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Depletion and extinction of Pacific salmon (*Oncorhynchus* spp.): A different perspective

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Conventional wisdom holds that the depletion of Pacific salmon is a consequence of the economic development and exploitation of Pacific Northwest ecosystems, including fur trade, mining, timber harvest, grazing, irrigation, dams, municipal and industrial development, pollution, and excessive harvest. An attempt to support the fishery through artificial propagation is also recognized as a contributor to the decline. However, those proximal causes of depletion fail to adequately explain the current status of the stocks. Fishery managers have known for at least 122 years what would destroy the Pacific salmon, but having possession of that knowledge, and adding more to it, did not prevent depletion. The decline and local extinction is also a consequence of the implementation of management programmes based on assumptions that have proven to be wrong. If the century of decline is to be halted and reversed, biologists, politicians, and the public will have to undertake the difficult task of evaluating and revising those assumptions and the management programmes derived from them.

Key words: artificial propagation, community values, conceptual framework, depletion, hatchery programmes, history, Pacific salmon.

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Introduction

Salmon yields in various rivers of the Pacific Northwest states of Oregon, Washington, and California peaked between 1882 and 1915 (Cobb, 1930). Since then the salmon and their fisheries have been in continuous decline. Investments in programmes to prevent depletion and to maintain the supply of salmon to the fishery began as early as the 1870s. However, in spite of massive funding for programmes attempting to restore populations to earlier levels of abundance, there is no evidence of a sustained recovery. For instance, the cost of restoration in the Columbia River is approaching half a billion dollars a year (Northwest Power Planning Council, 1994) while runs of salmon are now at the lowest level of abundance on record.

By the early 1990s, the general depletion of the stocks was evident (Nehlsen *et al.*, 1991). Salmon species throughout major parts of their range in the Pacific Northwest have been given or are being considered for protection under the US Endangered Species Act. In roughly 40% of their original range in California, Oregon, Washington, and Idaho the native species are already extinct (Anderson, 1993).

Scientists generally agree on the proximal causes of the current status of Pacific salmon. Beaver trapping, cattle and sheep grazing, irrigated agriculture, timber harvest, mining, dams, regulated river flow, pollution, and other forms of development have all been related to detrimental changes in salmon habitat (Meehan, 1991; National Research Council, 1996). Excessive harvests, fisheries on mixed aggregates of hatchery and wild stocks, and certain hatchery practices such as interbasin transfers of fish have also been implicated in the salmon's century of decline (National Research Council, 1996).

Recent analyses of salmon depletion by independent scientific panels suggest that the proximal causes of depletion by themselves are not an adequate explanation for the current status of Pacific salmon. Community values, opinions about nature and belief in the efficacy of technological solutions to ecological problems are other important factors contributing to the salmon decline (National Research Council, 1996) and to the decline in other fisheries (Finlayson, 1994). Values, assumptions and belief systems do not directly degrade habitat or kill salmon, but they may be more important than the activities that do because they comprise a conceptual framework which ultimately determines how information is interpreted, which problems are identified, and which technical approaches to their solution are given priority. For example, the assumption that salmon went no further in their ocean migration than 20–40 miles from the stream of their birth led notable scientists to argue against any special homing ability (Jordan, 1904). Any meaningful attempt to restore salmon will have to start with a reassessment of the conceptual frameworks that have guided management for the last 120 years.

Our purpose is to undertake such an examination and to stimulate further discussion. We focus on artificial propagation for two reasons: (1) fish culture dominated Pacific salmon management for 120 years; and (2) it easily reveals the fundamental assumptions underlying management.

History overview

The intensive commercial fishery for Pacific salmon began in 1866 with the introduction of canning technology. Within two decades, the canning industry had grown 100-fold in economic value (DeLoach, 1939). By 1875, business and political leaders were concerned about the future of this new and important industry so they petitioned the newly formed US Fish Commission for advice on how to maintain the supply of fish. Spencer Baird (1875), the first US Fish Commissioner, responded with a report identifying the factors that would eventually destroy the salmon industry: habitat alteration, dams, and over harvest. The perception of the importance of these three factors has not changed in 120 years, but having possession of that knowledge has not been sufficient to prevent depletion. The obvious question is, why?

The answer is also contained in the report. According to Baird (1875), it was futile to enact restrictive regulations and try to enforce them. As an alternative, he advised the region that an investment of $15 000 or $20 000 in artificial propagation would make salmon so abundant there would be no need for restrictive regulations. At that time, the McCloud Hatchery was just 3 years old and the first group of juvenile chinook salmon (*O. tshawytscha*) released in 1873 had not yet returned to the river to spawn. So there was no scientific evidence to support the advice.

In the late nineteenth century, artificial propagation became an important tool in the management of Pacific salmon. Hatcheries were popular not because there was scientific evidence of their success. They were popular because they were consistent with the prevailing ideology. At that time, *laissez-faire* access to resources in the American West was an accepted practice and even encouraged by the government (Robbins, 1994). Hatcheries permitted unregulated accesses to resources and watersheds.

Hatchery programmes grew rapidly and by 1910 half a billion artificially propagated salmon were being planted each year in Pacific coastal streams (Cobb, 1930). In 1895, Marshall McDonald (1895), the US Fish Commissioner, and Hershel Whitaker, former president of the American Fisheries Society, challenged the standard practice of releasing propagated fish without concern for their ultimate fate. However, managers failed to invest in meaningful evaluation of early hatchery programmes. This failure stemmed, in part, from the assumption that the virgin fishery resources of the United States were inexhaustible (Higgins, 1928). Another reason was artificial propagation's ideological rather than scientific roots. As the physicist Dyson (1997) has pointed out, ideologically driven technology is not allowed to fail. Its success is assured by ignoring signs of failure, so by the time these are finally recognized great damage may have been done. Consistent with Dyson's observation, salmon managers showed, "almost idolatrous faith in the efficacy of artificial culture of fish for replenishing the ravages of man" (Cobb, 1930, p. 493). In absence of evaluation, managers were asked to have faith in the success of hatcheries (Chamberlain, 1903). While the hatchery programmes continued to grow, habitat was degraded and the salmon were over harvested.

Around 1850, America was undergoing a flowering of science (Kohlstedt, 1991) and a renewal of the Baconian philosophy that scientific knowledge granted technological power and control over nature (White, 1967). These views are clearly expressed in the early writings on fish culture (e.g. Fry, 1854; Goode, 1886). Nature left alone was wasteful and inefficient and it was man's responsibility and mission to control the natural world, make it more efficient and place selected parts of it fully in the service of humans (Bottom, 1997). That attitude is clearly illustrated in Livingston Stone's (1884, p. 21) explanation for the large surplus of salmon eggs deposited in the gravels of the Columbia River every year:

> "Nature . . . produces great quantities of seed that nature does not utilize or need. It looks like a vast store that has been provided for nature, to hold in reserve against the time when the increased population of the earth should need it and the sagacity of man should utilize it. At all events nature has never utilized this reserve, and man finds it already here to meet his wants."

The belief that an excess of eggs was created in anticipation of human needs reflects the view that ecosystems and watersheds were merely warehouses where commodities were stored for man's use (Worster, 1977).

By 1910, conservation was beginning to replace *laissez-faire* policies towards resource exploitation (Townsend, 1911; Gray, 1913). However, conservation had a very different meaning then than it does today. Its original usage came from the damming of rivers in the American West to promote irrigation (Hayes, 1959). The conservation movement did not attempt to curtail the development and exploitation of natural resources but to organize, control, and direct it through technical experts in centralized bureaucracies. Pinchot (1910), conservation's strongest advocate, stated its objective: "The first great fact about conservation is that it stands for development."

Artificial propagation easily made the transition to Pinchot's vision of conservation, and it could be argued hatcheries were preadapted to lead the way for the adoption of conservation ideals in fisheries. Hatcheries removed the salmon from the river, theoretically making it possible to irrigate crops, graze cattle, harvest trees, generate electricity and still maintain the fisheries.

For 60–70 years managers pursued artificial propagation based on undocumented claims of success. In the absence of critical scientific evaluation, artificial propagation evolved into a myth: a set of unsubstantiated but strongly held beliefs which suspended healthy skepticism, impeded improvements, and contributed to the loss of natural production. However, by the 1930s, hatchery programmes were being openly questioned. Cobb (1930) called the "almost idolatrous faith" in hatcheries a threat to the fishing industry and Rich (1941) considered them an impediment to the development of effective conservation programmes. Even the American Fisheries Society, which was originally founded to promote artificial propagation, levelled serious criticism at hatchery programmes (Gottschalk, 1942).

Management institutions were dominated by hatchery programmes and largely staffed by fish culturists who resisted efforts to hire trained biologists (Moore, 1925), in part because biologists questioned the value of some long-standing fish culture practices (Allen, 1954). As Wright (1992) pointed out, "A given institutional order will generally try to perpetuate itself, whatever the ecological cost, and thus its official arbiters of rationality will at some point stop being ecologically rational." Salmon management institutions struggled with this problem in the 1930s and it persists.

Eventually the failure of hatchery programmes became too obvious to ignore and fishery managers recognized the need for programmes based on science (Higgins, 1928). The acquisition of more and better information on the biology of the Pacific salmon began to challenge the old assumptions and a new approach to management began to emerge (e.g. Rich, 1939). Life history studies were recognized as important to the understanding of how the salmon adjust to their habitat (Rich, 1925) and of the underlying complexity in population structure (Rich, 1939). These ideas followed and extended the earlier work on marine fish by Heincke, Schmidt, and Hjort reviewed in Sinclair and Solemdal (1988).

In the late 1930s, biologists had to face the prospects of massive hydroelectric and irrigation development in the major salmon rivers in the Pacific Northwest. They generally understood the consequences of large mainstem dams, especially in the Columbia River (e.g. Craig, 1935; Griffin, 1935; O'Malley, 1935; Rich, 1935, 1940). Managers and legislators responded to the construction of large dams by abandoning the newly emerging management principles and chose instead to maintain the status quo: nearly complete dependence on hatcheries to make up for losses in natural production. Conservation goals of locally adapted stocks in their native habitats would not emerge again until the 1970s (Calaprice, 1969) and these would not begin to influence management until the 1980s and 1990s (e.g. Allendorf *et al.*, 1987; Nielsen, 1995) after some stocks declined to the point that they required protection under the federal Endangered Species Act.

Although the mechanistic world view and its primary metaphor, the machine (Pepper, 1972), has a long history in science, it gained major support in ecology following World War II, due in part to the successful use of systems engineering during and immediately after the war (Golley, 1993). Large-scale hydro development in the mainstems of the Columbia, Snake, and other major rivers in the Northwest took place during a period of societal confidence that scientists and engineers could jointly perfect landscapes and rivers (Robbins, 1997).

Belief in the power of engineering naturally shifted to natural resource management. During the 1950s, ecology used the language of engineering and economics and the model of the machine to describe and analyse ecosystems (Botkin, 1990; Golley, 1993). The application of that approach to the management of Pacific salmon originated from the belief that engineering would solve the problem of making salmon and dams compatible.

The machine is a particularly appealing model for a management framework that depends heavily on artificial propagation. Hatcheries were already designed to resemble factories (Lichatowich, 1988) and the machine model is consistent with the primary aim of controlling and simplifying the production process.

The machine model converted rivers like the Columbia to effective systems for transportation, hydroelectric production, irrigation, and flood control. However, that model has also brought the salmon to the brink of extinction. Citizens of the Pacific Northwest have spent about three billion dollars over the last 15 years in a good faith but futile effort to restore salmon in the Columbia River to a part of their former abundance (Independent Scientific Group, 1999). Unfortunately, these restoration efforts have largely been based on the same assumptions and uses of technology that destroyed riverine ecosystems and caused the decline of salmon.

Prior to 1960, few of the juvenile salmon released from hatcheries survived to recruitment (Columbia Basin Fish and Wildlife Authority, 1989). Development of nutritious feeds (e.g. Hublou *et al.*, 1959) and improved disease control increased the survival and contribution to fisheries after 1960. However, solving the problems of survival created a new set of management conflicts. Harvest of mixed stocks of hatchery and wild salmon led to the over harvest, decline, and extinction of wild populations (Wright, 1993; Flagg *et al.*, 1995). Increased numbers of adults returning to hatcheries created a surplus supply of eggs in the hatchery programmes. Juvenile salmon in excess of the hatchery's capacity were planted back into the streams where adult abundance was depressed due to excessive harvest and habitat degradation. The indiscriminate planting of domesticated hatchery stock into natural production areas not only did not increase total production (McGie, 1980), but in some cases led to reduced natural production (Nickelson *et al.*, 1986). Domesticated fish that strayed into natural production areas and interbred with wild salmon produced offspring with survival rates lower than their purely wild counter parts (Reisenbichler and McIntyre, 1977; Chilcote *et al.*, 1986).

These side effects were ignored in evaluations of hatchery programmes since the 1960s. They rather addressed the narrow questions: did the propagated fish contribute to the fishery and did the economic benefit of harvest by sport and commercial fisheries outweigh the costs of operating the hatcheries (e.g. Wahle and Vreeland, 1978)? Managers were able to conclude hatcheries were a success while at the same time hatcheries contributed to the continuous decline in natural production and created a significant ecological cost (Lichatowich and McIntyre, 1987).

Conclusions

Throughout their history, hatchery programmes have been implemented under the assumption that relationships among reproduction, production, and harvest could through human intervention be simplified, controlled, and made more predictable. Production has indeed largely been brought under human control in some watersheds like the Columbia River where 80% of the adult salmon run is a product of the basin's hatchery programme. However, achieving that degree of control has come at a high price. Although most of the salmon are of hatchery origin there are fewer salmon today than at any time in recorded history. Clearly, hatcheries failed to achieve their original objective of replacing production lost through "the ravages of man". The traditional management framework which viewed the river and its habitat as something to be circumvented, and which arguably is largely intact, contributed to the depletion of salmon in the Pacific Northwest.

Faced with the general collapse of salmon in the Northwest, the region has once again turned to science for a solution. Four independent scientific advisory boards are now examining restoration programmes in various parts of the Northwest-Puget Sound, Columbia River (two panels) and the Oregon coast. One of those boards recently examined salmon management's conceptual framework and recommended that it be replaced with an alternative (Independent Scientific Group, 1999). The principle elements of the proposed framework differ sharply from the current approach to management. The new framework stipulates that restoration must consider the salmon's entire ecosystem from headwaters to the ocean. It recognizes that salmon production is dependent on complex and diverse habitats throughout the life cycle. And biodiversity of wild stocks must be conserved, because genetic variation, life history diversity, and metapopulation structure allow salmon to cope with environmental variation (Independent Scientific Group, 1999).

The reassessment of management's fundamental assumptions has led to a public debate about the possible removal or breaching of mainstem dams on the Columbia and Snake Rivers to re-establish natural habitat and aid the recovery of Pacific salmon (Idaho Statesman, 1997), a debate which would have been unthinkable only a few years ago. Recent actions by the US Congress and President make it likely that two high dams will be removed from the Elwha River in Washington State to enhance local salmon runs. However, changing deeply held values and assumptions will prove difficult and will not occur overnight. In addition, any new framework will not automatically be better. To avoid the problems of the past, fundamental assumptions need continuous examination and management programmes must be flexible enough to change when warranted by new information.

Throughout its history, the hatchery programme has exhibited a chameleonic behaviour, changing superficially to match the social and economic environment while retaining the same conceptual foundation. Artificial propagation has a legitimate role in salmon management, but that role will have to be based on a revised set of assumptions and concepts, if even a partial recovery of the salmon's former abundance is to be achieved (National Research Council, 1996).

The current status of Pacific salmon in the Columbia Basin is not what society intended to achieve. Managers, culturists, and researchers are a group of professionals dedicated to maintaining the "supply" of salmon. Given those good intentions, how did the outcome deviate so far from expectations? A major part of the answer to that question is found in the conceptual management framework. That framework which was so taken for granted that it was rarely discussed, turned out to be a major determinant of the salmon's future. Good intentions and hard work cannot overcome the shortcomings of programmes based on the wrong assumptions. Perhaps William Cronon described the situation best in his foreword to Susan Langston's book on forest management in the Blue Mountains of Oregon (Langston, 1995).

> "Even well-intentioned management can have disastrous consequences if it is predicated on the wrong assumptions, and yet testing those assumptions is always much harder than people realize. To do so, we must realize that ecosystems are profoundly historical, meaning that they exist in time and are the products as much of their own past as of the timelessly abstract processes we think we see going on in them."

Why was it impossible to protect the salmon resource, to prevent a century of decline and extinction even though the causes of that decline were known throughout the entire period? The politicians, the public, and even most of the scientists believed in the efficacy and desirability of a landscape restructured to meet the short-term needs of humans. They also believed that they had the wisdom and ability to control ecosystems and make them more productive. And their belief in those assumptions was so strong they could not see the signs of failure at the time they showed up clearly.

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