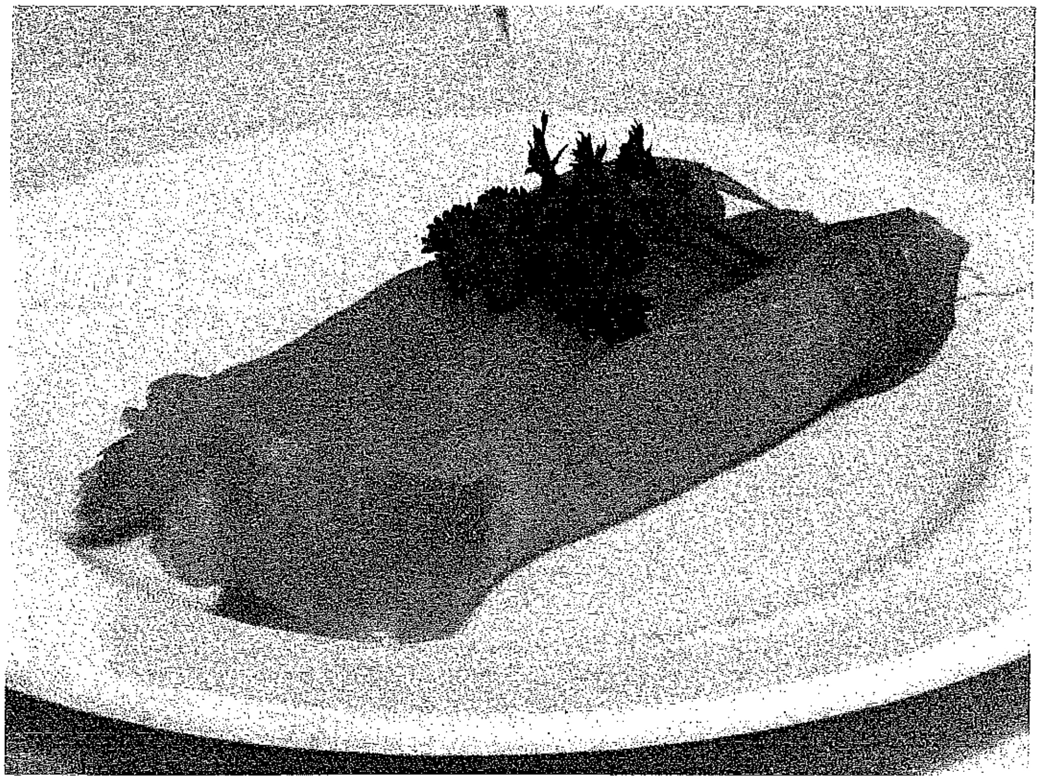


Figure 3. One of the great ironies in salmon policy is that salmon are the only species listed as threatened or endangered for which people regularly buy licenses to hunt and kill. (Source: Curtis Miller.)

anadromous salmonids such as Atlantic salmon (originally found only in the Atlantic and Arctic oceans and adjacent waters but widely distributed, including in western North America) and brown trout (originally found only in Europe and small portions of Asia and Africa but now widely distributed in North America).

Pacific salmon are native to California, Oregon, Washington, Idaho, Montana, British Columbia, Yukon, Northwest Territories, Alaska, the Russian Far East, Korea, China, and Japan (Groot and Margolis 1991; Augerot 2005). Their overall distribution has varied over the last several thousand years, with variations mostly due to climatic shifts, but the *approximate* distribution has been relatively constant (Chatters et al. 1995). Prior to 4,000 years ago, the distribution of Pacific salmon was considerably influenced by the residual effects of the last Ice Age. At certain periods in history, they were found in Baja California and Nevada, and even today, remnant runs are found as far south as San Diego (Hovey 2004). Today, it is evident that the distribution of salmon is far from fixed (McLeod and O'Neil 1983). Pacific salmon are found in Asian and North American rivers emptying into the Arctic Ocean. If northern climates warm in the 21st century, it is possible, perhaps even likely, that there will be a range extension in this region (Salonius 1973; Babaluk et al. 2000). Since 1948, three of the five warmest Canadian winters have been 1997/1998, 1998/1999, and 1999/2000 (Environment Canada, Climate Research

Branch). In a parallel manner, there may be a range contraction in more southern locales where warming creates less hospitable salmon habitat.

Pacific salmon usually have an anadromous life cycle. They migrate from the ocean to freshwater, spawn, and, a few months to a few years after hatching, the young migrate to the ocean, where they spend from a few months to several years (Groot and Margolis 1991; Meehan and Bjornn 1991; Quinn 2005). Wild salmon usually return to their parental spawning ground, although a small percentage stray and spawn elsewhere (Cooper and Mangel 1999). Fidelity to the parental stream results in adaptation of the breeding population in a particular environment. Straying allows salmon to colonize new areas or areas where salmon runs have been lost (Cooper and Mangel 1999). Because only a small *percentage* of salmon stray, the rate of expansion of the distribution is typically slow if the *number* of salmon is low, usually requiring from decades to centuries for salmon to occupy empty habitats or to reoccupy those habitats that have been restored. However, under other circumstances, expansion can be very rapid. Pacific salmon introduced into New Zealand, Chile, and Argentina rapidly established self-sustaining populations and fairly quickly (over several decades) expanded their distribution.

Migrations of salmon vary 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–San Joaquin, Columbia, Fraser, Skeena, Yukon, Mackenzie, and other large rivers. Salmon of some species, such as chum and sockeye, swim far out in the ocean, followed usually by a long ascension of a river to reach their home spawning grounds. Others, including anadromous cutthroat trout, stay close to the coast throughout the ocean portion of their lives.

Each salmon species is composed of many *stocks*—defined as self-perpetuating populations that spawn generation after generation in the same location (Nehlsen et al. 1991). Stocks are adapted to the specific local environment by inherited biological attributes, such as timing of migration and spawning, juvenile life history, and body size and shape. Local environmental or watershed conditions are often highly variable, so a stock must have the ability to respond to sometimes drastic environmental changes (Bisson et al. 1997). Debate over the extinction of wild salmon is usually focused on decline or loss of salmon *stocks*, not salmon *species* (Hyatt and Riddell 2000). Some *stocks* of salmon have been extirpated and a sizable part of the southern half of the range no longer supports runs of wild salmon, but it is unlikely that any *species* of salmon will entirely disappear from the region in the foreseeable future.

Even though the traditional unit of concern in salmon management is the stock, the number of salmon stocks is unknown because of prior undocumented extinctions, incomplete biological data on the current condition, and continuing scientific debates about the level of genetic distinctiveness appropriate to define a stock. Defining a stock is not just a scientific exercise because it has major policy ramifications (Hyatt and Riddell 2000). If a stock is considered a distinct population, it may be treated as a full species under government and court interpretations of the ESA (Waples 1995; Dodson et al. 1998). Unfortunately, the ESA does not specify how population distinctiveness shall be assessed, and that omission has fostered considerable confusion and debate in the act's application to salmon policy. For example, using a standard and fairly broad definition of a stock ("a group of interbreeding individuals that is roughly equivalent to a population"), the number of stocks in the southern half of the range is in the tens of thousands. By this definition, if each stock was considered a distinct population, potentially subject to legal protection as a species under the act, the socioeconomic ramifications for society would be profound (Hyatt and Riddell 2000).

Genetic variation is important to maintaining the viability of a salmon species because it represents a species' potential to survive in varying environments (Cooper and Mangel 1999; Levin and Schiewe

2001; Lynch and O'Hely 2001; Hilborn et al. 2003). Some scientists argue that protecting *every* stock may not be necessary to preserve sufficient genetic variation to sustain each species. For example, the concept of evolutionarily significant unit (ESU) was fashioned to describe a salmon population unit whose loss would be *significant* for the genetic or ecological diversity of salmon species (Waples 1995). Using ESUs as the unit of concern in salmon preservation has been criticized because no standard amount of significant difference among populations or stocks is required to identify ESUs (Dodson et al. 1998) and because ESUs deal with evolutionary time scales rather than shorter ecological time scales (Cooper and Mangel 1999).

Decisions about what constitutes significance and about the trade-offs implicit in protecting ESUs are largely societal choices that cannot be based on scientific grounds alone (National Research Council 1996). Some challenge even the premise that it is possible to judge the evolutionary significance of one spawning aggregate against that of another (Mundy et al. 1995). However, if the U.S. government agency responsible for implementing the ESA relative to salmon (U.S. National Marine Fisheries Service) chose to list an entire *species* as threatened or endangered, then the effect on society would be much greater than if some distinct population could be listed (Hyatt and Riddell 2000). Even though the listing process is ostensibly entirely based on scientific grounds, the political ramifications of each listing option (full species or a segment of a species) is apparent to those technocrats doing the listing. Hence, the apparent restraint in listing any but the most at-risk segments of the population.

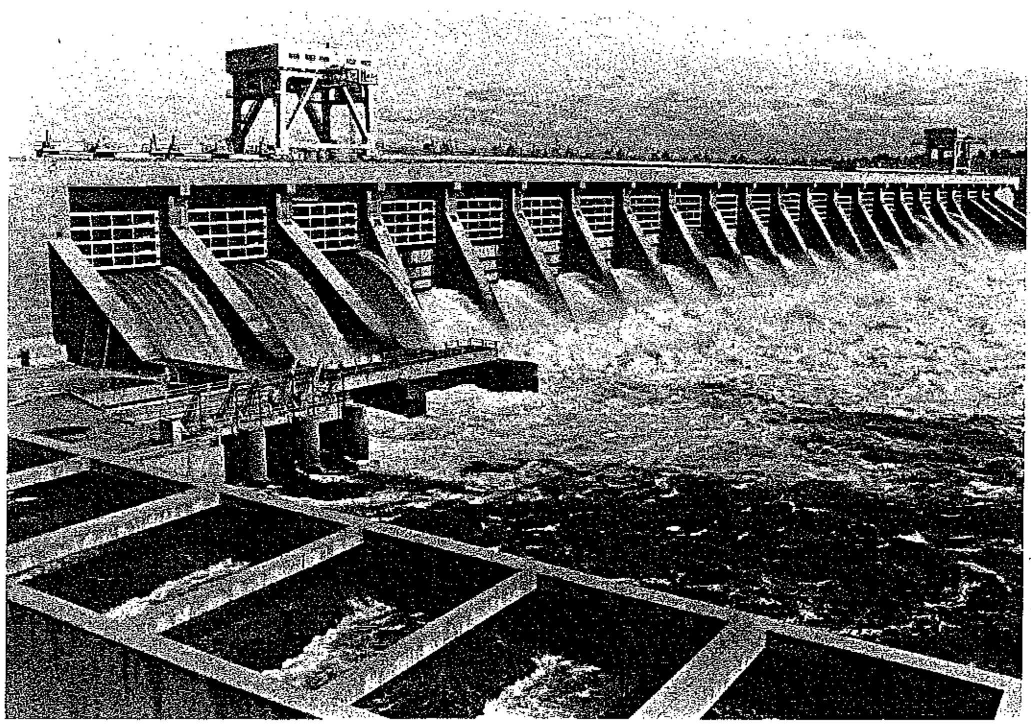


Figure 4. Dams come in all sizes and, along with many other human activities, caused the decline of wild salmon runs starting in the mid-1800s. (Source: Oregon Sea Grant.)

Decisions on salmon restoration will never be based solely on biological information (Waples 1995; Dodson et al. 1998; Wu et al. 2000). Ethical, moral, and religious values, combined with legal and economic factors, will also influence restoration decisions. Therefore, a biological unit of concern, the operational conservation unit (OCU) has been proposed (Dodson et al. 1998) as an explicit attempt to combine both scientific information and societal values and priorities in determining what aspect of a species will be considered for protection.

Beyond various concerns about the influence of declining salmon runs on their genetic diversity and long-term viability, there is the role salmon play in providing marine-derived nutrients (MDN), especially nitrogen, phosphorous, and carbon, to watersheds (Finney et al. 2000; Gresh et al. 2000). The death and decay of salmon after spawning results in the release of nutrients. Large runs of salmon provide an important source of MDN, especially in low-nutrient areas such as headwaters where their progeny spend their early lives (Cederholm et al. 1999; Bilby et al. 2001). Because of the dramatic decline in the size of wild salmon runs in the southern half of the range, it is estimated that the amount of marine-derived nitrogen and phosphorous now delivered to the region's watersheds is less than 10% of its historical level (Gresh et al. 2000). The implications of this decline in available nutrients for survival of juveniles are significant but, as yet, are not fully understood.

Another important ecological role that salmon play is providing food to terrestrial and other freshwater animals (Willson et al. 1998). Many mammals, birds, and invertebrates prey on or scavenge salmon while they are in freshwater habitats. Predators and scavengers feed on salmon at every stage in their life cycle: egg, fry, smolt, immature adult, and returning spawners. When the sizes of salmon runs are dramatically reduced, there is an effect, although not yet fully quantified, on the dependent predator and scavenger populations, many of which are charismatic megafauna in their own right (e.g., grizzly bears, eagles, condors, orca, cougars, and wolves).

Current Status of Pacific Salmon

Many efforts have attempted to quantify the extent of the wild salmon decline in western North America. For example, Nehlsen et al. (1991) concluded that more than 200 salmon stocks in California, Oregon, Idaho, and Washington were then at moderate or high risk of extinction; that is, extirpation is likely unless something changes rapidly. An assessment (using somewhat different criteria) of British Columbia and Yukon stocks (Slaney et al. 1996) identified more than 702 stocks at moderate or high risk. Across the southern half of the range, at least 100–200 stocks are already identified as extinct, but the actual number may be much higher. Even allowing for considerable scientific uncertainty over the past, current, and future status of wild salmon stocks, it is clear that some have become extinct, some are nearly certain to go extinct, and many more are at risk and will possibly go extinct (Huntington et al. 1996). Declines are widespread across the southern half of the range but are not universal, nor are they limited to large, highly altered watersheds such as the Sacramento and Columbia (Huntington et al. 1996). Declines are documented in many smaller rivers along the coast. Causes of the declines are numerous, vary by geography, species, and stock and will be reviewed in detail in later sections.

In California—the southernmost extent of the current range of salmon in the northern hemisphere—virtually all salmon stocks have declined to record or near-record low numbers (Mills et al. 1997; Table 2). Another survey concluded that most California salmon stocks are extinct or "unhealthy" (Huntington et al. 1996). Remnant runs of steelhead are found in a few streams in the San Diego area of California (Hovey 2004). A recent assessment of waters of the California Central Valley found that many of the principal streams and rivers that historically supported Chinook salmon runs still do, but nearly half of them had lost at least one stock, and several major streams had lost all their Chinook salmon stocks (Yoshiyama et al. 2000). Historical records document that for several major Central Valley streams and rivers, large salmon runs were severely reduced or extirpated in the 1870s and 1880s by hydraulic gold mining and blockage by dams (Yoshiyama et al. 1998). Hatchery-produced Chinook salmon constitute a substantial and increasing fraction of most runs in the Central Valley (Yoshiyama et al. 2000).

In Oregon, although there is considerable disagreement on the condition of specific stocks, the overall status of salmon stocks is mixed (Kostow 1997). Stocks from coastal rivers (e.g., those that are not part of the Columbia drainage) largely have stable to declining numbers, but some stocks are seriously threatened with extinction (Table 2). The absolute number of fish in most coastal wild salmon runs nonetheless appears to be a small fraction of that a couple of centuries ago (Huntington et al. 1996; Meengs and Lackey 2005). Wild salmon stocks from the Columbia River watershed are generally at low levels; an indeterminate number are extinct, and many others are declining. Salmon are excluded from large portions of the watershed by impassible dams.

The status of wild salmon in Washington is also mixed. Of 435 wild stocks (salmon and steelhead), 187 were recently classified as healthy, 122 depressed, 12 critical, 1 extinct, and 113 of unknown status (Johnson et al. 1997). Coastal and Puget Sound stocks were generally in better condition than those occupying the Columbia watershed, although there are many stocks at risk (Table 2). One section of the Columbia River, the Hanford Reach, supports a healthy population of wild salmon. Another survey, however, found only 99 healthy (defined as at least one-third of the run size that would be expected without human influence) stocks throughout the *entire* Pacific Northwest (Huntington et al. 1996).

Wild salmon have declined markedly in Idaho (Nemeth and Kiefer 1999). Idaho salmon travel as far as 1,500 km downstream as smolts to reach the ocean and eventually must return the same distance to reach natal spawning grounds to reproduce. Dam construction in the lower Columbia and Snake rivers has impeded salmon migrating to and from Idaho by converting a free-flowing river into a gauntlet of eight dams and reservoirs (Nemeth and Kiefer 1999; Kareiva et al. 2000). The decline has been especially sharp during the last three decades (Hassemer et al. 1997).

Assessments of British Columbia and Yukon salmon stocks show mixed results. Overall abundance of salmon in the Fraser River watershed decreased sharply since the late 1800s and early 1900s, although the most recent four decades (up to the early 1990s) have shown an apparent upward trend (Northcote and Atagi 1997). Similar patterns exist for much of British Columbia, although status varies by species. There appears to be a long-term decline, but there is considerable variation among species and over time

Table 2. Comparison of current and historical run sizes (Gresh et al. 2000).

Area	Historical run size	Current run size	Percent of historical run size
Alaska	150–200	115–259	106.7
British Columbia (non-Columbia River)	44–93	24.8	36.2
Puget Sound	13–27	1.6	8.0
Washington coast	2–6	0.07	1.8
Columbia basin	11–15	0.11–0.33	1.7
Oregon coast	2–4	0.10–0.032	7.0
California	5–6	0.28	5.1
California, Oregon, Washington, Idaho	33–58	2.16–2.60	5.2

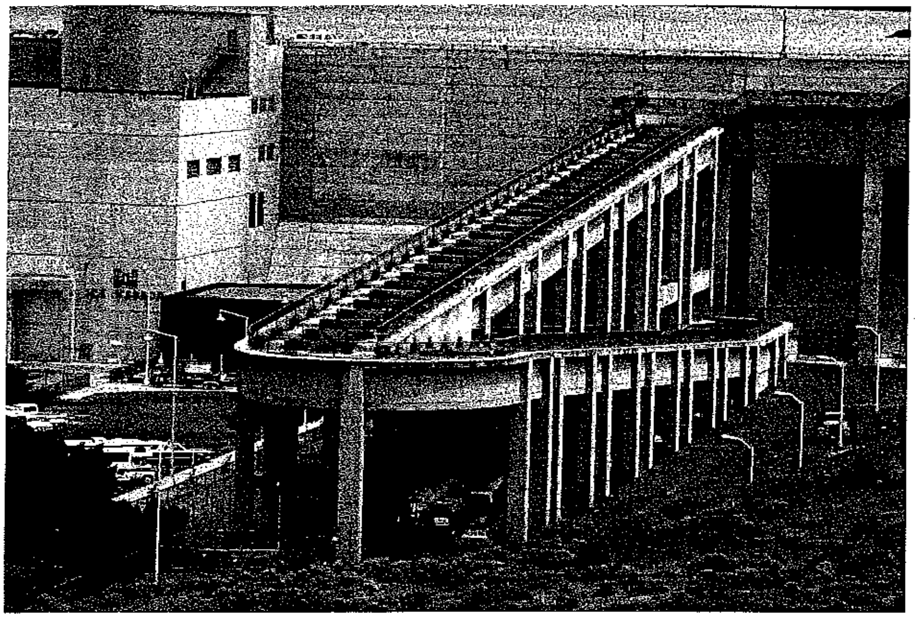


Figure 5. Various engineering structures have been developed to reduce the adverse effects of dams and their operation on salmon. Fishways, as shown here, have been incorporated as part of many dams across the region. (Source: U.S. Army Corps of Engineers.)

(Table 2). Of the 9,662 identified salmon stocks in British Columbia and Yukon, 624 were at high risk of extirpation and at least 142 have disappeared in this century (Slaney et al. 1996). In 1998, the total Canadian salmon catch was at the historic low for the 20th century (Noakes et al. 2000).

Through the early 2000s, surveys in southeastern Alaska showed salmon runs to be in mostly good condition (Baker et al. 1996; Adkison and Finney 2003; Table 2). Catches in the 1990s and 2000s were at record levels, and the numbers of salmon reaching the spawning grounds were generally stable or increasing for all stocks for which there were adequate data (Baker et al. 1996). The condition of salmon runs elsewhere in Alaska through at least the present was also good: runs of wild salmon either showed no change or increasing trends over time, indicating that the high catch levels are probably not due to overexploitation (Wertheimer 1997). Some runs in western Alaska did, however, collapse in the late 1990s (Adkison and Finney 2003).

Alaska produced approximately 80% of the wild salmon harvested in North America in the 1980s and 1990s (Wertheimer 1997). Most Alaskan catches (and runs) increased since the late 1970s and reached or exceeded historical highs through the mid-1990s and even later (Kruse 1998). The highest worldwide catch of Pacific salmon ever recorded occurred in 1995 and was composed principally of the Alaska harvest (Beamish 1999). A recent sharp reversal of record high returns in some of the largest salmon runs in Alaska may signal the beginning of a general downward trend. The number of sockeye salmon returning to Bristol Bay, Alaska (the world's largest sockeye salmon fishery) declined 50% in 1997 (Kruse 1998). Catches in other major Alaska salmon fisheries also dropped appreciably in 1998 and 1999.

The size of salmon runs varies inversely between the northern and southern halves of the distribution. When stocks in the southern half (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 high (Pearcy 1997; Hare et al. 1999). This reciprocal relationship in ocean conditions, the Pacific Decadal Oscillation, appears to be driven by climatic conditions; the resultant effect on ocean currents and upwelling determines the abundance of food for salmon (and predators) and, thus, has consequences for salmon during the ocean phase of their life cycles. As ocean conditions change, often abruptly, habitat that was ideal for salmon can rapidly become inferior (or vice versa) (Finney et al. 2000).

The Pacific Decadal Oscillation appears to reverse every 20–30 years (Downton and Miller 1998; Hare et al. 1999). Although still not well understood, the important role played by changing climatic and oceanic conditions in determining the size of wild salmon runs is amply documented (Finney et al. 2000; Noakes et al. 2000). For at least the short term, there is little that society can do to influence climate or ocean conditions, but it is important to understand climate and ocean influences in order to assess their role in influencing the condition of salmon runs.

Many salmon found in the wild are not the result of natural spawning and thus not considered wild fish. Aquaculture—growing fish in captivity—is well developed for salmon. For more than a century, salmon hatcheries along the Pacific coast have produced millions of salmon annually to supplement the

Figure 6. Massive stocking of salmon from hatcheries has had major effects on wild salmon runs. The long-term effects of these hatcheries are hotly debated by scientists. (Source: U.S. Fish and Wildlife Service.)

number of wild, naturally produced salmon (Levin et al. 2001; Brannon et al. 2004; Nielsen 2004). Further, because it is fairly easy to farm salmon and provide a steady, predictable supply to markets, salmon production for commercial purposes has dramatically increased in the past few decades. Atlantic salmon, a species not originally found in western North America, is the most popular species used in marine salmonid aquaculture (Noakes et al. 2000; Volpe et al. 2000). Some of the fish raised by the pen-rearing aquaculture technique invariably escape. In other cases, commercial hatcheries were built to supplement natural runs and produce a surplus returning to the hatchery, which could be sold to the retail market (ocean or salmon ranching) (Adkison and Finney 2003; Nielsen 2004). Over the past decade, more than 6×10^9 artificially produced salmon have been released annually into rivers and streams surrounding the Pacific Rim (Nielsen 2004).

Because of the extensive commercial production of salmon through aquaculture, salmon are relatively inexpensive and are readily available to consumers. Commercial quantities of salmon are grown in captivity in British Colombia, Washington, Scandinavia, Scotland, and Chile and provide markets with a continuous supply of fresh salmon. Aquaculture and hatcheries carry biological risks for wild salmon. These risks will be summarized in a later section.

Salmon are not the only anadromous fishes that are significantly affected by human actions and natural climatic and oceanic oscillations. The Pacific coast lampreys, green sturgeon *Acipenser medirostris*, white sturgeon *A. transmontanus*, and eulachon *Thaleichthys pacificus*, all native anadromous species, have also declined. Striped bass *Morone saxatilis* (an exotic anadromous species introduced into California in the late 1800s) are evidently declining in abundance. However, another exotic anadromous species, American shad *Alosa sapidissima*, introduced into the Sacramento River in 1871, is thriving in many places along the Pacific coast, including the Columbia basin.

In summary, no *species* of Pacific salmon is near extinction. For retail consumers, salmon are readily available and fairly inexpensive. Nonetheless, many wild *stocks* of salmon in the southern half of their North American range have been extirpated or are experiencing population decline. Overall, the 150-year trajectory of wild salmon numbers south of the Fraser River, British Columbia, is downward (Table 2).

Historical Ecological Context

Salmon runs vary greatly even in the absence of any human actions, but estimating the size of past salmon runs is useful because estimates provide benchmarks to measure the current state of wild salmon stocks and the effectiveness of restoration efforts. To assess changes in salmon runs during the past 150 years, it is possible to use cannery records, current field surveys, and harvest records (Gresh et al. 2000; Meengs and Lackey 2005). Such analyses show major declines in the aggregate size of wild salmon runs in California, Oregon, Washington, and Idaho, a smaller percentage decline in British Columbia, and no obvious change in Alaska (Table 2).

Estimating the size of salmon runs in California, Oregon, Washington, Idaho, and southern British Columbia prior to the late 1800s is more difficult. Explorers and settlers in the early to mid-1800s reported "massive" salmon runs, but it is difficult to interpret this descriptive information to create benchmarks and infer trends. A further complication is that relatively low rates of salmon harvest (as occurred in the early to mid-1800s) will often result in higher net reproduction and thus *larger* subsequent runs than would occur in the absence of harvesting (Chapman 1986). In short, some level of harvest may actually increase overall population productivity. Even discounting human influence, the size of salmon runs has varied enormously over the past 10,000 years (Chatters et al. 1995).

Anthropological data are inexact and open to various interpretations, but it is certain that at the end of the last Ice Age, 10,000–5,000 years ago, humans and salmon expanded into the Pacific Northwest (Pielou 1991; Chatters et al. 1995). Until 7,000–10,000 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 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 et al. 1995).

Aboriginal harvests of salmon increased gradually over the 4,000 years prior to European contact, and affected runs in at least some smaller rivers, especially toward the southern and eastern extent of the salmon distribution (Swezey and Heizer 1977; Taylor 1999; Yoshiyama 1999). It is often assumed that aboriginal fishing may be dismissed as an influence on historical run sizes. Taylor (1999), after reviewing the results of recent anthropological research, concludes

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

Research indicates the level of salmon harvest by aboriginal fishermen in the Central Valley of California and along the coast of Oregon, for example, was roughly comparable to the peak commercial harvest of industrial fishermen of the mid- to late 1800s (Yoshiyama 1999; Meengs and Lackey 2005).

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

Although aboriginal fishing may have affected individual stocks, especially those in smaller rivers and streams more vulnerable to the effects of fishing, the aggregate effect on salmon runs was less than that of the past 150 years (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 probably fluctuated greatly but with a long-term somewhat upward trend as continental habitat conditions improved from a salmon perspective.

The 1500s marked the beginning of a dramatic change in the history of the salmon/human relationship in western North America. 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, and gonorrhea) decimated aboriginal human populations (Denevan 1992; Harris 1997; McCann 1999), and this reduction in the human population caused a significant decline in fishing pressure (Taylor 1999). For example, to illustrate the extent of the decline, prior to 1800 the population of what is now British Columbia was greater, possibly much greater, than 200,000 (Harris 1997). By 1850, the total population of British Columbia was estimated to be only several tens of thousands. Thus, the large salmon runs observed in the early to mid-1800s were likely a reflection of the general, long-term trend of improving (from a salmon perspective) ecological conditions, coupled with a curtailment in harvest due to the diminished human population.

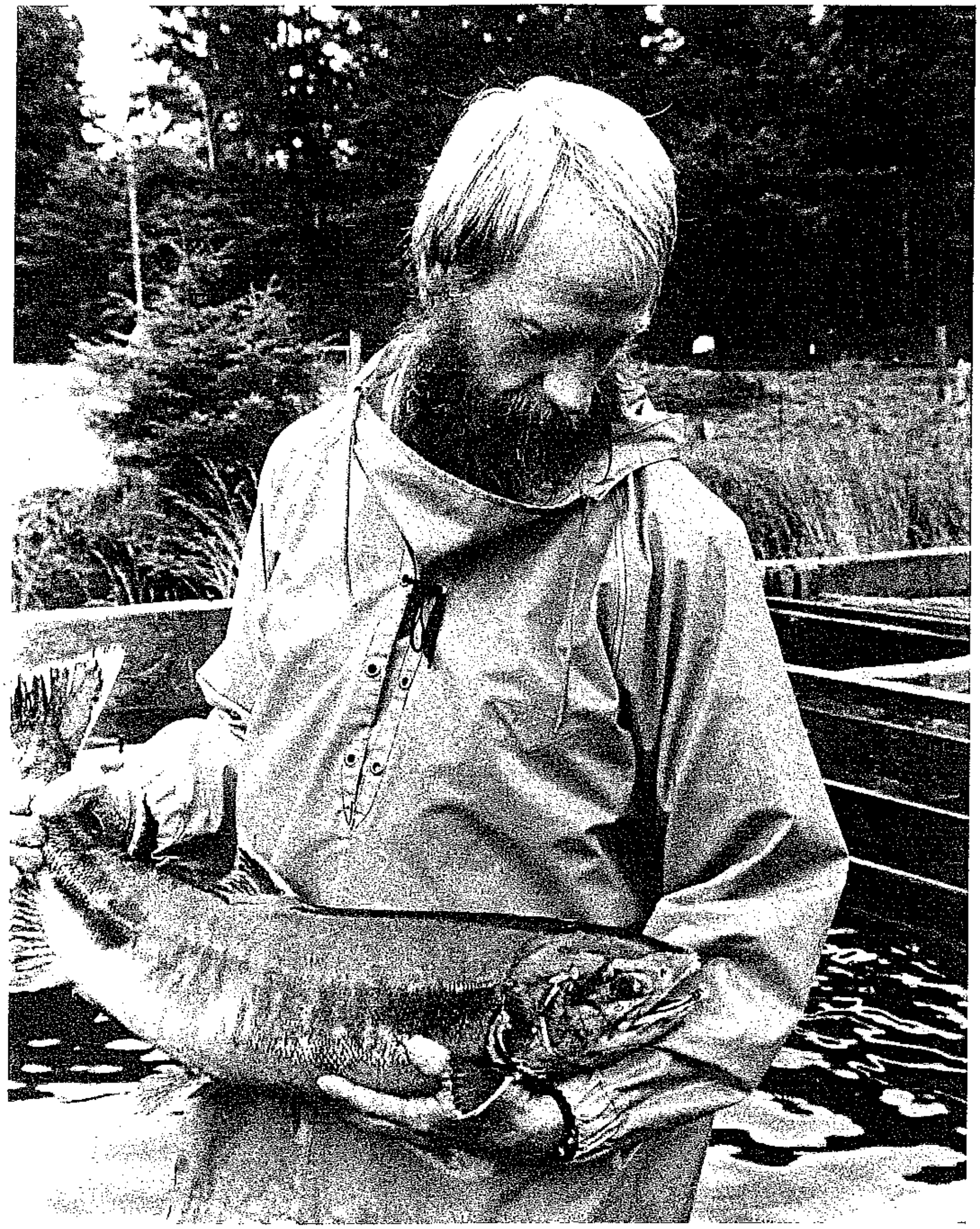


Figure 7. Aquaculture—growing fish and shellfish in captivity—is now highly developed for salmon. Salmon hatcheries annually stock hundreds of millions of young salmon throughout the Pacific Rim. (Source: Oregon Sea Grant.)

Figure 8. Salmon harvest by aboriginal inhabitants of western North America was large, possibly on a similar level to that of the commercial fishing harvest of the late 1800s. (Source: U.S. Department of Agriculture Forest Service).

Causes of the Decline

It is unknown whether there have been other general declines of wild salmon over the past 10,000 years. There certainly were prodigious volcanic eruptions, forest fires, land slides, and tsunamis that may have had widespread influences on salmon, but research has not confirmed this.

Commercial Harvest

The level of fishing for salmon in western North America began changing markedly in the mid- to late 1800s (Netboy 1980; McEvoy 1986; Robbins 1996; Mundy 1997; Lichatowich 1999; Yoshiyama 1999). By the early 1800s, the number of salmon harvested had been reduced due to the drastic drop in the Indian population, coupled with the breakdown in their social structure. Thus, salmon runs were being lightly harvested and were very large when substantial numbers of Euro-American immigrants began arriving in the 1840s. Because of this immigration, the human population ceased declining and began growing slowly by mid-century.

The mid- to late 1800s also saw the refinement and widespread adoption of powerful fishing methods (traps, fish wheels, gill nets) and the development of techniques to efficiently process, preserve, and distribute the catch using steel cans (Smith 1979). In addition to their abundance, consumer appeal, relative ease of capture, and amenability to mechanization of processing and preservation, salmon offered the allure of

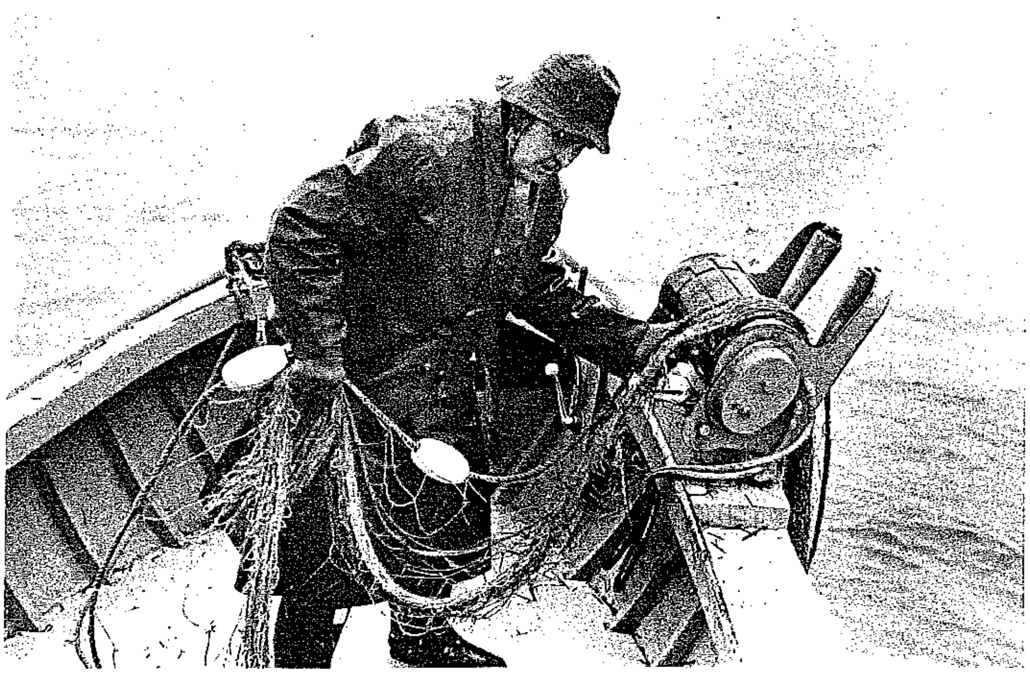


Figure 9. Commercial fishing in the late 1800s, aided by the development of commercially viable canning technology and better fishing gear, had a large effect on salmon abundance. (Source: Oregon Sea Grant.)

reliability. The timing and approximate size of annual salmon runs were dependable, so fishermen, canners, and distributors could plan with confidence.

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

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

> ... the Columbia River canned salmon industry, which began in 1866 [was] by the late 1880s... the biggest salmon-producing area on the Pacific Coast. During the early 1900s, the salmon industry was Oregon's third largest, but by 1975 the amount of salmon canned dropped to a level less than the pack of 1867, the second year of the industry. (Smith 1979).

Competition for salmon was severe throughout the 20th century; commercial, Indian, and recreational fishermen demanded a portion of dwindling runs and successfully pressured fisheries managers to

Figure 10. In many sections of western North America, floods continue to be common occurrences. The political pressure to eliminate or at least reduce the frequency of floods is significant, and constructing flood control dams was often the option of choice. (Source: Oregon Historical Society.)

sanction relatively high harvest levels (Smith 1979; McEvoy 1986; Taylor 1999). There was (and *is*) reluctance to reduce fishing pressure because the immediate economic and social consequences were and are real and often severe (McLain and Lee 1996). Further, U.S. and Canadian provincial fish and wildlife agencies, usually supported largely by the sale of fishing and hunting licenses and taxes on fishing equipment, have generally shown a distinct bias toward maintaining a high level of fishing (Volkman and McConnaha 1993).

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

Dam Construction

High harvest rates are not the only major cause of salmon decline. Dams were built on many rivers and streams for navigation, irrigation, power generation, log transport, and flood control, starting in the 1930s and continuing through the 1970s (Netboy 1980; Hartman et al. 2000). Floods, for example, have been common and devastating for humans. Particularly devastating floods occurred in 1861, 1876, 1894, 1948, 1964, and 1996. Therefore, flood control, and associated dam, levee, and channel construction, has been a societal priority for more than a century, even though salmon appear to have prospered before human disturbance in spite of periodic floods (Ligon et al. 1995; National Research Council 1996).

Dams impede passage of both returning spawners and out-migrating young fish. Moving salmon past dams has long been a challenge to fisheries managers and engineers. Some dams totally block salmon migration. In the Columbia basin, because of dams, access to more than one-third of the habitat formerly occupied by salmon is now completely blocked to salmon migration. Further, dams alter key characteristics of water, especially temperature, dissolved gases, sediment transport, and the quantity and timing of flow (Ligon et al. 1995; Power et al. 1996). Each dam in its turn has caused adverse consequences, some small, others huge, for salmon.

Agriculture

Salmon runs also dwindled as agricultural development took place in the region (Cone and Ridlington 1996). Because most of the region is arid and irrigation has been necessary for economically viable farming, water diversions (and dams) for irrigation, coupled with wide-scale agricultural use of chemical fertilizers and pesticides, have indirectly contributed to reductions in salmon runs (Scholz et al. 2000). While a substantial portion (probably 15–20%) of the annual flow of the Columbia basin is diverted for agricultural, commercial, and municipal uses, the extent of water withdrawals from individual streams varies markedly. Therefore, the true effect of water withdrawal on salmon runs must be assessed on a local basis. Also, cattle and sheep grazing (and many other agricultural practices) can adversely affect salmon by degrading water quality and physically altering spawning and nursery habitat. Agricultural practices can be especially harmful if the run size has already been reduced (Mundy 1997).

Pollutants can also cause adverse effects on salmon (Baldwin et al. 2003). Although highly visible fish-kills tend to be rare, sublethal effects of pollutants on salmon are well documented (Heintz et al. 2000).

Timber Harvest

Timber in the region is of high commercial quality (especially the forests in the Cascade and Coast Ranges), and there has been considerable economic incentive to use this natural resource. The harvest and transport of timber (initially by water released from splash dams and later by an extensive system of forest and rural roads) has also had adverse effects on salmon spawning and rearing. Logging and associated road construction (especially prior to governmental regulation and widespread adoption of improved management practices) caused increased water temperature and sediment load and other changes that decrease the quality of salmon habitat (Meehan and Bjornn 1991). It is unclear to date how changes in road-building practices, selective reductions in harvesting, global shifts in timber markets, and new harvest technologies have cumulatively affected salmon habitat through the last several decades.

Fish Hatcheries

Use of fish hatcheries has been blamed for causing major problems for wild salmon (Hilborn 1992; Waples 1999), but the full extent of the effects is difficult to assess. Pacific salmon can be spawned and easily raised under artificial conditions. Historically, fisheries managers focused on hatcheries as a tool to maintain declining runs and harvest levels (mainly responding to the adverse effects caused by dams, habitat deterioration, or overexploitation) (Levin et al. 2001; Brannon et al. 2004). Hatcheries were often successful in maintaining a semblance of salmon runs that would not otherwise have survived, but hatchery programs have probably accelerated declines of wild salmon (National Research Council 1996; Noakes et al. 2000). Hatchery-produced fish may introduce diseases, compete with naturally spawned fish, and alter genetic diversity through interbreeding, which affects the fitness of subsequent generations (Waples 1999; Noakes et al. 2000; Levin and Schiewe 2001; Lynch and O'Hely 2001).

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

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

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

> ... recognize that habitat has been so altered that the cost of producing meaningful numbers of wild anadromous salmonids is too high and that wild salmonids may become essentially extinct. In these areas there will be extensive artificial-production programs designed to provide desired levels of harvest.

Brannon et al. (2004), after a careful review of the extensive literature on the subject, conclude that "... hatchery fish have an important role in recovery and supplementation of wild stocks."

From the late 1800s to the late 1900s, attitudes toward hatcheries, at least among fisheries scientists, evolved from near universal support to widespread skepticism as policy priorities shifted toward preserving wild salmon rather than maintaining runs using artificially spawned fish (Bottom 1997; Taylor 1999). Many individuals are now hostile to the use of hatcheries, contending that the more than 100 hatcheries releasing salmon into the Columbia River system actually worsen conditions for wild salmon. There are probably 500 salmon hatcheries in California, Oregon, Washington, Idaho, and British Columbia. The counter argument is that hatcheries *can* maintain salmon runs, even in rivers where there is no other practical option (Michael 1999).

Hatcheries cause significant management challenges for maintaining runs of wild salmon (Levin et al. 2001). They can mask the decline of wild stocks by the presence of relatively abundant hatchery-bred salmon, a situation that takes place even in near-pristine habitat (Bottom 1997). Hatchery-produced fish mix with naturally spawned fish, resulting in simultaneous harvest (mixed stock fisheries) of abundant hatchery fish and less common wild fish. It is difficult, impossible perhaps in practice, to harvest abundant hatchery salmon and concurrently protect scarce wild salmon. McGinnis (1994) concludes that

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

In an effort to permit continued fishing for relatively abundant hatchery salmon, while protecting depleted wild salmon runs, agencies sometimes permit mixed stock selective fishing. The basic approach is to mark (by removing the adipose fin) each hatchery-raised salmon; thus, if an unmarked salmon is caught, it is assumed to be wild and must be released. If selective fishing worked as intended, it would allow capture of abundant hatchery salmon but would simultaneously safeguard less abundant wild fish.

Although conceptually appealing, the mixed stock selective fishing has the potential weaknesses of inflicting additional mortality on wild stocks that already may be at perilously low levels. The causes of additional mortality on wild salmon are (1) selective fishing does not work in situations where the harvest method (i.e., gill netting and purse seining) results in the death of most captured salmon; (2) some fish die after being hooked, caught, and released (collectively called hooking mortality); (3) not all fishermen comply with the legal requirement to release unmarked fish (noncompliance mortality); and (4) illegal fishing is more difficult to police when some legal fishing is permitted (poaching mortality).

Selective fishing regulations in fisheries management is expensive: hatchery-produced fish are costly to produce, marking *all* hatchery fish is labor-intensive and costly, monitoring the effects of fishing on wild

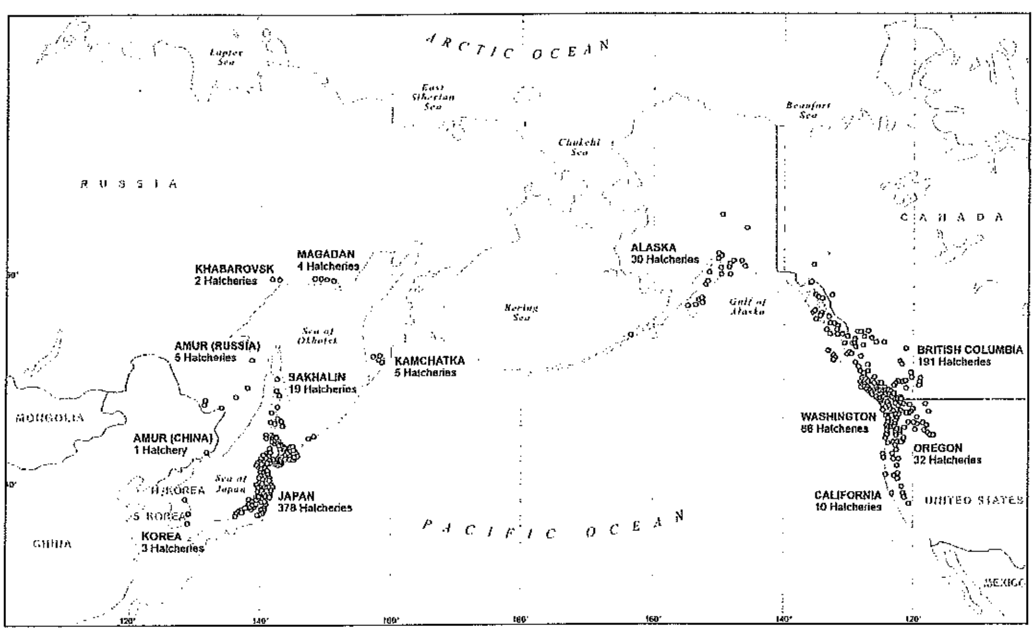


Figure 11. Many runs of salmon, especially in the southern half of the distribution, are supported by release from hundreds of hatcheries. (Source: The Wild Salmon Center.)

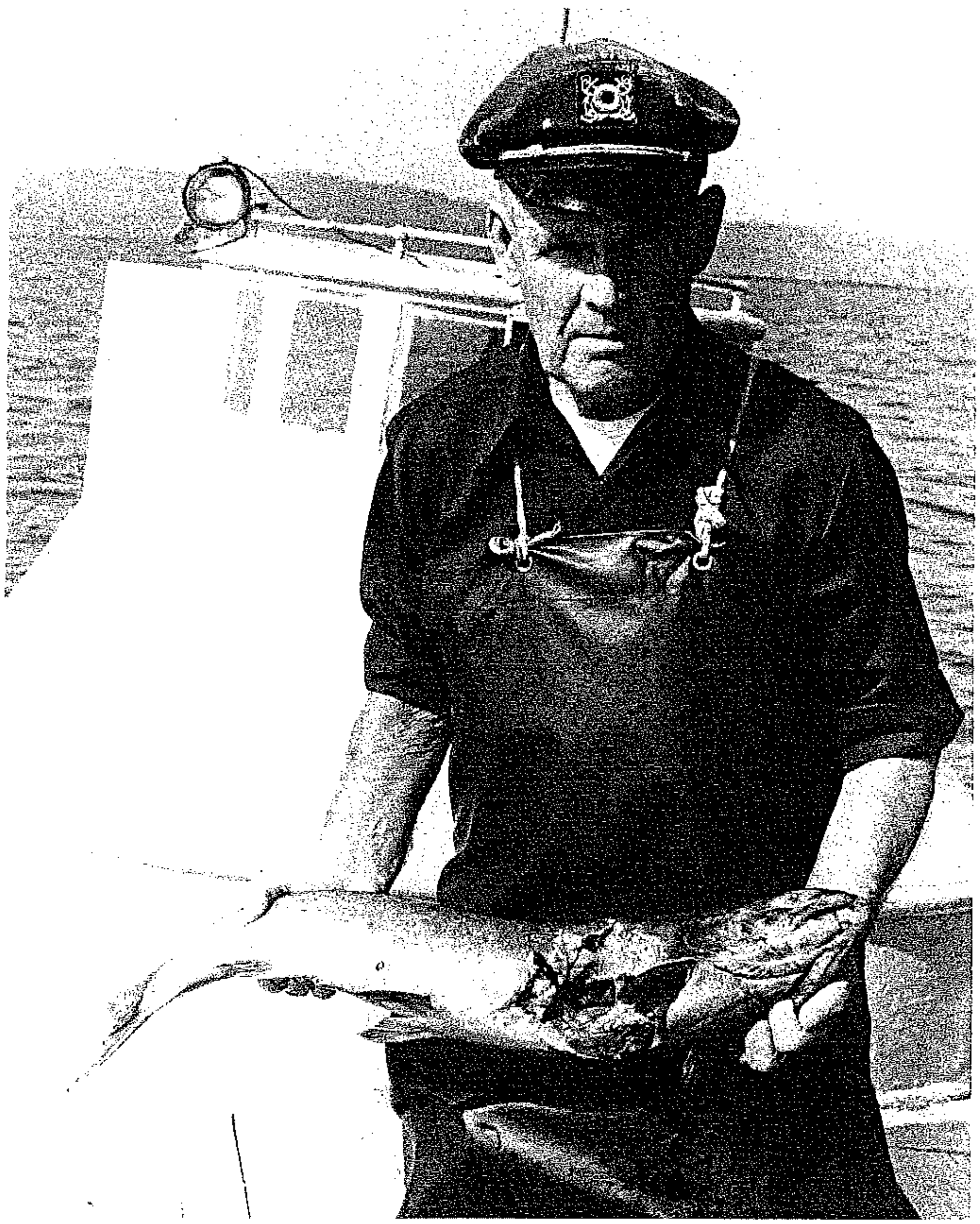


Figure 12. Many animals prey on salmon. Marine mammals prey efficiently on adult salmon and have generally increased in abundance over the past several decades. Notice the large bite missing from this salmon, most likely due to a marine mammal. (Source: Oregon Sea Grant.)

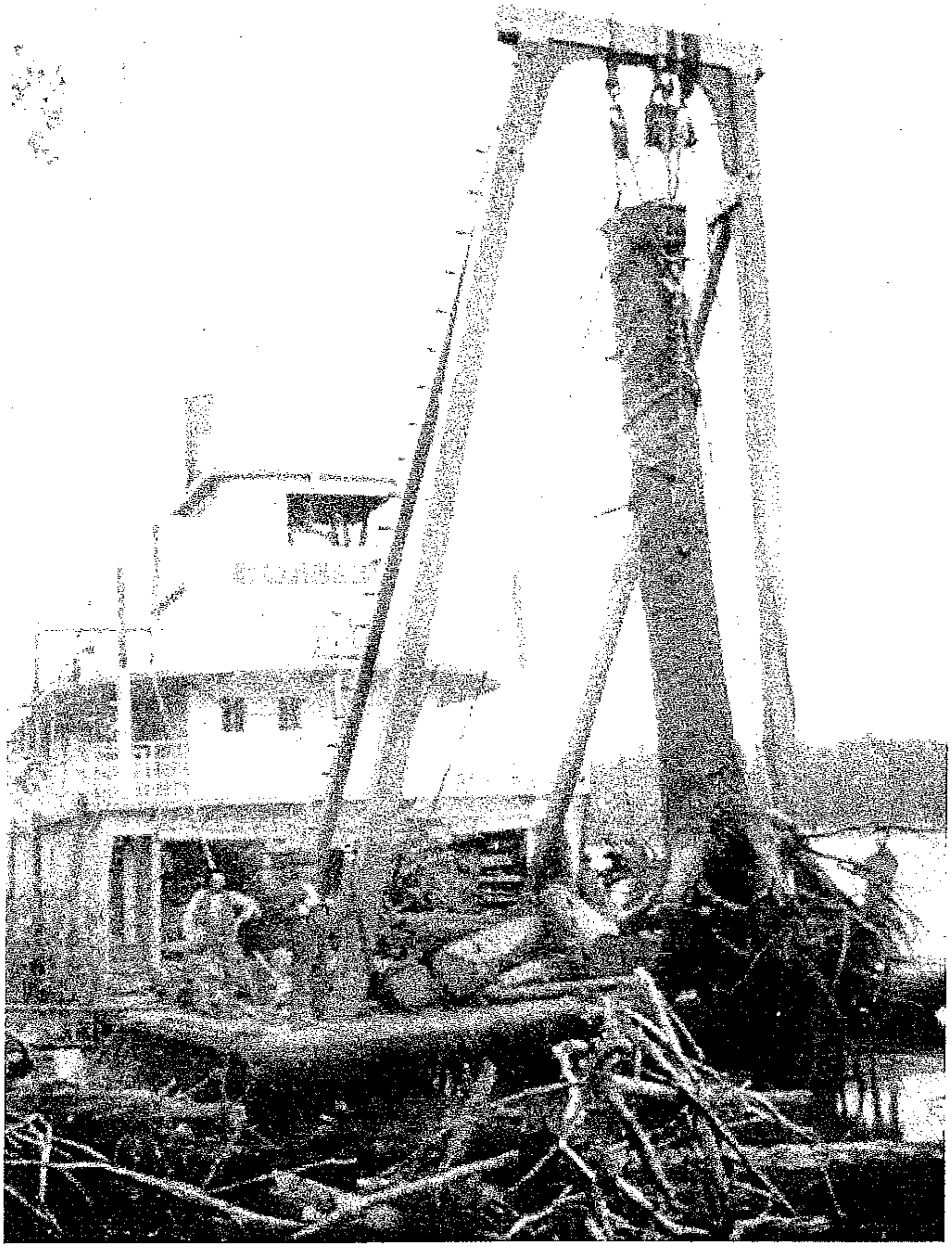


Figure 13. During the 1800s, many coastal rivers were cleared of navigation obstructions, which decreased the quality of salmon habitat. (Source: U.S. Department of Agriculture Forest Service.)

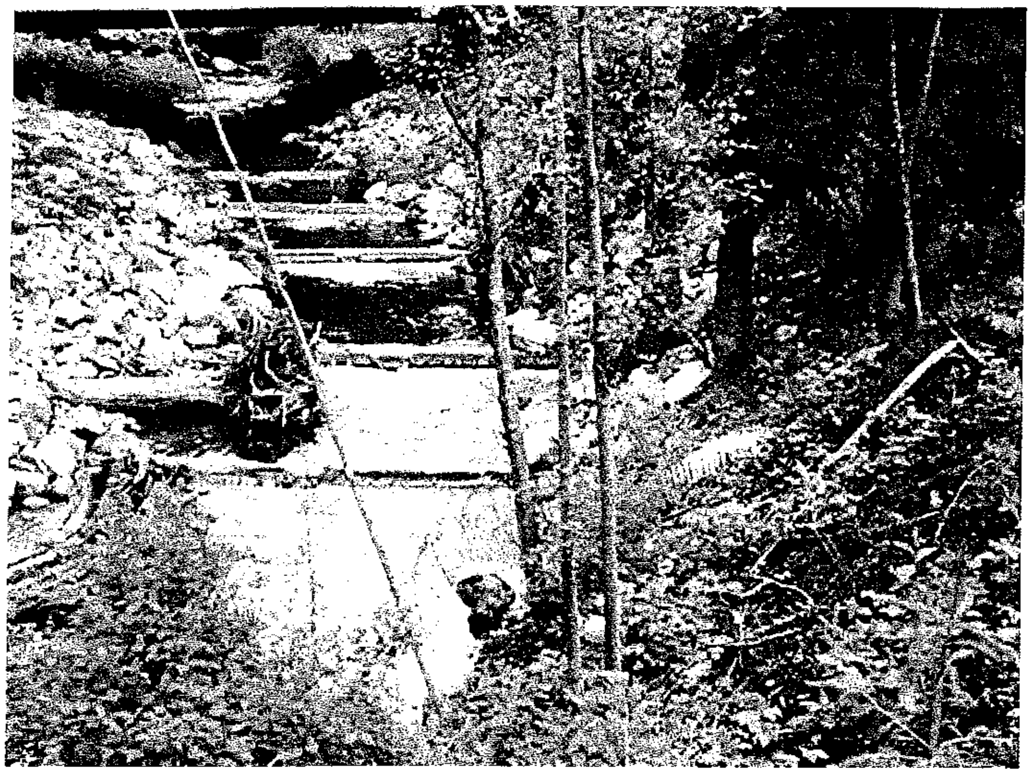


Figure 14. Altering streams to recreate habitat that more closely resembles the pristine environment is a commonly used salmon recovery tactic. (Source: Washington Department of Fish and Wildlife.)

stocks requires extensive field sampling, and law enforcement must be vigorous and continuous. For all of its risks, selective fishing currently may be the only way to permit fishing on mixed stocks with any chance of protecting vulnerable stocks. It is theoretically possible to use fish-friendly nets or other harvest gear that inflict less capture and handling mortality on salmon. It might even be possible to modify the run timing of hatchery fish so they do not mix with wild fish and can therefore be harvested without concern for wild stocks (Brannon et al. 2004).

Atlantic Salmon

In the past 25 years, Atlantic salmon *Salmo salar*, a species not native to the Pacific Ocean and its tributaries, has become the dominant species used in salmonid aquaculture. There are major pen-rearing operations in British Columbia and Washington (Noakes et al. 2000). One concern with these operations is that this exotic species might establish naturally reproducing populations and adversely affect wild native salmonids (Volpe et al. 2000). Among fisheries scientists, there has been debate about the likelihood of anadromous runs of Atlantic salmon becoming established in western North America (Noakes et al. 2000). Gross (1998), after reviewing the experiences with farming Atlantic salmon in many different places throughout the world, concluded as to their likelihood of establishment in the Pacific:

> ... the opportunity for invasion is unprecedented and success is probable at the current state of domestication of Atlantic salmon. Whether a new salmonid species in the Pacific drainage would result in a net decrease to all salmonid biodiversity through negative impacts, or instead increase total biodiversity through the addition of a new species, remains an open question."

There has been strong evidence of natural reproduction of aquaculture-escaped Atlantic salmon in British Columbia (Volpe et al. 2000)

In addition to those involved in commercial salmon aquaculture, there are other proponents of artificial propagation of salmon as an appropriate management tool. Some advocacy groups representing recreational, commercial, and Indian fishermen support use of hatcheries to supplement wild salmon runs. These proponents argue that there is no short-term alternative if significant levels of harvest are to be maintained. Indian advocacy groups usually argue that treaty rights require the maintenance of salmon runs by whatever means is available (Scarce 2000). Commercial fishermen often argue that they invested heavily in expensive gear with the implied commitment that salmon runs would be maintained.

Other Nonnative Species

From the perspective of proponents of salmon restoration, another troublesome development has been the intentional introduction of many nonnative fishes (exotics), including walleye *Sander vitreus*, striped bass, American shad, brown trout *Salmo trutta*, brook trout *Salvelinus fontinalis*, smallmouth bass *Micropterus dolomieu*, largemouth bass *M. salmoides*, bluegill *Lepomis macrochirus*, northern pike *Esox lucius*, yellow perch *Perca flavescens*, and channel catfish *Ictalurus punctatus* (Fresh 1997; Levin et al. 2002) and the expansion in distribution of native species such as northern pikeminnow (also known as squawfish) *Ptychocheilus oregonensis* due to habitat alteration such as dam construction. Certain highly valued native species, such as rainbow trout and steelhead, were stocked widely outside their range. Often helped by habitats altered by human actions, some exotic and native fishes flourished. Once these fishes establish thriving populations in habitats no longer favorable for salmon, it is extremely difficult to reestablish viable salmon runs. Further, some agencies continue to manage in favor of popular, exotic game species and indirectly abet the decline of wild salmon (Taylor 1999). Conversely, because many aquatic environments in western North America are vastly altered (generally changed from flowing water to impounded water, from multiple channels to single channels, and from flood prone runoff to regulated runoff), there would now be very little fishing in much of the region if exotic species had not become established.

Ocean Conditions

Most salmon spend the majority of their lives in the ocean, not in freshwater environments, so the oceanic and coastal portion of their life cycle must also be considered in assessing the causes of the current declines (Pearcy 1997; Finney et al. 2000; Welch et al. 2000). 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 weather system appears to correlate with trends in salmon run size (Hare et al. 1999). On shorter time scales, and depending on the salmon species, stock, and where individuals in the stock spend the majority of their ocean life, El Niño and La Niña events may have detrimental or favorable effects. Although usually poorly quantified, it is undisputed that high quality freshwater habitat plays a critical role in the persistence of salmon stocks and especially during periods of unfavorable ocean conditions (Lawson 1993; Bisson et al. 1997). Welch et al. (2000) concluded that sudden and large changes in ocean conditions directly and significantly affected steelhead and coho salmon stocks throughout much of their range on the west coast of North America.

Figure 15. Timber harvest along stream banks can cause erosion and other problems that are detrimental to salmon. (Source: Oregon Sea Grant.)

Climate Change

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

Predation

Predation on salmon (and all animals) is a natural phenomenon and would take place in the absence of humans. Some predators, especially marine mammals, birds, smallmouth bass, brook trout, mackerel, northern pikeminnow, and others, are often identified as contributing to the decline of salmon (Smith et al. 1998;

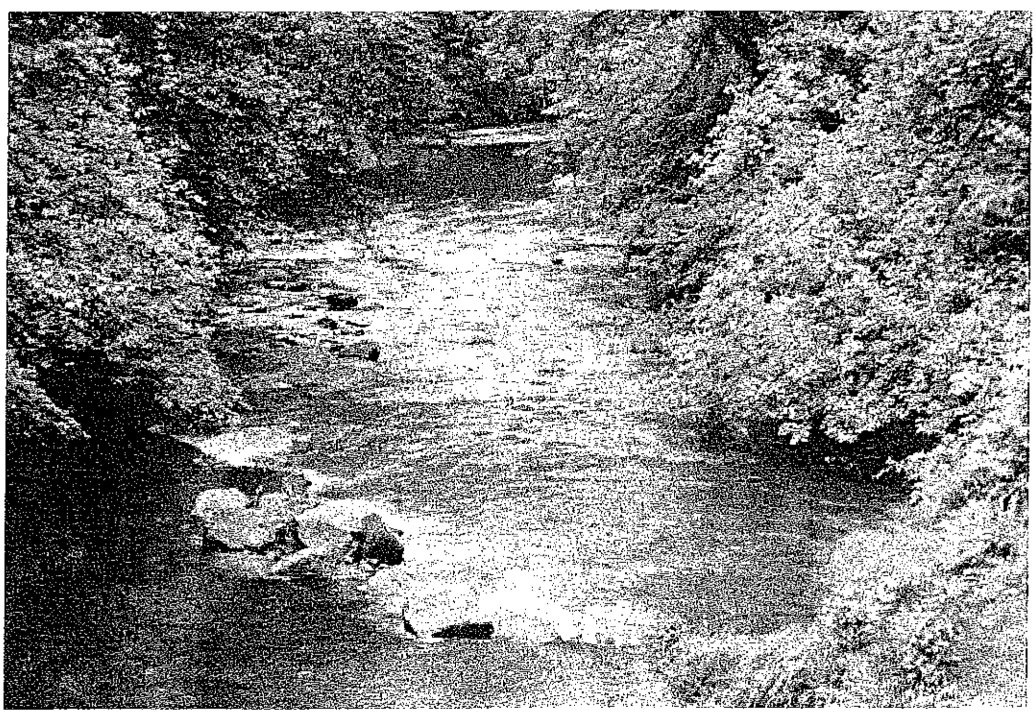


Figure 16. Many natural streams such as this one have been permanently altered to the point where salmon recovery would be all but impossible. Others still could be transformed back at least to a state to support some level of salmon run. (Source: Oregon Sea Grant.)

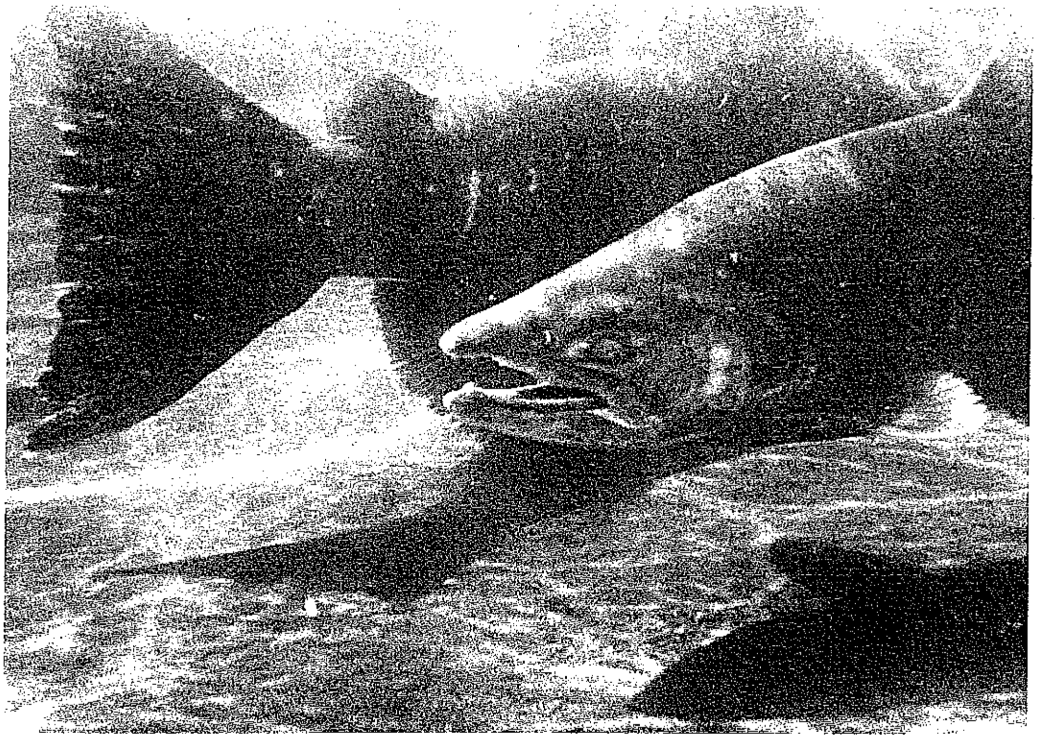


Figure 17. Wild salmon runs are declining and large wild salmon such as these are becoming harder and harder to find and observe in their natural habitat. (Source: Oregon Sea Grant.)

Levin et al. 2002; Fritts and Pearsons 2004). Since the early 1970s, the number of Pacific harbor seals and California sea lions has increased to historical levels because harvest of these animals has been prohibited by U.S. and Canadian laws (Fresh 1997). These animals are especially efficient in capturing returning adult salmon congregated at river mouths and artificial constrictions in rivers (National Research Council 1996). Marine mammals do have significant effects on some salmon runs, but they are not believed to be one of the overriding causes of the general decline of wild salmon stocks (Fresh 1997). However, when a salmon run is threatened with extinction, any mortality is cause for concern and tends to prevent or retard recovery.

Northern pikeminnow, gulls, Caspian terns, and double-crested cormorants tend to congregate around dam sites and in estuaries and, in some locations, can consume large numbers of juvenile salmon (National Research Council 1996). Northern pikeminnow populations in the Columbia and Snake rivers, for example, consume significant numbers of uninjured juvenile salmon (an estimated 16 million individuals or 8% of the population of juveniles) that would otherwise have survived migration (Beamesderfer et al. 1996). Caspian terns, a species that often congregates in large nesting colonies, have become well established on the lower Columbia (on islands created by deposition of dredge spoil) and are now a major local source of predation on young salmon migrating to the ocean. When considering all the causes of salmon decline, predation by marine mammals, birds, and northern pikeminnow 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).

Endangered Species Issues

Salmon policy and management in both the United States and Canada have recently become much more tangled with the application of the ESA and SARA (Rohlf 1991; Smith et al. 1998). A spirited debate over the policy-effectiveness of listing individual stocks or groups of stocks (e.g., evolutionarily significant units, metapopulations, or distinct population segments) as threatened or endangered has dominated salmon policy debate through the 1990s (Hyatt and Riddell 2000). Some people (e.g., McGinnis 1994) hail the ESA 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 act as an inflexible law based on a narrow set of societal preferences and predicated on a naive understanding of modern ecology. Yet others claim that ecology itself may not be up to the task (Carpenter 2002).

Many ethical, political, and scientific issues envelop policies on threatened and endangered salmon (Polasky and Doremus 1998). To some, the debate over declining salmon runs is simply a matter of choosing among options, similar to choices required for deciding energy, transportation, or international trade policies. Agreement on a plan to save wild salmon would be achieved by following the classic political process of compromise and trade-off.

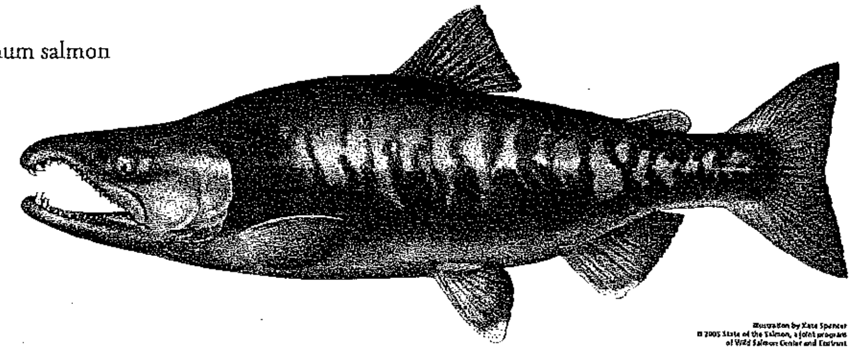
Others view endangered salmon issues in the stark terms of right and wrong, moral and immoral, and ethical and unethical. Indian advocates often base their arguments on a religious argument that is protected in law by court interpretations of treaties. If a participant in the policy debate perceives the salmon decline issue as principally a moral or ethical one, it is not realistic to expect a political compromise. Such strongly held policy positions mean the ultimate resolution will be perceived unconditionally as win–lose.

Still others hold strong moral and ethical views on endangered salmon concerns but view such issues through the prism of competing rights—the rights of the public at large versus the rights of individuals. An example is the ongoing debate over the legal adjudication of situations where a public action constitutes a taking of private property and requires financial compensation to the owner (Polasky and Doremus 1998). Society may conclude that preservation of salmon is important, but temper this position with the proviso that regulations to achieve this objective should not disproportionately burden particular members of society. The political argument is usually that no one should be required de facto to relinquish his or her private property without compensation caused by a regulatory taking. The counter argument is that those individuals and segments of society that exacerbate the salmon decline or impede recovery ought to bear the cost of recovery. Those segments of society (e.g., Native American groups or other countries) who believe that their position is protected by treaties are likely to seek adjudication through the courts.

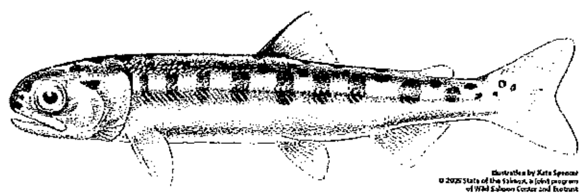
Debate over the ESA and SARA, especially their implementation relative to salmon restoration, is characterized by truculent adversaries who denigrate the motives of other combatants. The opposing sides have different motives and each policy choice involves winners and losers.

Some skeptics question how democratic institutions are to choose among salmon restoration options when the losers cede so much, and there is little societal consensus except at the most general, abstract level. Others assert that we have de facto accepted the philosophy of those who hold it morally improper to extirpate a species or subspecies under any circumstances. Is compromise possible when options are mutually exclusive? Can public policy be implemented when a choice can end up in court for years? And what is so important to society about individual stocks, much less the emerging but contentious concept of evolutionarily significant units? Are critics correct in asserting that the act is preordained to failure because compliance costs 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

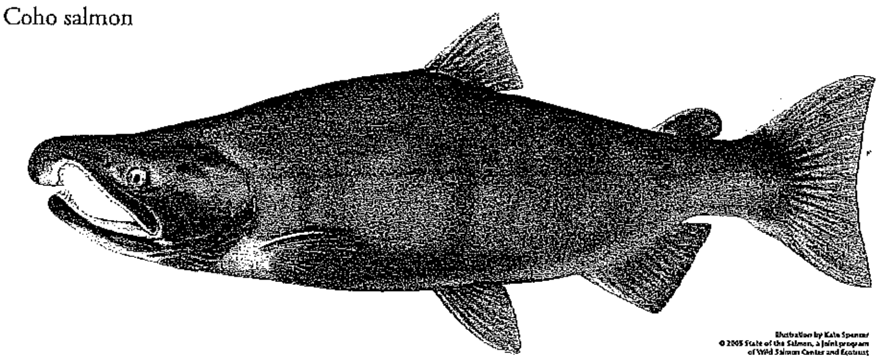
Chum salmon



Chum salmon fry



Coho salmon



Coho salmon parr

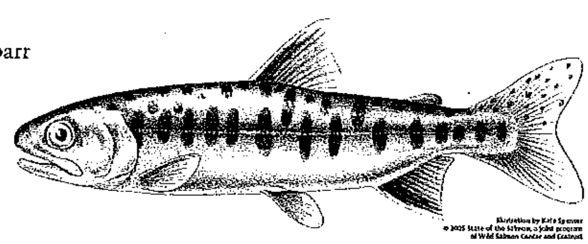
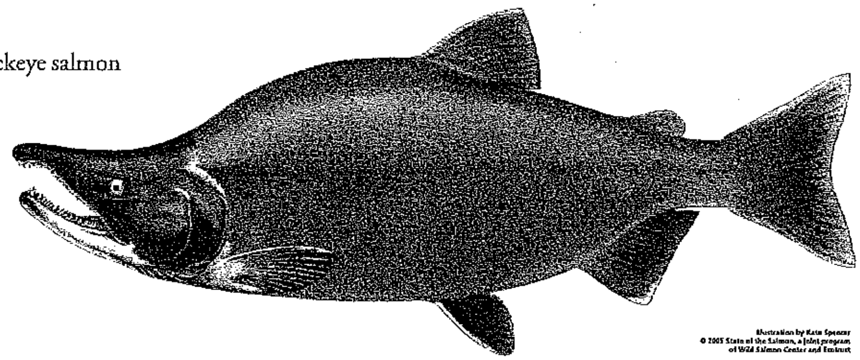
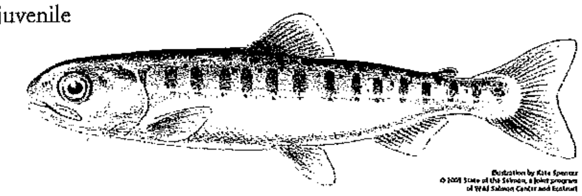


Figure 18. The six species of focus for the Salmon 2100 project. (Source: Augerot 2005.)

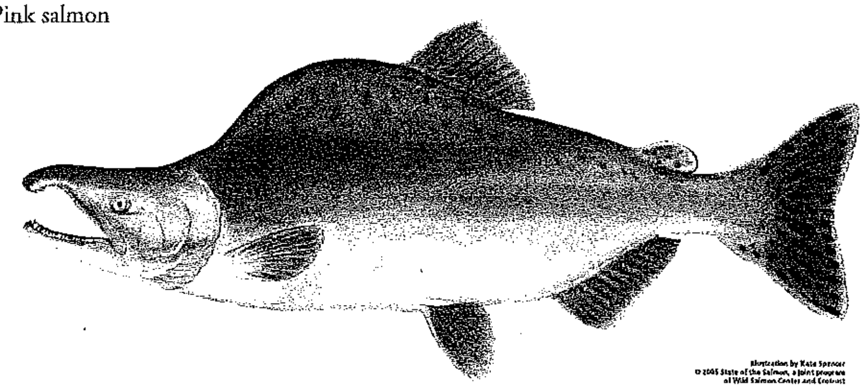
Sockeye salmon



Sockeye salmon juvenile



Pink salmon



Pink salmon fry

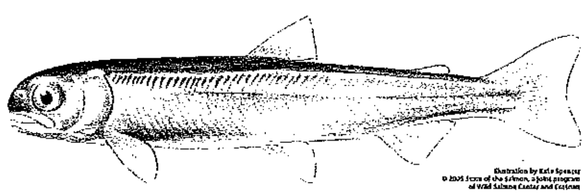


Figure 18. Continued.

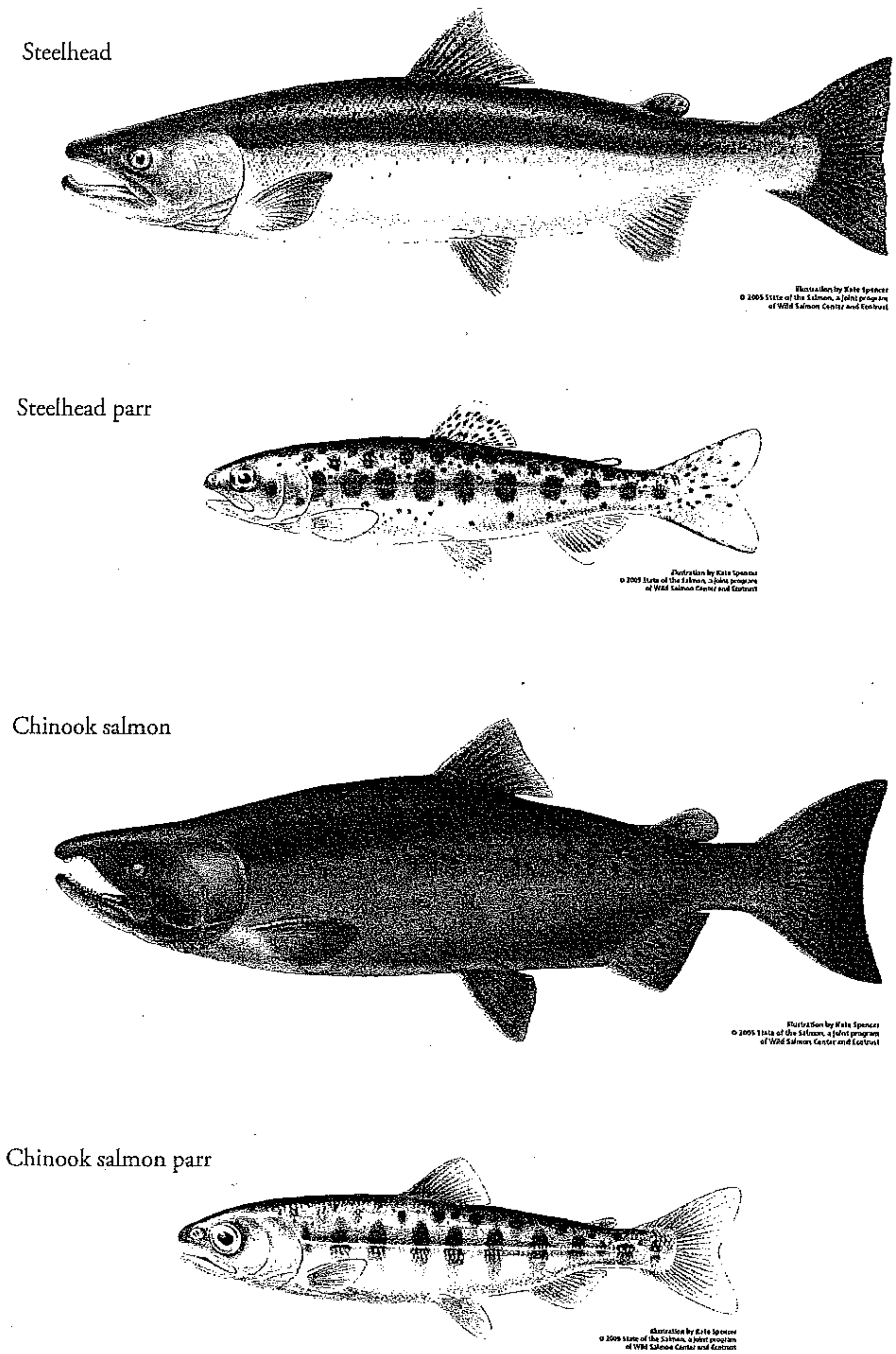


Figure 18. Continued.

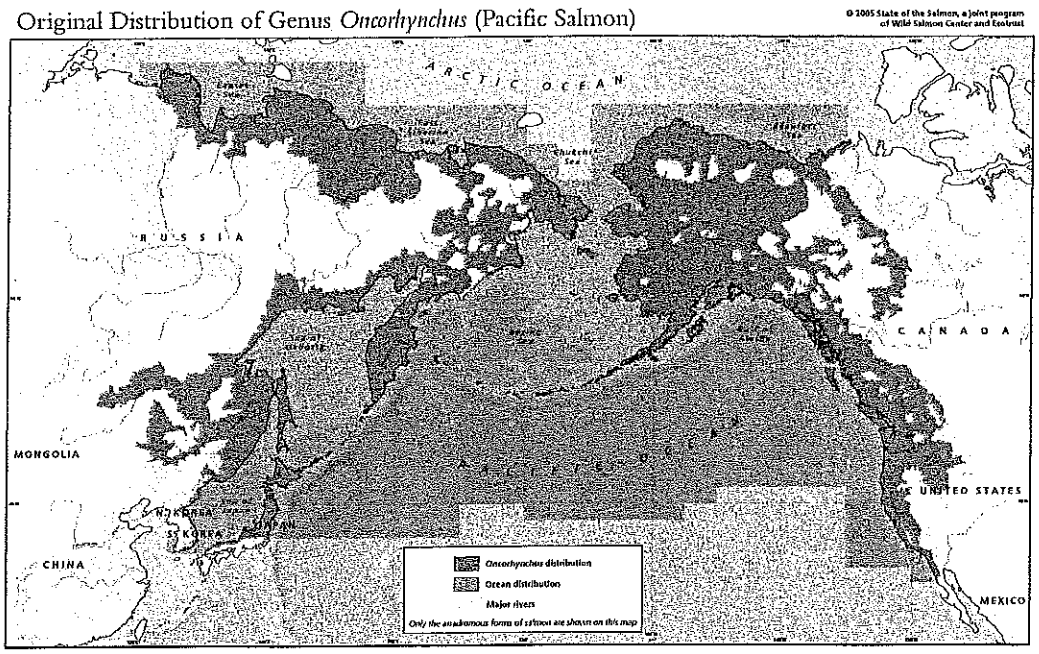


Figure 19. Original distribution of genus *Oncorhynchus*. (Source: Augerot 2005.)

charges playing on people's skepticism of government? Each of these questions, of course, has many answers, and the answers help explain the various political viewpoints that characterize the salmon policy debate.

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

> This is as much a human crisis as a salmon crisis. We must commit ourselves to restoring a balance between the interests of humans and of salmon, and must do so soon. We used to ask how we could save salmon without hurting people, but that compromised nature too often. The Endangered Species Act reversed the equation by blocking all development that threatened salmon, but that raised protests because the law ignored important human interests. Neither way has worked. (Taylor 1999)

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

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

While species (and stock) extinctions are not new in the region, it is the rate and scale that are the issue today and that the causes chiefly reflect human actions (Hartman et al. 2000). Salmon gene pools (stocks) that survived perhaps 10 millennia were eradicated within a few human generations. Only mighty events such as cataclysmic volcanic eruptions, colossal earthquakes, and severe climatic episodes such as droughts have previously caused salmon stock extinctions at the scale observed today in California and the Pacific Northwest.

“For the salmon technocrat, providing useful scientific information to assist decision makers takes place on a battlefield of intractable policy alternatives, complex and contentious scientific challenges, and confused roles.”

Is the ESA or SARA the appropriate type of policy tool to reverse the salmon decline? Was it envisioned by its proponents as a legal tool to address effectively such a complex ecological and social problem? Jack Ward Thomas (2000), former chief of the U.S. Forest Service and veteran of endangered species conflicts in the Pacific Northwest, concluded

> It does not seem possible that the Endangered Species Act was written, debated, and passed with any inkling that an issue of the magnitude of the Columbia salmon issue would arise. Magnified by the collateral issue of tribal fishing rights, this set of circumstances makes the spotted owl/old growth issue pale into relative simplicity and insignificance.

Salmon Policy

Even more than a new policy or management paradigm, any credible effort to restore wild salmon will require the active involvement of salmon technocrats (salmon scientists working within bureaucracies of various kinds). Technocrats do not *make* policy decisions, but because of their expertise, they provide information to those who do or those who implement policy decisions made by others. The appropriate role of salmon technocrats, however, is not often appreciated by the public nor by policy officials because providing information that is both policy-relevant and policy-neutral is often quite complicated (Smith et al. 1998; Lackey 1999b; Mills 2000).

For the salmon technocrat, providing useful scientific information to assist decision makers takes place on a battlefield of intractable policy alternatives, complex and contentious scientific challenges, and confused roles (Scarce 2000). There are forceful advocacy groups representing commercial, recreational, and Indian fishermen; agricultural activities; various elements of the transportation sector; forest and rangeland users; electrical generators and users; natural resource management agencies; various segments of the environmental movement; endangered species and animal rights proponents; and municipal and local governments. Further, the general public is only marginally aware of the implications and trade-offs of the various policy options, in part attributable to superficial reporting by much of the media (Black 1995). Technocrats themselves often have strong personal policy preferences and end up arguing for salmon-friendly policy positions.

What role salmon technocrats should play in salmon policy is a time-honored discussion topic among technocrats and policy advocates (Cooperrider 1996; Lackey 1999b; Salonius 1999; Mills 2000). Some advise staying out of the policy arena; others bluntly encourage all technocrats to argue for those public policies they prefer. In their conferences and publications, members of the American Fisheries Society regularly squabble over the proper role of members and the society relative to advocacy.

The public and policy makers have a right to expect salmon technocrats to be honest in providing scientific information, but though that may seem uncomplicated, such honesty is not necessarily a given. It is easy to avoid communicating the entire truth about the ecological consequences of various salmon policy decisions, and partial truths can unintentionally mislead people:

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

However, organizations typically direct their fisheries technocrats to work with their counterparts in other organizations to attempt to minimize the effect of human actions on salmon runs.

Policy debates often focus on narrow, relatively insignificant technical or scientific issues (Smith et al. 1998). For example, there are more than 250 major dams in the Columbia basin. Arguments over removal of a few dams, or the options for transporting smolts around dams, are interesting and controversial technical debates, but aquatic and terrestrial habitats *have* drastically changed in the Columbia basin over the past 150 years (Ligon et al. 1995; Kareiva et al. 2000). It is highly unlikely that *wild* salmon in substantial numbers (by historical standards) can be supported in such a highly modified environment. Society may choose to make the trade-offs necessary to maintain a relatively small number of wild salmon (current levels, perhaps), but technocrats should be bluntly realistic about the actual number of wild salmon that can be expected in the face of continuing watershed alteration that adversely affects salmon.

> "Being honest in providing scientific information also extends to full disclosure about scientific uncertainty and unknowns."

Being honest in providing scientific information also extends to full disclosure about scientific uncertainty and unknowns (Stephenson and Lane 1995). Presenting traditional statistical expressions of uncertainty is imperative but so is acknowledging the boundaries of scientific knowledge and explaining them in clear language. Predicting the ecological consequences of policy options is often little more than enlightened conjecture based on professional judgment, and that reality should be clearly conveyed to decision makers and the public (Scarce 2000).

Further, it is important for salmon technocrats to be honest and forthright about the assumptions used in developing and presenting scientifically based predictions (Mills 2000). Different predictions will emerge from the work of different scientists, depending on which, arguably valid, assumptions (e.g., anticipated human population growth or evolving life styles) are used in the technical analysis. Reasonable people differ on what are the most realistic assumptions, but the assumptions used will substantially determine the likelihood of success of most salmon policy options. It is wrong to hide these important assumptions from the users of the scientific information.

Few salmon technocrats intentionally misinterpret data, but what does the public *hear*? Much of the current salmon policy debate is over the extent to which freshwater habitat improvement and/or changes in oceanic conditions will stimulate a rejuvenation of wild salmon runs. Absent from the debate is the trajectory of human population growth in the United States in general and the Pacific Northwest in particular (Table 3). If the average annual growth rate for the past half century (1.9%) continues, the current population of approximately 10 million (Oregon, Washington, and Idaho) will swell to 65 million by 2100 (National Research

Table 3. Human population growth (in millions) from 1900 to 2100.

Area	1900	1950	2000	2050	2100
Oregon	0.4	1.5	3.3	4–8	5–24
Washington	0.5	2.4	5.8	7–15	9–41
Idaho	0.2	0.6	1.2	1.5–3.3	2–9
British Columbia	0.2	1.1	4.0	5–11	6–29
Total Pacific Northwest	1.3	5.6	14.3	18–39	23–103

Council 1996). Using the same growth rate for BC's human population, we might arguably anticipate the human population of the Pacific Northwest to expand by the year 2100 from its current 14 million to 85 million. California, of course, supports a large (compared with the Pacific Northwest) human population that will be much larger by 2100.

On a worldwide scale, human population growth rates appear to be decreasing (Lutz et al. 2001), but the human population in western North America will be much larger in 2100 than now (Hartman et al. 2000). Current U.S. and Canadian policies in fact support human population increase through relatively open immigration, even as the current reproductive rate of the American- and Canadian-born segment of the human population is below the population replacement level (Salonius 1999). To overlook the near certain reality of a much larger human population, and the corresponding implications for the future of salmon, is misleading the public (Salonius 1999; Hartman et al. 2000). Some overall improvement in salmon spawning habitat *may* be possible *if* the number of humans in the Pacific Northwest remained static, but habitat improvements will be increasingly more difficult to achieve if the human population increases several-fold by 2100.

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We know and understand the direct causes of the decline of wild salmon numbers. The trajectory remains downward. Nothing will change unless we address the core policy drivers of this trend: the rules of commerce, particularly market globalization; the increasing demand for natural resources, especially high-quality water; the unmentionable human population growth in the region; and individual and collective preferences regarding life style. Do we, as a society, understand the connections? Can we, and do we want to, turn the ship around?

Wild Salmon in Western North America: Forecasting the Most Likely Status in 2100

Robert T. Lackey, Denise H. Lach, and Sally L. Duncan

Introduction

Restoring wild salmon to the Pacific Northwest and California is one of the most vexing public policy problems facing the region (Wu et al. 2003). Billions of dollars have been spent, people's lifestyles have been affected negatively, and commercial activities altered, but still the prognosis for the long-term future of wild salmon has not appreciably changed.

The prognosis is problematic in spite of support for restoring salmon remaining a high priority policy goal, and a massive and far-reaching restoration effort continues. The recent and much improved salmon runs have been due primarily to changes that made ocean conditions more favorable to salmon; the improved runs do not appear to be the result of an effective or comprehensive restoration effort. As recently as 2004, a senior official of the federal agency in the United States responsible for recovering salmon observed that "there are no recovery plans in place for Pacific salmon" (Darm 2004).

The purpose of this chapter is to describe the most likely future for wild salmon given the best available current scientific information and the most likely future policy drivers. This chapter is *not* seeking to pass judgment on the desirability of current policies affecting salmon, nor to offer an opinion on what *should* be done, if anything, regarding the future of salmon in western North America.

Let us start with a simple statement of fact, one that, even for contrarian scientists, will likely engender little argument: in spite of abundant uncertainty about the relative importance of the various factors that drove the decline of wild salmon in California, Oregon, Washington, Idaho, and southern British Columbia, we essentially know and understand the direct causes of the long-term decline. The causes have been, and in many cases still are

- Intense commercial, recreational, and subsistence fishing and, especially since the 1990s, mixed stock fishing;
- Freshwater and estuarine habitat alteration due to urbanizing, farming, logging, and ranching;
- Dams built and operated for electricity generation, flood control, irrigation, and other purposes;

The views and opinions presented in this chapter are those of the authors and do not necessarily represent those of any organization.

- Water withdrawals for agricultural, municipal, or commercial requirements;
- Stream and river channel alteration, diking, and riparian corridor modifications;
- Hatchery and aquacultural production to supplement diminished runs or produce salmon for the retail market;
- Predation by marine mammals, birds, and other fish species, often exacerbated by unintentionally concentrating salmon or their predators;
- Competition, especially competition with exotic fish species, many of which are better adapted to the highly altered aquatic environments we now have in the region;
- Diseases and parasites;
- Pollutants from many sources; and
- Reduction in the annual replenishment of nutrients from decomposing, spawned-out salmon.

To no one's surprise, it is a long list and it spans the entire human enterprise. The causes are not many, but they interact in synergistic ways that are not well understood. We also know that ocean and climatic conditions greatly influence salmon abundance, even if we do not understand how this happens (Sharp 2003).

If we examine the history of the other three regions where salmon originally occurred, the Asian Far East, eastern North America, and Europe, we find a similar list of causal agents and the same ultimate result

Figure 1. Culverts often impede migrating salmon. While individual culverts do not typically completely block salmon, in aggregate they can have a significant negative effect on salmon runs. (Source: National Park Service U.S. Department of the Interior.)

Figure 2. Salmon are relatively easy to grow in captivity. Farmed and wild salmon now compete in a worldwide commodity market where the lowest cost producer usually wins out. Such commodity markets typically drive down the price of both farmed and wild salmon, often with adverse affects on fishermen. (Source: U.S. Army Corps of Engineers.)

(Hindar 2004; Nagata 2004; Whoriskey 2004). The specifics in each region differ, but the causal agents and resulting decline in salmon runs follow a markedly similar pattern.

Scientists and salmon advocates know much about the long-term trajectory for wild salmon, even if many do not like to acknowledge it publicly. Let us offer a second statement of fact: as we move into a new century in California and the Pacific Northwest, in spite of ups and downs, good years and bad years, favorable and unfavorable ocean conditions, and newspaper headlines proclaiming record runs, wild salmon have been on a 150-year downward trend and wild runs are now at very low levels.

Newspapers regularly trumpet the fact that runs of both wild and hatchery fish in the region are generally larger than the past several decades. Given shifting ocean and climatic conditions, the increases are not surprising. For accurate assessments of the future, we need to focus on long-term trends and not be distracted by short-term variations in background conditions.

In our area of focus, wild salmon are well on their way to attaining a status enjoyed by some of their notable brethren—wolves, condors, grizzlies, bison—wild animals that are unlikely to disappear entirely but struggle to hang on as remnants of once flourishing species in small portions of their original range.

But how can it be that the recovery prognosis is poor when the direct causes of the decline are reasonably well known and have been studied in great detail and the public is generally supportive of reversing the long-term downward trend?

The answer is captured in a simple policy statement of fact: effecting any change in the long-term downward trend of wild salmon is futile in the absence of shifts in the core policy drivers of this decline. It is the core policy drivers—the root causes—that have determined the status of wild salmon and will continue to determine that status through this century. Habitat alteration, dams, water withdrawals, fishing, hatcheries, and many more are simply the ways in which the core policy drivers have been expressed. Intended or not, by focusing on these highly visible, but *secondary* factors, government agencies have instituted a patchwork approach to salmon restoration that has distracted attention away from the less obvious, but fundamental core policy drivers.

What are these elusive drivers of the future status of wild salmon in western North America and especially in southern British Columbia southward—these agents of decline that must also be the agents of any recovery? We argue that there are four of them, which society can choose to influence, or not, over the 21st century.

The four crucial drivers play out within the context of changes in climate and changes in ocean conditions, two factors over which society has minimal control, at least in the near term. A 2,200-year reconstruction of Alaska sockeye salmon *Oncorhynchus nerka* abundance, for example, demonstrates that shifts in salmon productivity, lasting several centuries, have occurred without human influence (Finney et al. 2002). In a policy sense, these are largely givens, essential for assessing the relative importance of the more immediate causes of the decline, but pretty much beyond our control (Francis and Mantua 2003).

To the extent that human actions are effecting changes in ocean and climate patterns, we could conceivably do something about them, at least over the long term. Reducing greenhouse gas emissions may have

Figure 3. Competition for key natural resources, especially for high quality water, will continue and increase in severity through the 21st century. Use of water for salmon recovery is one of many competing priorities. (Source: Crissy Watkins.)

some effect on wild salmon by the end of this century, but climatic and ocean cycles are predominantly independent of human influences as the 500-year and longer reconstructions of salmon, sardine, and anchovy abundance clearly demonstrate (Sharp 2003).

The four core drivers are ones society *does* control and *could* change, so we will elaborate on each of these core policy drivers and defend why we think each must be at the crux of any serious effort to restore wild salmon in California and the Pacific Northwest.

Core Policy Driver #1—Rules of Commerce

The first core driver is an overarching one and, like everything else in salmon science and policy, difficult to rigorously quantify as to its influence on wild salmon. It is that the rules of commerce, especially trends in international commerce and trade as reflected in increased market globalization, tend to work against increasing the numbers of wild salmon. The drive for economic efficiency and low-cost production is a widely professed approach to trade, both within and between nations. Our purpose is not to argue for, or against, such a philosophy of commerce, but rather to note its impact on wild salmon.

Our assumption is that economic efficiency, and the corollary of free trade, will continue to be a dominant government policy through this century. One upshot of such an approach to commerce is that noneconomic values, such as preserving remnant wild salmon runs, tend not to be considered in decision making.

We obtain our computers from where they can be manufactured most cheaply. We move our automobile assembly plants to where they can produce cars most inexpensively. We tend to produce electricity in the most cost-effective way. We obtain most of our wheat where it can be grown most productively and consistently. We obtain wood products where they can be grown and harvested most efficiently and sold at the lowest price. We buy our salmon from Chile, Scotland, Norway, and British Columbia where they can be grown most cheaply. Most consumers appear to be unwilling to pay a premium for wild fish, nor are they willing to limit their salmon consumption to only a few months of the year.

“It is simplistic to hide behind the political rhetoric that bread, electricity, and automobiles can be produced just as cheaply in a salmon-friendly manner. They cannot.”

The benefits of public policies that favor economic efficiency are well recognized, but there are also consequences that, in our view, are not all that favorable to wild salmon. How much more are people willing to pay for bread, for electricity, or for automobiles produced in ways that will help restore wild salmon? It is simplistic to hide behind the political rhetoric that bread, electricity, and automobiles can be produced just as cheaply in a salmon-friendly manner. They cannot.

Global free trade also removes or at least dampens the negative feedback that might otherwise reduce adverse ecological effects because wealthy importers can transfer negative ecological effects to distant, unknown, and policy-irrelevant ecosystems (Rees 2004). As much as we might wish it otherwise, the affluence of the wealthy cannot be extended significantly without bearing the corresponding ecological consequences.

Whether that ecological cost is borne locally or in some distant land is a policy choice.

There are no scientifically “right” policy choices, but there are winners and there are losers associated with any choice, and that point is rarely made clear. As we observe consumer behavior today and project

Figure 4. Both high quality water and high quality spawning and rearing habitat are relatively scarce in western North America and will become even more so through the 21st century. (Source: Michal Zacharzewski.)

it into the future, most people seem unwilling to pay much more for what might be called salmon-friendly products. Society's collective preferences and values may change somewhat in response to salmon decline, but we do not see much indication of a wholesale transformation.

Core Policy Driver #2—Increasing Scarcity of Key Natural Resources

The second core driver is reflected in many of the past, current, and likely future *proximal* causes of the decline of wild salmon. It is that the demand for critical natural resources, especially for high quality water, will continue to be great (and increase) through this century.

Many rivers in California and the Pacific Northwest suffer from severe water shortages, especially of high quality water (Service 2004). Our seemingly insatiable demand for freshwater shows little sign of letting up, nor do we expect it to do so anytime soon. We are not arguing that allocating water for salmon is more important than allocating it for alternative uses, but as competition for scarce water continues and becomes more intense, how will advocates for wild salmon fare relative to advocates for competing priorities such as drinking, irrigation, manufacturing, generating electricity, recreation, or any of a thousand other water needs?

The continuing water war in the Klamath basin, along the California–Oregon border, gives us an indication of the future: farmers defying law enforcement agents and illegally opening locked valves and releasing water to irrigate their fields, streams choked with dying salmon caused by low water flows and poor water quality, and lawyers from various competing interest groups dueling in court over who will get how much water. Every faction in the battle is dissatisfied with the result, and each believes that its interest did not get a fair share of the water. Each faction then continues to plot ways to be more politically effective in next year's battle.

It is not just water that is becoming increasingly scarce. We demand land: somewhere to build a second home, a place to build the next Disneyland, a mountain watershed to accommodate the next Whistler Resort. Paper, wood, wheat, transportation, airports, and shopping centers—they all require scarce natural resources.

Figure 5. The number of humans in California, Oregon, Washington, Idaho, and Southern British Colombia will assuredly increase through this century, and the aggregate demand for chosen life styles will continue to constrain the abundance of wild salmon. (Source: U.S. Army Corps of Engineers.)

Life for individuals, as for society, is a series of trade-offs, choices, and selections between appealing alternatives. Policy choices are arguably zero-sum games. As key natural resources become scarcer through this century, it appears from current and likely future behavior that the individual and collective choices permitting long-term salmon abundance will become increasingly unacceptable to more and more people.

Core Policy Driver #3—Regional Human Population Levels

The third core driver that will determine the status of wild salmon through this century is that the number of humans in the region will continue to increase and their aggregate demands to support chosen life styles will constrain the abundance of wild salmon.

The most probable—indeed the most nearly certain—scenario for the human population trajectory through this century in this region is upward, substantially upward. As core drivers go, population growth is right up there at the top, but it is no longer popular to raise this issue. It has been a taboo subject in most circles. Environmental advocacy groups avoid it like the plague, even though it dwarfs most of the human behaviors they are trying to modify. Wild salmon advocacy groups likewise rarely mention population expansion, much less take policy positions based upon it.

Advocacy groups avoid raising it for some very good reasons. As a colleague told one of the authors when discussing what he might say before giving a talk on the subject of salmon restoration,

> You are absolutely right, most people already know it, and that's exactly why you should let it rest. Back off. You'll leave the proponents of wild salmon restoration depressed. Worse, you'll have the rest of the audience wondering why you are pontificating on the intuitively obvious. And you run the risk of being attacked as a racist, nativist, xenophobe, cultural imperialist, or, at the least, an economic elitist.

Undoubtedly, he was providing some very good advice. However, if society wishes to do anything meaningful about moving wild salmon off their current trajectory, then something must be done about the unrelenting growth in the number of humans in western North America (Langer et al. 2000). We are not arguing necessarily that we collectively *ought* to change any specific policy. But the simple and inescapable fact is that in our region of interest, the human population level we should realistically anticipate through the rest of the 21st century is a serious barrier to achieving any significant long-term wild salmon recovery. We therefore need to initiate candid conversations about the past and likely future growth of the region's human population as an important, even dominant, determinant of the future for wild salmon.

Many readers may wish it otherwise, but that is the way it appears. Yes, the latest demographic forecasts show a flattening of the world population growth rate toward the end of this century, and such may well be the case. For example, most countries in Western Europe have declining and aging human populations, and the attendant economic and social consequences are the focus of policy debates. For the Pacific Northwest, however, there is another story. It is largely one of immigration—continuing immigration to the Pacific Northwest from all directions.

“Life for individuals, as for society, is a series of trade-offs, choices, and selections between appealing alternatives. Policy choices are arguably zero-sum games.”

Washington, Oregon, Idaho, and British Columbia combined are home to 15 million humans. Assum-

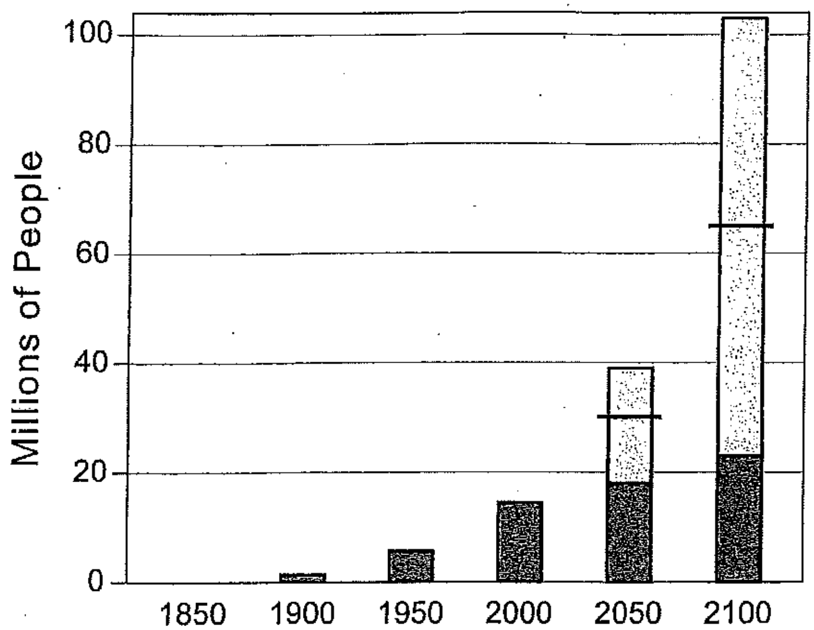

Figure 6. Forecasts of the human population level in the Pacific Northwest (Oregon, Washington, Idaho, and British Columbia) through this century are based on a number of assumptions, but *any* realistic set of assumptions generates a predicted large increase. (Source: Lackey 2003.)

ing a range of likely human reproductive rates, migration to the Pacific Northwest from elsewhere in Canada and the United States, and continuing immigration policy and patterns, by 2100, this region's human population will not be its present 15 million, but rather will be somewhere between 50 and 100 million, a quadrupling or more of the region's human population by the end of this century.

Visualize 50 or 100 million people in this region, and their demands for housing, schools, tennis courts, football stadiums, expressways, planes, trains, automobiles, Starbucks, McDonalds, Tim Hortons, WalMarts, electricity, drinking water, pipelines, marinas, computers, DVDs, 12-screen movie theaters, ski resorts, golf courses, weed-free lawns, big city hotels, and university conference centers.

Let us speculate about 2100 and the footprint of the human population for which we should plan.

Visualize Washington and southern British Columbia in 2100 with its metropolis of "Seavan," which mushroomed into a truly great city as smaller, discrete cities grew together. Seavan in 2100 stretches from Olympia in south Puget Sound northward through the once stand-alone cities of Tacoma and Seattle, and on to Vancouver, east to Hope, and west to cover the southern half of Vancouver Island. Rather than the 6 million people back in 2005, Seavan in 2100 rivals Mexico City or Tokyo in 2005 with its 24 million inhabitants.

Visualize Oregon and southern Washington in 2100 with "Portgene," the other great metropolis in the Pacific Northwest. Portgene extends from its southern suburbs of what was once the stand-alone city of Eugene northward to Portland and across the Columbia River to Vancouver, Washington and onward to sprawling suburbs to the east, west, and north. Remember back in 2005, when what was to eventually grow into Portgene had a population of a mere 3 million. In 2100, it is a whopping 12 million.

You do not have to visualize California. We already have such metropolises there today.

Regardless of whether our assessment turns out to be right or wrong, population issues are not easy ones to raise, much less discuss, without seeming to advocate curbing the birth rate. There are understandable, strategic reasons why the big environmental groups, most groups in fact, stay clear of population issues. But the current and expected population level in this region is at the core of any credible analysis of potential recovery strategies, or at least those strategies that are offered as serious attempts to actually recover wild salmon.

Core Policy Driver #4—Individual and Collective Preferences

Let us offer a fourth and final core policy driver—one that is very closely tied to the prior three: individual and collective preferences directly determine the future of wild salmon, and substantial and pervasive changes must take place in these preferences if the current long-term, downward trend in wild salmon abundance is to be reversed.

This core driver is perhaps the most obvious and arguably the most important. Among individuals working directly on salmon policy and science, it is easy to assume that salmon are near the top of the public's priorities. Just look at the polling results. Everyone supports salmon and especially wild salmon! But the fact is that salmon recovery is only one of many priorities that society professes to rank highly. It is difficult for us to conceive of this, but that is the situation out there. Even the first author's own children—and he's had over three decades to inculcate them—regularly admonish him, "Dad, get a life. Most people out here in the real world just don't care that much about restoring wild salmon. They have other things to worry about!"

It is society's collective behavior—not opinion polls, nor massive, impenetrable recovery plans but our individual and collective behavior—that provides the best indication of the relative priority of wild salmon as a public policy objective.

Let us offer an example. In western North America in 1991, the first salmon "distinct population segment" was listed under terms of the U.S. Endangered Species Act. With this listing of salmon as a protected species, the policy debate in Washington, Oregon, Idaho, and California shifted away from restoring salmon runs in order to support fishing, to protecting wild salmon runs from extinction. Note that these are two very different policy objectives. In 1991, protecting at-risk runs of wild salmon won out over providing fishing opportunities through supplemental stocking or other efforts to put fish on the hook or fish in the net. The residents of the western United States apparently made a choice.

"There are understandable, strategic reasons why the big environmental groups, most groups in fact, stay clear of population issues."

But did they? Jump ahead to 2001. Just a decade after the first salmon listing, a severe drought, combined with several electrical blackouts, provoked the Bonneville Power Administration to declare a power emergency, abandon previously agreed upon interagency salmon restoration commitments, and generate electricity using water reserved to help salmon migrate. In one of the most striking recent barometers of competing societal priorities, air conditioners and electricity took priority over both wild and hatchery-bred

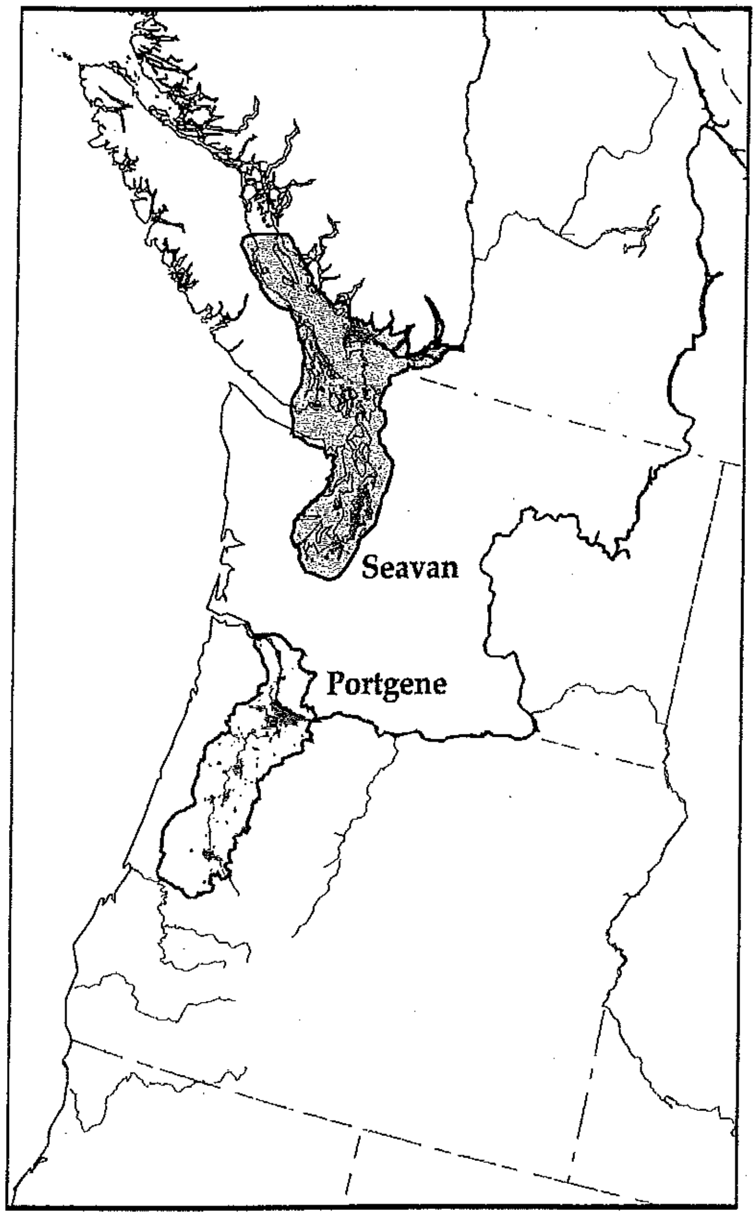

Figure 7. Extrapolating the past 50-year growth rate of the human population in the Pacific Northwest generates more than 100 million people in 2100. Under this scenario, cities growing together will result in two major urban centers, Seavan (Seattle and Vancouver, British Columbia merging) and Portgene (Portland and Eugene merging). (Source: Robert T. Lackey.)

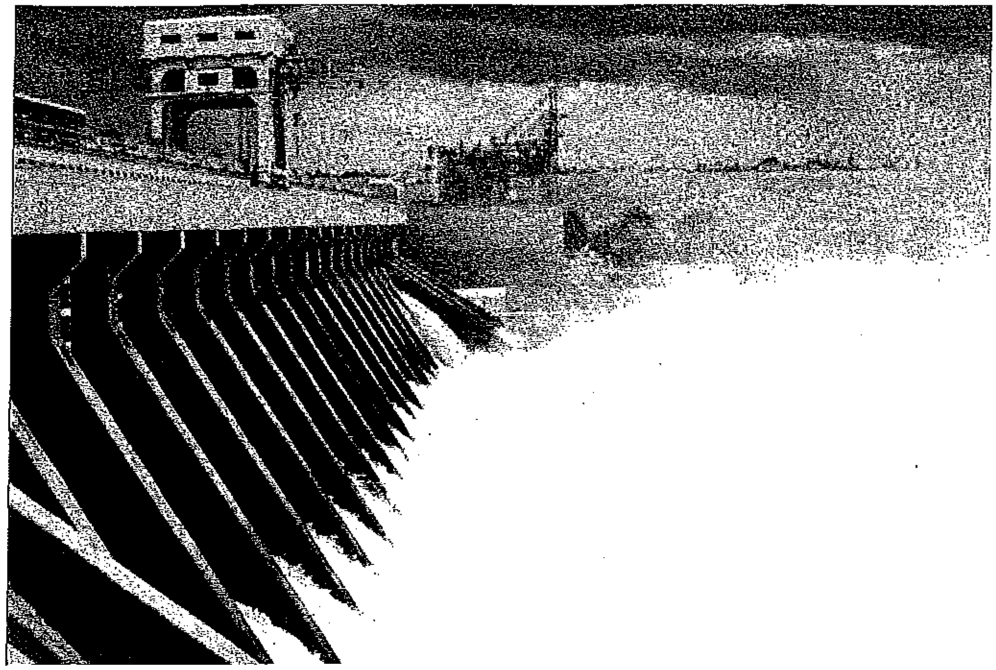

Figure 8. Dams and many other human enterprises produce substantial benefits for society but at great cost to wild salmon runs. How society balances such benefits and costs will be one key to the long-term viability of wild salmon in western North America. (Source: U.S. Army Corps of Engineers.)

salmon and with scant public opposition. No street protests. No legal challenges. No elected officials publicly pleading for salmon. No environmental groups blanketing the Internet with calls to mobilize fax machines in defense of salmon. What we witnessed instead was near complete silence.

Over the past 150 years, we have made plenty of these kinds of choices: contradictory, opposing, apparently inconsistent. They roughly reflect our collective and relative priority for wild salmon. These choices, which we continue to make, are trade-offs, and they are the real measure of the relative importance of salmon.

We are *not* cheerleading for wild salmon. Nor are we cheerleading for electricity, property rights, hatcheries, deeper shipping channels, or having fast food restaurants, donut shops, or coffee bistros on every corner. However, it is naive, if not downright disingenuous, to consider salmon recovery as anything but one potentially minor element in a constellation of competing wants, needs, and preferences, many of which are mutually exclusive. Whether we can ever change enough of our collective preferences to benefit wild salmon is a wide open question.

Conclusion

We have offered here a forecast of the 21st century from a salmon-centric perspective, a forecast driven by assessing four core drivers that largely will determine the future of wild salmon in California and the Pacific

Northwest. For those with a predilection to restoring wild salmon, it is not a cheerful message. For those readers who rank restoring wild salmon as just one of many societal priorities, this forecast also may not be uplifting because society will probably continue to spend billions of dollars in a restoration effort that will likely be only marginally successful over the long term.

By making a few different assumptions about the future, my 21st century salmon forecast would change, but in making the assumptions we did, we struggled to avoid succumbing either to unfounded pessimism or to baseless optimism. Nor should anyone fall into the trap of equating the well-being of wild salmon with overall environmental health from a human perspective. Good water quality is much easier to maintain than large runs of wild salmon. Just because runs of wild salmon in California and the Pacific Northwest almost assuredly will be reduced even further by 2100, it does not inevitably follow that these areas will have worse water quality.

“As for ecological forecasting, it should always be mixed with a strong dose of humility about the track record of salmon technocrats for predicting the future.”

As for ecological forecasting, it should always be mixed with a strong dose of humility about the track record of salmon technocrats for predicting the future. Ecological prediction requires scientific understanding but also some guesses about the likelihood of technological breakthroughs and sometimes drastic social change. Considering technological breakthroughs, who, for example, would have predicted that, within a half century, computers would have dropped from the size of a small house to the size of a deck of cards, yet be many times more powerful? Or, on the social side, who would have predicted that by the beginning of the 21st century, France would have more Muslims than practicing Christians? Predicting the future is, indeed, risky.

We will end this chapter with a prediction, a challenge to wild salmon advocates, and also an opportunity: any policy or plan targeted to restore wild salmon runs must at least implicitly respond to these four core drivers or that plan will fail. It will be added to an already long list of prior, noble, earnest, and failed restoration attempts.

Look down the road to the end of this century, to 2100, less than 10 decades away, only a few dozen generations of salmon beyond today's runs, a few human generations, just two or three ocean regime shifts from now, to a time when this region's human population will not be its present 15 million but rather will be somewhere between 50 and 100 million. However, there are still salmon recovery options that are likely to be ecologically viable and probably socially acceptable, but the more time passes, the more the range of options will narrow.

For professional fisheries experts, for fisheries scientists, technocrats, analysts, and managers, for those who are involved with salmon issues in California and the Pacific Northwest, it is a time neither for crippling pessimism nor for delusional optimism. Rather, we contend it is a time for uncompromising ecological and social realism, leading to forthright policy analysis.

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