Addressing Fish Uncertainty:

The Quest for Rational Decisionmaking

Mike Katz, Patricia Koss, Jennifer Shawcross
Portland State University, Department of Economics

Abstract. This paper explores the policy efforts dealing with the problem of declining Pacific Northwest fish runs. Results have been disappointing. Decades of expensive efforts costing billion of dollars have been relatively ineffective in increasing salmon runs. Many species of wild fish continue to decline or remain significantly below target levels of recovery. The issue of scientific and economic uncertainties is examined. Past and current policies have failed to adequately account for these uncertainties. One overall recommendation of this paper is that policymakers and their advisors should explicitly identify any decision criteria upon which they base their judgments or conclusions. A second recommendation is that policy analysis should be explicit about uncertainties. We offer the eighteen decision rules for fashioning fish recovery decisions in an environment of uncertainty.

1. THE PROBLEM

Columbia River salmon runs were reckoned once the largest in the world. Before 1850, an estimated 10-16 million wild adult salmon returned from the ocean to the basin each year.[1] [2]

Today's runs are significantly reduced, something on the order of one-fifth to one-eighth of historic levels. And of the present diminished runs, only 20 percent or so are wild fish which are esteemed; the remainder are derived from hatcheries. [2] [3]

Many plausible factors, alone or in combination, have been singled out for blame. Virtually all cited causes for diminished fish runs are putative; none is unchallenged or accepted uncritically by everyone.

There are many stakeholders. Controversy seethes among them – Indian tribes, industries, state and federal agencies, cattle grazers, power producers, industrial power customers, navigation interests, environmentalists, irrigators, sports and commercial fishers, timber operators, farmers, recreationists, et al. – as to causes and as to remedies. There is debate, too, within the scientific community. [4] Additionally, there is debate as to who should bear the costs of restoration, full or partial, if indeed restoration is feasible or possible.

Uncertainty and dispute have not, however, led to paralysis. Many fish enhancement or restoration activities have been undertaken starting with installation of fish ladders to assist returning adults when the first main-stem Columbia River dams were constructed. But there has been an intensification of concern and activity in the last 20 years.

The Northwest Power Act was enacted in 1980 and led the following year to creation of the Northwest Power Planning Council. As a result, substantial sums have been spent to address the problem. Since 1981, more than $3 billion has been spent to restore diminished Columbia River fish runs. Although some financial guesswork is involved, it is now estimated that very close to $1 billion will be spent by state and federal agencies in the year 2000 alone in Pacific Northwest fish recovery efforts. [5]

Results have been disappointing. Decades of expensive efforts costing billion of dollars have been relatively ineffective in increasing salmon runs. Many species of wild fish continue to decline or remain significantly below target levels of recovery.

1.1 Amplification of the Problem

Many circumstances – some human-caused, some natural, and some no doubt interrelated with others – may have contributed to diminished fish runs. A great deal is unknown.

Some things, however, are known and not in dispute. Several undisputed pieces of information are relevant. For example, sharp reductions in Columbia Basin fish runs are nothing new. The problem has been around for a long time. Estimates indicate that 60 to 90 percent of the decline in salmon runs since the mid-nineteenth century occurred before the 1930s when Bonneville Dam was constructed! Declining fish runs in the Columbia Basin are not a recent phenomenon. [6] [7] [8]

Not everyone agrees on the causes of the diminished fish runs but no one disputes that a partial list of the putative fish killers would include forestry, farming, cattle grazing, harvesting (sports, commercial and tribal fishing, in streams or at sea), industrial activities, road building, riparian clearing, urbanization, dams, hatcheries, culverts deterioration, predatory birds and sea mammals, and variations in ocean conditions. All and more have been cited as principal causes of salmon stocks slumping to unsatisfactory levels.

Some of these "causes" are susceptible to policymaking intervention; others are not. Fishing, for example, can be curtailed or prohibited. Indeed, increasing escapements may

be necessary for restoring fish runs. It is, not without protest to be sure, the easiest mortality factor to control. [9] Ocean conditions, on the other hand, are more or less beyond human control.

2. QUESTION: WHAT MIGHT A RATIONAL POLICYMAKER DO?

With controversy raging among stakeholders and alternative theories disputed even among experts, what might a rational policymaker do?

It makes intuitively good sense to seek and rely upon the advice of experts, primarily fish biologists and assorted specialists, in identifying the problem in terms of fish species threatened or endangered, of river stretches affected, of causes and, importantly, of remedies. That is precisely what the Northwest Power Planning Council did in the 1980s in crafting its first fish and wildlife programs to guide federal agencies exercising hydroelectric responsibilities. Most of the "science" identifying the nature of the problem and recommending solutions has been obtained from fish biologists and related disciplinarians, in federal and state government agencies, associated with Indian tribes, and working with or for environmental and other nongovernmental organizations.

There were what are called cross-sectional anomalies: at any given time experts did not always agree with one another. And there were time-series anomalies as well: over time, the conclusions of experts as to both causes and remedies varied widely.

Proposed solutions to salmon recovery problems range over a broad spectrum. Different solutions impact different constituencies differently. The region has become increasingly polarized. And because no one sees how the issues will ultimately play out, stakeholders tend to stake out the most extreme positions at the outset. This discordant atmosphere, even among experts, has been evident for years but seems to be intensifying.

The Northwest Power Planning Council's fish and wildlife programs notwithstanding, fish stocks have continued to decline. Flow augmentation was a capstone of the Council's initial fish and wildlife programs. And for the last several years the National Marine Fisheries Service has emphasized river flow augmentation to assist spring and summer salmon migration. It is reported, however, that review of data collected from PIT-tagged chinook salmon and steelhead migrating downstream from Lower Granite Dam from 1993 through 1998 shows no correlation between flow and survival within any season, and a weak correlation among years. [10] Other data collected on other fish runs in other streams shows strong correlation between flow and survival. It is confounding.

2.1 What To Do

Economics is not different from other disciplines in some respects. Although it is pretentious, a common belief held by economists (and biologists, meteorologists, philosophers, oceanographers, law professors, hydrologists and brain surgeons as well) is that each of their profession can provide umbrella answers to many if not all problems. As economists, it should not be unexpected that we think our discipline might bring to bear some useful techniques for addressing the problem of diminished fish runs in general and for addressing that problem under conditions of uncertainty in particular.

One overall recommendation of this paper is that policymakers and their advisors should explicitly identify any decision criteria upon which they base their judgments or conclusions. With many different actors, each with different interests and objectives, a single decision criterion may be impossible. In that case, *multiple* decision criteria should be identified. All too frequently, however, individuals and organizations undertake analysis without explicitly choosing *any* decision criteria.

A second recommendation is that policy analysis should be explicit about uncertainties. In the area of salmon recovery analysis, uncertainties include:

a. doubts about scientific, economic and political values
b. doubts about accuracy of technical, scientific, economic and political models

These uncertainties are often exacerbated by disagreements among experts. They should be declared, not concealed.

Historically, the most common approach to uncertainty in policy analysis has been to ignore it. It is our assertion, shared by many scholars, that there is value in knowing how little we know.

We do not recommend inaction in the face of uncertainty. No decision at all is itself a decision and one that could have significant consequences. Even in the absence of certainty, it may be desirable to embark on programs that fit some sensible criteria. What might those criteria be?

Is it possible, based on established principles of economics, operations research, decision analysis, risk assessment and related disciplines to formulate decision rules that in the face of uncertainty would improve the prospects for fish recovery and reduce the prospects of costly mistakes? At the risk of appearing immodest, we think it is possible. And we offer the following 18 decision rules for fashioning fish recovery decisions in an environment of uncertainty.

These decision rules or working principles are not presented in order of importance. Each is accompanied by some brief exposition or elaboration that explains or clarifies by

examples or references to familiar cases.

2.2 Circumscription

Decision rules or working principles addressing uncertainty, cerebral as they may be, are not meant to wrench decisionmaking discretion or flexibility from policymakers. These rules and principles are not to be followed uncritically as with step-by-step cook-book recipes, conceptually ideal as that might be to theoreticians.

Political realities in a democratic society trump these rules. We are persuaded, however, that employing these rules in policy analyses under conditions of uncertainty will permit policymakers – federal, state and local; legislative, executive and judicial – to proceed with an appreciation of possibilities and consequences, with eyes open rather than on the basis of hunch and intuition.

3. DECISION RULES FOR DESIGNING AND OPERATING FISH RECOVERY PROGRAMS IN AN ENVIRONMENT OF UNCERTAINTY AND LIMITED KNOWLEDGE

3.1 Socioeconomic Benefit-Cost Analysis Is Indispensable

If one looks only at the benefits of a particular measure, virtually every proposal is justified and should be pursued. If one looks only at the costs, nothing is worth pursuing. Clearly to get an idea of how desirable a fish restoration measure is, one must look at both benefits and costs. To the extent that benefits are realistically assessed and that costs accurately reflect the true value of society's scarce resources that must be dedicated, one can determine whether or not a proposed measure is socially desirable. All measures where benefits exceed costs should be undertaken. No measure should be undertaken where costs exceed benefits.

3.2 Measures should be ranked according to their cost-effectiveness.

Any given target level of fish restoration should be achieved at the lowest possible cost. If two or more alternative measures each achieve equivalent outcomes, the least-cost measure should be ranked highest and preferred over higher cost measures.

This is a textbook principle to which economists subscribe unambiguously. But it is sometimes misunderstood by non-economists who do not appreciate what is meant by the term "cost effective." In its strictest sense, a measure is cost-effective if it is the least-cost way of achieving an *identical* result. Many uninitiated persons mistakenly believe that cost effective merely means cheaper and consequently less beneficial.

When products are correctly priced to embody all costs including externalities, such price tags reflect the value of scarce resources to society. Because resources such as land, labor, capital and raw materials are scarce, they should be used as efficiently as possible. The way to do that is to select from among alternative ways of getting a job done, the one that is cost effective, that is to say the one that uses less of society's scarce resources.

3.3 Keep Options Open; Future Opportunities Should Not Be Foreclosed

Options are valuable and thus beneficial to society. That is why options command a price in the marketplace. The nice thing about an option, and the feature that gives it value, is that it does not have to be exercised if it is not advantageous to do so but can be exercised if circumstances become propitious.

If a fish recovery measure doesn't seem particularly worthy at the moment but has potential and might subsequently become attractive with acquisition of superior knowledge or technology or lower cost, its implementation should not be precluded by measures that have a preemptive character.

Options should be preserved where feasible.

3.4 Reversible Measures Are Preferred to Irreversible Measures

Since we rarely know enough about a problem to solve it definitively, it is generally appropriate to adopt "adaptive-look-ahead" management strategies. This will likely allow us to retain "reversibility" as an option. At any moment, knowledge is limited. As time goes by, more and better information arrives. Until sufficient knowledge is in hand, it is best to avoid irreversibilities.

For example, if two mutually exclusive approaches to solving a problem are judged side by side, one with the potential for destroying an important asset or resource which once gone cannot be subsequently retrieved while the other buys time for more or better information to arrive and permits decisionmakers to change their minds, the time-buying reversible approach is to be preferred over the irreversible approach (assuming, of course, that its costs are acceptable).

3.5 Recognize that Large-Scale Projects Include the Costs of Inflexibility which Should Be Part of Any Cost-Benefit Analysis

Other things equal, cost effective measures or measures with comparable benefit-cost ratios that are small and less resource intensive should be preferred to grandiose and expensive measures.

Smaller measures are usually less expensive, have shorter lead-times and can be implemented in stages that make them susceptible to earlier evaluation and, if necessary, tweaking. Large capital-intensive measures once launched reduce planning flexibility and diminish the prospects for abandonment or discontinuation if found unsatisfactory.

3.6 Discontinue Projects and Measures that Don't Work – Sunk Costs Should Be Ignored

Effective measures that provide benefits in excess of economic costs should be continued, obviously. Once identified, ineffective measures, including those involving heavy sunk costs, should be abandoned.

There should be recognition that sunk costs are just that – sunk. They represent the dead hand of the past. Future costs, not past costs, are the gauge by which continuation of a fish recovery measure, once launched, should be judged. Future costs, large or small, are what the decisionmaker has to work with from this moment forward. Sunk costs represent expenditures of the past that are irretrievable. What's done is done.

Too often, once measures are launched they tend to assume a life of their own. The main argument for continued funding of failed measures is that substantial sums have been spent on their implementation and would be wasted if the measures were discontinued. It has plagued investors and other decision-makers since the beginning of time. It is, as Mark Twain said, "as if having determined to do an unwise thing, one is thereby bound to go ahead and make two unwise things of it, by carrying out that determination."

3.7 Sound Cost-Benefit Analysis Does Not Ignore Opportunity Costs

Because there are limited resources to go around, the real costs to society of undertaking one or several fish recovery measures include not only cash outlays but the resulting sacrifice of competing measures or alternative benefits that must be foregone.

In a sense there are two different sorts of opportunity costs. In one case, a measure designed to obtain beneficial uses of a particular resource such as a stretch of water may preclude an alternative opportunity to use that same resource to restore fish populations, or vice versa. In the other case, limited funding means foregone benefits to which funds might be otherwise placed.

Dismantling or breaching a hydroelectric resource is an example. No serious analysis of such a measure would neglect evaluating the costs of securing replacement energy, of alternative transportation modes due to lost navigation locks, of diminished irrigation opportunities, and of the potential increase during dismantling and stream restoration in mortality of endangered species until clear water once again flows. These foregone opportunity costs should be considered in addition, of course, to the added costs of breaching itself.

3.8 Externalities Should Be Taken into Account, Where Feasible they Should Be Internalized

To the extent that fish recovery measures impose uncompensated burdens or gratuitous benefits upon others, such spillover costs or benefits should not go unreckoned. Externalities are actions that affect others for better or worse without those others paying for the "better" or being compensated for the "worse."

A private landowner who at her own expense improves fish habitat beyond any damages to fish she may have imposed provides a positive externality and deserves compensation. Similarly, habitat improvements for fish that simultaneously improve water quality for domestic or industrial use create benefits that deserve to be credited to the measure and, ideally, should be recompensed by the beneficiaries.

On the other hand, agricultural activities such as cattle grazing or chemical fertilizer runoff that damage fish spawning sites are negative externalities. It is not fair that costs of rectification be borne by society at large. They should be charged against the offender.

3.9 It Is Appropriate to Discount over Time

Some measures to restore fish yield proximate results. Curtailed harvesting is an example. Other measures may take many years to begin bearing fruit. Other things equal, the sooner benefits are realized, the better. As a *reductio ad absurdum*, no one would seriously suggest that substantial up-front capital outlays be deployed today to improve fish runs if benefits don't kick in for a thousand years. With costs incurred early on, the longer the wait for results, the less valuable are the benefits and the less cost beneficial are such measures.

3.10 Measures Should Be Assessed Based on Their Capacity To Recover Fish

This decision rule sounds almost too obvious to deserve

mention.

In assessing measures, it is important to remember that the primary goal of fish restoration measures is to restore fish. It is not to provide employment, to promote economic development in depressed communities, to offset reductions in public-agency budgets, to redistribute income, to redress inequities, to perpetuate earlier contractual arrangements, or to do the thousand and one other good things having little or nothing to do with recovery of fish. Such other goals may or may not have merit but when it comes to restoring fish runs, they should be regarded as spillover benefits (i.e., external economies). These other goals are ancillary, and so should be subordinate, to the principal purpose: saving fish.

3.11 "No Regrets" Measures Should Be Pursued. "Small Regrets" Measures Should also Be Looked Upon with Interest.

In 1991, the National Academy of Science report on global climate change advocated the implementation of "no regrets" measures. In the context of that report, it meant that measures of the sort that should be pursued in any event, even if greenhouse warming were not a problem, should be undertaken unhesitatingly. Why not? Cost-effective energy conservation by definition uses less of society's scarce resources to achieve identical levels of comfort, convenience and performance as more expensive conventional energy sources. It should be deployed. The fact that such conservation also contributes to reduced CO_2 emission is a costless blessing.

In the context of fish restoration measures about which there is substantial uncertainty as to outcome, it is obvious that steps that would be undertaken anyway for other reasons and which coincidentally benefit fish are surefire winners. For example, some habitat improvement projects and economic riparian forestry methods improve the nonfish attributes of waterways and can be advanced on their own merits. It they are otherwise economic and incidentally improve fish restoration prospects, they should be urged unambiguously as "no regrets" measures.

"Small regrets" measures, as the name implies, means there are some measures that might be marginal or not quite cost beneficial without considering their impact on fish become exceedingly attractive when fish benefits are added. It is akin to a small premium being paid for a large insurance policy. It isn't free as in the case of "no regrets" measures but it may be exceedingly inexpensive.

3.12 Recognize Diminishing Returns

Twenty-five years ago, the National Water Commission, a presidential commission, noted that cleaning up the nation's polluted waters, as with all environment efforts, bumps up against the Law of Increasing Costs. Beyond some point, successive improvements in water quality become progressively more costly. For example, going from 50% to 95% clean water can be less expensive than going from 95% to 98%. But going from 98% to 99% may be even more expensive requiring diversion of substantial amounts of limited resources to a minuscule improvement in water quality.

It is easy to understand why the public is sometimes confused. At the least sophisticated level, it is common to assume that if a given expenditure is expected to achieve a certain level of results, doubling the expenditure would double the results.

Persons familiar with the phenomenon are aware that inaugurating operations usually involves startup and other expenses that can be quite formidable but that subside after a certain size of operation is attained. As operations scale up and operators become experienced, "mass production" economies of scale emerge and costs per unit fall. Doubling expenditures can more than double results. This is true – up to a point.

There comes a point, however, where costs per unit of result begin to rise, sometimes sharply. Initiating a habitat improvement project on a stretch of river, for example, involves planning and organizing the effort, acquiring staff and equipment, training, hauling equipment to the site, initiating operations and sundry activities that all add to startup costs. Once the project is underway, per unit costs are likely to drop as operations become routinized and operators more skillful. Plowing in additional resources may at first improve operations incommensurately. But beyond a certain size, the number of workers and pieces of equipment begin to get in each others way. Congestion takes a toll. Too much attention is being paid to this stretch of river and insufficient attention to otherwise neglected stretches where large payoffs may lurk.

Failure to recognize such increasing costs, or diminishing returns, no matter how worthy the objective, distort the efficient allocation of resources.

3.13 Assignment of Infinite Values Should Be Shunned

Politicians are frequently heard asserting that certain objectives must be achieved at any cost. Or that if only one life is saved, it is worth unlimited sums of public investment. Or that saving all species from extinction is worth whatever it takes. (Fortunately, eradication of female anopheles mosquitos has not yet captured the attention of such at-all-cost preservationists.) With limited public resources and with significant foregone opportunities, the notion of some worthy objective having infinite value, to be undertaken at any cost, is irrational.

Rational analysis rejects assigning infinite values to anything. The politically popular term "at any cost" may be alluring rhetoric but if carried to its logical conclusion leads to tragic misallocation of resources. The infamous Delaney Amendment of the Pure Foods Act and the Endangered Species Act in effect said that certain objectives should be achieved no matter how modest the benefits or how large the costs in terms of diverted resources and foregone opportunities.

3.14 Where Feasible and Efficient, Invoke the "Approval Compensation Criterion"

In fish restoration efforts, as in other environmental efforts, regulators frequently attempt to impose constraints on stakeholders by a "command and control" approach. Parties whose behavior has an adverse impact on salmon are frequently "ordered" to modify their conduct; compliance is then enforced by the threat of punishment, usually in the form of monetary penalties. Affected stakeholders generally react adversely to such constraints, and may use legal avenues or political influence to thwart imposition of constraints and achievement of goals. Even where regulators are successful in invoking "command and control" measures, enforcement is often costly.

Policymakers should seek out opportunities for stakeholders to agree to modify their behavior in "salmon-friendly" ways in return for a mutually acceptable level of compensation. While such agreements may not internalize externalities, they might not only reduce the extent of legal and political adversity, they may allow more progress to be achieved and in a more timely fashion. "Approval compensation" approaches become particularly attractive whenever their costs are less than the command-and-control costs of enforcement, litigation, delay, and diminished achievement.

3.15 Undertake Project Evaluation

Prior to implementing any decision, or even after implementation, models which provide alternative explanations of the problem and alternative solutions should be explored. Any fish recovery measure should be continuously tested against alternative measures. Scientific and economic uncertainties lead to disagreements among experts. Hence, model development should involve repeated exploration of alternative formulations. With luck, an improved model can be framed from a synthesis of the initial ones. The analysis itself can assist in the process of both goal discovery and disclosure of the optimal path toward achievement.

The history of fish restoration approaches in the Pacific Northwest shows that it is unwise to assume that measures once approved, launched and in operation are necessarily worthwhile.

Once a fish project is undertaken, its impact on fish recovery should be continuously tested. If it works it might be a candidate for replication elsewhere. If it doesn't work, it might be tinkered or tweaked to make it work or, alternatively, dismantled or abandoned.

3.16 Improve Knowledge for Future Decisions: A Plea for R&D

To increase the return on investments in fish recovery measures and the prospects for fish restoration, scientific investigations that improve the base of knowledge about what causes diminished fish runs and what remedies might prove effective should be pursued. Where feasible, explorations should be undertaken by disinterested scientific investigators.

Less uncertainty and more knowledge will yield superior results at lower costs. It is obvious that research into causes and remedies would be valuable.

Adaptive management wherein fish restoration measures are undertaken on a trial and error basis to test various approaches is tacit recognition that we face uncertainties and are in possession of limited knowledge. Adaptive management also recognizes that doing nothing is also a decision that carries with it risk as well. But adaptive management falls into disrepute when it becomes an open-ended justification for questionable proposals that are fanciful or expensive and unlikely of achieving desired results.

For research to be credible, it should, to the extent practicable, be undertaken by investigators having neither a real nor an apparent conflict of interest. Just as the results of research on the health risks of smoking performed under the auspices of the American Tobacco Institute may be regarded with suspicion, so, too, research on Pacific Northwest fish runs should not be undertaken by parties with a financial (or other) stake in the outcome. With considerable investigational and other professional talent tied up in the very federal and state agencies and Indian tribes that manage fish restoration programs, it may be difficult to obtain complete objectivity. How likely is it, for example, for any fish biologist employed by the mythical Commercial Fisheries Association of the Pacific Northwest to recommend that the least-cost approach to restoring salmon runs in the Columbia River basin is to curtail harvesting fish by fishers? Answer: Not very.

3.17 Sensitivity Analysis Is Beneficial

It is clear that a great deal remains unknown. That means that even socioeconomic cost-benefit analyses to select salmon restoration tasks, no matter how conceptually elegant they are formulated, will very often be subject to uncertainty. Sensitivity analysis is helpful in determining the extent to

which decisionmakers can select options with elevated levels of confidence.

Suppose uncertainty clouds a proposed fish restoration measure that appears capable of yielding important improvements of desirable fish runs at respectable costs. Based on the best data available, the proposal seems to be cost-effective, and the value of the expected outcome exceeds the costs. But if there is doubt as to either benefits or costs, or both, sensitivity analysis is just the ticket to test the proposition

In this case, after the initial cost-benefit analysis is completed, a series of iterative secondary sensitivity analyses might hypothetically increase the projected costs by certain percentages and/or reduce anticipated benefits similarly. This process tests different assumptions with respect to calculating both costs and benefits. If, for example, a doubling of cost and a halving of benefits still yields a positive (i.e., attractive) benefit-cost ratio, it signals that notwithstanding uncertainties as to costs and benefits, the attractiveness of the measure is robust. Decisionmakers can proceed with elevated confidence. The chances of making a costly mistake are reduced.

3.18 Efforts to Establish and Calibrate Cause and Effect Linkages Should Be Pursued

There are often long lags between causes and effects. And numerous confounding factors flourish. Thus it is not always evident whether fish restoration measures work or not. Merely because a measure is implemented and improvement (or deterioration) in subsequent fish runs in the affected water is noted is not clear evidence that the measure works (or is a failure). The pertinent inquiry requires "with-and-without" analysis. With-and-without analysis would ask how much better or worse might fish runs be after implementation of a measure than they would otherwise be without the measure? It is often much easier to ask this question than to answer it.

Then, too, unsophisticated assessments sometimes fall victim to the *post hoc ergo propter hoc* fallacy, the illogical reasoning that after an event, therefore because of that event. For example, there are evidently changes in ocean conditions from one decade to another that can have very large effects on the extent to which Northwest salmon runs prosper or worsen. These interdecadal variations in the ocean environment are presently boosting salmon fish counts throughout the Pacific Northwest most agreeably. But changes in ocean conditions can mask changes in fresh water survival resulting from restoration efforts. [4] *(Independent Scientific Advisory Board, 1999)* It would be fanciful to credit these improved runs to restoration measures implemented 5 or 10 years ago although, to be sure, such measures could contribute in part to the improved runs, making them candidates for with-and-without analysis.

4. CONCLUSIONS

The issue of declining Columbia River basin fish runs and what to do about it has been "symposiumed" to death. There have been no end to conferences on the subject. It has become an industry.

This paper takes a different tack – dramatically so. It does not purport to know the answers. Nor is it in possession of received wisdom on the subject. Indeed, it is the very lack of information, particularly with respect to causes and remedies, that inspires this paper. The authors are not advancing a complementary or competing dogma. Instead we are fashioning working principles and decision rules for scholarly investigation, and for the design and implementation of fish recovery schemes in an environment of uncertainty and limited knowledge.

In recent years, affected interests in the region have become more polarized and unbending, disinclined to view matters with scientific objectivity or on the basis of intellectually disciplined inquiry. What is needed, among other things, is objective guidelines for evaluation of merits and demerits of fish recovery programs in a scientific framework . These decision rules are meant to provide that framework.

We repeat our earlier admonition: using these decision principles to address uncertainty is not meant to remove decisionmaking from policymakers. The principles advanced here are analytical mechanisms for gauging alternative approaches. We believe these principles will equip decisionmakers with tools for rational analysis. In the final analysis, elected legislators and executive branch decisionmakers must render the ultimate decisions on salmon recovery measures. It is hoped that the principles enumerated here will advance the quest for rational decisionmaking.

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