PROFILE

Sailing the Shoals of Adaptive Management: The Case of Salmon in the Pacific Northwest

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ABSTRACT / Emerging ecosystem science builds on adaptive management as an approach to dealing with salmon problems in the Pacific Northwest. Adaptive management brings scientific and democratic processes together. However, managers, the public, resource users, and scientists differ in their views on the causes of salmon decline. Managers emphasize habitat loss and over-harvest as the primary causes; commercial fishers point to habitat loss, management practices, and predators; and the public gives greatest weight to water pollution and ocean drift nets. Scientific studies of salmon often produce results that seem contradictory or unclear to the public. For adaptive management to be effective, scientists' and the public need to better understand one another's perspectives.

Adaptive management merges science with democratic processes in order to learn from experience. This approach is widely applied to Pacific Northwest forestry and fishery problems (Holling 1978, Walters 1986, NPPC 1987, FEMAT 1993, Lee 1993, Bormann and others 1994, Gunderson and others 1995). Application of adaptive management is a continuous process of planning, acting, monitoring, and evaluating. In adapative management, human and ecological changes to ecosystems are treated as experiments and the results used to learn and adjust with each step.

The Northwest Power Planning Council (NPPC) has a major role in dealing with the Northwest's salmon problems. Kai Lee, a member of the NPPC from 1984 to 1987, introduced adapative management to the Council (Mahar 1990). Lee (1993) uses a metaphor of "compass and gyroscope" for integrating science and democracy, in which science "linked to human purpose is a compass, a way to gauge directions when sailing beyond the maps;" and democracy, "a way to maintain our bearing through turbulent seas," is the gyroscope (Lee 1993, p. 6). The compass, grounded in the scientific method, warns when the direction is off course, while the bounded conflict of the democratic process lends stability when humans encounter turbulence in their relations with nature.

In the Northwest salmon crisis, science is experiencing a paradigm shift (Kuhn 1970). The scientific compass often points in more than one true direction, and the public gyroscope tilts precariously with political turbulence. Furthermore, scientists and the public vary widely in their understanding of the causes for salmon decline, and what actions should be taken to reverse it. This creates a dynamic situation filled with complexity, change, and uncertainty.

KEY WORDS: Perception; Fishery management; Salmon; Pacific Northwest; Science

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Background

The life cycle of salmon (*Oncorhynchus* spp.) touches every interest in the Pacific Northwest—from ocean fisheries to mining industries and from the "silicon" forests of the Puget–Willamette corridor to foresty, farming, ranching, agriculture, and recreation in the interior Columbia basin. Salmon begin their life cycle in inland streams, where their environment is influenced by farming, ranching, large irrigation projects, and a multitude of other factors. As young salmon migrate downstream, they pass dams built for hydropower, flood control, navitation, water supply, and recreation. Wastewater from cities pollutes streams, and loss of stream cover and heated water discharges raise temperatures. Pollution, dredging, and filling of estuaries degrade habitat, and exotic species, introduced to fulfill various human objectives, compete with salmon. As salmon mature and reach catchable size, they face a gauntlet of Alaskan, Canadian, and local fisheries. Commercial and recreational fishing reduce the returning population, which must again negotiate the riverine hazards to reach their spawning grounds.

Numerous studies explain the decline of salmon and what should be done to reverse it (NPPC 1986, 1987, 1992, Nehlsen and others 1991, Nichelson and others 1992, Palmisano and others 1993, SRSRT 1993, Botkin and others 1995, Huntington and others 1996, Ridlington and Cone 1996, ISG 1996, NRC 1996, USDI 1996, Stouder and others 1997). Further, many writers attempt to assess the problem (Mighetto and Ebel 1994, Cone 1995, Dietrich 1995, Peterson 1995, White 1995), and pollsters and social scientists seek to learn where the public stands (Brunson and Steel 1994, Martilla and Kiley 1994, Steel and others 1994, Rudzitis and others 1995, Smith and others 1997). The result is a cacophony of voices and little consensus regarding the problems and their solutions. The causes of salmon decline range from the dozens described by Botkin and others (1995, p. 152) to the ''four Hs''—hydro, habitat, hatcheries, and harvest—used by the NPPC in its *Strategy for Salmon* (1992). Some say, ''Let science save salmon'' (Landauer 1993) while other science writers ask, ''[W]hat sort of public policy is best when scientific research is incomplete and inconclusive?'' (Cone 1992).

Growing concern for wild and naturally spawning salmon has led to Endangered Species Act listings. The Shoshone-Bannock tribes petitioned the listing of Snake River sockeye in 1990. Then came a petition on lower Columbia coho, Snake River fall chinook, cutthroat trout, and coastal coho. In 1991, the Endangered Fisheries Committee of the American Fisheries Society published its findings that 214 stocks of naturally spawning were depleted. This study, suggested by Kai Lee when he was on the NPPC (Cone 1995, p. 35), showed that nearly half of these stocks were judged to be at high risk of extinction (Nehlsen and others, 1991). Additional listings continued throughout the Pacific Northwest during the 1990s.

Competing Concepts

Because of the significance of the Northwest's salmon problems leading society toward a solution is tremendously compelling. Groups of scientists convened by the NPPC, National Research Council (NRC), National Marine Fisheries Service, Columbia River treaty tribes, Forest Service and Bureau of Land Management, regional states, scientific societies, and nongovernmental organizations have each tried to identify the scientific principles for dealing with this problem. Each new study introduces a key concept that anchors its paradigm. Paradigms for management of the Columbia basin and other rivers have centered on such concepts as ''pristine,'' ''virtual,'' ''normative,'' ''ecosystem,'' ''recovered,'' ''restored,'' and ''rehabilitated.'' These approaches overlap somewhat, but each stresses a unique vision for guiding management.

- Some environmentalists and biologists favor a return to ''pristine'' conditions, akin to those found by European settlers in the region. They regard precontact ecology as an ideal condition (Robbins and Wolf 1995).
- The ''virtual'' river arises from Richard White's critique of river development in which he calls the Columbia ''an organic machine, a virtual river.'' He wants to move beyond human control of the river to a realization that the Columbia is '' . . .at once our creation and retains a life of its own beyond our control'' (White 1995, p. 109).
- The Independent Scientific Group of the Northwest Power Planning Council (ISG) developed the concept of the ''normative'' river, a river that retains many, but not all, of the processes that occur under natural conditions (Collette 1996; ISG 1996). The normative concept recognizes that the river cannot be returned to some pristine condition, but that some of the processes of a natural river are advantageous to salmon and humans.
- The Interior Columbia Basin Ecosystem Management Project, sponsored by the US Forest Services (FS) and Bureau of Land Management (BLM), based their forest health environmental impact assessment on ''ecosystem'' principles (USDI 1996, p 18). An ecosystem is comprised of all living things in a given area (including humans), in addition to atmosphere, land, and water. The FS and BLM are managing most of the remaining high-quality habitat to limit the decline of fish stocks (USDI 1996, p. 47).
- The Endangered Species Act (ESA) requires a ''recovered'' river, mandating a recovery plan for species listed as threatened or endangered. The National Marine Fisheries Service (NMFS) ruled in 1991 that there was a probable cause for listing petitioned salmon stocks as a result of evidence

submitted by the Shoshone-Bannock tribes of the Fort Hall Reservation and several environmental and professional groups. The Snake River Salmon Recovery Team (SRSRT 1993) developed a plan for recovery of Snake River sockeye (*O. nerka*), and for spring, summer, and fall chinook (*O. tsawytscha*).

- The ''restored'' river reflects the Columbia River tribes' restoration plan, *Wy-Kan-Ush-Mi Wa-Kish-Wit* (CRITFC 1995, 1996), which focuses on returning the spirit of the salmon to the rivers of the Pacific Northwest through a blend of science and traditional tribal values. According to Phil Roger, the tribal plan is '' . . .consistent with scientific principles, tribal culture and laws, and feasible in terms of the regions' economic and political realities'' (Berg 1995, p. 15). The plan uses the salmon's life cycle as its organizing framework.
- The National Research Council (NRC) convened a scientific committee on Protection and Management of Pacific Northwest Anadromous Salmonids, composed of 15 specialists, to assess stocks, analyze causes of decline, and recommend options for management. The committee said the focus should be on ''rehabilitation, . . . a process of human intervention to modify degraded ecosystems and habitats to make it possible for natural processes of reproduction and production to take place'' (NRC 1996, p. 27).

These are some of the paradigms offered by scientific groups, each of which is advancing an intellectual approach that they believe will improve conditions for salmon. While scientists argue that these efforts show convergence to a common identification of problems and prescriptions, those not familiar with the emerging language of ecosystem science see each approach as different.

Although each of the teams emphasizes the importance of functional ecosystem processes, each offers different suggestions for dealing with salmon problems. On the question of drawdowns, the tribes expect that the dams will eventually be removed altogether. They believe economic calculations should be made with salmon as the first priority, rather than giving priority to dams and their services. Before the dams, the Columbia River produced salmon, not hydroelectric power.

In contrast, the Snake River Salmon Recovery Team (SRSRT 1993, pp. VIII 8–10) recommends obtaining additional water for augmenting river flows and experimenting with the effectiveness of drawdowns to the spillway crest. The NRC (1996, pp. 366–367) says in regard to flow problems: ''Secure water as need is demonstrated . . . from water-consumers by subsidizing water conservation by buyout of water rights . . . and by improved reservoir-system operation. . . '' The ISG (1996, p. 268) says, however, ''permanent drawdown to expose and revitalize drowned alluvial reaches to create riverine habitat for salmonids similar to the Hanford Reach is warranted in view of our normative river concept.'' The ISG suggestion complicates the drawdown picture by emphasizing that variability in river heights is important for creating food sources for downstream migrating salmon.

Regarding transportation, the tribes advocate in-river survival over transportation. The ISG (1996, p. 329) says that certain salmon ''life history types'' benefit from transportation, but that this is not sufficient to overcome '' . . . habitat loss, hydropower operations and other sources of mortality.'' They hold that adopting the normative river concept may make transportion unnecessary. The SRSRT favors transportation and the NRC accepts transportation with experimental controls.

Evaluating hatcheries, the tribes propose, ''Use supplementation to help rebuild salmon populations at high risk of extinction. Use supplementation to reintroduce salmon to watersheds from which they have been eliminated'' (CRITFC 1996). The ISG (1996, p. 403) says, ''Use of artificial propagation to restore depleted populations should be preceded by an assessment of risks. . . '' The SRSRT (1993, pp. VI-ii) recommends, ''Improve hatchery contributions to recovery of natural chinook stocks through supplementation and captive brood stock programs.'' According to the NRC (1996, p. 371), hatcheries ''should be used only when they will not cause harm to natural populations.''

An Erratic Gyroscope

The competing concepts show scientists suggesting a variety of compass headings. Where is the public as gyroscope? Since 1992, three studies have investigated manager, user, and public perceptions of the salmon problem. These studies were conducted at different times, and each had a specific purpose. The studies suggest that the public, users, managers, and scientists do not see the causes of salmon decline in the same way.

Managers and Fishermen

In the first study, undertaken in 1992, Mrakovcich (1993) compared the perception of 36 managers and 47 fishermen, hypothesizing that participation at meetings where information on salmon was exchanged would bring managers and fisherman closer in their views. Mrakovcich compared fishermen who did and did not attend meetings where decisions about the salmon fishery were made, with managers who did and did not participate in decision making. Joint participation in meetings about salmon management decisions did not seem to change the views of either managers or fisher-

Table 1. Percent of fishermen and managers giving a cause as most and least significant

	Managers		Fishermen	
	Most	Least	Most	Least
Habitat loss	48	0	23	2
Dams	31	0	30	2
Poor management	5	0	23	8
Logging practices	5	0	2	0
Overharvest	5	5	0	35
Hatchery practices	0	0	2	2
Drought	2	0	2	4
Treaty–Indian harvest	0	3	0	18
Adverse ocean conditions	2	16	2	18
Marine mammals	0	27	4	8
Driftnet fisheries	2	49	12	2

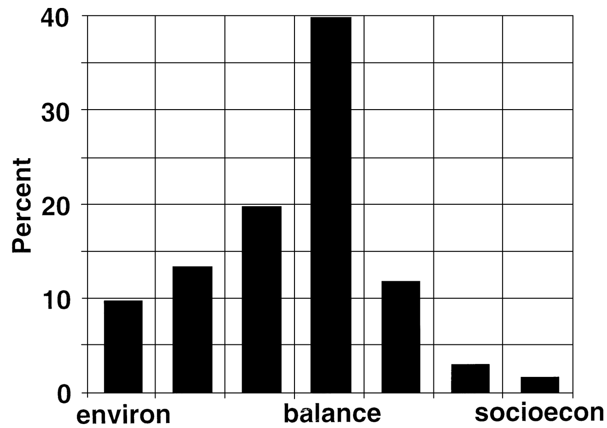

Figure 1. Percent giving highest priority to environmental versus socioeconomic considerations. The middle is the percent wanting to balance environmental and socioeconomic considerations equally.

men, and the two groups differed significantly in their perspectives about the causes of the salmon decline.

Mrakovcich interviewed nearly a complete sample of managers involved with the Pacific Fishery Management Council's (PFMC) salmon planning process, as well as State of Oregon salmon managers. Fishermen were chosen from a local port, and those involved in the management process were selected from the PFMC salmon advisory committee. Mrakovcich found that fishermen prioritized several of the most and least significant problems differently than managers (Table 1). Both agreed on the importance of habitat, but they differed on the influence of marine mammals, drift nets, management, and over-harvest. Neither fishermen nor managers saw ocean conditions as having a very significant impact.

The Public

In 1994, Steel surveyed a representative sample of 1912 Northwest citizens about their views on the causes of the salmon problem. The survey approach followed Dillman's (1978) ''total design method.'' Surveys were mailed to a random sample of Washington, Oregon, and California households south of the Canadian border, west of the Cascades, and north of San Francisco. The response rate was 50%.

Steel explored why some people place a higher priority on salmon over socioeconomic consequences, and why othes prioritize socioeconomic considerations over the consequences to salmon, by asking respondents to rank themselves on a scale ranging from favoring salmon recovery even if it is economically costly, to giving economic factors greatest weight. The distribution of responses is given in Figure 1. Forty percent of the public wanted salmon and socioeconomics to be given equal priority. The largest number, 43%, leaned toward giving salmon greater priority, while 17% leaned toward socioeconomic priorities. Ten percent strongly favored salmon while 2% strongly favored socioeconomics.

To assess public perceptions of the threats to salmon, 11 factors associated with salmon degradation were provided and respondents were asked to rate the factors from ''no threat'' (1) to a ''definite threat'' (4). The public ranked water pollution (3.2) and ocean drift nets (3.1) as the biggest threats and gave predators (2.0) and ocean conditions (2.0) the lowest rankings. The causes ranked highest by the public differed from those of managers, particularly in regard to drift nets.

During the early 1990s, drift netting was much in the news, and this may have affected the public's perception of the problem. In 1991, the United States imposed sanctions on Taiwan and South Korea for their continued use of drift nets. In 1992, Japan announced that it was ending all high-seas drift netting for salmon; the United Nations called for a global moratorium on pelagic drift netting; and the United States Congress enacted the High Seas Driftnet Fisheries Enforcement Act. At the time, Korea, Japanese, and Taiwanese vessels ostensibly fishing for squid (*Ommastrephes bartrami*) were also taking significant amounts of salmon (NRC 1996, p. 263). In 1992, US investigators uncovered a Japanese ''salmon laundering'' conspiracy that accounted for illegal catches of 2.64 million pounds of North Pacific salmon, and in 1993, the US Coast Guard discovered four vessels illegally drift netting in the North Pacific (Paul 1994). One Taiwanese boat was found illegally drift netting in 1996. Managers interviewed by Mrakovcich most frequently cited drift nets as the least significant cause of decline, with predators and ocean conditions second and third least significant.

To compare group differences, respondents were asked their age, gender, level of educational attainment, self-reported level of knowledge about salmon, participation in environmental organizations, ideological orientation, and support for the ''new environmental paradigm'' (NEP). As defined by Brown and Harris (1992), people who subscribe to NEP value natural amenities, biocentrism, environmental protection over commodity outputs, and less intensive resource management. They think in long time frames, believe the earth has a carrying capacity, and want consultative, participatory, and decentralized democracy.

The causes of the salmon decline were combined into a ''salmon threat scale.'' Those perceiving higher levels of threat were compared with those who did not. The average level of threat was 2.6 on a scale of 1 to 5. Younger people, women, the well-educated, those who belonged to environmental organizations, those who considered themselves well-informed, liberals, and NEP supporters were most likely to perceive threats to salmon (Table 2).

Table 2. Sociodemographic and value correlates of postulated threats to salmon

	Level of threat (%)			
	High	Medium	Low	
Age (yr) cohort				
18–34	47	27	26	$\chi^2 = 43.5$
35–54	40	21	39	$df = 6$
55–64	40	17	43	$P < 0.001$
65 plus	23	34	43	
Gender				
Female	47	26	27	$\chi^2 = 6.5$
Male	39	32	29	$df = 2$
				$P < 0.039$
Education				
High school	22	40	38	$\chi^2 = 49.9$
Some college	34	44	22	$df = 6$
College	43	23	34	$P < 0.001$
Environmentalist				
Environmentalist	49	40	11	$\chi^2 = 25.8$
Other	36	28	35	$df = 2$
				$P < 0.001$
Self-assessed informedness				
Not informed	32	30	38	$\chi^2 = 40.4$
Mod. informed	48	30	22	$df = 4$
Very informed	61	21	18	$P < 0.001$
Ideology				
Liberal	49	25	27	$\chi^2 = 10.7$
Moderate	38	29	33	$df = 4$
Conservative	33	33	34	$P < 0.031$
New environmental paradigm				
High support	48	27	24	$\chi^2 = 22.1$
Mod. support	32	31	37	$df = 4$
Low support	33	31	36	$P < 0.001$

Trollers and Gillnetters

Gilden and Smith (1996a, b) studied commercial gillnetters' and trollers' attitudes about the salmon problem. In the fall of 1995, 53% ($N = 353$) of gillnetters responded to a 100% sample of 666 Oregon and coastal Washington licensees. Then, in the spring of 1996, a 20% sample of 1988 and 1994 Oregon salmon troll permit holders were surveyed. This mail survey received a 54% response rate ($N = 357$).

Gilden and Smith focused on how fishing families were coping with changes in the salmon fishery and how federal salmon disaster relief programs had worked. They found that many gillnetters and trollers were coping with lost opportunities in salmon fishing by relying more on other fisheries like crab (*Cancer magister*), albacore (*Thunnus alaunga*), long-lining, and fishing in Alaska. Many took jobs outside of fishing. A number of retired people and part-time fishermen who entered salmon fishing to supplement their incomes left the fishery. Fishermen were angry with the government and managers, whom they felt had not considered their interests when making policy and rules. Beginning in 1994, federal disaster relief programs helped many salmon fishermen. After an initial broad unemployment insurance program, subsequent years resulted in fewer people being helped, and many fishermen felt that society still owed them for the losses they had suffered.

Salmon gillnetters and trollers were asked if they agreed or disagreed with statements about the factors most important to the future of salmon. The statements were chosen to reflect issues important to each group, so not all statements were asked of both groups.

Between Mrakovcich's 1992 study and 1996, the fishermen maintained generally the same priorities. Both gillnetters and trollers placed the highest priority on restoring habitat and increasing hatchery production (Table 3). The most significant difference was the rise in concern over marine mammals. In 1976, policy toward marine mammals changed significantly with the passage of the Marine Mammal Protection Act, which was very successful in protecting California sea lions (*Zalophus californianus*) and seals (*Phoca vitulina*), both of whom prey on salmon. In 1992, marine mammals were not highly ranked as a cause of decline. By 1996, they were believed to be nearly as threatening as habitat loss and dams (Table 3).

While foreign fishing was less of an issue in 1996, fishermen blamed large domestic freezer trawlers for reducing salmon stocks. The very large decline in salmon stocks also could be part of the reason for

Table 3. Comparison of troller and gillnetter perceptions of salmon problem[a]

Item	Gillnetters	Trollers
Modify dams	3.8	3.4
Remove predators	3.7	3.4
Increase hatchery production	3.6	3.7
Consider fishermen's views more	na	3.4
Protect endangered species	2.9	2.6
Develop terminal fisheries	2.9	na
Maintain genetic diversity	2.9	2.6
Remove dams	2.7	2.2
Prevent mixed stock fishing	2.0	na

[a]Based on a scale where 4.0 is strongly agree, 0.0 is strongly disagree.

increased concern about trawlers among fishermen. With a very small fish population, any competitor becomes a greater threat.

Contrary to public and managers' perceptions, gillnetters and trollers felt that predation by marine mammals and birds was a much greater problem than is generally accounted for in scientific analyses. Gillnetters and trollers agreed with managers on the importance of habitat protection, but disagreed with many scientists and managers on the issue of hatchery production. Many scientists feel that hatcheries are more a part of the problem than the solution, while fishermen see them as a way to compensate for lost salmon stocks.

Where Is "True North?"

Managers, fishers, and the public all look to science to provide clearer understanding of the salmon situation, and hundreds of million of dollars have been spent studying salmon. During the 1990s, research received over $70 million per year from federal, state, and private sources for salmon studies (NRC 1996, p. 349).

By expecting the scientific compass to point toward clear directions, people fail to recognize the true nature of science. Science is more about identifying directions that will not work than setting a true direction; it is better at disproving cherished ideas than proving that new methods will work.

Northwest ecosystems are highly complex, constantly evolving, and responding to continually varying ecological conditions. They are affected by the cumulative effects of many small actions, as well as large-scale, global ecological and economic processes. Not only is it difficult to know scientifically how all of these complexities interact; scientific findings are often published in technical forums and are difficult to translate into everyday language for public understanding. People become confused when studies of similar topics yield what appear to be different scientific results. Unless something is ''new,'' the media loses interest in reporting scientific conclusions. In addition, scientists are employed by competing interest groups, and point out weaknesses in each other's findings. These ''realities'' of doing science lower public confidence in science as a definitive source of information.

Conflicting Scientific Headings

The volume of scientific studies on salmon is huge. We do not seek to cover it, but instead to show that the scientific compass often does not show a clear direction. A few examples regarding hatcheries, predators, and ocean conditions highlight these problems. Often organizations structure research agendas that attempt to validate, rather than test, hypotheses.

Hatcheries

Until the 1980s, hatcheries were used to mitigate habitat lost due to dams or other human activities. In the 1960s and 1970s, coho (*O. kisutch*) hatcheries appeared to improve the fishery markedly—the more salmon produced, the more returns for fishing. Scientific studies increasingly point to problems caused by reliance on hatcheries. First, hatchery stocks can sustain higher harvest rates than naturally spawning salmon. With hatchery fish present, fishery managers set the harvest rates too high, without taking into account their effect on naturally spawning stocks (NRC 1996, pp. 281-283). This results in overfishing the naturally spawning runs. Hatchery fish live in a sheltered environment and do not develop some of the survival traits of naturally spawning salmon (Suboski and Templeton 1989, Mesa 1991). In addition, economic efficiency goals mean that hatcheries tend to select for stocks that are easiest and cheapest to obtain. Fish are taken at the peak of the run, when more are available and collection is faster and less expensive. This practice, combined with the selection of only certain stocks, results in less genetic variability (Busack and Currens 1995). One of the adaptive strategies of salmon is to stray to new habitats, leading to mixing of hatchery and naturally spawning stocks. The lower genetic diversity of hatchery fish reduces that of the naturally spawning ones, and hatchery stocks may infect naturally spawning populations when the stocks mix (Steward and Bjornn 1990).

In 1978, the Oregon Fish and Wildlife Commission adopted a ''wild fish policy.'' With this policy came greater concern for preserving native fishes and natural stocks. The wild fish policy questioned the assumption that lost stocks could be replaced by captive breeding in hatcheries. Concern for genetic diversity also changed the Northwest Power Planning Council's program from one emphasizing ''supplementation,'' the process of augmenting natural production by seeding natural spawners with fish bred and cultured in hatcheries, to greater consideration for retaining genetic diversity and naturally spawning stocks.

Biologists disagree on the effectiveness of hatcheries. Some argue that hatcheries can never work for the long-term (Hilborn 1992); while others see a modified role for them (CRITFC 1995, NRC 1996).

Predators

In the 1970s, the marine mammal population was very low and the quantity of salmon for harvest was much larger (Beach and others 1985, Olesiuk and others 1990). By the early 1990s, the reverse was true. Palmisano and others (1993) estimate that marine mammals account for 16% of the total catch, while Park (1993) claims that marine mammals and birds may take more salmon by weight than are caught by fishermen. Other scientists do not see the significance of marine mammals this way; in 1996 the NRC reported, ''Predation by marine mammals is probably not a major factor in the current decline of salmon in general'' (NRC 1996, p. 43).

Ocean Conditions

Ocean conditions are receiving much scientific attention. Associations between temperature and catch rates have been discussed for 40 years (Bell and Puter 1958), but not until the 1980s did systematic studies start to document the effects of ocean conditions on salmon. Prior to the 1980s, most science focused on the early riverine life history of salmon (Bottom and others 1996) as an attempt to improve hatchery production. The approach was agricultural: if early salmon survival could be improved, more adults would be available for harvest.

Pearcy (1992) reports that the early stages of ocean migration, when slight changes in water temperature result in much higher death rates, are the most critical mortality period for young salmon. Water temperature also correlates with the presence of predators. Other studies by Beamish (1993), Francis (1993), Greenland (1994), Beamish and Bouillon (1995), and Welch (1995) highlight the effect of ocean conditions. The ocean influences the overall temperature and food supply; changes inland precipitation and the probability of extreme events, such as floods and forest fires; and regulates the number of marine predators. A very large percentage of the coho entering the ocean in 1994, 1995, and 1997 were consumed by unusually northerly schools of mackerel (*Scomber japonicus*), and high ocean water temperatures were lethal to young coho.

Nevertheless, Botkin and others' (1995) list ''unfavorable ocean conditions'' as ''potentially important factor'' after the major factors of ''agriculture, dams, drought, fish harvest, forestry, and urbanization.''

Emerging Gyroscope?

Some elements of the ''public as gyroscope'' are beginning to emerge. Statements about the preservation of riparian habitat have received the highest positive response in most surveys. On three surveys, the statement ''Greater protection should be given to fish and wildlife habitats on public lands'' received the highest percentage of those who agreed and strongly agreed with the statement (Steel and others 1994, Brunson and Steel 1994, Shindler and others 1995). A University of Idaho study found that protecting water and watersheds ranked higher than recreation, wilderness, and ecosystems (Rudzitis and others 1995).

Smith and Steel (1997) found that younger, well-educated, well-informed, female, environmentally oriented, and more liberal people were more likely to give salmon highest priority (Table 4). They found support for environmental protection and a desire to balance economic and environmental goals.

Surveys find the public willing to pay for the improvement of salmon runs. In a 1994 Washington State poll, Columbia Basin Public Utility Districts found that two thirds of the respondents were willing to accept up to a $5 per month increase in their electric bill in order to improve salmon runs (Martilla and Kiley 1994). A 1996 Washington Department of Fisheries and Wildlife (WDFW 1997) survey found 75% of households willing to pay $8 per month if the money was earmarked for fish and wildlife. An Oregon Progress Board study found a willingness to pay an average of $4 per month, with 91% saying it was very or somewhat important to improve salmon runs.

Surveys merely reflect people's opinions on questions designed by researchers and do not equal participatory democracy. The Northwest Power Planning Council (NPPC), along with federal and state agencies, solicit public participation by providing vast quantities of information to inform and encourage public involvement. Public affairs represents 14% of the 1997 NPPC (1996) budget of $8 million, and includes administration (one third of the public affairs budget), publications, media relations, public meetings, and public involvement.

Many federal and state agencies aggressively pursue public involvement, but when asked the public says it

Table 4. Sociodemographic and value correlates of salmon tradeoffs

	Priority (%)			
	Salmon highest	Salmon and economy equal	Economy highest	
Age (yr) cohort				
18–34	60	27	12	$\chi^2 = 43.4$
35–54	37	40	22	$df = 6$
55–64	44	44	12	$P < 0.001$
65 plus	36	49	15	
Gender				
Female	47	39	14	$\chi^2 = 5.2$
Male	40	41	19	$df = 2$
				$P < 0.07$
Education				
High school	39	50	11	$\chi^2 = 16.9$
Some college	47	36	17	$df = 6$
College	48	32	20	$P < 0.009$
Environmentalist				
Environmentalist	57	36	7	$\chi^2 = 13.2$
Other	41	40	18	$df = 2$
				$P < 0.001$
Self-assessed informedness				
Not informed	41	39	20	$\chi^2 = 9.1$
Mod. informed	43	42	15	$df = 4$
Very informed	55	27	17	$P < 0.05$
Ideology				
Liberal	63	30	7	$\chi^2 = 54.8$
Moderate	40	47	13	$df = 4$
Conservative	38	37	26	$P < 0.001$
New environmental paradigm				
High support	60	36	4	$\chi^2 = 123.1$
Mod. support	39	45	17	$df = 4$
Low support	27	38	36	$P < 0.001$

does not feel involved and reports that it lacks trust in scientists and government agencies. In a national survey conducted in 1992, Steel and Brunson (1993) found that 42% of national and 46% of Oregon respondents agreed with the statement, ''Technical and scientific experts are usually biased.'' Only half that number disagreed with the statement: 22% and 23% for national and Oregon respondents, respectively. A 1997 statewide survey (Sahr and others 1997) found Oregonians did not give much credence to higher education, where much salmon-related science originates. Public confidence in higher education ranked lower than that for the state governor and business. Forty-five percent of respondents had a ''great deal'' of confidence in the governor; 28% had great confidence in business; 22% in higher education; and 5% in the Oregon Legislature. Meanwhile, 36% of respondents said they had ''hardly any'' confidence in the legislature, 29% had low confidence in higher education, and 16% had low confidence in business and the governor.

Discussion

In convening expert panels, society is asking scientists to be both compass and gyroscope. The experts and scientific teams attempting to resolve salmon issues in the Columbia and other river basins base their approaches on the ''pristince,'' ''virtual,'' ''normative,'' ''ecosystem,'' ''recovered,'' ''restored,'' and ''rehabilitated'' concepts. Each group promotes a direction for society to take to improve the status of salmon. The problem is very complex, and being the one to provide solutions is very compelling.

Sometimes it is desirable to readjust the conceptual base, and this appears to be taking place with salmon issues. The concepts offered by experts and scientific teams point to a paradigm shift taking place in thinking about salmon and other ecological issues. However, science is more effective at determining which directions will not work than identifying the right direction. A principle finding of Gunderson and others (1995, p. 526) in a review of a half dozen large adaptive management examples is that ''Mission-oriented research, whose goal is to validate existing theory . . . generally hinders the development of alternative views and leads the system to brittleness.'' The scientific method is one of disproving hypotheses, not proving what will work.

Scientific results are being used to support many different positions and paradigms. Where many experts see convergence, the public sees—and is confused by—competing scientific ideas and findings. Meanwhile, as scientific concepts become more complex, so does the process of public education and participation. As one of the primary conclusions of their adaptive management review, Gunderson and others (1995, p. 532) ''see the involvement and education of the people who are part of the system as crucial to building resilient solutions and removing gridlock.'' This is not happening in the salmon situation. Despite efforts at public involvement, people report a feeling of alienation from the decision-making process.

Society invests far more resources in conducting science than in communicating the results. In general, scientists publish in academic journals. Sometimes journalists and science writers translate significant and relevant findings for the public, but this remains a one-way delivery of information. The result is very limited public understanding of the knowledge gained by scientists.

Members of the public say they have useful knowledge and want to contribute and be involved. People will participate if they think they can influence decisions. The review of adaptive management by Gunderson and others (1995) and our review for the Pacific Northwest both suggest that sufficient public involvement is not occurring. Too often, public participation merely fulfills a legal requirement rather than helping to improve decision making.

Perhaps a first step toward improving public involvement is to engage scientists and the public in a dialogue about what the region is to become in the next several decades—not only in fisheries, but also in forestry, water resources, and economic development. The debate needs to focus on habitat restoration; the relationship between energy costs and salmon restoration; the appropriate use, if any, of hatcheries; the role of genetic diversity in long-term sustainability and how to achieve it; and, most importantly, the public's place in adaptive management. These numerous and complex topics compete with others like welfare, health care, crime, and taxes for people's attention.

A paradigm shift is occurring. Scientists have tried to be the compass and gyroscope, thus confusing their roles and public perceptions of their findings. Science is much better at pointing out compass headings that will not work than in determining the correct heading.

With only scientists at the helm, we increase the danger of sailing onto the shoals of too little public involvement. Yet shoal has another meaning—a school, a throng. This meaning encourages broadening participation in the debate. While many approaches to public involvement are available—some proven, some not—scientists must demonstrate a real interest and a clear commitment to broadening participation. The legal responsibilities for public involvement are being met, but this has not translated into the bounded conflict necessary to chart a course through the turbulent seas of the salmon problem.

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Literature Cited

Beach, R. J., A. C. Gieger, S. J. Jeffries, S. D. Treacy, and B. L. Troutman. 1985. Marine mammals and their interaction with fisheries of the Columbia River and adjacent waters, 1980–1982. Third annual report. Washington Department of Wildlife, Wildlife Management Division, Olympia, Washington, 86 pp.

Beamish, R. J. 1993. Climate and exceptional fish production off the west coast of North America. *Canadian Journal of Fisheries and Aquatic Sciences* 50:2270–2291.

Beamish, R. J., and D. R. Bouillon. 1995. Marine fish production trends off the Pacific Coast of Canada and the United States. Pages 585–591 *in* R. J. Beamish (ed.), Climate change and northern fish populations. National Research Council Canada, Canadian Special Publication of Fisheries and Aquatic Sciences, No 121. Ottawa, Canada.

Bell, F. H., and A. T. Puter. 1958. Climatic temperature changes and commercial yields of some marine species. *Journal of the Fisheries Research Board of Canada* 15:625–683.

Berg, L. 1995. Tribes release salmon restoration plan. *Wana Chinook Tymoo* 2–3:12–23.

Bormann, B. T., P. G. Cunningham, M. H. Brookes, V. W. Manning, and M. W. Collopy. 1994. Adaptive management in the Pacific Northwest. US Department of Agriculture, Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-341. Portland, Oregon, 22 pp.

Botkin, D., K. Cummins, T. Dunne, H. Regier, M. Sobel, L. Talbot, and L. Simpson. 1995. Status and future of salmon of western Oregon and northern California: findings and options. The Center for the Study of the Environment, Santa Barbara, California, 300 pp.

Bottom, D. L., J. A. Lichatowich, and C. A. Frissell. 1996. Variability of marine ecosystems and relation to salmon production. Pacific Northwest ecosystem region study discussion paper 2. Portland, Oregon, 61 pp., plus figures.

Brown, G., and C. C. Harris. 1992. The US Forest Service: Toward the new resource management paradigm? *Society and Natural Resources* 5:231–245.

Brunson, M. W., and B. S. Steel. 1994. National public attitudes toward federal rangeland management. *Rangelands* 16:77–81.

Busack, C. A., and K. P. Currens. 1995. Genetic risks and hazards in hatchery operations: Fundamental concepts and issues. Pages 71–80 *in* H. L. Schramm, Jr. and R. G. Piper (eds.), Uses and effects of cultured fishes in aquatic ecosystems. American Fisheries Society Symposium 15. American Fisheries Society, Bethesda, Maryland.

Collette, C. 1996. *Northwest Energy News* 15:6–12.

Cone, J. 1992. If science's best answer isn't much good, then what? *The Oregonian* 19 November:C10.

Cone, J. 1995. A common fate: Endangered salmon and the people of the Pacific Northwest. Henry Holt and Company, New York, 374 pp.

CRITFC (Columbia River Inter-Tribal Fish Commission). 1995. Matter of trust. Part III of the Chinook triology video series. Portland, Oregon, 30 minutes.

CRITFC (Columbia River Inter-Tribal Fish Commission). 1996. Executive summary: *Wy-Kan-Ush-Mi Wa-Kish-Wit*, Spirit of the salmon. Portland, Oregon, not paginated.

Dietrich, W. 1995. Northwest passage: The great Columbia River. Simon & Schuster, New York, 448 pp.

Dillman, D. A. 1978. Mail and telephone surveys: The total design method. Wiley, New York, 325 pp.

FEMAT (Forest Ecosystem Management Assessment Team). 1993. Forest ecosystem management: An ecological, economic, and social assessment. US Departments of Agriculture, Commerce, and the Interior and Environmental Protection Agency. Washington, DC, not paginated.

Francis, R. C. 1993. Climate change and salmonid production in the North Pacific ocean. Pages 33–43 *in* K. R. Redmond and V. L. Tharp (eds.), Proceedings of the ninth Pacific climate workshop 1993. American Geophysical Union, Sacramento, California.

Gilden, J. D., and C. L. Smith. 1996a. Survey of gillnetters in Oregon and Washington: Summary of results. ORESU-T-96-001. Oregon State University Sea Grant Program, Corvallis, Oregon, 16 pp.

Gilden, J. D., and C. L. Smith. 1996b. Survey of Oregon trollers: Summary of results. ORESU-T-96-002. Oregon State University Sea Grant Program, Corvallis, Oregon, 16 pp.

Greenland, D. 1994. Offshore coho salmon populations near the Pacific Northwest and large-scale atmospheric events. Pages 109–119 *in* C. Isaacs and V. Tharp (eds.), Proceedings of twelfth annual Pacific climate workshop, Sacramento, California.

Gunderson, L. H., C. S. Holling, and S. S. Light. 1995. Barriers and bridges to the renewal of ecosystems and institutions. Columbia University Press, New York, 593 pp.

Hilborn, R. 1992. Hatcheries and the future of salmon in the Northwest. *Fisheries* 17:5–8.

Holling, C. S. 1978. Adaptive environmental assessment and management. International Institute for Applied Systems Analysis, Laxenburg, Austria, 377 pp.

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

ISG (Independent Scientific Group). 1996. Return to the river: Restoration of salmonid fishes in the Columbia River ecosystem. Northwest Power Planning Council, Portland, Oregon, 584 pp.

Kuhn, T. S. 1970. The structure of scientific revolutions. University of Chicago Press, Chicago, 212 pp.

Landauer, R. 1993. Let science save the salmon. *The Oregonian* 24 September:D6.

Lee, K. N. 1993. Compass and gyroscope: Integrating science and politics for the environment. The Island Press, Washington, DC, 243 pp.

Low, L. L., and J. D. Berger. 1994. Incidental catch of salmon in US groundfish fisheries in the Bering Sea / Aleutian Islands region, Gulf of Alaska and the pacific coast, 1990–1993. US Department of Commerce, National Marine Fisheries Service, Alaska Fish Science Center, Seattle, Washington, 84 pp.

Mahar, D. 1990. Point of view: Kai Lee. *Northwest Energy News* September / October 16–23.

Martilla and Kiley. 1994. Mid-Columbia public utility districts public opinion survey. *Public Affairs Report and Action Plan*. Martilla and Kiley, Boston, Massachusetts, 54 pp.

Mesa, M. G. 1991. Variation in feeding, aggression, and position choice between hatchery and wild cutthroat trout in an artificial stream. *Transactions of the American Fisheries Society* 120:723–727.

Mighetto, L., and W. J. Ebel. 1994. Saving the salmon: A history of the US Army Corps of Engineers' efforts to protect anadromous fish on the Columbia and Snake rivers. Historical Research Associates, Inc., Seattle, Washington, 262 pp. plus appendices.

Mrakovcich, K. L. 1993. Fishermen verus managers: Perceptions and conflicts in the salmon fishery. Unpublished thesis, Master of Science in Fisheries Science. Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon, 105 pp.

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. *Fisheries* 16(2):4–19.

Nichelson, T. E., J. W. Nicholas, A. M. McGie, R. B. Lindsay, D. L. Bottom, F. J. Kaiser, and S. E. Jacobs. 1992. Status of anadromous salmonids in Oregon coastal basins. Oregon Department of Fish and Wildlife, Portland, Oregon, 83 pp.

NPPC (Northwest Power Planning Council). 1986. Compilation of information on salmon and steelhead losses in the Columbia River Basin. Appendix D of the 1987 Columbia River Fish and Wildlife Program. Portland, Oregon, 165 p. plus maps.

NPPC (Northwest Power Planning Council). 1987. Columbia River Basin fish and wildlife program. Portland, Oregon, 246 pp.

NPPC (Northwest Power Planning Council). 1992. Strategy for salmon, Volume 1. Document 92-21. Portland, Oregon, 43 pp.

NPPC (Northwest Power Planning Council). 1996. Fiscal year 1998 budget and fiscal year 1997 revisions. Document 96-12. Portland, Oregon, 87 pp.

NRC (National Research Council, Board on Environmental Studies and Toxicology, Committee on Protection and Management of Pacific Northwest Anadromous Salmonids). 1996. Upstream: salmon and society in the Pacific Northwest. National Academy of Sciences Press, Washington, DC, 452 pp.

Olesiuk, P. F., M. A. Bigg, G. M. Ellis, S. J. Crockford, and R. J. Wigen. 1990. An assessment of the feeding habits of harbor seals (*Phoca vitulina*) in the Strait of Georgia, British Columbia, based on scat analysis. Canadian Technical Reports in Fisheries and Aquatic Sciences, No. 1730, 143 pp.

Palmisano, J. F., R. H. Ellis, and V. W. Kaczynski. 1993. The impact of the environment and management factors on Washington's wild anadromous salmon and trout. Washington Forest Protection Association and Washington Department of Natural Resources, Olympia, Washington, 371 pp.

Park, D. L. 1993. Transportation as a means of increasing wild juvenile salmon survival: Recovery issues for threatened and endangered Snake River salmon. US Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Technical Report 4 of 11, Subcontract of Don Chapman Consultants to S. P. Cramer & Associates, Inc., for BPA Project No. 93-013, Contribution No. DE-AM79-93BP99654, 156 pp.

Paul, L. 1994. High seas driftnetting: The plunder of the global commons. Earthtrust WWW document [http://www.earthtrust.org/dnpaper/contents.html].

Pearcy, W. G. 1992. Ocean ecology of north Pacific salmonids. Washington Sea Grant Program, University of Washington, Seattle, Washington, 179 pp.

Petersen, K. 1995. River of life, channel of death: Fish and dams on the lower Snake. Confluence Press, Lewiston, Idaho, 321 pp.

Ridlington, S., and J. Cone (eds.). 1996. The Northwest salmon crisis: A documentary history, 1854–1994. Oregon State University Press, Corvallis, Oregon, 374 pp.

Robbins, W. G., and D. W. Wolf. 1994. Eastside forest ecosystem health assessment, Volume 3: Landscape and the intermontane northwest: an environmental history. Pacific Northwest Research Station, Portland, Oregon, 56 pp.

Rudzitis, G., C. Watrous, and H. Johansen. 1995. Public views on public lands: A survey of interior Columbia River Basin residents. University of Idaho, Department of Geography, Moscow, Idaho, 40 pp.

Sahr, R. C., B. S. Steel, S. W. Sellers, and N. P. Lovrich. 1997. Pacific Northwest survey of governmental issues, 1996–1997, report of the Oregon 1996–97 fiscal choices survey. Oregon State University, Corvallis, Oregon, 8 pp.

Shindler, B., P. List, B. S. Steel, T. Boehm, and C. Smith. 1995. Initial social assessment of proximate communities: Central Cascades adaptive management area. USDA Forest Service, Cascade Center for Ecosystem Management and Oregon State University, Sustainable Forestry Program, Corvallis, Oregon, 34 pp.

Smith, C. L., and B. Steel. 1997. Values for valuing salmon. Pages 599–616 *in* D. J. Stouder, P. A. Bisson, and R. Naiman (eds.), Pacific salmon and their ecosystems: Status and future options. Chapman and Hall, New York, New York.

Smith, C. L., J. D. Gilden, J. S. Cone, and B. S. Steel. 1997. Oregon coastal salmon restoration: Views of coastal residents. Oregon State University Sea Grant Program, ORESU-S-97-001. Corvallis, Oregon, 16 pp.

SRSRT (Snake River Salmon Recovery Team). 1993. Draft recovery plan recommendations for peer review. National Marine Fisheries Service, Portland, Oregon, Chapters I–XII, plus appendices A–E.

Steel, B. S., and M. Brunson. 1993. Western rangelands survey: Comparing the responses of the 1993 national and Oregon public surveys. Washington State University at Vancouver, Vancouver, Washington, not paginated.

Steel, B. S., P. List, and B. Shindler. 1994. Conflicting values about federal forests: A comparison of national and Oregon publics. *Society and Natural Resources* 7:137–153.

Steward, C. R., and T. C. Bjornn. 1990. Supplementation of salmon and steelhead stocks with hatchery fish: A synthesis of published literature. Part 2. Pages 16–26 *in* W. H. Miller (ed.), Analysis of salmon and steelhead supplementation, Part 103. Technical Report 90-1. US Department of Energy, Bonneville Power Administration, Portland, Oregon.

Stouder, D. J., P. A. Bisson, and R. J. Naiman (eds.). 1997. Pacific salmon and their ecosystems: Status and future options. Chapman and Hall, New York, 685 pp.

Suboski, M. M., and J. J. Templeton. 1989. Life skills training for hatchery fish: Social learning and survival. *Fisheries Research* 7:343–352.

USDI (US Department of Agriculture, Forest Services). 1996. Status of the interior Columbia basin: Summary of scientific findings. General Technical Report PNW-GTR-385. US Department of Agriculture, Forest Service, Pacific Northwest Research Station; US Department of the Interior, Bureau of Land Management, Portland, Oregon, 144 pp.

Walters, C. J. 1986. Adaptive management of renewable resources. Collier Macmillan, New York, 374 pp.

WDFW (Washington Department of Fisheries and Wildlife). 1997. Opinion survey. Olympia, Washington, 7 pp.

Welch, D. W. 1995. Upper thermal limits on the oceanic distribution of Pacific salmon (*Onchorhynchus* spp.) in the spring. *Canadian Journal of Fisheries and Aquatic Sciences* 52:489–503.

White, R. 1995. The organic machine: The remaking of the Columbia River. Hill and Wang, New York, 130 pp.