SB

285

Alaska State Legislature

Senate

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Official Business

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Sponsor Statement

"An Act relating to the management of discrete salmon stocks"

A great deal of controversy and total lack of consensus has surrounded the allocation of Alaska's salmon stocks. These allocative battles have left all user groups unsatisfied and have been to the detriment of the sustained yield of some population segments, and to the genetic diversity of the overall population.

Current salmon management centers around heavy exploitation of mixed stock fisheries and disregards the negative effects this policy has on discrete stocks of all salmon species. Not until we recognize the importance of implementing a management plan for discrete salmon stocks, based on the necessary information, can we fulfill our constitutional obligation to preserve the sustained yield of all stocks of the resource.

The need for this change in management philosophy and implementation of a discrete salmon stock policy is heavily supported by information from the scientific community. The National Research Council of the National Academy of Science assembled the leading experts in the field of salmon management and published Upstream: Salmon and Society in the Pacific Northwest, in December 1995.

An extensive review by leading experts to analyze data on salmon stocks, their decline and options for intervention supports the need for discrete stock management. The following is excerpted from their findings:

- Because of their anadromous life cycles and homing behaviors and the variety of environments they occupy, each species tends to differentiate into local breeding populations that are in general reproductivity isolated from other populations and adapted to each stream. To sustain productive natural populations of salmon, it is crucially important to maintain this genetic variation and local adaptation.

• When fishing occurs on a mixture of populations with different stock-recruitment functions and fishing cannot be regulated at a rate appropriate for each component population, the stage is set for overfishing of the less-productive components.

The conclusion of this report points out the flaws in Alaska's current management philosophy and supports the need for the discrete salmon stock management policy. The experts conclude:

> The long-term survival of salmon depends crucially on a diverse and rich store of genetic variations. Because of their homing behavior and the distribution of their populations and their riverine habitats, salmon populations are unusually susceptible to local extinction's and are dependent on diversity in their genetic make-up and population structure. Therefore, management must recognize and protect the genetic diversity within each salmon species, and it must recognize and work with local breeding populations and their habitats. It is not enough to focus only on the abundance of salmon.

In order to uphold our Constitutional mandate to provide for sustained yield we cannot afford to ignore the biological realities and maintain the status quo. The passage of SB 285 is intended to redirect our attention from the past mistakes of allocation driven management system toward a system which will fully meet our constitutional responsibility to sustained yield.

LEGAL SERVICES

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<u>MEMORANDUM</u>

February 23, 1996

SUBJECT: Sectional Summary of SB 285; An Act relating to management of discrete salmon stocks and to a salmon management assessment.

TO: Senator Rick Halford

FROM: George Utermohle
Legislative Counsel

You have requested a sectional summary of SB 285; An Act relating to management of discrete salmon stocks and to a salmon management assessment.

As a preliminary matter, please note that a sectional summary of a bill is not an authoritative interpretation of the bill. The bill itself is the best statement of its contents.

<u>Section 1</u> of the bill sets out the legislative purpose underlying the bill.

<u>Section 2</u> of the bill adds a new section, relating to discrete stock management of salmon, to AS 16.05. The Board of Fisheries shall adopt and implement policies for the management of discrete salmon stocks over the next 15 years in accordance with the schedule set out in subsection (a). The Department of Fish and Game shall determine the stock composition of each mixed stock salmon fishery, develop escapement objectives for each discrete salmon stock, develop the ability to project escapements for each discrete salmon stock, and provide necessary information to the board in a timely manner. The commissioner of fish and game may establish by regulation that proportion of the value of salmon taken from an area that is to be collected under AS 43.76.150 - 43.76.170, added by sec. 3 of the bill, to cover the costs of the research and data collection required for discrete salmon stock management. The terms "discrete salmon stock" and "river of origin" are defined.

<u>Section 3</u> of the bill adds new sections to AS 43.76 providing for the imposition and collection of a salmon management assessment.

<u>Section 4</u> of the bill provides that sec. 3 of the bill, salmon management assessment, takes effect January 1, 1997.

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PREPUBLICATION COPY

Upstream

Salmon and Society in the Pacific Northwest

Committee on Protection and Management of
Pacific Northwest Anadromous Salmonids

Board on Environmental Studies and Toxicology

Commission on Life Sciences

1995

National Research Council

Executive Summary

Pacific salmon have disappeared from about 40% of their historical breeding ranges in Washington, Oregon, Idaho, and California over the last century, and many remaining populations are severely reduced. Most runs that appear plentiful today are largely composed of fish produced in hatcheries. Recreational and commercial fishing for several salmon species has been restricted or even prohibited from the coastal waters of the region to the headwaters of many streams, and tribal fishing has been much reduced. Petitions have been filed to list several populations as endangered or threatened under the Endangered Species Act; a few have been listed, and more could be soon.

Salmon have great cultural, economic, recreational, and symbolic importance in the Pacific Northwest. As a result, their declines—which have numerous interacting causes—have resulted in much concern. The often expensive efforts to reverse the declines have been controversial and unsuccessful in many cases. Faced with the possibility of dozens or perhaps even hundreds of listings of Pacific salmon under the Endangered Species Act, and faced with controversies over the effectiveness of proposed actions to slow, halt, or reverse the salmon declines, Congress requested advice from the National Research Council (NRC). In response, the NRC's Board on Environmental Studies and Toxicology assembled the expert Committee on Protection and Management of Pacific Northwest Anadromous Salmonids to review information concerning the seven species of anadromous salmonids[1] in the Pacific Northwest.

The committee was asked to "evaluate options for improving the prospects for long-term sustainability of the stocks, and [to] consider economic and social implications of such changes" (statement of task; see Preface). It was asked to perform the following tasks:

- Assess the status of the salmon stocks.
- Analyze the causes of declines.
- Analyze options for intervention.

The committee was asked to consider all stages of salmon life histories, including the ocean phase, and to consider the appropriate roles of hatcheries. Congress did not request advice on whether society *should* make the investments needed to halt and reverse salmon declines. However, the committee's analysis of options for intervention and their likely effectiveness should help to inform that policy decision.

[1] This report deals with anadromous forms of the seven species of the genus *Oncorhynchus*. They are chinook, chum, coho, pink, and sockeye salmon and the anadromous forms of rainbow and cutthroat trout: steelhead and searun cutthroat. In this report, the general term *salmon* refers to all seven species.

STATUS OF SALMON POPULATIONS

The status of many specific salmon populations in the Pacific Northwest is uncertain, and there are exceptions to most generalizations with regard to overall status. Nevertheless, a general examination of the evidence of population declines over broad areas is helpful for understanding the current status of species with different life cycle characteristics and geographical distributions, and with some caution, the following generalizations are justified:

- *Pacific salmon have disappeared from about 40% of their historical breeding ranges in Washington, Oregon, Idaho, and California over the last century, and many remaining populations are severely depressed in areas where they were formerly abundant.* If the areas in which salmon are threatened or endangered are added to the areas where they are now extinct, the total area with losses is two-thirds of their previous range in the four states. Although the overall situation is not as serious in southwestern British Columbia, some populations there also are in a state of decline, and all populations have been completely cut off from access to the upper Columbia River in eastern British Columbia. Even if the estimate of population losses of about 40% is only a rough approximation, the status of naturally spawning salmon populations gives cause for pessimism.
- *Coastal populations tend to be somewhat better off than populations inhabiting interior drainages.* Species with populations that occurred in inland subbasins of large river systems (such as the Sacramento, Klamath, and Columbia rivers)—spring/summer chinook, summer steelhead, and sockeye—are extinct over a greater percentage of their range than species limited primarily to coastal rivers. Salmon whose populations are stable over the greatest percentages of their range (fall chinook, chum, pink, and winter steelhead) chiefly inhabit rivers and streams in coastal zones.
- *Populations near the southern boundary of species' ranges tend to be at greater risk than northern populations.* In general, proportionately fewer healthy populations exist in California and Oregon than in Washington and British Columbia. The reasons for this trend are complex and appear to be related to both ocean conditions and human activities.
- *Species with extended freshwater rearing (up to a year)—such as spring/summer chinook, coho, sockeye, sea-run cutthroat, and steelhead—are generally extinct, endangered, or threatened over a greater percentage of their ranges than species with abbreviated freshwater residence, such as fall chinook, chum, and pink salmon.*
- *In many cases, populations that are not smaller than they used to be are now composed largely or entirely of hatchery fish.* An overall estimate of the proportion of hatchery fish is not available, but several regional estimates make clear that many runs depend mainly or entirely on hatcheries.

Chapter 4 discusses some of the difficulties in evaluating the status of wild populations and how these difficulties have been addressed in recently published status reports. Regional trends are summarized, and the overall conditions of the species are presented.

THE SALMON PROBLEM

The salmon problem is the decline of wild salmon runs and the reductions in abundance of salmon even after massive investments in hatcheries. The declines—largely a result of human impacts on the environment caused by activities such as forestry, agriculture, grazing, industrial activities, urbanization, dams, hatcheries, and fishing—are widespread, although not universal. They have a variety of causes, and they are exacerbated by the unusual life cycle of Pacific anadromous salmon, which spawn in freshwater, migrate to sea to grow and mature, and return to their natal streams to reproduce. Salmon thus require high-quality environments from mountain streams, through major rivers, to the ocean. Economic development and population growth have created widespread declines in anadromous salmon abundance in the Pacific Northwest. Variations in ocean conditions—especially in water temperature and currents and the associated biological communities—also contribute to the rise and fall of salmon abundance, often thwarting the interpretation of events in freshwater and the surrounding terrestrial systems.

GENERAL CONCLUSION

To achieve long-term protection for a diversity and abundance of salmon in the Pacific Northwest, two general goals must be achieved:

- The long-term survival of salmon depends crucially on a diverse and rich store of genetic variation. Because of their homing behavior and the distribution of their populations and their riverine habitats, salmon populations are unusually susceptible to local extinctions and are dependent on diversity in their genetic make-up and population structure (Chapter 6). Therefore, management must recognize and protect the *genetic diversity* within each salmon species, and it must recognize and work with local breeding populations and their habitats. It is not enough to focus only on the abundance of salmon.
- The social structures and institutions that have been operating in the Pacific Northwest have proved incapable of ensuring a long-term future for salmon, in large part because they do not operate at the right time and space scales. As described in Chapter 13, differences among watersheds mean that different approaches are likely to be appropriate and effective in different watersheds, even where the goals are the same. This means that institutions must be able to operate at the scale of watersheds; in addition, a coordinating function is needed to make sure that larger perspectives are considered.

As a framework in which to approach its deliberations, the committee chose to focus on *rehabilitation*—a pragmatic approach that relies on natural regenerative processes in the long term and the selected use of technology and human effort in the short term—rather than on attempts to restore the landscape to some pristine former state and rather than on a primary reliance on substitution, i.e., the use of technologies and energy inputs, such as hatcheries, artificial transportation, and modification of stream channels. Rehabilitation would protect what remains in an ecosystem and encourage natural regenerative processes.

The solutions will not be easy or inexpensive to implement; even a holding action to prevent further declines will require large commitments of time and money from many people in many segments of society in the Pacific Northwest. Therefore, broad-based societal decisions are needed to successfully provide a long-term future for natural salmon populations.

ENVIRONMENTAL FACTORS

Natural and human-caused environmental changes affect all aspects of salmon life histories. Although humans can do little in the short term to control or even predict large-scale changes in environmental conditions, salmon-management programs must expect such changes and take them into account. Managers must also recognize that the natural variability in environmental conditions and people's desires for large and stable catches of salmon are often not compatible. Natural changes in environmental conditions in the ocean, in fresh water, and on land occur continually; sometimes they can lead to increased salmon productivity in an area; at other times they can lead to decreased productivity.

The emerging understanding of interdecadal changes in the ocean climate and the related mechanisms that affect salmon at sea have implications that are both exciting and disconcerting to scientists thinking about resource management. Humans are beginning to understand what happens to salmon during the majority of their lives—the portion spent at sea. Although we know little of the details, the new insights already demonstrate that variations in salmon abundance are linked to phenomena on spatial and temporal scales that humans and human institutions do not ordinarily take into account. Consider that the apparent effectiveness of hatcheries might have resulted from favorable ocean and climatic conditions in the era when the hatcheries were built; what looked like human manipulation of the total number of salmon might have been only a reapportionment among different populations. Or consider that the decline of some populations might be a direct result of introducing new hatchery populations into an ocean pasture of limited capacity.

The scale of human endeavor often has been incommensurate with the scale of salmon ecology. Some of our current policies are based on deep ignorance: it is not reasonable to assume that ocean conditions vary in ways that are generally uniform and random in their impacts on populations of salmon. Interdecadal variations and the importance of the ocean phase should be incorporated into human thought, planning, and actions in response to the effects of and attempts to repair damage that occurred during the freshwater phases of the salmon lives. The possible overriding effects of interdecadal changes in ocean conditions on salmon, the results of freshwater salmon management, and the overwhelming focus of human attention on the more-visible freshwater phases of the salmon history combine to provide the key ingredients for surprises in future.

Recently, natural environmental conditions in the Pacific Northwest appear to have been unfavorable to salmon production. As changes continue to occur, environmental conditions will probably favor salmon and lead to larger runs in some areas for a time, even without human intervention. If such changes do occur, they should be regarded as providing time to develop better strategies for rehabilitation of salmon populations. They should *not* be used as reasons for abandoning efforts to rehabilitate salmon, for they will surely be followed by other natural changes. Inappropriate short-term responses to large-scale environmental changes at sea or on land should be avoided, because there can be long lags between causes and effects.

LIMITS ON SALMON PRODUCTION

The salmon production cycle has three principal components that determine abundance:

reproductive potential of adults returning from the sea to spawn, which is affected by their growth at sea; production of offspring from natural reproduction in streams and artificial propagation in hatcheries; and sources of mortality (including natural mortality, fishing mortality, dam-caused mortality, mortality from habitat alterations and changes in environmental conditions, and so on). All three components are affected by changes in environmental conditions as well as by human activities. Variation in the three components and their interactions ultimately determine the ability to sustain salmon populations and their production. These limitations cannot be easily overcome through technology. Although it has been widely assumed that a loss of natural salmon production can be compensated by enhancement (e.g., by increasing hatchery production), chapters 6, 11, and 12 show that such an assumption is untenable by explaining the need to conserve sufficient genetic variation in natural populations to support the evolutionary and ecological processes needed for sustained salmon production. Compensating for salmon loss from any source over the long term therefore requires reducing other losses. Furthermore, an increasing appreciation of the marine environment and its effects on the above components is emerging as an essential consideration in salmon management.

VALUES

The salmon problem, like many other environmental issues, has been addressed through choices made within economic, political, and individual ethical frameworks. Values and ethical positions held by people involved in and affected by the salmon problem encompass a pluralistic, pragmatic and evolutionary approach to natural resource management. Recognizing and articulating that pluralism is important because problems in managing and protecting fish populations are due in part to the failure to articulate divergent interests, goals, and values and to address them explicitly. Chapter 5 describes how the widely varied ways that humans intervene in salmon populations are linked to socially validated values.

From a policy perspective, the salmon problem is one of long-standing and serious conflict in fact, interest, and values. People often invoke widely held values to protect particular interests, but values are genuine sources of conflict in themselves. Value conflict stems from different assessments of the desirable goals of public action. From a scientific perspective, wild salmon populations are an example of an ecosystem's natural capital. Our greatest success has been in designing ways to use human-food benefits from wild salmon. Our corresponding failure has been in protecting indirect and nonhuman benefits.

One way to present the salmon problem is to say that the value of the Pacific Northwest's salmon-capital asset has depreciated over time as its productivity has declined. A major problem is that the market does not account for the full range of costs and benefits of salmon. That is called a market distortion. When such market distortions exist, some resources are underpriced and overused, and others overpriced and underused. Many nonmarket values of salmon are underrepresented and are not easy to measure or compare. Thus management decisions often do not adequately reflect the importance of salmon to society and decisions about resource use may not achieve societal goals. To correct the discrepancy between social values and resource use, attempts can be made to design policies that reflect the full range of resource values.

Full value is a public, not a private, question. Consequently, public choices are central to the salmon problem. Public choices have to take into account many owners with multiple preferences, attributes that are not fully observable and sometimes unknown, and prices that reflect only part of the resources' full value to society. The concept of full value points to the problem of "externalities"—the problem that some costs and benefits are beyond the accounting of the decision-making unit.

Environmental variability creates economic uncertainty, which causes people to discount the future more heavily, and this leads to pressures to increase rates of immediate, direct use. Environmental variability also creates scientific uncertainty about biological processes, which can be perceived to call for a cautious approach and lead to pressures to lower rates of immediate, direct use. The resulting tension between economic and scientific responses to uncertainty adds complexity to decisions about appropriate rates of resource use. That tension is widespread in decisions concerning the salmon problem.

Problems like these emphasize the need to develop more appropriate interdisciplinary approaches. The idea of rebuilding the salmon runs of an industrialized ecosystem is heroically optimistic—a hope that might not have occurred to anyone except those who had rehabilitated the Willamette River basin in Oregon or Lake Washington near Seattle. Those environmental successes came through the disciplined execution of the planning paradigm that has been fitfully applied to the much larger Columbia basin. The extension of those experiences to the multijurisdictional, multifunctional situations of the Pacific Northwest would require coordinated action and learning on a new, larger scale—a scale on which planning and action have been tried but have not been successful. A more explicit appreciation of the values, interests, and institutions involved in this undertaking is required. Chapter 13 explores this further and urges constructive change in institutions that include cooperative management, bioregional governance, and adaptive management.

GENETICS AND CONSERVATION

Pacific salmon reproduce in freshwater streams. Their progeny migrate to the sea to grow and mature, and then return to freshwater streams to reproduce and (nearly always) die. This pattern of freshwater reproduction and growth at sea is called *anadromy*. Most of the adults actually return to the streams where they hatched. This behavior—called *homing*—is an essential part of salmon biology and makes their genetics and conservation unusual. There is a great deal of environmental variation among the various streams and lakes where salmon spawn and in the rivers through which they migrate. Because of their anadromous life cycles and homing behaviors and the variety of environments they occupy, each salmon species tends to differentiate into local breeding populations—called *demes*—that are in general reproductively isolated from other populations and adapted to each stream. To sustain productive natural populations of salmon, it is crucially important to maintain this genetic variation and local adaptation. Chapter 6 describes examples of such local adaptation.

However, more is involved than only local adaptation to various streams. Natural environmental fluctuations, including major disruptions caused by geological activity, can cause the extinction of local populations. Because homing is not perfect, fish that stray from nearby streams can replenish those populations. Strays are more likely to re-establish a population if the environment in the new stream is similar to that in the stream where they hatched. Thus, strays into tributaries in the same major river system or into nearby streams are more likely to succeed than those that stray into very different environments. This network of local populations (known as a *metapopulation*) provides a balance between local adaptation and the evolutionary flexibility that results from exchange of genetic material among local populations (Chapter 6). It likely also explains why artificial attempts to re-establish populations from a captive broodstock have often failed—too often, the gene pool of the broodstock has had reduced variation or has been derived from a population adapted to a different environment (Chapter 12). The metapopulation structure provides a balance between local adaptation and evolutionary flexibility; therefore, maintaining a metapopulation structure with good geographic distribution should be a top management priority to sustain salmon populations over the long term. Many of the committee's recommendations are based on this crucial conclusion.

There is no "correct" answer to the question of precisely how much biological diversity and population structure should be maintained or can be lost to provide a long-term future for salmon. Scientific estimates—including uncertainties associated with them—are only part of the argument. Society must decide what degree of biological security would be desirable and affordable if it could be achieved, i.e., the desired probability of survival or extinction of natural populations, over what time and what area, and at what cost. Nonetheless, biological diversity and the structure of salmon populations are being lost at a substantial rate, and this loss threatens the sustainability of naturally reproducing salmon populations in the Pacific Northwest.

HABITAT LOSS AND REHABILITATION

The main habitat requirements of salmon in freshwater include a stream or lake, the adjacent border of vegetation (riparian zone) that serves as the interface between aquatic and terrestrial ecosystems, and the quality and quantity of water (Chapter 7). The water must be clean enough and cool enough to support returning adults, for eggs to hatch, and for young to survive and grow until they migrate to sea. There must be enough water in the rivers at crucial times to make migration possible, to allow fish to escape predators, and to allow fish to find adequate food. Well-aerated streambed gravels are important for spawning. Streamside vegetation provides shade, which keeps the water cool; it provides a buffer against soil erosion, which maintains water quality; it provides living space for various animals that provide food and nutrients for streams; and it provides a source of large woody debris, which plays a key role in the formation of physical habitat and storage of sediment and organic matter and provides habitat complexity in stream channels, thus improving the stream environment for salmon. These requirements for environmental conditions in streams and adjacent riparian zones depend on the condition of the entire watershed in which they occur.

Many human activities—such as forestry; agriculture; grazing; industrial uses; commercial, residential, and recreational development; and flood control—have a variety of adverse effects on salmon habitats. For example, they can increase soil erosion, reduce the amount of woody debris in streams, raise the water temperature, add contaminants to the water, affect water flow, and reduce the amount of water available, with resultant loss or degradation of riverine and adjacent riparian and near-river habitat. Therefore, protection and rehabilitation of riverine and riparian habitats and associated watershed processes will be an integral part of rehabilitating salmon populations, although it is a major and difficult undertaking (Chapter 8). In the past few years, genuine improvements in protecting forested streams have been initiated. Nonetheless, for real progress to occur, habitat protection must be coordinated at landscape scales appropriate to salmon life histories, and they must be more consistent across different types of land use (chapters 8 and 13).

DAMS

Hundreds of dams have been built on rivers of the Pacific Northwest. They range from small irrigation dams with a hydraulic head of only a few feet to massive dams at Grand Coulee, Dworshak, and Hells Canyon on the Columbia and Snake rivers that are several hundred feet high and completely block upstream and downstream passage of anadromous fish. Dams on various rivers—some of them impassable—have greatly reduced wild runs. Even smaller dams (e.g., those associated with many hatchery operations and irrigation-diversion dams) can block salmon runs. In addition to their effects on migration, large storage dams affect the quantity and timing of water flow in the river as well as flow velocities, water chemistry, and water temperatures. Reservoirs behind dams can also inundate extensive areas of spawning and rearing habitat, although in some cases the reservoirs provide new (but different) rearing habitat. Many water diversions for irrigation lack protective fish screens of modern design; installing such screens would reduce mortality of smolts as they migrate downstream.

Even when fish ladders provide passage for adult salmon, many young salmon (smolts) migrating downriver die at dams. Although as many as 90% of young salmon might survive passage over, around, and through any single major project on the Columbia-Snake mainstem, the cumulative reduction in survival caused by passing many projects has adversely affected salmon populations. To counteract these effects, it is essential to improve the survival of smolts migrating through hydropower projects, especially in the Columbia and Snake rivers. Serious consideration needs to be given to all available alternatives for doing so; even a small improvement in survival would be helpful if it were repeated at several dams.

Controversy surrounds the effects of dams and how best to mitigate them. Alternatives include removal of dams, modification of turbines and other structural aspects of dams to improve fish survival during passage, drawdown of the water during the seaward migration of smolts to restore the river's profile to its pre-dam (river-grade) configuration to increase the flow rate and diminish the smolts' travel time, drawdown of the river to some level above river grade, augmentation of water flows during smolt migration to speed their passage downriver, transportation of smolts around dams by truck or by barge, control of predators in reservoirs and below dams, and spilling of water over dams instead of through the turbines. However, there is a dearth of good scientific information on which to base evaluations of the alternatives, some of which would be very expensive and would cause large losses of hydropower revenues.

Dam removal and drawdown of those rivers to river grade would be enormously expensive, would take many years, and probably would have long-term adverse impacts on the rivers. However, because the many dams on the Columbia River and its tributaries cumulatively have large effects on salmon survival, the addition of any new major dams in undammed reaches in the system (e.g., the Hanford Reach of the Columbia River) would make the situation worse;

existing dams should have adequate fish-passage facilities where feasible and appropriate before being relicensed. The committee is unaware of any scientific data that unequivocally support drawdown to a level above river grade as the best available dam-mitigation option for the Columbia River or the Snake River. Based on limited information, transportation appears to be the most biologically effective and cost-effective approach for moving smolts downstream. It should be continued on an adaptive basis (i.e., in such a way that additional information can be obtained about its effectiveness). Additional information is needed on effects of transportation on survival to the adult return stage, on homing, on success of natural spawning, and on genetic diversity of returning adults. Because any action that could jeopardize all of the fish in a stream must be avoided, not all the fish in any stream should be transported.

Research is needed on the effects of various options on the survival of both smolt and adult migration through dam and reservoir systems. Any management option should be applied on an adaptive (experimental) basis. The committee is not recommending that the salmon be "studied to death," a criticism often leveled at those who urge further studies. Indeed, enough is known now to take some actions. In recommending "adaptive" actions, the committee is recommending that any mitigative actions be taken in a way that allows their effects and effectiveness to be measured and assessed objectively. For example, if some fish in a stream are transported downstream, the action should be designed so its effectiveness can be assessed and compared with other alternatives. Despite the paucity of information, it is clear that no single approach would eliminate the adverse effects of dams on salmon.

HATCHERIES

Hatcheries have been used for more than 100 years in attempts to mitigate the effects of human activities on salmon and to replace declining and lost natural populations. As a result, a major proportion of salmon populations in the Pacific Northwest now consist largely of hatchery fish. These hatchery fish appear to have had substantial adverse effects on native fish populations.

For many years, people did not recognize the potential for hatchery fish to affect wild fish and did not believe that there was any limit to the ocean's capacity to provide food for growing salmon. It therefore seemed that producing more juveniles would result in more returning adults. The difficulties and shortcomings of hatchery production did not become apparent until fishing pressure and habitat-related mortality increased and marking technologies became available. As a result, hatcheries were not part of an adaptive-management program; that is, they were not considered as scientific experiments—they were not even adequately monitored—so many of their effects were not well known.

It is now clear from synthesis of experience and from consideration of well-established biological knowledge that hatcheries have had demographic, ecological, and genetic impacts on wild salmon populations and have caused problems related to the behavior, health, and physiology of hatchery fish. They have resulted (among other effects) in reduced genetic diversity within and between salmon populations, increased the effects of mixed-population fisheries on depleted natural populations, altered behavior of fish, caused ecological problems by eliminating the nutritive contributions of carcasses of spawning salmon from streams, and probably displaced the remnants of wild runs (Chapter 12). Hatchery fish have at times exceeded the capacity of streams and are increasingly being associated with reduced marine growth and survival in wild salmon populations (Chapter 12).

Many of the problems stem from purposes to which hatcheries have been put—mainly to provide substitutes for natural populations lost or displaced because of human development activities. Because of their deleterious impacts, however, hatcheries should no longer be viewed solely as factories for producing fish. Hatcheries should also be thought of as laboratories that can provide controlled environments for studying juvenile fish and for testing treatments to improve our understanding of what happens to juveniles after they leave spawning areas. Seen in that light, hatcheries can be a powerful tool for learning about salmon.

Hatchery planning, management, and operations should be changed so that their goals are to assist recovery of wild populations and to increase knowledge about salmon. As described above and in many parts of this report, especially chapters 6, 11, and 12, precautions must be taken to protect the genetic diversity and ecological productivity of naturally spawning populations of salmon. Those precautions will include an overall decrease in hatchery-fish production and—over the short term—in fishing opportunities. The basic guideline is to ensure that any hatchery production for fishing is not detrimental to natural populations. Because adaptive-management experiments should be tailored to the circumstances in different watersheds of the Pacific Northwest, decisions about use of hatcheries will differ across these watersheds. Therefore, decisions about uses of hatcheries should include a focus on the whole watershed and its linkage to the region and the ocean pasture, rather than only on the fish.

FISHING

Fishing for salmon is important in the Pacific Northwest. It includes commercial, recreational, and treaty fishing at sea and in rivers and is an important source of mortality, especially for adults returning to spawn. Salmon mortality caused by other human activities and structures such as dams, habitat loss or degradation, pollution, and water diversion and by natural factors such as predators, disease, and environmental variability together usually exceed fishing mortality. Those causes of mortality have a major effect on the production of adult fish and thus influence the rate of fishing that can be sustained. However, fishing is the easiest mortality factor to control. Control of fishing has rehabilitated marine and anadromous fish populations in various parts of the United States.

Managing salmon fisheries is more difficult than managing many other fisheries because of the geographic distribution of salmon, their metapopulation structure, and the fact that most adult fish spawn only once and then die. In the jargon of Pacific salmon fisheries, managers refer to groups of salmon populations that are identifiable for management as *stocks*. Frequently, *stock* refers to a geographic aggregate of populations that includes many local breeding populations of varied size and productivity; this is too large a unit for conservation of genetic diversity and rehabilitation of salmon production. Managing at the stock level obscures critical biological complexity. But even managing such large units is difficult because of the complex relationships, responsibilities, and obligations among a large number of institutional entities in the region (including nations, states, provinces, federal agencies, tribes, interest groups, and other organizations), the mandates of the Endangered Species Act and other laws, and the diverse array of interests and values in the region.

For rehabilitation of salmon populations, the aim for fishery management—as for other management efforts—should be to achieve long-term sustainability based on maintaining diversity of gene pools and population structures. Therefore, a successful fishery-management component for protecting natural salmon runs in the Pacific Northwest should explicitly recognize the need to maintain and rehabilitate the genetic diversity of salmon and recognize the interdependence of genetic diversity, habitat, and salmon production. It must also account for the uncertainty in scientific predictions and the inherent variability of biotic and abiotic environmental factors.

In general, the aim should be to assure adequate escapements for depleted populations. To achieve long-term sustainability, which requires sufficient genetic diversity, fishing should occur only where the identity (i.e., the originating population) of the salmon is known, when total fishing mortality is consistent with productivity of the fish, and when the catching technology ensures minimal mortality in depleted demes. This will require fishing methods that allow different degrees of fishing effort on various salmon populations and that allow identification of fish taken from depleted demes so that they can be avoided or released alive. Two methods of achieving these goals (but not the only ones) are terminal fisheries and live-catch fisheries.

In general, the serious declines of wild salmon populations show that not enough fish are being allowed to return to spawn. The number of fish returning to spawn (escapements) must be substantially increased to conserve genetic diversity within and between demes, use available habitats, rehabilitate ecological processes (including the return of nutrients to aquatic ecosystems), and increase the sustainable production of salmon. Increasing escapements will disrupt fisheries, industry, and communities, but it is necessary for restoring production. As salmon abundance increases and fisheries begin operating at lower, but sustainable, catch *rates*, actual catches will gradually increase, although probably not to the sizes of some historical catches, because those were based on excessive catch rates. Implementing this recommendation will initially require low fishing effort in many areas, especially in the ocean, and it will require cooperation from British Columbia and Alaska, because many salmon that originate in the Pacific Northwest are caught at sea in British Columbia and southeastern Alaska (chapters 10 and 11).

INSTITUTIONAL CHANGE

The long and serious decline of salmon in the Pacific Northwest has been promoted—often unwittingly—by human institutions; effective remedies, if they are to be found, will have to involve changes in those institutions. Growth in human populations and economic activity threatens the continued existence of salmon in the Pacific Northwest. Institutions developed in different times for diverse purposes have been asked to do things foreign to their original objectives and capabilities. Political changes have hindered attempts to take a long-term perspective. There has been fragmentation of effort and responsibility.

Changing institutional structures is notoriously difficult, but it is possible. Because the problems facing salmon have many aspects, a multidisciplinary approach to their solution is essential. Indeed, if the money that has been spent to date on salmon research had been spent with a more unified, regional vision, greater progress would have been made in maintaining viable salmon populations (Chapter 14). Unless agencies cooperate more effectively, salmon populations are unlikely to recover.

One problem is that current institutions and the boundaries of their jurisdictions usually do not match the spatial, temporal, or functional scales of the salmon problem. In addition, current institutional structures lack both a fine-grained aspect to respond to local concerns and variations and a coarse-grained aspect to integrate across small regions and to make sure that the interests of a few small areas do not jeopardize larger regional interests.

Because we often do not know what the effects of a management option will be, management must be undertaken with an experimental, adaptive point of view. Flexibility must be built into institutional structures to allow for changes in management practices based on experience. Institutions must allow and encourage refocusing the energies of salmon management to recognize the importance of demes in maintaining genetic processes and to maintain and expand their diversity. The goal of management should be to achieve a biologically sound escapement (instead of focusing on a "sustainable" or permissible catch) for each metapopulation and an explicit adoption of time scales for management and planning that are commensurate with the multiyear scale of salmon life cycles.

Beyond those facilitating changes, the formal institutions that manage salmon need to be restructured or refocused to reflect three important institutional principles. First, decision-making authority should be shared among all legitimate interests (cooperative management); legitimate interests that are excluded from decision-making are likely to block desirable changes. Second, the organizational structures and decision-making processes should allow for local conditions and variations and the management strategies should vary accordingly. Third, systematic learning using appropriate experimental designs (adaptive management) should be an essential goal.

As a first step, the relevant agencies in the Pacific Northwest, including the National Marine Fisheries Service, should agree on a process to permit the formulation of salmon recovery plans *in advance* of listings under the Endangered Species Act, and the Pacific Northwest states, acting individually and through the Northwest Power Planning Council, should provide technical and financial assistance to watershed-level organizations to prepare and implement these preemptive recovery plans.

A SCIENTIFIC ADVISORY BOARD TO ADDRESS SALMON PROBLEMS

A great deal is known about salmon and their difficulties, but a great deal remains unknown or controversial despite the expenditure of large amounts of money and time on research. Part of the reason for the lack of knowledge is that people have not agreed on what information is needed, have duplicated each other's work, and have been unwilling to fund needed research. An independent, multidisciplinary, standing scientific advisory board should be established to ensure that the limited money available for research is spent most productively to answer the most critical questions in a timely manner. A standing scientific advisory board would also help to ensure that when urgently needed actions are taken, they are designed so that their effects and effectiveness can be properly assessed. The board's reports should be public.

AN APPROACH TO SOLVING THE SALMON PROBLEM

The salmon problem took many years to develop, and its solution will require the commitment of considerable time, money, and effort. The committee's analyses of the problems and potential solutions lead to the conclusion that there is no "magic bullet." Therefore, like the problem itself, solutions will be complex and often hard to agree on; to be successful, they will need to be based on scientific information, including information provided by social and economic sciences. In addition, to be successful, consensus will be needed about the size of the investments to be made in solving the problem and how the costs should be allocated. This means that solutions will have to be regionally based, just as the salmon problem has regional variations (see Chapter 13).

The committee recommends the following general approach. *For each major watershed or river basin*, the following should be assessed.

- All causes of salmon mortality, including their estimated magnitude and the uncertainties associated with the estimates. Factors known to decrease natural production should also be listed.
- Ways of reducing those sources of mortality or compensating for them, their probable effectiveness, and their drawbacks.
- The probable costs of each method of reducing mortality. To be most useful, the estimates should include both market and nonmarket costs. To the degree possible, it is important to identify what societal groups would bear the major portion of the costs of each method and significant uncertainties in the estimates. (For example, reductions in catch rates would primarily affect fishers and tourists; changes in water use could affect agricultural interests or ratepayers; changes in riparian management could affect forest-products industries or private landowners.)

All the estimates would include substantial uncertainties, due both to lack of knowledge and to fundamental environmental, socioeconomic, and biological uncertainties. Nonetheless, such a process of assessment and evaluation is essential for rational decision making. They will provide a basis for evaluating options—for weighing benefits and costs—and for identifying areas where research is critical. *All the recommendations in this report should be viewed in this context: they need to be considered on a regional basis (i.e., major watersheds) and in a comprehensive framework that includes an analysis of their costs, probable effectiveness, and the ability and willingness of various sectors to bear the costs.*

This will be challenging for several reasons. First, in many cases, the desired information has not been collated or does not exist. Second, considerable time and resources will be needed to perform such analyses even for one watershed. But the most important reason is that estimates of costs and how they might be distributed will require intimate knowledge of each watershed and of people's preferences and habits. These essential estimates should be made with input from the people involved. The committee believes this approach will lead to improved effectiveness and—if not reduced costs—at least increased cost-effectiveness and reduced controversy.

THE FUTURE

The best approach to establishing a sustainable future for salmon in the Pacific Northwest is to use currently available information to develop workable, comprehensive programs rather than reacting to crises. This report has analyzed many parts of the salmon problem and assessed many options for intervention. However, if current trends continue, the Pacific Northwest will continue to see the effects of more people, more resource consumption, changing economic demands and technologies, and changing societal values. Because the success of programs to improve the long-term prospects for salmon in the Pacific Northwest will depend on the societal and environmental contexts, it is important to develop ways for improving our ability to identify changing contexts and to respond to them. As long as human populations and economic activities continue to increase, so will the challenge of successfully solving the salmon problem.

11

Salmon-Fishery Management Concepts

While Pacific salmon fisheries developed rapidly during their early history, our ability to manage them did not. Much of the basic biological understanding of Pacific salmon and information that could be used to manage salmon fisheries were being developed as the fisheries developed, but their application to management developed much more slowly. In his review of salmon management during the first century of Pacific salmon fisheries, Larkin (1970) suggested that almost from the beginnings of the industry two ideas were implicit in attempts at management: that salmon returned to their home stream to spawn and that catches in each river had to be limited. Those continue to be the biological bases for management, and we continue to struggle with their incorporation into a sustainable management concept.

Papers by McHugh (1970) and Larkin (1970) provided historical perspectives on the development of fishery science and management of Pacific salmon in North America. Initially, scientific investigations consisted largely of descriptive biology and examination of the "home-stream concept." The scientific basis of that concept was debated long after its acceptance in management (see, for example, Jordan 1925, Moulton 1939). But acceptance, coupled with the early recognition that salmon eggs were easily cultured, resulted in hatcheries' becoming the major management activity during the first 50 years of the industry. By the late 1930s, however, management of Pacific salmon was in transition. Larkin (1970:226) reported that "regulations for controlling harvest were inadequate, but insufficient information existed on which to construct better techniques; hatchery practices were fairly advanced but of dubious value; inroads on salmon production as a consequence of the development of other resources were beginning to cause concern." The 1930s began a period of more-quantitative assessment in fishery management (Cushing 1988, McHugh 1970). The quantitative basis of salmon management was provided by Ricker's 1954 seminal paper on stock and recruitment. Since then, management of Pacific salmon fisheries has been premised on his stock-recruitment theory.

STOCK[1] AND RECRUITMENT

Salmon-fishery management assumes that there is surplus production below some upper size of the spawning population. *Surplus* in the case of salmon means that a given number of spawners in an adult generation produces, on average, more progeny than needed to replace the parents and overcome all natural mortality sources from the time fertilized eggs are deposited in the gravel of natal streams, through juvenile and immature life phases, to adulthood. The number of surplus animals varies with the size of the population and the natural mortality rate. Smaller populations tend to have higher productivity than larger populations (i.e., number of

[1] The terminological difficulties associated with the word *stock* are discussed in Chapter 4. To permit comparison of the discussion in this chapter with much of the published literature on fisheries, we use the term *stock* here, although we use the term *population* in most of the rest of the report.

progeny returning per adult spawner), and their total production is limited mostly by the number of eggs deposited. In larger populations, production depends more on the interactions between spawners and habitat required for sustaining survival and growth of progeny.

Ricker (1954) noted that factors that become more effective at high densities, called "compensatory" factors by Neave (1953), control or regulate salmon populations. Compensatory mortality factors place more pressure on high-density than on low-density populations. For example, when large numbers of pink salmon reach their spawning grounds, some adults are forced to use less-suitable gravels at stream margins; in crowded conditions, late spawners might even dig out developing embryos deposited by earlier spawners. Those factors decrease the number of progeny produced per female. When chinook or steelhead spawners are less abundant, the resulting fry, fingerlings, and pre-smolts have more access to feeding positions and cover, so they may grow faster and be less vulnerable to predation.

Ricker (1954) termed the relationship between the number of spawners (stock or S) and the production of progeny (recruitment or R), the stock-recruitment function. The term *recruitment* refers to the potential availability of fish to a fishery or to form the next spawning generation. The stock often is referred to as the *escapement*, because these fish escaped capture by a fishery and return to spawn.

Fishery managers have attempted to maximize surplus production (i.e., animals available for catch) by maintaining the number of spawners at an abundance at which, according to Ricker's stock-recruitment theory, they are likely to produce the largest sustainable catch. Figure 11-1 is an example of a hypothetical Ricker stock-recruitment function. In reality, the function would be fitted statistically through a scatter of data points collected over time. The function represents the average response expected given an escapement under the environmental conditions that existed when the data were collected. If escapements merely replaced themselves in the next generation, those returns would fall along a "replacement line" where R = S (line A in Figure 11-1). However, if the function value R_1 expected for a particular S_1 exceeds the replacement value, then a surplus production ($R_1 - S_1$) could be caught and the population maintained in equilibrium at the same future S and R numbers. Salmon populations can maintain themselves at several levels of abundance, and different salmon populations have different stock-recruitment curves. In Figure 11-1, curve B describes a population with greater productivity than curve C, but one with greater density-dependence at large spawning stocks. Populations with greater productivity can sustain their production at higher exploitation rates.

The S number that, on average, maximizes the catchable number of fish generation after generation is referred to as the optimum escapement, and the associated catch is the maximum surplus reproduction or maximum sustained yield (MSY). The escapement expected to provide MSY is indicated as S_{MSY} in Figure 11-1. It occurs where the slope of the recruitment curve is 1.0, the tangent to the curve parallel to the replacement line. Once S_{MSY} is determined, the rate of exploitation that can be sustained by the population to maintain MSY can also be determined, i.e., $(R_{MSY} - S_{MSY})/R_{MSY}$. In this figure, the surplus production ($R_1 - S_1$) is equal to MSY.

Other stock-recruitment models have been proposed. The Beverton-Holt model (1957) predicts that the number of recruits increases with spawning stock ever more slowly and never exceeds a particular value (asymptote). This model does not turn downward at high S, as with Ricker's model.

Stock-recruitment functions, whether Ricker's or Beverton-Holt's, share several serious limitations for application to salmon management. The principal limitations are related to

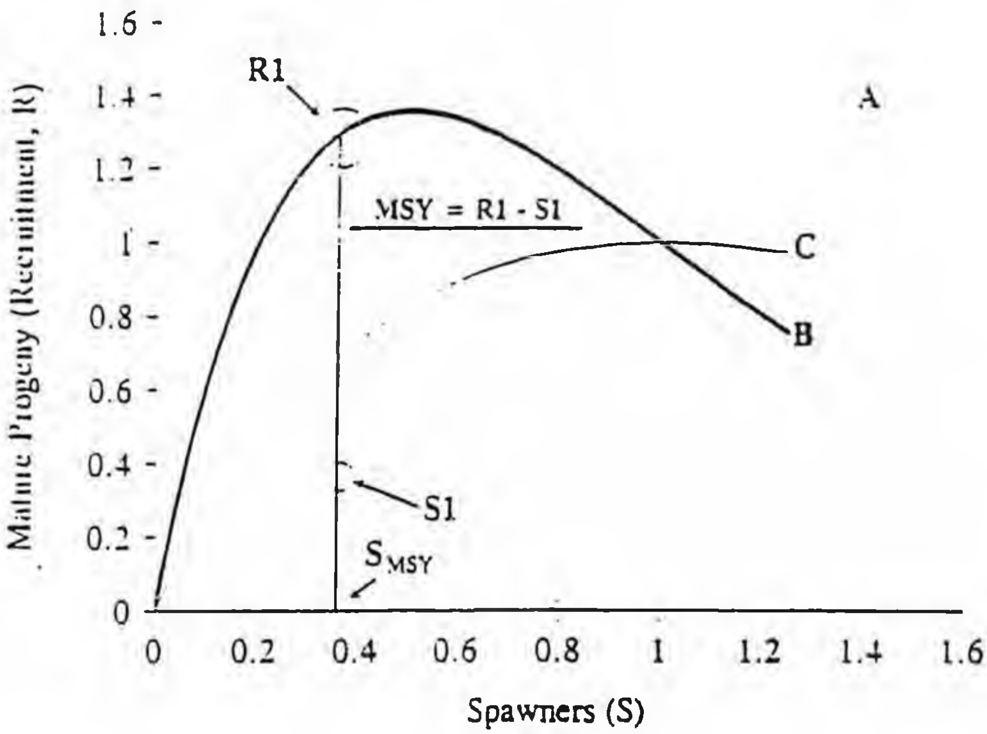


Figure 11-1 Hypothetical Ricker stock-recruitment curves relating number of animals reproducing (spawners) and production of mature progeny (recruitment). Other letters explained in text.

- The estimation of the biological production function in a highly variable natural environment.
- Differences between populations and change over time within populations.
- The necessity for accurate data on total fishing mortality by age and population over all fisheries, on number of spawners by age, and on future production.

An individual data point (i.e., the recruitment from a parental spawning stock) reflects biological processes, effects of environmental variability, and random events. Determining an appropriate production function in the presence of this variability requires a long series of data on returns over a wide range of spawning-stock sizes. The uncertainty about a recruitment function is usually high. For example, even in a sockeye population with 41 years of good assessment information, a characteristic recruitment function is not evident (Figure 11-2a). The relationship between spawners and juvenile production in freshwater is more evident (Figure 11-2b), but variability in marine survival weakens both the relationship between spawners and adult returns (Figure 11-2a) and between downstream migrants (smolts) and adult returns (Figure 11-2c). The latter relationship would already account for variation in returns attributable to variation in freshwater survival. Even in the population modeled in Figure 11-2, the estimate of S_{MSY} is uncertain; S_{MSY}= 332,000 with a 90% confidence range between 203,000 and one million spawners. This confidence range was estimated from 1,000 computer simulations of the

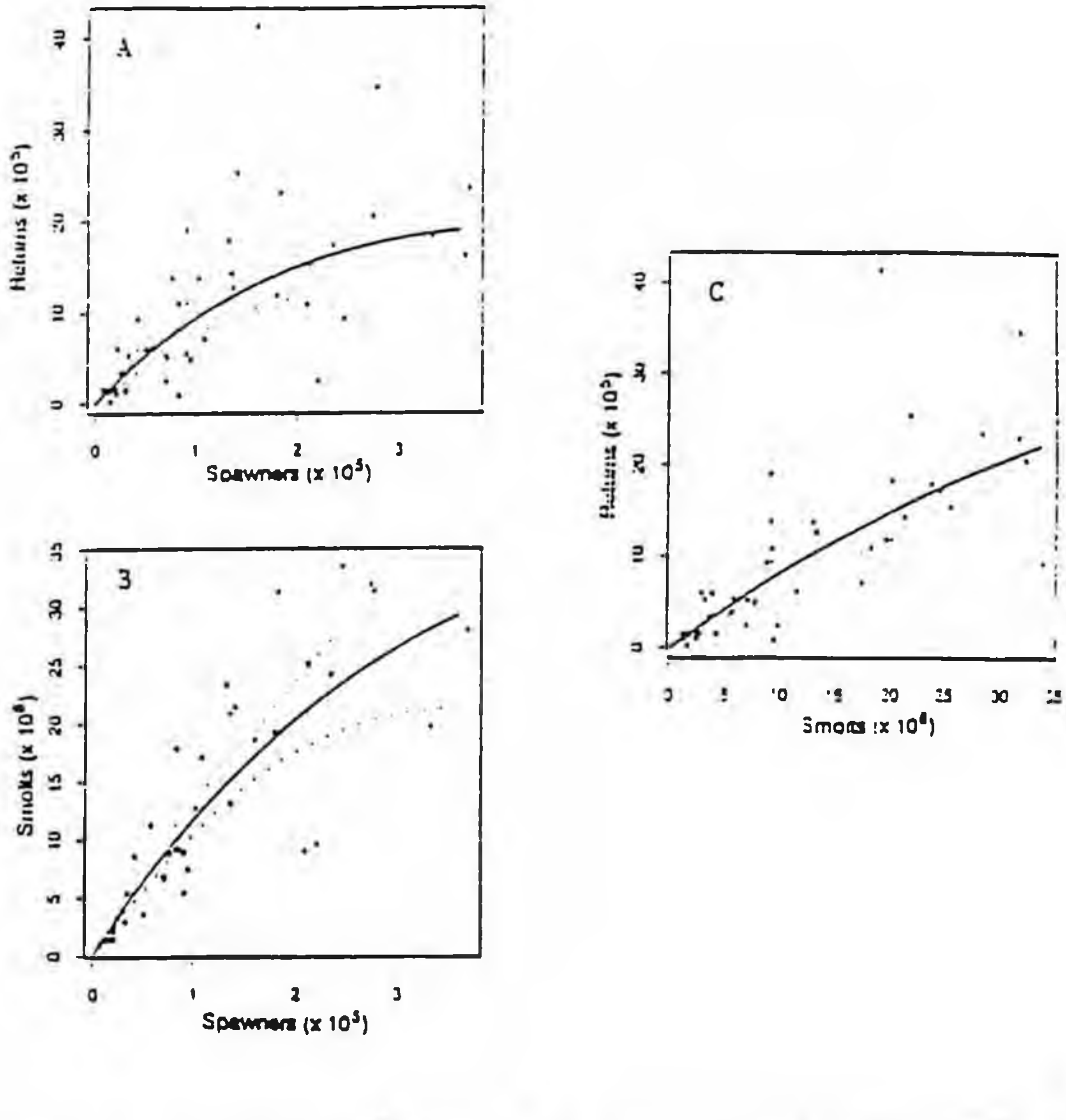


Figure 11-2 Ricker stock-recruitment data and functions for Chilko Lake sockeye salmon from Fraser River. A, adult spawners and adult recruitment; B, adult spawners and juvenile downstream migrants (age 1 + smolts); and C, migrants and adult returns.

relationship between adult spawners and adult recruitment. The distribution of the simulation results (Figure 11-3) indicates the uncertainty associated with estimates of the optimal escapement value for this population. Furthermore, the scatter plot of alpha versus beta values (S/R parameters in the Ricker function) indicates that these parameters are correlated (the oval shape of the 90% joint confidence limit indicates correlation). The wide variation in the alpha

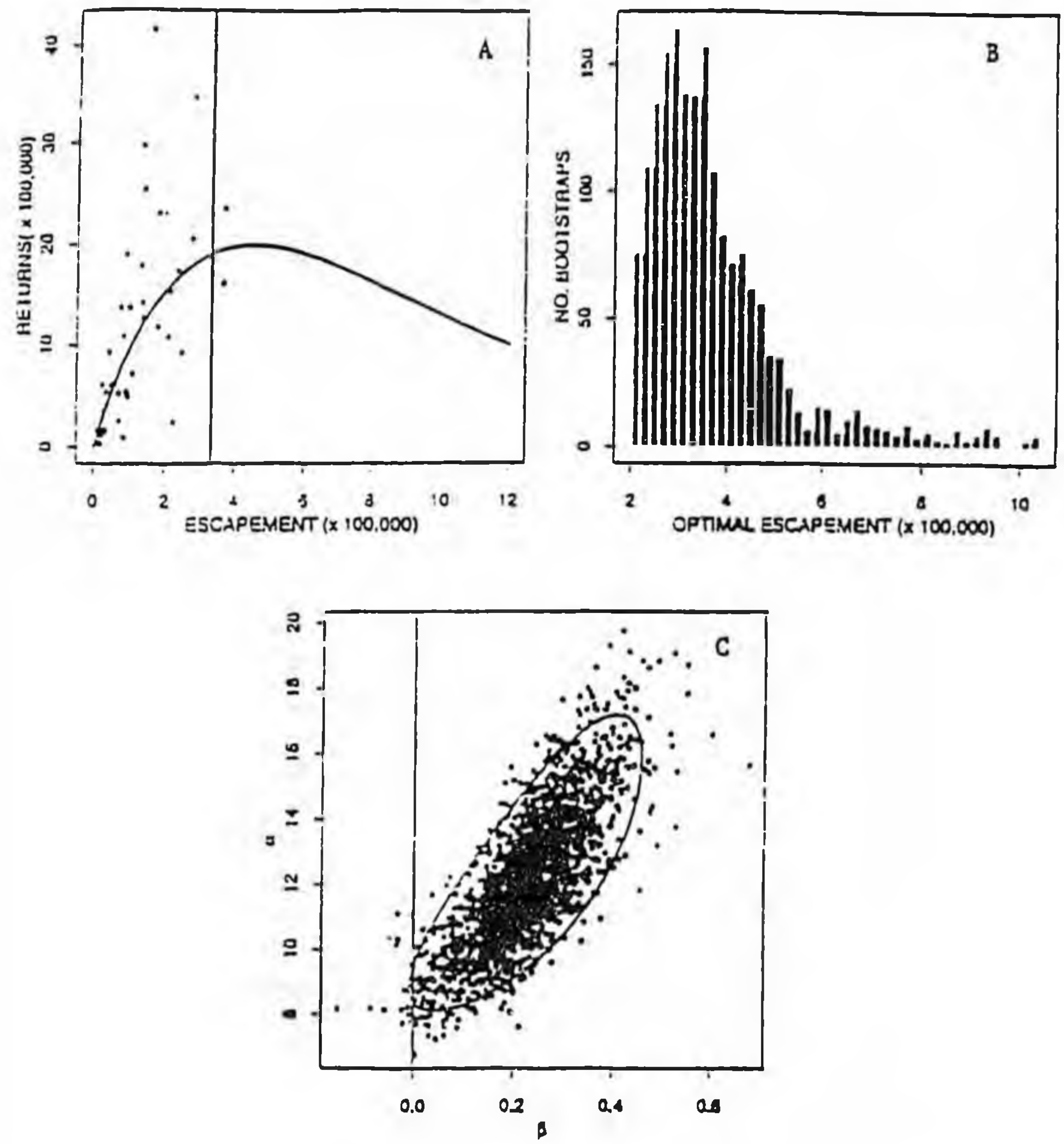


Figure 11-3 Results of 1,000 bootstrap simulations of Chilko sockeye Ricker stock-recruitment function (top left). Top-right figure is distribution of 90% confidence interval for optimal spawning-stock sizes determined by simulations. Lower figure is bivariate scatter plot of Ricker stock-recruitment parameters determined from each simulation.

value is associated with wide variation in beta; this results in a highly uncertain stock-recruitment function for this population. In salmon populations in which recruitment and spawning stock sizes have been monitored, annual variation in the ratio of returns to spawners can vary by a factor of 10. Recently the marine survival rate of chinook salmon released from Robertson Creek Hatchery (on the west coast of Vancouver Island, B.C.) has been shown to vary by a factor of more than 100 (0.1% - 13.7% survival to the second year).

Many years of data would assist in accounting for that variability, but long-term data can involve another problem. The function calculated reflects returns per spawner under past environmental conditions. If the environment changes, the stock-recruitment function changes. An obvious example is deterioration of freshwater environments, as evidenced in increased deaths associated with dams, reduction in area available for spawning or rearing because of water abstraction, or sedimentation in spawning gravels. Change in marine survival (see Beamish and Boullion 1993) also can alter the stock-recruitment function. Environmental variability makes questionable how representative any stock-recruitment function will be for current and future environmental situations. Limiting data to periods considered to be more "typical" of existing conditions might be possible, but the resulting decrease in data points would increase uncertainty substantially.

The most common concern about managing for MSY in salmon fisheries is that stock-recruitment functions vary among populations. The MSY for a population is determined by its productivity and sources and magnitudes of density-dependent mortality rates, which reflect the life history of the species and the specific habitat in which the population lives. Stock-recruitment functions are expected to vary, but the paucity of reliable data on population-specific functions makes it hard to account for the differences. An obvious example is the comparison of wild-spawned versus hatchery-reared salmon. A hatchery population can sustain its maximum catch at substantially greater exploitation rates than can a natural population because mortality associated with spawning and freshwater rearing is much lower in a hatchery than in natural systems. Assuming that after release marine mortality sources do not compensate, fewer parents are needed to reproduce the recruitment from a hatchery population (see Chapter 12). Direct comparisons of stock-recruitment functions for hatchery and wild populations (in the same geographic area and period) are rare. One good comparison involves sockeye salmon in the lower Fraser River (Figure 11-4), where an artificial spawning channel in Weaver Creek enhances the fry productivity of that population but later rearing occurs in the natural environment. Two other populations, from Birkenhead and Cultus lakes, are produced naturally and have the same adult run timing as Weaver Creek; all three populations are fished simultaneously. The catchable surplus from Weaver Creek is greater than that in the natural populations. The exploitation rates to sustain these populations at MSY are 0.76 for Weaver Creek, 0.70 for Birkenhead Lake, and 0.62 for Cultus Lake. The spawning channel has increased the productivity of the Weaver Creek sockeye, but fishing to maximize the catch from Weaver Creek would mean overfishing returns to both natural populations.

The hatchery-wild dichotomy presents an extreme example of the "mixed-stock" fishing problem. If fishing responds to apparent abundance without consideration of the stock composition (i.e., the mixture of portions of stock from source populations) or if fishing levels are based on hatchery production, the natural population will be overfished and its production will, on the average, decline. Alternatively, if the fishery is managed to sustain the natural population, substantial surplus production will return to the hatchery or could be caught in a single-population, terminal fishery.

The example of mixed-stock fishing represents a much more general problem. Differences in productivity between natural populations cause the same problem, and by-catch of other species in fisheries that are directed at a more productive species is an analogous problem. When fishing occurs on a mixture of populations with different stock-recruitment functions and fishing cannot be regulated at a rate appropriate for each component population, the stage is set

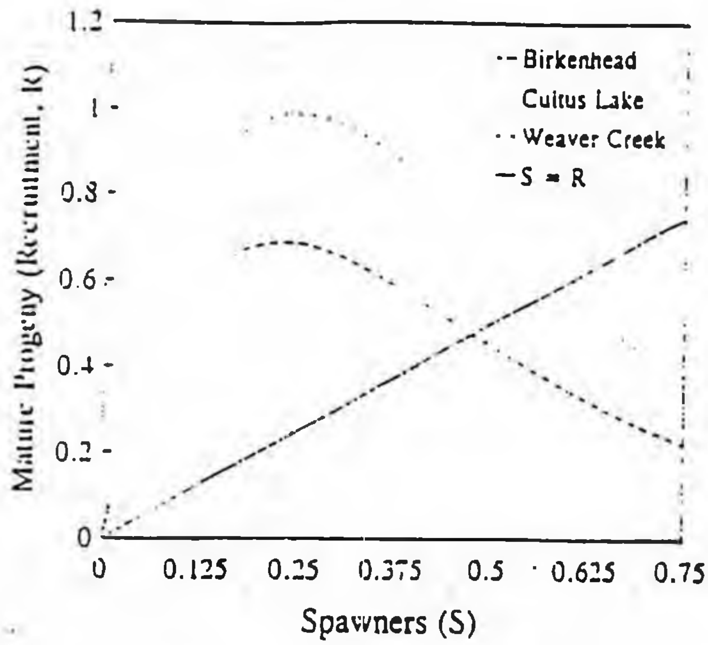


Figure 11-4 Ricker stock-recruitment curves for three Fraser River sockeye salmon populations. Weaver Creek population is enhanced but Cultus and Birkenhead populations are both naturally spawning. Source: data collected 1946-1990 by International Pacific Salmon Fisheries Commission and Canada's Department of Fisheries and Oceans.

for overfishing of the less-productive components (Ricker 1958, 1973; Hilborn 1985). For example, extinction of wild coho salmon in the lower Columbia River has occurred as fishing pressures at sea and in the lower Columbia increased to take hatchery returns; catch levels of 85-95% were directed at the returning fish (Cramer et al. 1991). The less-productive stocks are referred to as "weak stocks," but that term leads to confusion. "Weak" cannot be equated with "small", nor does it imply anything maladaptive, inferior, etc., about animals in the population. The "mixed-stock" (or mixed-population) fishery problem is related to differences in *production rates*, not the relative size of populations.

Apart from natural variability and variation among populations or over time, estimating the S_{MSY} for just one population raises a serious question. Larkin's (1977) discussion of MSY as a management concept identifies the issue of the poor quality of the data available for use in stock-recruitment analysis, and recently the joint U.S.-Canada committee on chinook salmon stated (PSC 1993b:87):

> At present, complete information necessary to determine stock productivity is not available for any individual chinook stock! For a few stocks, enough information has been available to apply stock-recruitment type analyses to estimate productivity parameters, but even these had to involve some major assumptions about age structure in catch and/or escapement and about the error structure of these data. And none include environmental factors, which are known to produce variability in annual production. . . .

To determine stock-recruitment functions is data-intensive, expensive, and statistically nontrivial. Data and cost issues are related to accurate determination of a population's mortality in each fishery and its spawning escapement by age so that production can be related to the parental generation. Salmon tend to be caught in many sequential, mixed-stock fisheries, and their escapement is not determined easily. There are few cases in which this challenge has been met to study salmon population dynamics, and the sensitivity of stock-recruitment analyses to errors in the data is poorly understood. Hilborn and Walters (1992) stated that stock-recruitment analyses can provide "terribly misleading answers" and that (p. 287)

> the types of misleading answers produced by stock and recruitment analysis are almost always the same; the answers mistakenly lead you to believe that recruitment will not decline very much with spawning stock. We think that bad stock-recruitment analyses have been a significant factor leading to over-exploitation and stock collapse for some major fisheries. . . .

Hilborn and Walters reviewed the problems associated with stock-recruitment analyses in greater detail than is appropriate here, but the committee has developed an example of the consequences of such analyses (Box 11-1). The most common outcome of simple stock-recruitment analyses is that the optimum exploitation rate is overestimated and the S_{MSY} underestimated. The consequence of this outcome could be management advice that unintentionally would lead to overfishing and contribute to declining production.

Although MSY concepts have provided the basic paradigm for salmon management since the 1950s, the paradigm has been inadequate, given the fishing pressure and economic development in the Pacific Northwest. Mixed-population fisheries, habitat change, and uncertain assessment advice have all contributed to overfishing and loss of less-productive populations. The committee reiterates Larkin's caution about the inadequacy of the MSY concept for salmon management (Larkin, 1977:9):

> The foregoing has demonstrated, I hope, that MSY is not attainable for single species and must be compromised: (1) to reduce the risk of catastrophic decline and reduction of genetic variability; and (2) to accommodate the interactions among the species of organisms that comprise aquatic communities.

Given that the limitations of stock-recruitment analyses have been known for many years, why are management strategies based on those models? Part of the answer is that technical improvements in analyses has led to unjustified confidence in abilities to compensate for deficiencies. Much of the answer, however, lies in the socioeconomics of fisheries and fishery management. In the United States and Canada, marine fish are generally viewed as "common property" resources, owned by no one—or by the public—until they are caught. Such a situation is well known to lead to excessive investments in capital and labor and to pressures to overfish resources, particularly when there is open entry (i.e., no limit on the number of people who can fish) (Gordon 1954, Scott 1955, Crutchfield and Pontecorvo 1969). However, salmon fishing in the Pacific Northwest is not now (and has not been for a long while) an open-entry fishery. The states of Washington, Oregon, and Alaska and the province of British Columbia have limited

Box 11-1 Stock-Recruitment Simulation

Stock-recruitment functions are usually nonlinear, which means that natural environment fluctuations can produce systematically skewed estimates of the long-term response of salmon populations to exploitation. The direction of this error appears to lead to overexploitation, even when statistical procedures generally accepted by fisheries biologists are properly applied. In this example, the committee develops ideas suggested by Hilborn and Walters (1992) to show how advice to management might produce serious errors.

The simulation begins with a "known" stock-recruitment relationship, the values for which are typical for chinook salmon in the Pacific Northwest: $R_t = S_{t-1} \exp(a - bS_{t-1}) \exp^{\sigma \varepsilon}$ where a = 1.6, b = 0.2, and sigma (σ_ε) = 0.7.

Each brood year was fished at a 75% exploitation rate: this is common for many fall chinook populations but exceeds the 60% rate sustainable at MSY for this stock-recruitment function.

Each simulation was run for 100 years, and data from the last 30 years were collected for stock-recruitment analysis. At the end of each simulation, stock-recruitment parameters (a, b, S_{MSY}) were estimated from the 30 data points. The effects of three known error sources were examined:

Type 1: Environmental variation in recruitment, normally distributed with mean zero and standard deviation σ_ε. The value of σ_ε was chosen so that production varied by a factor of 2–4.

Type 2: Environmental variation plus observation error in spawning-escapement estimation. The error about S_t was simulated as $S_t * \exp^{\sigma_s \varepsilon}$, where the random normal error has mean zero and standard deviation = 0.57. This value of σ_s was chosen to produce escapement-estimation error of ≈ 50% about the true S_t.

Type 3: Environmental variation, observation error in spawners, and error in catch estimation. Catch error was simply generated by smoothing the catch (three-point moving average) to simulate assumed age structures or errors in catch allocation between populations.

One thousand simulations of each type were conducted, and frequency distributions for parameters a and b were compared with values of the "known" function. The solid vertical line in the figures represents the parameter values of the "known" function, and the dashed lines encompass 95% of the estimates.

Both a and b have been rescaled for clarity in presentation. The a values are expressed as the expected recruits per spawn ($\alpha = \exp^a$), and b as logarithms to spread out the distribution.

The distributions of results for Type 1 to 3 simulations are presented from top to bottom. In each distribution, the most common result of the simulations is represented by the tallest bar. In every case, the most common result is to the right of the value that we are trying to estimate (i.e., the values in the original, or "known", stock-recruitment function). Furthermore, for the productivity parameter (α), the effects of the error types are compounded as the most common value progressively deviates from the vertical line. Comparing the means of the simulations demonstrates the tendency for errors in stock-recruitment analyses to overestimate productivity and underestimate the number of spawners needed to sustain MSY.

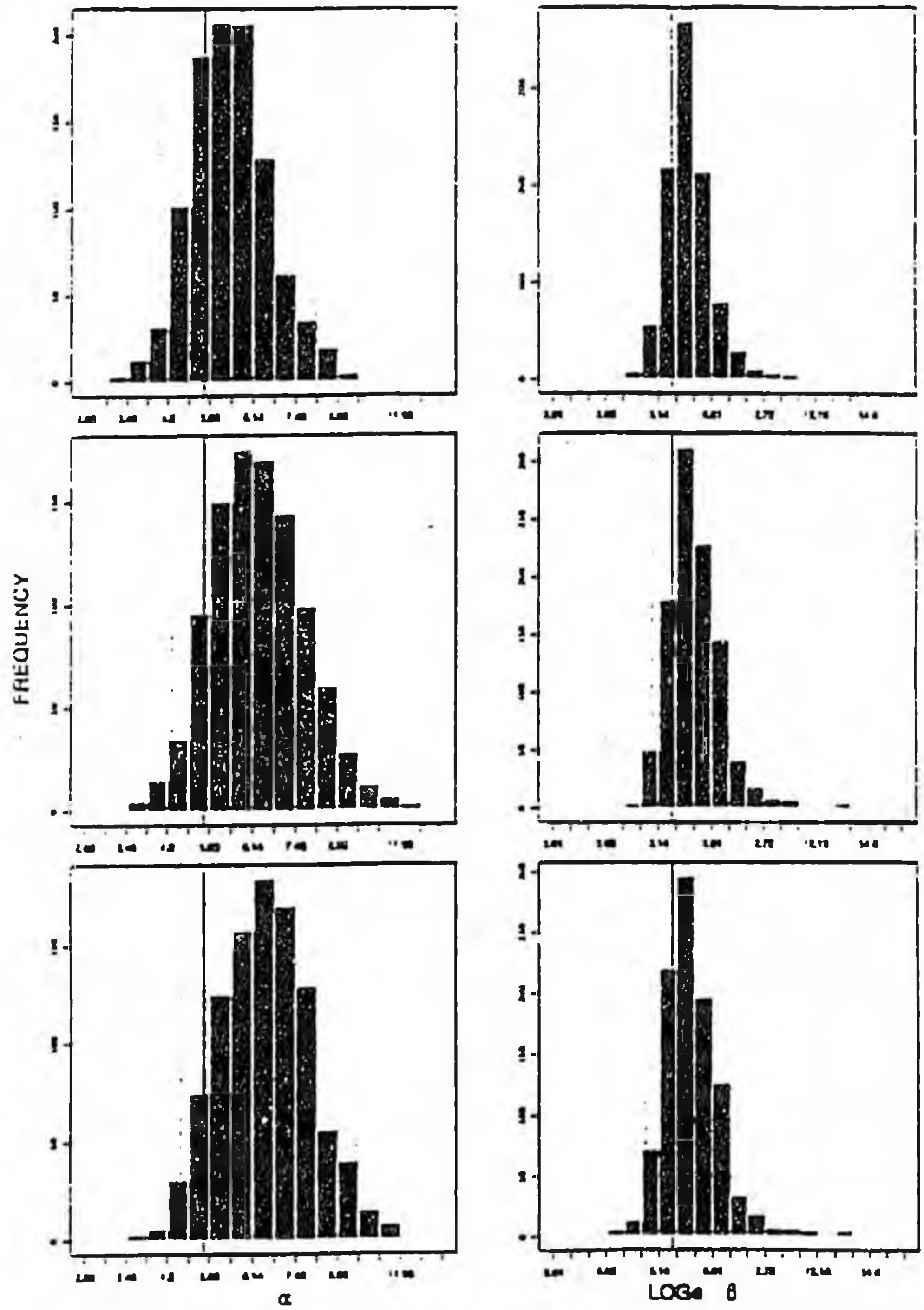
	Recruits/spawner	S_{MSY}	Sustainable exploitation rate at MSY
"Known" function	4.95	3.43	0.60
Type 1 results	5.51	1.44	0.63
Type 2 results	6.28	0.98	0.67
Type 3 results	6.49	1.11	0.675

These analyses are clearly very limited and were intended only to demonstrate, under realistic assumptions about error, the potential for misleading information (see Hilborn and Walters 1992). Advice based on these analyses would recommend a sustainable exploitation rate, at MSY, 12.5% greater than could actually be sustained by the population. While we thought we were managing correctly, the population would continue to decline.

. . . continued on next page

Box 11-1 (continued)

Simulation results for Type 1 to 3 errors described in this box. Solid vertical lines in each figure are true parameter values. Frequency histograms on left show distribution of estimated returns per spawner, and on right, natural logarithm of beta parameter (natural lags used to spread distribution). Results of 1,000 simulations for Type 1 to 3 errors are presented from top to bottom.



entry into the salmon fishery since the 1960s; this has not prevented overcapacity in boats, gear. and fishing technology, but it has raised greatly the costs of participating in the fishery and reduced overall numbers of people and boats in it. Higher costs of entry and higher investments increase the needs of fishers to pressure regulatory agencies to allow higher catches at the expense of spawning requirements.

The problem has long been recognized (e.g., Wright 1981, Ludwig et al. 1993). Wright stated (p. 38)

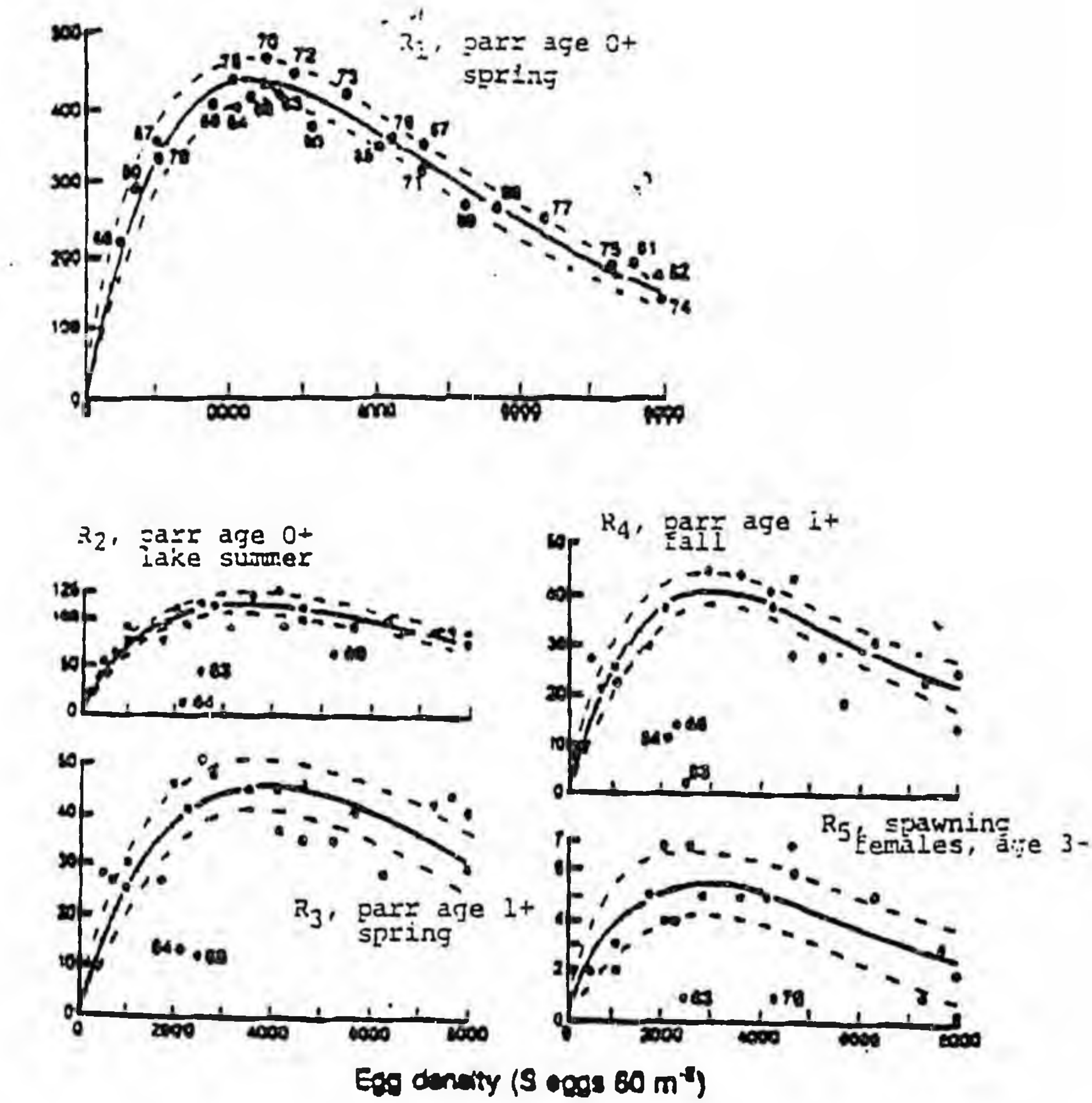
> Fishermen make poor management allies due to their perpetual optimism about strengths of the salmon runs and their understandable preoccupation with short-term economic considerations.
>
> There can be little doubt, however, that the salmon fishery lobbyists are currently winning the battle against the spawning-escapement protectors. A team of fishery scientists formed by the Pacific Fishery Management Council concluded that 40% more chinook salmon and coho salmon were needed to meet spawning-escapement requirements, under existing habitat conditions, for the combined areas of California, Oregon, and Washington (PFMC 1978:39).

Similar appraisals can be found in Fraidenburg and Lincoln (1985), Walters and Riddell (1986), and National Research Council (NRC 1994). The remedies suggested most commonly, besides complete but preferably temporary closures of the fisheries (as occurred in 1994), include restructuring managing bodies to remove apparent conflicts of interest (NRC 1994) and privatizing rights of access to salmon stocks through individual transferable quotas or similar devices, perhaps combined with buyouts or other compensations for displaced fishers. A third approach, paradoxically, is to strengthen the involvement of fishers in the management process so that they are encouraged to take more responsibility as stakeholders in either a common property or a privatized fishing situation (cf. Scott 1993). Hanna (1994) suggested that the Pacific Fishery Management Council (PFMC) has already moved a long way toward involving fishers in the management process, at least for other species of fish.

The application of stock-recruitment theory and MSY as the basis of salmon management is complex and of limited applicability. The multitude of populations and habitats, the extent of enhancement programs, and the variability and uncertainty in the data make determining an accurate optimal escapement goal elusive. However, where the necessary data are available, stock-recruitment relations can be clear (see Box 11-2). The definition of the relationship depends on the degree of environmental variability, the causes of density-dependent mortality, and data quality. Given the poor quality of the data available on almost all Pacific salmon populations, we cannot test the stock-recruitment theory rigorously. We have learned that the theory is more applicable in freshwater phases of salmon life history and that environmental variability in the marine habitat ultimately can determine the number of returning adults. Principal lessons are that salmon stock-recruitment relationships are inherently uncertain, that the determination of a specific escapement goal (S_{MSY}) is seldom justified by available data, and that the MSY concept has been inadequate for conserving population diversity or production.

Box 11-2

A most striking example of stock-recruitment relations in a salmonid is the detailed study of Elliot (1994) on anadromous brown trout (*Salmo trutta*). The figures below from Elliot's recent book show a clear curvilinear relation between spawning (measured as egg density) and recruitment to later life phases. Note that recruitment is more strongly associated with egg density at the lower ages (R_1 to R_4). The relation becomes much more variable when adult returns (R_5, age 3+ female returns) are related to egg density. The committee readily acknowledges, however, that this population inhabits a spring-fed stream not subjected to extremes of climate or high water velocities.



FISHERY MANAGEMENT IN THE FUTURE

The committee explored four general options for managing fisheries to help frame the process of developing a new management paradigm: status quo, no fishing, limited entry, and terminal fisheries.

The Status Quo

One management option is to continue to use the MSY concept while working to improve its predictive powers. The committee has concluded, however, that the MSY concept by itself is inadequate and impractical as a basis for salmon management because the model implies the existence of a continued surplus production, which is fundamentally inconsistent with historical data. In overfished populations, most stock-recruitment data will be from the lower range of escapement numbers. We can adjust for biases in data, but we cannot correct for the absence of data at larger escapements without actual observations. If we estimated S_{MSY} on the basis of historical data and managed perfectly by annually achieving this value, we would learn nothing about the productive potential or dynamics of a population; we would learn more only about natural variability in recruitment because all the return data would be scattered vertically above the S_{MSY}.

The prevailing social acrimony, particularly in connection with listings under the Endangered Species Act, argues for change in management objectives and a fuller understanding of the salmon problem. As the economic return from the salmon resource declines, debates have become increasingly po' .ız. because action would increase economic disruption in other resource industries. The com ittee heard considerable testimony lamenting the inability to make the changes needed. No one is willing to accept responsibility; each interest feels that another should do more. The status quo in this social environment will perpetuate further decline and will not sustain salmon population diversity or production.

The No-Fishing Option

One solution is to stop fishing. In many situations, such as those of the Chesapeake Bay striped bass and North Sea plaice, populations have rebounded after cessation of fishing. Because of recent emergency measures taken by the PFMC, this option is in effect for most river and most ocean fisheries in Oregon, California, and Washington waters and in federal waters off those states. In other cases where fishing was stopped, such as the California anchovy fishery, depressed populations have not rebounded. One common argument is that stopping catch certainly cannot hurt and that fishing should not continue when threatened and endangered species are mixed with salmon targeted for catch.

The major problem with the no-fishing option is that the social and economic hardships caused by stopping are substantial, particularly to those who depend on salmon fishing for their livelihood. Fishing cessation usually occurs only when the overall benefits from continued fishing are so reduced that every party gets little from the population. Furthermore, people always expect the factors causing the decline to go away soon and more favorable conditions to return.

Fishers argue that commercial and recreational uses of salmon constitute an important value. They say that fishing is an excellent way of keeping the status of the populations in the public eye. Fishing is a livelihood for professional fishers. Catches are important for economic, subsistence, and ceremonial purposes for American Indians, and the expectation that catches are possible drives the recreational fishery. Eliminating fishing makes salmon less valuable economically.

Eliminating fishing is not a simple issue. Salmon are caught from southern Alaska to the central California coast by netters, trollers, anglers, and charter boats and by both Indian and non-Indian fishers. Should fishing be stopped for Alaska salmon fishers whose runs are generally in much better shape than those returning to the Columbia River? The position of Alaska salmon fishers is that salmon problems in the Pacific Northwest are due to choices made by people of the Pacific Northwest and that Alaskans should not be penalized to fix the region's problems (Pacific Salmon Commission 1993). Salmon from the Pacific Northwest are also caught in Canadian fisheries, and U.S. treaty and nontreaty fishers catch salmon from Canada. The position of Alaskan salmon fishermen has prevented the Pacific Salmon Commission (PSC) from making progress in protecting threatened and endangered salmon runs.

When elimination or control of fishing is discussed, people often think only of commercial fishing, but that is too restricted a view; all fishing kills fish. Is it legally possible to stop treaty fishing? As long as any salmon are available, treaty fishing will continue. Thus, the no-fishing option is complex; it does not imply just a simple decision to close a fishery. Closing one part of the fishery results in another group's getting a larger catch. Treaties give tribes the right to fish in their usual and accustomed places in common with non-Indians. And treaties require the United States to maintain the health of salmon stocks. In a legal sense, treaty fishing would be difficult or impossible to stop; and as long as there is fishing, other fishers will demand fishing opportunities.

If fishing cannot be eliminated legally for some peoples, such as Canadians and treaty fishers, which fishers can be restricted from fishing? Should recreational and charter fishing be stopped? Recreational and charter fishers take relatively few fish and contribute substantially to the economies of coastal communities. One variant of the no-fishing option could be for the United States to stop all ocean recreational, charter, and commercial fishing for salmon in Alaska and the Pacific Northwest. Such a ban would have favorable effects on negotiations with Canada in the PSC. However, it would be fought by all those affected. Another variant of this option would be to close all ocean fisheries in the Pacific Northwest. A complete ban of ocean fishing is close to being realized. It was proposed in 1993 for coho by the PFMC. It was proposed again in 1994 and implemented for coho, leaving only limited fishing periods for chinook. That was not the first time a no-fishing option has been proposed. In 1904, J. P. Babcock, the British Columbia fisheries commissioner, unsuccessfully proposed closing fishing on the Fraser River during 1906 as a conservation measure to build up sockeye stocks. The problem with any partial closure is that, although it might allow some increased escapement, it also redistributes catch among different fishing interests.

Canada and the United States have many points of complementary and cooperative interest that might be negotiated on a smaller, more-specific scale, rather than simple wide-scale closures. One point of complementarity is the catches of Pacific Northwest coho and chinook off the west coast of Vancouver Island and Puget Sound catches of Fraser River sockeye.

Another point of complementarity is the possibility of opening ocean fishing areas to a joint fishery of trollers from Alaska, Canada, and the Pacific Northwest.

The Limited-Entry Option

If cessation of fishing is too strong an option, limiting the number of fishers might be helpful. All West Coast commercial salmon fisheries have some form of limit on the number of gill-net and troll licenses. The underlying idea is that the number of fishers should be limited to correspond to the size of catch that can be taken. The objective of the license- limitation program is to restrict fishing capacity to a level closer to the effort that can be maintained. One problem with limited entry is that it has many of the same elements as the status quo. Limiting entry to the degree necessary to produce the needed effect is perceived as a severe step.

A second problem that limited entry does not solve is the natural tendency of fishers to become more effective. New technology, knowledge, and fishing methods make fishers more efficient with the gear that they have. Thus, a limited-entry program must continually reduce the number of fishers in accordance with both resource availability and the capacity of fishing vessels and fishers to catch salmon (Smith and Hanna 1990); a reliable way to do this has not been perfected.

A third problem is that, as with open-access fisheries, successful application of limited entry depends on the ability to calculate accurately the quantity available for fishing. People want a consistent number, but fisheries are inherently variable; no stable number can be given. A safe number would have to be conservative, and fishers would probably complain that it is too low. The MSY mode of management has continually overestimated the amount available for fishing. With management for genetic diversity, as we have been recommending throughout this report, the focus is on achieving spawning escapements. That will mean highly variable catch opportunities for a much smaller fleet of vessels.

The Terminal-Fishery Option

Catching salmon closer to the place where they spawn allows greater separation of hatchery from wild and threatened from nonthreatened populations. A way to achieve that separation is to allow only terminal fisheries. The separation can be even better achieved with live traps. With live-trap, terminal fishing, salmon needing protection can be released if they are identifiable with minimal potential for harm. Because natural mortality in the ocean, after early transitions to ocean life, reduces biomass more slowly than body growth adds biomass to the population, fishing closer to the spawning grounds would increase salmon yields.

Ocean fishers might question the quality of salmon taken in terminal fisheries; the meat of fish caught nearer to their spawning grounds will tend to be less oily and the skin more colored, and they will be less preferred by some consumers. Salmon do deteriorate in quality as they get closer to spawning, but terminal fisheries in estuaries and river mainstems would not necessarily decrease quality and the average size of the fish would be greater. Two advantages of live-trap, terminal fisheries are the potential to separate populations from one another and the ability to set catch rates for what each population can sustain. For example, salmon from threatened populations could be released. The treaty fishery in the middle Columbia would be a place to experiment with terminal fishing. Shifting to a live-trap fishery also has the potential to increase employment. Recreational fishers view set nets as wasteful of the resource and as yielding lower-quality fish. Live traps would improve the perception of Indian fishing on both conservation and quality grounds.

A major problem with the no-fishing option is at least partially solved by adopting terminal fisheries. Alaskan fishers catch salmon destined for Alaska and British Columbia streams, as well as for the Columbia River and the north coastal area. Alaskan ocean fishers question why their opportunity to fish for healthy Alaskan populations should be jeopardized by habitat and hydropower problems in the Pacific Northwest. Canadian fishers who fish mixed U.S., Canadian, and Alaskan populations do not see a reason to limit themselves when the problem is not theirs. They have not built dams on the Fraser River, and in British Columbia the habitat is less altered.

Although the current catch situation—which is unbalanced between areas—will make it politically difficult to restrict fishing to locations of origin, the committee concludes that it is worthwhile and important. Salmon management—especially p--ulation-specific management—is likely only practical if catch were allowed onl ar the point of origin. and in the long run, the salmon and many fishers would benefit once p ction increased, although which fishers benefit most would involve social factors.

Developing a New Management Paradigm

Given the complexity and scope of the salmon problem, developing a new management concept will be difficult and contentious. The committee starts by identifying several premises based on its experience:

- In Pacific salmon, the presence of many diverse, spatially distributed spawning populations is closely aligned with genetic diversity, maximal use of available habitat, and potential for increasing production from natural spawners.
- The sustainable exploitation rate is a function of a population's productivity determined over all life phases. Catch is only one of numerous mortality sources and cannot be viewed as independent or as an alternative to other sources over which we do not have control. The fishable portion of a return is determined by the brood-year survival to the time of the fishery and the desired spawning-stock size.
- Salmon are a component of ecosystems and they exist in a dynamic evolutionary process. Their production is variable and interconnected with the condition of their communities and habitats.
- Catch is a function of the fishing rate exerted by a fishery and the abundance of salmon recruited to the fishery. A low fishing rate and a high abundance can yield the same catch as higher fishing rate and a lower abundance.
- Productivity varies among populations and over time. The projected return from any

population and brood year is highly uncertain. Any management process must acknowledge and account for limitations and uncertainty in assessment information and management capabilities.

Those premises consider only biological aspects of fishery management. But the sustainability of salmon in the Pacific Northwest also is inextricably linked to economic development and social values. Society in the Northwest has exchanged natural salmon populations for economic development or argued about who was to blame as the resource declined. Figure 11-5, based on data from Matthews and Waples (1991), demonstrates the decline in Snake River spring and summer chinook salmon since the late 1950s. In spite of a progressive decline, major corrective actions were not taken until 1992, when the chinook were listed as threatened under the Endangered Species Act. The greater the decline in the resource, the greater the disruption will have to be to correct the problem. The committee believes that a stronger social commitment to the biological-resource base must be established if salmon are to be sustained. For the fishery-management process to be effective, a strong commitment to the salmon must be an integral part of the process.

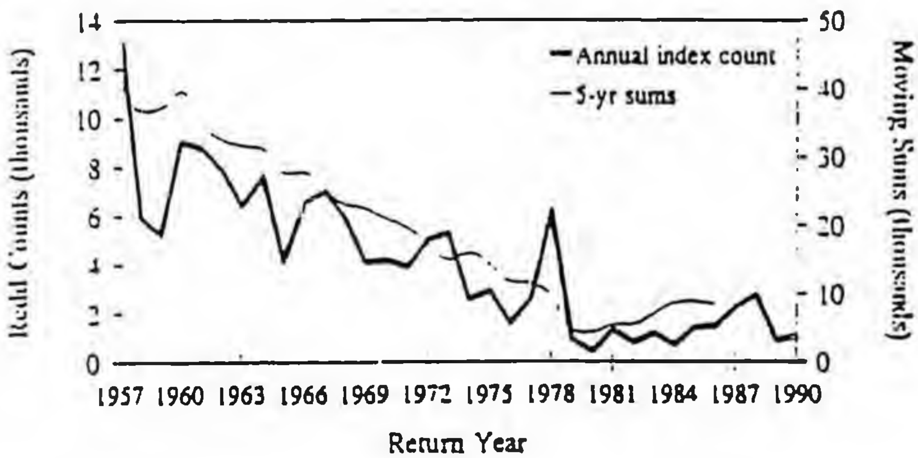


Figure 11-5 Trend in spawning-escapement index for Snake River spring and summer chinook salmon. Trend in annual redd counts and 5-year sum (for smoothing) are presented. Data from Matthews and Waples (1991) for Snake system minus Grande Ronde returns.

A management cycle for fisheries involves four activities: stock assessment to provide the biological advice, development of management plans, conducting the fisheries, and evaluation. The critical elements are sound biological advice, explicit and assessable management objectives (biological, social, economic, etc.), an institutional process for developing management plans, control of fisheries, and accountability in achieving management objectives. We consider those elements below, except for institutional processes and accountability, which are discussed in Chapter 13.

Stock Assessment and Biological Advice

Biological advice is only as sound as the information on which it is based. Advice must recognize limitations and uncertainties in knowledge and in abilities to predict recruitment. For example, the committee suggests that the concept of "optimum escapement" be replaced with a more conservative notion of a minimum sustainable escapement (MSE). An MSE concept avoids a single target escapement value and acknowledges that estimates of S_{MSY} are often biased low and rely on weak historical data. The committee emphasizes that MSE is a minimum and that actual escapements would exceed it and not be scattered about it. The committee's notion was based on protecting against the continued decline in salmon production and on concern about the use of an uninformative, possibly misleading, statistic.

The concept of MSE is analogous to minimum viable population size (Shaffer 1981, Simberloff 1988) and population viability analysis (Gilpin and Soule 1986, Shaffer 1990). It acknowledges that the longer-term sustainability of salmon populations depends on reducing the risk of extinction due to over-fishing and stochastic events (environmental and demographic variability). However, in assessing these risks, society must determine the level of security desired for salmon populations over what time period (i.e., how confident do we want to be that a population will exist in 100 or 200 years).

The MSE level could initially be determined from historical stock-recruitment data, when available. Where the data are not available, initial escapement levels may be derived from habitat assessments and/or historical escapement trends. This information may then be incorporated in demographic or life history models to determine MSE at a particular level of confidence. Uncertainty about the biological basis of this level must be allowed for when assessing the risk of extinction, but in many cases, the appropriateness of the initial MSE will be unknown. However, under the MSE concept, populations would generally be at less risk than under the earlier MSY approach, because escapements should exceed the minimum value (unless survival is so poor that the MSE is not achievable even under the absence of fishing mortality).

Estimates of MSE should ideally include information about the composition of spawning populations, the maintenance of connections between salmon demes, the role of carcasses as nutrient sources for freshwater ecosystems, intraspecific competition in reproduction, mate selection, and gene flow, but relatively little attention has been given to these factors. The need for levels of escapements that promote competition and fertilization or that maintain niches used by salmon is not well demonstrated with direct research.

In summary, the committee recommends the establishment of minimum safe levels of spawning escapements to reduce the risk of continued loss of salmon populations and production. Actual escapements should always exceed this value, with allowances for assessment error for abundances near this minimum level. Escapements would vary above the minimum depending on the population abundance and sources of mortalities. Escapements substantially above these minima will be needed to maintain salmon productivity (and therefore, sustainable exploitation rates) in many more populations than are presently available. These increased escapements are also likely to have benefits in expanding the number of spawning populations, increasing genetic diversity within populations, and enhancing natural ecological processes.

Management Objectives

The major change in objectives related to the sustainability of salmon must be to broaden the set of biological objectives. That does not imply a priority of biological objectives over socioeconomic objectives, but socioeconomic objectives should complement biological objectives. The committee concludes that the resource base necessary to sustain salmon production consists of genetic diversity (both within and between natural breeding populations) and the habitat used by all life stages of the species. Genetic diversity provides for the continuing evolutionary process and is the biological basis of future salmon production. Therefore, the committee recommends managing for the joint biological objectives of MSE and increased diversity in local breeding populations, which will result in increased production in the long run. Increasing the size and number of spawning populations will, on average, increase the abundance of salmon. The committee acknowledges that increasing diversity will require initial reductions in catch because animals must survive to reproduce. However, catch in future years should increase as salmon production increases, even though fisheries probably would be managed at lower catch rates to maintain the diversity within local breeding populations and promote the development of interpopulation diversity.

Figure 11-6 shows what is expected in accordance with MSE. Graphs A, B, and C represent what has occurred commonly in the past. Natural or wild (N) and hatchery (H) populations have been fished simultaneously, but the hatchery population has higher productivity. As total population (N + H) increases, catch often increases to a maximum (Figure 11-6b), but the catch rate (i.e., the portion of the available salmon abundance that is caught) may not be sustainable by N. Consequently, the catch of N + H begins to decrease because of the declining production from N. Eventually, management responds to conservation concerns for N and reduces the catch to conserve N. If that situation is visualized over many natural populations, loss of population diversity can be characterized by Figure 11-6c. Diversity, if measured simply by the existence of spawning populations, would be maintained for a longer period than the catch (N + H). But under increased fishing pressures, the less-productive N will begin to be lost. Diversity would probably stabilize as catch is curtailed to conserve population diversity. Under a management policy to increase interpopulation diversity and achieve minimum escapement levels, the expected outcomes would be increased habitat use by spatially and temporally more diversified salmon populations and an increased catch achieved at a lower, sustainable rate of fishing (Figure 11-6d). The potential cost of this plan is an initially decreased catch of N while diversity is increased. The magnitude of initial loss depends on the specific situation.

A useful analogy of this plan is the idea of salmon runs as a tree. Each stem, branch, and twig on the tree is a potential home for a local breeding population, an isolated reproductive group adapted to the conditions of that particular stem, branch, or twig. Some salmon climb mighty trees like the Columbia and Sacramento with complex branching. Others climb much smaller, less-complex trees like coastal streams. Cutting limbs from the dendritic structure of these salmon "trees" or placing obstructions on major limbs prevents local breeding populations from filling out the evolutionary potentials offered. That reduces the genetic diversity and viability of the salmon population as a whole and reduces habitat use and the potential production of salmon. A more holistic approach in salmon management would focus attention

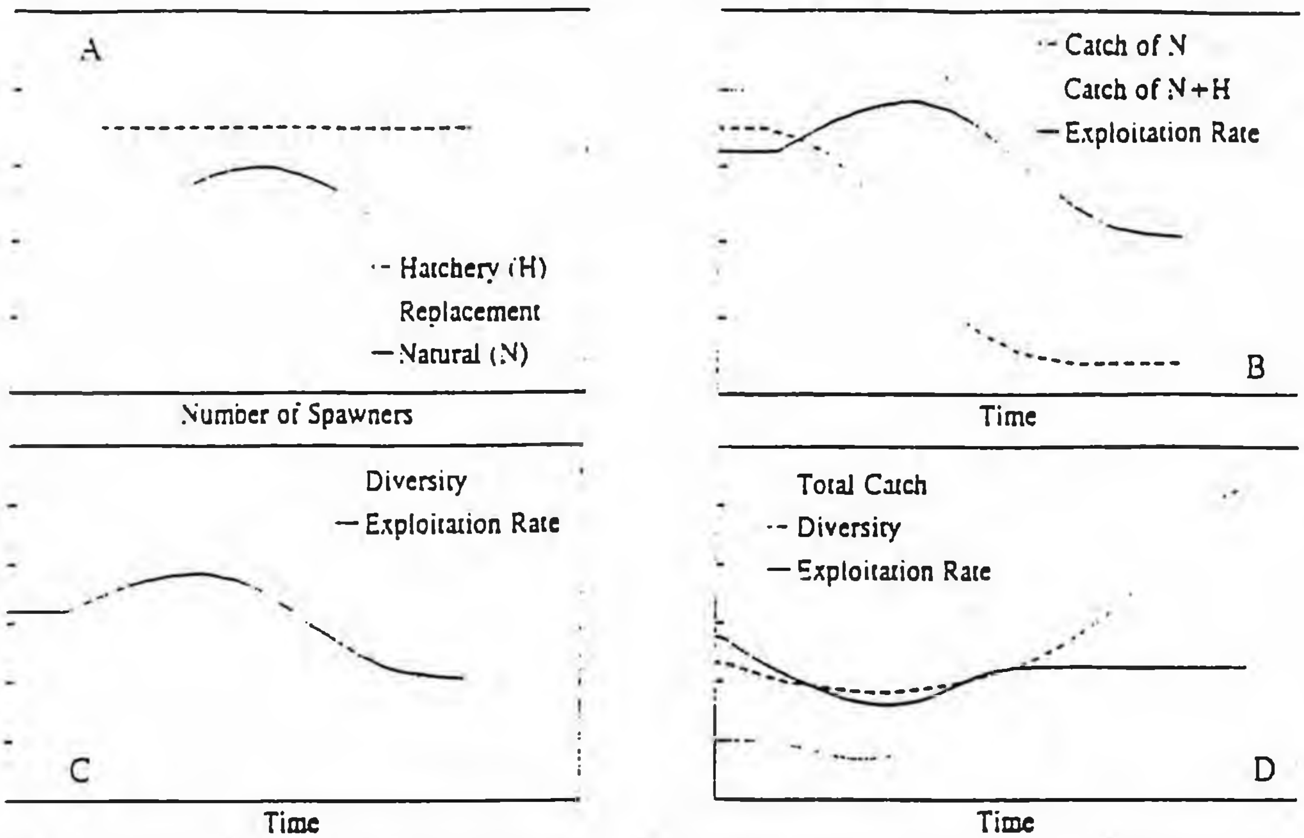


Figure 11-6 Schematic portrayal of observed historical trends in salmon populations, catch, and exploitation (plots B and C) and the expected outcome of managing for a minimum safe escapement (MSE) objective and rehabilitation of interdemic diversity (plot D). Plot A is a stock-recruitment curve showing number of recruits as a function of the number of spawners. In plots B - D, the vertical axes represent numbers of fish (for catch curves), numbers of populations (for diversity curves), and percentages (for exploitation rates). The exploitation rate is the total mortality associated with fishing activities, including the landed catch, incidental catch, discards, and hooking mortality. See text for further details.

on filling out the trees' foliage so that viable local breeding populations of salmon inhabit as many branches as possible.

How could those joint biological and socioeconomic objectives be implemented in a management plan? The committee has considered only a general process because details of implementation would involve social values and decisions. For example, how quickly diversity increases will be associated with how much social change is acceptable or with the array of economic alternatives in a specific area. A possible process would involve the following:

• Identification of natural populations with the quantitative information needed for a credible population assessment and determination of an MSE and exploitation rate that, on average, would be allowable at this level of spawning-population size. Currently there are few of these "assessment" populations, but the application of a safe escapement level will reduce the risk of misapplication to other populations and should provide reasonable starting points in the plan development. Total fishing mortality would initially be limited to the exploitation rates at the MSE.

• Predictions of available abundance to fisheries. The methods might vary between regions, species, etc., but should account for spawning-population sizes, environmental variation, and interceptions in fisheries outside the management zones. Abundance forecasting also might prove to be highly uncertain, but methods to incorporate in-season information with pre-season estimates (see Noakes 1989) could be useful in controlling fishing impacts.

- Establishment of survey designs for estimating diversity within local breeding populations. The essential need is to measure diversity and how it changes over time. Surveys would be designed to be repeatable annually and to measure quantitatively the spatial and temporal diversity of local breeding populations.
- Conduct of annual evaluations involving quantitatively assessed indicator populations, surveys of the spatial and temporal diversity of local breeding populations within geographic areas, and fishery dynamics. The indicator populations would include natural populations on which accurate stock-recruitment data can be collected and whose dynamics (e.g., freshwater and marine survival rates, productivity, etc. [see Holtby and Scrivener 1989]) can be studied, natural populations that are conducive to repeatable annual estimates of spawning escapement, and hatchery populations whose exploitation rates can be determined. Fishery dynamics are assessed to understand units of effort, relationships between catch and effort, and effort responses to abundance and ultimately to estimate catch levels for a fishery.
- Assessment of progress toward the biological objectives and incorporation of what is learned from evaluations into future management plans. Given the limitations in our knowledge and the inherent variability in the environment, the committee strongly endorses adaptive management (Walters 1986) to achieve sustainability for salmon. For example, the response of natural populations to management changes can be confounded by environmental variability. Experimental designs can be useful in controlling this interaction (see Walters et al. 1988) and in improving detection of changes in diversity over time and under different management plans or fisheries. The use of adaptive management, however, emphasizes the need for effective institutional processes for communication and participation in the development of longer-term management plans.

Control of Fisheries

Meeting the joint management objectives of achieving the MSE and increasing diversity of local breeding populations diversity will not resolve the mixed-population fishing problem or settle allocation debates. Without greater control on fishing impacts, meeting the objectives could even exacerbate these problems. Furthermore, the sequential alignment of fisheries in the Pacific Northwest, from ocean mixed-population fisheries to more terminal fisheries involving fewer populations, could result in inequitable disruption of fisheries. But sequential fisheries also present an opportunity to compensate for fishing impacts among fisheries. Given the complex of fisheries, variations in population size, and the need for social decisions in establishing a fishing plan, the committee felt that it was impractical to comment on any specific fishing options. There are only two general kinds of strategies for meeting the objectives through fishing controls:

- Reducing exploitation rates over all populations in a fishery—fishery-oriented strategies.
- Increasing the specificity (in time, area, gear, species, etc.) of a fishery to avoid or minimize impacts on particular populations—population-oriented strategies.

There are many ways to implement each kind of strategy. Fishery strategies can vary from no fishing through allowing exploitation only in specific fisheries to reducing exploitation rates in all fisheries. Population strategies can divert fishing effort to another time or area, develop a selective fishery for only marked animals (i.e., prohibit retention of unmarked fish), or develop selective fishing gear, such as live traps and fishwheels. Strategies can also be combined to limit exploitation of some populations while maintaining a fishery on others. For example, an ocean troll or recreational fishery might be managed at low exploitation rates that are sustainable by most populations. Terminal fisheries could then be managed to compensate for these ocean-fishery mortalities by either increasing or decreasing further exploitation on a population.

In developing a fishing plan, managers have to balance fishing capacity (number of vessels, effort, market prices, etc.), availability and quality of biological data (on abundance, stock composition, previous fishing impacts, etc.), and social agreements (allocation requirements, treaty vs. nontreaty, ocean recreational vs. ocean troll, etc.). Each balance has problems. In the Northwest, more people would participate in fisheries if there were more fish. The potential for additional fishing pressure is an important source of uncertainty in how a fleet will respond to a particular fishing plan. The quality of biological data varies among fisheries, but the catch rate is seldom known until after the fishing has ended for the season. Achievement of allocation agreements is uncertain because population-specific fishing mortalities often are unknown or a substantial portion of the allowable catch might be taken in fisheries outside the management region, e.g., in Canada or southeastern Alaska. The most common problem, though, is our limited ability to control in-season fishing impacts, especially on a population-specific level. In the absence of reliable pre-season predictions of population and fishery abundance, fishery managers have developed in-season estimation procedures to monitor abundance and run timing. These procedures normally compare historical test-fishery catches or catch-per-unit effort from specific fisheries, with run-size estimates to develop in-season prediction models. These models frequently also have large uncertainties due to variation in run timing, stock compositions, and environmental conditions; or simply due to measurement error in historical data. In summary, the quality of biological data varies widely between fisheries, and exploitation rates in fisheries are seldom known. This uncertainty places the objective of increasing genetic diversity at risk and argues for the continued application of conservative fishing plans, particularly in the mixed-population ocean fisheries. Fishers should recall, however, that fishing at a lower rate on an increasing population will eventually restore catch levels.

Developing fishing plans for each of the Pacific Northwest regions will necessitate consideration of specific resource problems, distribution of fisheries, and social groups. Choosing a strategy requires establishing priorities and making a number of difficult social choices. But fishing is only one mortality factor. Fishers can enhance the spawning population by forgoing catch, but salmon also require habitat for long-term sustainability. The control of fishing as a means to approach sustainability in salmon will be only as successful as our ability to address the freshwater-habitat issues. We would also expect greater support from fishers if they could see a successful return on the spawners invested. Presumably, the same would be true of Canada's participation in the Pacific Salmon Treaty

CONCLUSIONS

Since the nineteenth century, in an effort to maximize catch, salmon fisheries of the Pacific Northwest have exploited a mix of wild-spawning and hatchery-produced salmon. Fishing moved farther into the ocean to catch more and better-quality salmon earlier in their life cycle, but the stream origins of these fish were unknown. Social pressures pushed catch levels toward those which only the most-productive populations could sustain, but they were often too high for natural populations. Mixed-stock fisheries developed for human convenience, and society watched as local breeding populations of salmon went to extinction or were depressed severely. Fishing impacts and the promotion of regional economic growth combined to alter salmons' environment to their detriment. The existing technocratic model for fishery management, productivity enhancement, and environmental modification has not been able to sustain salmon catches or the diversity of salmon populations. The result has been a major reduction in economic opportunity for fishers. All fishers have without doubt suffered possibly irreparable injury from the status of salmon and the management prescriptions to deal with it. The decline in income is much greater than that in any other major resource industry in the Pacific Northwest, and catches by American Indian fishers are now smaller in numbers of fish than before the Boldt decision.

The committee concludes that fishery management objectives must explicitly recognize the need to conserve and expand the genetic diversity of the salmon resource. To accomplish this, emphasis must be given to minimum sustainable escapements and filling out the dendritic structure of salmon habitats.

A more holistic management approach must recognize the connections between the genetic resource base, habitat, and the resulting salmon production; it must also account for the uncertainty in our scientific advice and for inherent environmental variability. The committee has outlined a process intended to improve the potential sustainability of salmon in the Pacific Northwest. Furthermore, the committee does not believe that the sustainability of Pacific Northwest salmon can be achieved without limiting the interceptions of U.S. salmon in Canada and obtaining the cooperation of Alaska. An effective and cooperative Pacific Salmon Treaty is necessary. The committee does not provide specific recommendations about altering specific fisheries, because there are numerous options and interactions between fisheries. Achieving agreement on changes in fisheries will be difficult and necessitates an effective institutional process.

Kenai River Sportfishing Inc

March 12, 1996

Senator Loren Leman
Chairman Senate Resources
Alaska State Legislature
Room 115
State Capitol
Juneau, AK 99801-1182

Dear Sen. Leman:

The Board of Directors of Kenai River Sportfishing Association, Inc. support SB285 and urges the Senate Resource Committee to support it also.

SB285 will provide the direction and funding needed to uphold our constitutional mandate to provide for sustained yield of wild salmon. SB285 is also based upon the latest scientific information concerning the collapse of salmon runs in the Pacific Northwest.

As stated by the National Research Council of the National Academy of Science in their December 1995 publication Upstream: Salmon and Society in the Pacific Northwest, "A crucial aspect of the recommendations is the overriding need to focus management goals primarily on genetic diversity rather than on biomass production."

The current management goal of maximum sustained yield for single stocks in a mixed stock fishery focuses on biomass production. By attempting to regulate the spawner-recruit ratio for the maximum sustained yield (harvest,) we are choosing, as our primary management goal, biomass production.

This bill provides the framework where science may be gathered in an organized manor so that we can move toward management of genetic diversity of discrete salmon stocks with the minimum amount of disruption to commercial fisheries.

It also places the burden of data gathering on the commercial fisheries. This is only rational.

In the February, Alaska Board of Fisheries meeting in Anchorage, the Board decided to increase the in-river allocation of red salmon into the Kenai River based upon a concept of no-net-habitat loss. In other words, sport fishermen will be held accountable for their actions (whether it increases habitat degradation or leads to improved habitat measures.)

P.O. Box 1228 • Soldotna, Alaska 99669 • 907-262-8588 • Fax 907-262-8582 • 1-800-478-0724

We see SB285 applying the same measure of fairness on the prosecution of commercial fisheries. I am sure the Committee will agree that, give the best available science, commercial fisheries should not be conducted in a manor that threat sustain yield. That would be unconstitutional.

SB285 will allow the continuation of commercial fisheries, as long as data supporting such prosecution is not at the expense of discrete salmon stocks.

SB285 also calls into question the Department of Fish & Game's decision to manage on a Maximum Sustained Yield (MSY) principle. While MSY neither appears in the state Constitution nor in statute, it is used interchangeable in the Department's Escapement Goal Policy with the term sustained yield. Sustained yield does appear in both our Constitution and statute.

The most common concern about fisheries management for Maximum Sustained Yield in salmon fisheries is that stock recruitment functions vary among populations. As stated in Upstream: "When fishing occurs on a mixture of populations with different stock-recruitment functions and fishing cannot be regulated at a rate appropriate for each component population, the stage is set for overfishing of the less-productive component... Apart from natural variability and variations among populations or over time, estimating the MSY for just one population raises a serious question.."

The report says the most common outcome of single species MSY management in a mixed stock fishery "has been inadequate for conserving population diversity or production...The MSY mode of management has continually overestimated the amount available for fishing."

What SB285 does is move the State of Alaska toward the recommendations by the country's leading scientists. The committee noted that the concept of "optimum escapement" should be replaced with a more conservation-related concept of Minimum Sustainable Escapement (MSE).

"A MSE concept avoids a single target escapement value and acknowledges that estimates of MSY are often biased low and rely on weak historical data."

The committee went on the say that the major change in objectives related to sustainablility of salmon must be to broaden the set of biological objections to include MSE and increased diversity in local breeding populations, which will result in increased production in the long run.

SB285 will allow the state to gather the data needed to insure sustained yields and protect the important discrete salmon stocks. We ask for your endorsement of the Bill and your vote for the bill when it reaches the Senate floor.

Sincerely,

Ben Ellis

Ben Ellis
Executive Director
Kenai River Sportfishing Association, Inc.

ALASKA SPORTFISHING ASSOCIATION
P.O. BOX 241847
ANCHORAGE, AK 99524

Senator Rick Halford
Senator Lyda Green
Alaska State Senate
State Capitol
Juneau, AK 99801-1182

Dear Senators Halford and Green,

The Alaska Sportfishing Association's Board of Directors, representing the state's largest sport fishing group, have unanimously voted to support Senate Bill 285 "An Act relating to the management of discrete salmon stocks".

This legislation is a key document in the evolution of the management of our salmon stocks. The recent Board of Fisheries meeting on Upper Cook Inlet fishing issues highlighted the need for more emphasis on management for genetic diversity of our mixed stocks. The era of managing for maximum yield (harvest) of a single dominant species without regard for the other species and their natal streams must come to an end if we want to preserve our incredible salmon resource for future generations of Alaskans.

Both the "Upstream: Salmon and Society in the Pacific Northwest" report, the reports by Dr. Phillip Mundy, as well as several ADF&G staff reports to the Alaska Board of Fisheries last month emphasize that more attention must be placed on management of the weaker stocks of fish or they will cease to exist.

We feel that the Board of Fisheries, by adopting a list of fishery management principles, have taken a giant step towards better salmon management. SB 285, by requiring the Board of Fisheries to manage for these discrete stocks, and by requiring ADF&G to provide them with the information to do so, will provide the vehicle to make salmon management in Alaska more consistent with our Constitutional mandate of sustained yield.

Please call us if we can help work this bill through the process.

Phil Cutler, President 3/11/96

Big Fisherman Charters
P.O. Box 873206
Wasilla Alaska 99687

Sen. Rick Halford
Room 508 State Capital
Juneau, Alaska 99801-1182

Dear Senator Halford,

Your bill on genetic diversity is needed to bring salmon management in Alaska into the 20 century and will save the salmon runs on numerous creeks and streams in the upper Cook Inlet. The science report published by the governors mediation team identified the need to develop additional data for managing salmon in the e Northern District of Cook Inlet. They have identified a data gaps that must be filled if our salmon are to be protected. Additionally the need to reduce or halt the incept or mixed stock, due to fact that that the streams of origin can not be determined, and that termanial fisheries allows for precise management strategies.

The concept of genetic diversity will require that the state develop the data needed to effectively manage all of our salmon. Currently Cook Inlet salmon management is being driven by the Kenai River king and sockeye runs. The mediation science committee recommend that the management strategies be change to incomes all of Cook Inlet. I am concerned that the current commercial marked will have a detrimental effect on our salmon runs. Low prices will increase the pressure on the Department of Fish and Game to allow increased commercial fishing periods to allow them to increased their take due to low fish prices, the only effect will be lower prices. What will happen to the less desirable species caught, and processors do not want to buy?

I know that funding is a problem and must be addressed. I will support an increase in the cost of fishing licenses or a tag such as the king salmon tag. Would it be possible to establish a salmon manage fund were people could donate money and have a check off from the permanent fund. Please feel free to contact me for support. Thank you for your active support in protecting our resources.

Bruce Knowles
Bruce Knowles

February 15, 1996

Senator Rick Halford
State Capitol, Room 508
Juneau, AK 99801-1182

RE: SB 285

Dear Senator Halford:

The Alaska Council of Trout Unlimited wishes to inform you of our support of this bill (SB 285).

Trout Unlimited in Alaska is comprised of 550 members involved in 10 chapters statewide. Trout Unlimited Nationally has over 75,000 members and I can speak for them also as supporting discrete stock fisheries harvest management.

Scientific data (both recent and historic) indicates that mixed stock fisheries harvest has contributed to the decline of salmonid productivity worldwide. Most recently the National Research Council's Pacific Salmon study recognizes the problems with mixed stock harvests when attempting to manage the harvest of individual stocks.

Discrete stock harvest management will address several conservation issues including: the Alaska Constitutional mandate for sustained yield of all salmonid resources (not just commercially exploitable stocks), concerns over loss of species diversity, ecosystem health, and last but not least the burden of conservation (which the Alaska Board of Fisheries acknowledges to be disproportionately shared among users) will be more equitably shared.

Sincerely yours in conservation,

Dennis H. Randa, Chairman
Alaska Council of Trout Unlimited
P.O. Box 3055
Soldotna, Ak 99669-3055

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TROUT UNLIMITED

February 15, 1996

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State Capitol, Room 508
Juneau, AK 99801-1182

RE: SB 285

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Sincerely yours [illegible]

Dennis H. Randa, Chairman
Alaska Council of Trout Unlimited
P.O. Box 3055
Soldotna, Ak 99669-3055

FEB 19 1996

KENAI RIVER SPORTFISHING, INC.
P.O. Box 1228 • Soldotna, AK 99669
(907) 262-8588 • Fax (907) 262-8582

February 14, 1996

Senator Rick Halford
Alaska State Senate
State Capitol
Juneau, Alaska 99801-1182

Dear Senator Halford,

As the executive director of Kenai River Sportfishing, I would like to commend you for introducing Senate Bill 285, "An Act relating to the management of discrete salmon stocks."

The future of Alaska's fisheries will depend upon the passage and enactment of legislation that directs the department to protect the genetic diversity of the total salmon population within a drainage while providing for sustained yield.

Our sportfishing association's objectives are to promote responsible angling and habitat protection. But unless the Department of Fish & Game changes their focus of maximum sustained yield of a single stock species within the Kenai, efforts to preserve this unique resource will fall to overfishing of the system's discrete stocks which could lead to a ecosystem collapse. We can already point to what this type of management is doing to discrete salmon stocks in the Northern District rivers and streams of Cook Inlet.

You are correct when you state: "In order to uphold our Constitutional mandate to provide for sustained yield we cannot afford to ignore the biological realities and maintain the status quo."

I look forward to participating in public hearings to support this measure. If I can be of further assistance, please do not hesitate to contact me.

Sincerely,

Ben Ellis
Executive Director
Kenai River Sportfishing, Inc.

MAR 15 1996

Big Fisherman Charters
P.O. Box 873206
Wasilla Alaska 99687

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Room 508 State Capital
Juneau, Alaska 99801-1182

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Bruce Knowles
Bruce Knowles

Weak Stock Management is Contrary to the State's ESA Position
Under the Endangered Species Act, Alaska fishermen have lost fishing time and 56,000 chinook since 1993, to save a handful of Snake River fall chinook that spawn 1000 miles away. This is weak stock management in action. The State opposed Alaska's loss of fish administratively and legally.

Senator Drue Pearce and Representative Gail Phillips took issue with weak stock management in their April 24, 1995 testimony on the Endangered Species Act, stating that it is " contrary to common sense" because it is impossible to " protect every species from naturally expanding or contracting" . They went on to ask that Congress concentrate on " species" and drop the term " distinct population segment".

ADF&G Has Much More Serious Research and Analysis Needs
ATA doesn't support research for research sake. While we would like to know everything about the stocks we harvest, this just isn't practical in the face of declining budgets. This bill would demand valuable staff time for escapement goal analysis which may not be critical to the management of our fisheries.

Through General Fund Contributions Commercial Fishing Industry Is Already a Substantial Provider to ADF&G
The state collects millions of dollars each year from the commercial fishing industry. In FY 94, that figure was $79 million dollars. This money provides substantial revenue to address fisheries management and research needs, in addition to money that is used by our communities for roads, schools and other needs they would otherwise ask the state to finance. Still, SB 285 seeks to impose another tax on fishermen. This state of affairs is confusing for an industry that generates state revenue at a rate second only to oil and gas.

In conclusion, I am amazed to read a sponsor statement that refers to " experts" in the field of salmon management as if Alaska was somehow lacking in technical expertise. I have spent years in the presence of some of the same " experts" the sponsor quotes and I assure you, Alaska can be proud of the fact that we have the finest management team on the Pacific coast. As proof positive, remember the state of our fisheries at statehood, look at the vibrant health of our salmon resources today and compare this to the decisions and subsequent success rate of the " experts" to the south. Alaska knows how to manage fish, don't fix what's not broke!

Sincerely,

Dale A. Kelley

Dale A. Kelley
Executive Director

Testimony of
Dale Kelley, Executive Director
Alaska Trollers Association
Before the Alaska Senate Finance Committee
on SB 285
May 1, 1996

Good afternoon Mr. Chairman and members of the committee. The Alaska Trollers Association opposes SB 285, which mandates weak stock management and establishes an industry financed data collection program.

First, I would like to emphasize the importance of recognizing that few, if any, fisheries exist in this state that are not mixed stock in nature.

Perhaps the best reason to oppose this bill is the fact that weak stock management hasn't work anywhere its been employed. A good example is the terrible condition of salmon in the Pacific Northwest. Despite a court order mandating weak stock management 20 years ago, historic fisheries have collapsed right along with salmon stocks.

This state has consistently opposed weak stock management in state, national and international forums. As a result, we have salmon and salmon fisheries. This was not always the case. Prior to statehood and those years immediately following, Alaska conducted aggressive terminal fisheries. Our stocks suffered. The Taku River is an example of a lesson learned. In the late 1970s the condition of Taku River chinook was so bad that the Board of

Fisheries closed gillnet, sport and troll fisheries in front of the river and implemented time and area closures in other distant fisheries. Today, the Taku River is healthy and productive.

Abundance based management is working in Alaska, as exhibited by vibrant production in most rivers statewide. The current Board of Fisheries process and emergency order authority vested in ADF&G provides maximum flexibility to manage stocks. This includes the option of conducting more selective fisheries when appropriate. However, one prescription definitely does not fit all in salmon management.

Weak stock management is cost prohibitive at a time of declining statewide revenues. Weak stock management will demand aggressive management and enforcement, taxing an already stressed agency. This is one reason our present system evolved -- it is a cost effective and efficient means of managing our huge salmon resource.

Further, if SB 285 is enacted, there will be a duplication of data collection, particularly in the Southeast region.

The cost of this bill is prohibitive and unfair to the commercial fleet. In some cases it will penalize a user group that doesn't even harvest the stock in question, like the Alsek River.

The salmon industry already pays significant revenues to the state which are used for research and management. If the state is going to impose additional taxation on the fishing industry, it should provide the industry a role in the selection of programs.

Weak stock management is contrary to Alaska's positions in key national and international forums, like the Pacific Salmon Treaty and the Endangered Species Act. Under the ESA. Alaska fishermen have lost fishing time and 56,000 salmon since 1993, to save a handful of Snake River fall chinook. This is weak stock management at its finest!

I urge you to vote no on SB 285.