16 The History and Status of Pacific Northwest Chinook and Coho Salmon Ocean Fisheries and Prospects for Sustainability

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Abstract.—Since the turn of the century, Pacific Northwest ocean fisheries for salmon have undergone remarkable changes. From their beginnings as the last frontier to escape the jurisdictional reach of state and federal management, these fisheries are now being subjected to intensive and extensive regulation. Today there is increasing societal concern for impacts on the salmon resource base caused by ocean salmon fisheries that harvest extraordinarily complex mixtures of stocks with different productivities. Computer simulation models have become important tools for managing ocean salmon fisheries, as demands for more detailed and precise information have escalated. Regulations are becoming ever more complex and intricate with various interests vying to squeeze out the last drop of fishing opportunity that political processes will permit. Yet, at the same time, funding for resource management is declining and public trust in government and regulation is rapidly disappearing. Within this social climate, sustainability of ocean fisheries for Pacific salmon will require a new management paradigm rooted in better information about the salmon populations and principles of risk aversion.

THE DEVELOPMENT OF OCEAN SALMON FISHERIES

For thousands of years, salmon supported the cultures and economies of Indian communities in the Pacific Northwest. Fishing methods varied, depending on location and species. While a few tribes harvested salmon to a limited extent in ocean waters, the predominant fishing strategy consisted of patiently waiting to catch the fish when they were easiest to harvest—in the rivers when the salmon returned on their spawning migrations. This pattern of limited use provided a successful management regime for countless generations.

In the mid-1800s, the U.S. entered into treaties with many Indian tribes of the Pacific Northwest as a peaceful means of opening the way for settlement by non-Indians. Through these treaties, Indian tribes ceded their claims of aboriginal title to millions of acres and received in return promises by the U.S. that their rights to fish, hunt, and gather would be protected. For the first few decades after the treaties were signed and ratified, Indian people continued to provide fish to sustain both their own tribes and a growing population of non-Indians (AFSC 1970). However, as more and more settlers flooded in to homestead, changes in the environment and utilization of resources began to take their toll on the salmon resource. Major improvements in fish canning and processing spurred the development of fisheries as business enterprises to process huge quantities of salmon for worldwide markets.

Under the open access, common property principle of fisheries management that prevailed in non-Indian society, harvesters began to leapfrog over one another in a race to catch the fish before their competitors. When state legislatures turned their attention to regulation of harvesting activity in rivers and estuaries, fishermen developed new methods and places of harvest further from the rivers. From fish wheels, to gillnets, to traps, to purse seines, salmon exploitation moved from the rivers to nearby marine waters. In the early 1900s, a highly mobile troll fishery developed to catch salmon on offshore banks, several months, even years, before the fish would return to their natal rivers (Cobb 1921). By moving the fishery out of the rivers, the trollers escaped the seasonality of river fisheries, the reach of the regulatory and enforcement agencies, and the pervasive influence of the canning industry. The pattern of exploitation that emerged to harvest salmon was complex, costly to administer, economically inefficient, and nearly impossible to control (Crutchfield and Pontecorvo 1969; Pearse 1988).

THE SALMON RESOURCE

Six species of salmon originate in river systems along the eastern Pacific coast: chinook *Oncorhynchus tshawytscha*, coho *O. kisutch*, chum *O. keta*, sockeye *O. nerka*, pink *O. gorbuscha*, and steelhead *O. mykiss*. This chapter focuses on the Pacific Northwest ocean troll and recreational fisheries for chinook and coho salmon. Pink, sockeye, and chum, the mainstays of commercial net fisheries, are harvested to a much lesser extent by these fisheries. These species are anadromous—they hatch and rear in freshwater, migrate to sea to grow 1 to 6 years, and finally return to their rivers of origin to spawn. Except for a small proportion of steelhead, all salmon species originating on the eastern Pacific coast die after spawning (Groot and Margolis 1991).

During their ocean residence, salmon are so similar in physical appearance that, for many years, agencies involved in the harvest and management of salmon believed that one fish was just like any other. Very little scientific knowledge was available about Pacific salmon as ocean salmon fisheries began to develop. For instance, Samuel Wilmot, whom Canada called upon to address problems with the developing Fraser River fishery in the late 1800s, knew surprising little about the biology of Pacific salmon. Hailed by Canada as the father of artificial propagation who had demonstrated the feasibility of producing "unlimited quantities of any species of fish" in hatcheries, Wilmot reportedly believed that all Pacific salmon were the same species and were capable of spawning several times, just like Atlantic salmon (Meggs 1995).

Scientific knowledge of salmon biology has advanced considerably since that time. The concept that salmon occur as locally-adapted, self-sustaining reproductive populations (i.e., stocks) began to emerge in the late 1920s, when the results of high-seas tagging studies off the coasts of Canada and southeast Alaska started to become available. However, the stock concept was still not fully accepted in the scientific community even into the late 1930s. For example, Henry Ward (Ward 1939), commenting on a conclusion reached by one of his colleagues, W.H. Rich, that the parent stream theory had been conclusively proven, stated:

> ...Under joint auspices extensive tagging of adult salmon was carried on off the west coast of Vancouver Island, and off the Queen Charlotte Islands. These fish scattered widely, reaching many different spawning grounds. But at no point in the chapter is any evidence furnished to show that the author who was in charge of the operation knew from what streams these fish had come as young or by what route they had reached the points at which they were captured.... this comment by Rich is purely an assumption based on the fact that these adults after being tagged were recaptured in the Columbia.

Information as to the stocks being exploited by ocean fisheries was scant into the late 1960s. Managers expressed great concern and frustration over the inability to constrain harvest impacts. The manager of the Washington troll fishery (DiDonato 1965), for instance, stated:

> The obvious lack of information regarding our offshore chinook stocks becomes apparent to all. The offshore troll fishery seems to defy the conditions which effective biological management demands, that is, regulation by stock. The foremost question then is not how best to manage the offshore troll fishery, but simply if this fishery can be managed on any biological, social, or economic basis. Until the marine life history of the various chinook stocks is uncovered, this question will remain unanswered.

Today, we know that the salmon resource is comprised of several hundred distinct reproductive populations, which have evolved over millennia to adapt to environmental conditions that are characteristic of their parent streams. Each stock has its own specific pattern of survival — a pattern of growth, maturity, and migration that have proved successful in sustaining its cycle of life. A sustainable fishery depends upon limiting the harvest to production that is surplus to the needs of reproduction. When overfishing, or other sources of mortality, exceeds these limits, a vicious downward spiral is set in motion: a progressively diminishing resource, the loss of some stocks and lower productivity of others, reduced catches, escalating pressures to harvest at excessive rates to try to save a declining fishing industry, and ever increasing regulatory restrictions (PFMC 1997a). Donald Hodel, in a May 4, 1982 letter to U.S. Secretary of Commerce Malcolm Baldrige, nicely summarized the basic problem:

> Once a depleted stock becomes a minor component of a fishery, socioeconomic factors prohibit their protection because of benefits foregone from not harvesting "healthy stock." With this concept, depleted runs contributing to mixed-stock fisheries will not be permitted to recover.

IMPACTS OF OCEAN SALMON FISHERIES

Although the remarkable ability of the salmon to return to their rivers of origin provided an obvious, convenient, and efficient means of harvest, state management agencies have favored fisheries that exploited several stocks simultaneously. While such a strategy may have simplified tasks of regulation and enforcement, it ignored the complexity of the salmon resource and greatly increased the difficulty of protecting the individual stocks that were the basis for production. As the predominant harvest pattern moved away from rivers to marine areas, fishing on complex mixtures of mature and immature fish from several stocks became the norm.

This pattern of exploitation had two major repercussions. First, the biological yield attained from chinook and coho by ocean fisheries is considerably less than the maximum potential. Parker (1960) concluded that "Critical size is not attained prior to maturity" (critical size is the age at which rates of growth and mortality are equivalent). The Pacific Fishery Management Council (PFMC 1978) environmental impact statement prepared for consideration of alternative ocean fisheries management strategies echoed this conclusion:

> Achieving maximum yield levels in pounds would require elimination of ocean troll and sport fisheries and the taking of fish at or near river mouths. This action would be required because rate of growth exceeds rates of natural mortality in the ocean.

Ocean fisheries are also inefficient because immature fish, which are too small to market profitably, are often discarded. This practice results in substantial mortality losses and loss of yield. It has been estimated that between 63% and 98% of the potential yield for Columbia River chinook was lost due to harvest and incidental mortalities of immature fish (Ricker 1976).

Second, the resource base deteriorated as less productive stocks became progressively overfished. In Washington, Oregon, California, and British Columbia, whole stocks of salmon have been eliminated (Walters and Cahoon 1985; Nehlsen et al. 1991; Slaney et al. 1996). Unfortunately, the lack of protection for individual stocks by fisheries managers was coupled with massive degradation of the habitat, putting additional pressures on the resource (Palmisano et al. 1993;

Meggs 1995; Walters 1995). In many Pacific Northwest areas, the salmon resource now consists of an assortment of declining stocks, some of which have been perpetuated by management intent, many others of which exist only as a result of the vagaries of chance.

HATCHERY PANACEA

As the abundance of wild stocks declined, managers turned to the technology of fish hatcheries in an attempt to increase the supply of salmon. Hatcheries churned out millions of salmon while managers avoided politically unpopular restrictions on harvest and society refused to impose constraints on economic activity that was degrading the streams, rivers, and estuaries essential for healthy wild stocks. From 1933 through the early 1970s, major investments in hatchery propagation were made as mitigation for damage to fish runs due to the construction of hydropower projects. Early attempts at hatchery production proved unsuccessful. Improvements in hatchery practices in the 1960s, involving diet, disease control, and rearing conditions, greatly increased survival rates (ISG 1996). Hatchery production of chinook salmon increased from 6 million smolts in the early 1900s to over 375 million smolts by the early 1990s; for coho, production has increased from 2 million smolts in the early 1900s to nearly 160 million smolts in the 1990s (Ruggerone et al. 1995).

The availability of large numbers of hatchery fish spurred increased fishing pressure and improved the efficiency of ocean troll and sport fleets. Since hook and line fisheries are density dependent (Shardlow 1993), exploitation rates on stocks can be elevated by the availability of large numbers of fish produced by hatchery facilities. In addition, hatchery stocks can withstand higher exploitation rates than their wild counterparts. Since some fisheries were regulated to achieve hatchery production objectives with little regard for impacts on wild stocks, less productive wild stocks were gradually eliminated from the resource base as the mixed-stock fishing patterns harvested both hatchery and wild fish simultaneously (Kaczynski and Palmisano 1993). The indiscriminate introduction of large numbers of hatchery fish into the environment has also been implicated in the proliferation of disease, attraction of predators, and reduced productivity of naturally spawning populations (Weitkamp et al. 1995).

For a few years, increasing hatchery production supported the fisheries and masked the continuing decline of natural production from overharvest and habitat deterioration. By the late 1970s, however, the failure of the "put and take" strategy of hatchery production as a panacea to resource depletion problems had become apparent. Survivals of hatchery fish decreased, the fish were getting smaller, and ever fewer salmon were returning to spawn (Ricker 1980; Ricker and Wickett 1980; Healey 1986; CTC 1996).

REGULATION OF OCEAN SALMON FISHERIES

The need to regulate ocean salmon fisheries has long been recognized. The earliest expressions of concern centered on the harvest of small, immature fish by trollers.

> The taking of immature salmon in the Puget Sound and on the banks along the coast of Oregon, Washington and Vancouver Island is responsible for a great loss in one of the important food products of the region; not only is the loss great but much of the food is of inferior quality. The most inexcusable waste is caused by the spring fishing in the Puget Sound near the south end of Whidbey Island. Here many tons of young silver and spring salmon are taken whose weight average not more than one and one-half to two pounds. The silver salmon would mature in the fall of the same year and produce 5 to 7 tons of fish for every ton taken in the spring. The chinook salmon, if left until mature, which would be in two to three years, would yield even greater returns.*

* Smith, V.E. The taking of immature salmon in the waters of the State of Washington. State of Washington, Department of Fisheries, Olympia, 1920.

When the troll fishery moved to ocean waters, state fisheries managers were powerless to do much about the problem because of the lack of jurisdictional authority. Management of ocean fisheries was not really possible until federal regulatory authority was enacted and treaty obligations, both domestic and international, were firmly established.

Regulation of Ocean Troll Fisheries

The ocean troll fishery began as a fleet of row and sail-powered boats using hand-pulled gear, which operated around the mouths of harbors and rivers. Over time, the entry of large, powered vessels with freezers, sophisticated navigational equipment, improved fishing gear, and the capability to make trips lasting several days drastically increased the range and efficiency of the fleet. Trollers have historically located salmon by searching, although fishing technology is becoming increasingly reliant on fish finders, geographic positioning systems, computers, and communications equipment. As trolling developed, the hook and line nature of the fishery made it more "sporting" than commercial net fisheries and a segment of the fleet historically was comprised of "com-sport" vessels operated on a part-time basis using rod and reel gear.

The early history of regulation of ocean troll fisheries has been reported by Rathbun (1899); CDFG (1949); Fry and Hughes (1951); Kauffman (1951); Van Hyning (1951); Parker and Kirkness (1956); ODFW (1976); NRC (1981); and Argue et al. (1987). Regulation of Pacific Northwest ocean troll fisheries has changed dramatically over the last few decades as jurisdictional authorities of coastal states have expanded to contend with a highly mobile fleet that had the capacity to move freely along the coast. Until the late 1970s, participation during liberal seasons enjoyed by ocean fisheries was constrained principally by weather and market-driven minimum size limits. Both foreign and domestic vessels commonly fished outside coastal 3-mile territorial limits. Canadian vessels harvested significant quantities of Washington coastal, Puget Sound, and Columbia River salmon off the U.S. coast, and U.S. vessels, principally from Washington, harvested significant quantities of those same stocks off the coast of Canada.

During the development of the ocean troll fisheries, the variety and complexity of regulations led to difficulty in enforcing state landing laws, such as minimum size limits. This in turn led to attempts to coordinate management among jurisdictions. The Pacific Marine Fisheries Commission (PMFC) was established in 1947 through a tri-state compact by the States of Washington, Oregon, and California with the consent of Congress (Idaho and Alaska later became members). The objectives of this compact were set forth in Article I as:

> The purposes of this compact are and shall be to promote the better utilization of fisheries, marine, shell, and anadromous, which are of mutual concern, and to develop a joint program of protection and prevention of physical waste of such fisheries in all of those areas of the Pacific Ocean over which the states of California, Oregon and Washington jointly or separately now have or may hereafter acquire jurisdiction.

During the late 1940s and early 1950s, there were efforts to constrain the effects of increased fishing pressure by controlling fishing seasons and establishing minimum size limits to reduce the loss in potential yield resulting from the harvest of small, immature fish. Enforcement, however, was difficult due to frequent changes in these regulations.

Managers were learning that coordination was also a biological necessity because salmon did not respect political jurisdictions. For example, the 1948 recommendations of the PMFC were made not only to the member states of Washington, Oregon, and California, but also to Canada and the U.S. Fish and Wildlife Service (since that agency managed Alaskan salmon fisheries within 3 miles of the Alaskan coast and all Alaskan inshore waters prior to statehood in 1959). Efforts were made throughout the ensuing years to coordinate regulations, but coastwide consistency was not achieved.

During the mid-1950s, the harvest by the Canadian ocean troll fleet off the west coast of Vancouver Island and the Washington coast rapidly increased, taking large numbers of U.S.-origin chinook and coho. This fishery was part of a larger and more serious international problem of salmon interceptions; that is, the harvesting of salmon originating in one country by fishermen of another. Interceptions were a matter of growing concern, especially in the northeast Pacific, where high seas fisheries conducted principally by Japanese fleets were catching large numbers of U.S. salmon. In 1953, the U.S., Canada, and Japan entered into the International Convention for the High Seas Fisheries of the North Pacific Ocean that banned Japanese fisheries from operating east of 175°W. This boundary was meant to avoid exposing the vast majority of North American-origin salmon to Japanese nets. The so-called *abstention principle* of the North Pacific Fisheries Convention holds that fully exploited, scientifically managed stocks should not be exposed to effort from other countries. Japan has continued to abide by this principle since 1963, even though it is entitled to terminate the agreement with a year's notice (Van Cleve and Johnson 1963).

At this same time, increasing competition was pushing Washington and Canadian net fisheries seaward at the mouth of the Strait of Juan de Fuca. This complicated domestic management of fisheries under their respective jurisdictions and raised questions about the inconsistency of these ocean fisheries with positions taken by the U.S. and Canada over high seas net fishing by Japan. In 1957, an agreement to ban gillnet fishing outside the "surfline" was reached between the U.S. and Canada at an informal Conference on Coordination of Fisheries Regulations. As part of that agreement, Canada agreed to adjust its minimum size and season regulations and the U.S. agreed to bring management of Fraser River pink salmon under the jurisdiction of the International Pacific Salmon Fisheries Commission.

In the late 1940s and 1950s, both Canada and the U.S. were becoming increasingly alarmed over the inability to exercise jurisdiction over their own fishing vessels and the intrusion of foreign vessels operating off their coasts. President Truman issued a proclamation on September 28, 1945 that asserted the U.S. had the right to "establish conservation zones in those areas of the high seas contiguous to the coasts of the United States wherein fishing activities have or in the future may be developed and maintained on a substantial scale." The primary motivation for the declaration was the incursion of Japanese fishing fleets into the sockeye fishery in Alaska's Bristol Bay. During the late 1950s, initiatives by Canada in the United Nations Conferences on the Law of the Sea were aimed at the extension of jurisdictional authority. Canada proposed that an exclusive economic zone (EEZ) be established within 12 miles of the coast while the U.S. proposed a 6-mile territorial sea and an additional 6-mile exclusive fishing zone, subject to recognition of historic fisheries conducted by foreign nationals. The U.S. proposal was influenced by the desire to protect the vested interests of Washington State trollers who had been fishing off the coast of Canada for several years. Concerns of Washington fishermen over the prospect of being prohibited from fishing grounds off the Canadian coast were reflected in a July 1958 memo from the Washington Department of Fisheries:

> If the 12-mile limit were ratified, it would not only deny our fishermen the right to historical fishing areas off Vancouver Island but the right to harvest and participate in conservation measures of stocks of salmon from United States rivers. In other words, we would be responsible for maintaining the runs of salmon in our rivers and streams, but have no means of regulating the fishing pressure placed on them once they leave the ocean waters adjacent to our coast.

As a result of shared concerns over salmon, the U.S. and Canada initiated a series of periodic "Conferences on Coordination of Fisheries Regulations." These discussions led to the establishment of a number of technical committees that began to focus on the information available for management and the implications of salmon interceptions for the ability to conserve the resource.

In the late 1960s and early 1970s, the Seabed Committee of the United Nations supported provisions for the establishment of 200-mile fishing zones by coastal states during its Conference on the Law of the Sea Treaty. When U.S. and Canadian proposals failed to be ratified at the U.N.'s Law of the Sea Conference, Canada proposed that a multilateral treaty be negotiated to provide for a 6-mile territorial sea and an additional 6-mile contiguous zone for restricting fisheries. When this proposal was rejected by the U.S., Canada unilaterally extended its jurisdiction to 12 miles offshore. The U.S. followed by establishing a 12-mile zone for fisheries regulation off its coast in 1966.

Since both countries had already established troll fisheries within 3 miles of the other's coastline, the extension of territorial seas and the desire to continue to provide for established fisheries prompted the U.S. and Canada to negotiate bilateral reciprocal fishing agreements. These agreements began in 1970 to restore the fisheries that were threatened by the 12-mile limit. The first agreement, signed on April 24, 1970 in Ottawa, Canada, lasted for 3 years and specified that salmon trolling by the Canadians would be permitted in the 3- to 12-mile limit of the U.S. only along the Washington coast north of the Columbia River. U.S. salmon trollers would be permitted to fish within 3 to 12 miles off Vancouver Island. The U.S. and Canada revised the agreement in 1973, reducing reciprocal fishing areas for both countries. The amended agreement was extended annually until 1977.

Prior to the mid-1970s, management of ocean salmon fisheries was virtually nonexistent. Catch limits were not in effect and even seasons and minimum size limits could not be enforced because different jurisdictions had different requirements. Regulation, to the extent that it existed at all, was principally through the landing laws and licensing requirements of coastal states. There was no capability to limit participation by ocean fisheries outside of 12 miles from shore and limited regulation of the fishery within 12 miles did not effectively restrict harvest. There were no limitations on the number of salmon that could be harvested by ocean fisheries under the jurisdiction of the states, U.S., or Canada. Management for individual stocks was virtually impossible.

In 1975, the United Nations Conference on the Law of the Sea reached a consensus over the right of coastal states to establish an EEZ for the harvest and management of resources found within 200 miles of shore. By 1977, both the U.S. and Canada had enacted EEZs and fishery conservation zones that extended 200 miles offshore. In the U.S., it was only after the Fishery Conservation and Management Act (FCMA) was enacted, establishing the 200-mile EEZ, that efforts were undertaken to directly constrain the number of fish harvested by U.S. ocean fisheries. When the Pacific Fishery Management Council (PFMC) began to manage ocean salmon fisheries off the coasts of Washington, Oregon, and California within the 200-mile zone, Canada raised considerable objections over reduced Canadian fishing opportunities.

The U.S. and Canada suspended the reciprocal fishing agreement in the late 1970s. On August 1, 1977, the Governments of Canada and the U.S. appointed Special Negotiators to reach a comprehensive agreement covering their maritime boundaries and related marine resource issues. The negotiators recommended to the two governments the terms of a reciprocal fishing agreement that provided new mechanisms for consultation and resolution of differences.

An important aspect of this new arrangement was Canada's agreement to consult with the U.S. about the conservation need to close the Swiftsure Bank Area of Canada (Area 21) to all salmon fishing from April 15, 1978 through June 14, 1978, because of the presence of a large number of immature salmon originating in U.S. rivers. Incidental mortality resulting from the capture and release of fish smaller than the minimum size limits, or of species that could not be legally retained, became a matter of increasing management concern. Canada's refusal to completely close Swiftsure Banks, along with disagreements over east coast fisheries, led both countries to close their reciprocal fishing areas in June 1978, denying fishermen from each country access to fish off the other's coast. The 1978 accord was the last annual reciprocal salmon fishing agreement between the U.S. and Canada. However, the two countries agreed to accelerate negotiations on other fishery problems of mutual interest, particularly salmon interception issues.

The debate by the U.S. and Canada over the implications of salmon interceptions had begun with the 1959 Conference on Coordinated Fisheries Regulations and would continue for the next

25 years. Discussions eventually turned into full-fledged treaty negotiations to establish principles for conserving the salmon resource and sharing available harvests. During this period, Canada escalated its ocean fisheries off the west coast of Vancouver Island, an area where coho and chinook from Washington and Oregon predominated, to exert pressure on the U.S. to agree to a treaty to constrain salmon interceptions. During the 1970s, there were extensive negotiations between the U.S. and Canada. Numerous bilateral committees were established to consolidate information and address various technical issues.

Regulation of Ocean Sport Fisheries

The ability to catch chinook and coho salmon by hook and line methods attracted sportsmen to the ocean fishery in search of recreation. Combined, the ocean troll and sport fisheries collectively can impart intensive harvest pressures on salmon stocks. Troll and sport fisheries have been estimated to be capable of removing 15% of the available population of coho salmon per week during seasons lasting several months (CoTC 1984).

Ocean sport fisheries for salmon developed later than troll fisheries, after World War II, and were of relatively minor concern to fishery managers before catches, spurred by the rapid expansion of charter fishing businesses, began to soar. Harvest by the ocean sport fishery in Oregon peaked in 1976 at 79,000 chinook salmon and 500,000 coho salmon. The ocean sport fishery in Washington also peaked in 1976 with 538,000 angler trips and a catch of 170,800 chinook salmon and 942,800 coho salmon. Since the mid-1970s, the Washington ocean sport fishery has been severely restricted (PFMC 1993; PFMC 1997a).

Prior to the early 1980s, ocean sport fisheries enjoyed liberal bag limits and were subjected to only minimal time/area restrictions. Since then, bag limits have been reduced and more direct regulatory measures such as catch ceilings for individual ports have been implemented to control harvests in several areas off the U.S. and Canadian coasts.

Increasing competition between sport and commercial troll fisheries has led to the development of specific allocation schedules between the two fisheries off the Washington and Oregon coasts. Generally, sport fisheries in these areas receive a larger share of available harvests at low levels of abundance. Inter-port allocation for sport fisheries off the Washington coast has been incorporated into the PFMC's Framework Plan and has become a subject of increasing interest off Oregon. Historical data on the ocean fisheries off the coasts of Washington, Oregon, and California are documented by the PFMC's Salmon Technical Team (PFMC 1993).

However, even as agencies began to regulate the ocean fisheries within their respective jurisdictions, escapements and catches were plummeting. Although it was clear that something had to be done, it was not clear what needed to be done or how to go about doing it on a comprehensive basis.

DEVELOPMENT OF THE CAPACITY TO MANAGE OCEAN FISHERIES

Prior to 1970, fisheries agencies had neither the scientific nor the legal basis to effectively manage ocean fisheries in the Pacific Northwest. However, the need, the authority, and technical capacity to manage these fisheries evolved virtually simultaneously in the early and mid-1970s. As such, the convergence of three factors, including social circumstance, information availability, and technological advancement, led to the development of the capacity to manage ocean salmon fisheries in Canada and the U.S.

While dwindling stocks and declining catches emphasized the need for management of ocean salmon fisheries, several social developments were needed before fisheries managers could effectively address the impending conservation and economic concerns. Among the most important of these was the entrenchment of Indian fishing rights in 1974. In a landmark decision, the Honorable George H. Boldt ruled that the tribes have enforceable property rights to take up to 50% of the

harvestable surplus of each run of fish that originates in or passes through their usual and accustomed fishing places. The concept of harvestable surplus of individual stocks necessitated a change in management focus by providing protection for the portion of the run required for escapement. In addition, this decision recognized the need to manage fisheries so as to assure that a substantial portion of each run's harvestable surplus of fish was allocated to more terminally-located fisheries. In this way, the individual stock was recognized as the basic unit of fisheries production and management.

Within the last decade, the stock concept has been further refined to include evolutionary significant units (ESUs), as defined under the Endangered Species Act (ESA) of 1973. A number of salmon and steelhead ESUs have now been listed as "threatened" or "endangered" under the ESA (Knudsen et al. 2000). Considering these new legal obligations, it was clear that fisheries managers needed novel scientific, administrative, and legislative tools to generate the information required to provide for specific harvest entitlements and ESU protection.

While the need for advancements in the management of ocean fisheries was apparent, the legislative basis for such reforms was lacking prior to 1976. Washington Senator Warren Magnuson described that situation succinctly when he indicated that fisheries management in the Pacific Northwest was characterized by weak, divided authority and inadequate enforcement (Magnuson 1977). As a result, the federal governments of Canada and the U.S. were virtually powerless to control fishing outside their territorial waters, where ocean troll fisheries often operated. Establishment of EEZs within 200 miles of their respective coasts improved the situation by making it possible to regulate the ocean fisheries that operated outside state and provincial jurisdictions. However, establishment of EEZs did not obviate the need for international cooperation because the fish still crossed international boundaries. Hence, the actions of one management entity could have profound effects on the stocks that were being managed by another.

In recognition of the need for international cooperation, the U.S. and Canada initiated negotiations to establish a comprehensive salmon treaty in the late 1970s. In 1981, interim agreements for a limited set of fisheries were reached. Two years later, a general framework for a salmon treaty was established. However, the preliminary agreement was not ratified by the U.S. due, in part, to the omission of the west coast Vancouver Island troll fisheries, which could prevent the U.S. from achieving its fisheries management objectives. Therefore, further negotiations focused on developing a coastwide approach, eventually resulting in the ratification of the Pacific Salmon Treaty in 1985. With the establishment of the treaty, the social circumstances needed to affect fisheries management reform had been established. Yet, advancements in the available scientific information and technology were still needed to fully achieve fisheries management objectives.

The scientific information that was available until the 1980s was rudimentary by today's standards. These data were largely limited to trends in spawning escapements and catches in and near the rivers of origin. The lack of an effective means of sharing information further constrained the ability of fisheries managers to conserve the salmon resource base. However, the development of coded wire tag (CWT) technology in the early 1970s made it possible to obtain previously unavailable information on the distribution, abundance, survival, and recovery of salmon and steelhead populations throughout their range. Data collected using this technology showed that many stocks were being harvested at several stages of maturity over an extensive geographic area. Moreover, many populations were being harvested in mixed stock fisheries at rates that jeopardized their sustainability.

The emergence of personal computer technology in the early 1980s provided fisheries scientists with an essential tool for managing ocean salmon fisheries. This technology enabled scientists to quickly process large quantities of data to develop a better understanding of salmon exploitation on a coastwide basis. This technology was rapidly incorporated into fisheries management, particularly through the development of computer models that made it possible to analyze the copious CWT data that had been gathered over the previous decade. Importantly, the computer models provided a means of utilizing data on stock distribution, fishing mortality rates, and other biological variables to evaluate the effects of various regulatory regimes on individual stocks and stock aggregates. As such, the models provided much-needed tools for establishing catch quotas for each species by geographic area for commercial and recreational fisheries. Since their inception, such models have been further developed and refined to meet the specific needs of a variety of regulatory agencies throughout the Pacific Northwest.

Experience with successful application of computer simulation models in salmon management on the Pacific coast reveals four major lessons. First, successful models have been developed through an open, multi-jurisdictional effort; there must be a shared sense of ownership of the data and analysis underlying the workings of the model. Second, successful models force resolution of technical issues so policy implications can be evaluated in terms meaningful to decision makers; technical debates over data, assumptions, analysis procedures, and interpretation are eliminated or at least contained. Third, successful models are readily modified to meet changing demands for information and they must be capable of producing the information needed within an acceptable decision time frame. Last, successful models provide a consistent, convenient framework for evaluating options for complex conservation problems; they are easily accessible to allow positions to be developed and evaluated independently within each affected jurisdiction.

IMPACTS ON THE BIOLOGICAL POPULATIONS

The reluctance of managers to constrain fisheries under their jurisdictions, unless others do so first, has led to the collapse of some salmon stocks. During the last decade, the mandate of law has appeared on the scene to force U.S. fishery managers to consider impacts of harvest activity on individual, imperiled stocks. The Endangered Species Act (ESA) of 1973 has come to wield a powerful influence on the management of U.S. ocean salmon fisheries. Under the ESA, ESUs are protected and must meet two requirements: (1) reproductive isolation; and (2) be deemed to represent an important component of the evolutionary legacy of the species. For salmon ESUs listed as "endangered" or "threatened" under the ESA, biological opinions are required to permit fisheries to incidentally take listed fish. Stocks that have been listed include Sacramento winter run chinook, Snake River spring, summer, and fall chinook, Snake River sockeye salmon, and California coho (PFMC 1997b). In addition, several coho salmon ESUs are considered to be depressed and are possible candidates for listing under the ESA (Weitkamp et al. 1995).

Today, ocean salmon fisheries along the entire west coast are being constrained to limit stock-specific impacts. Some of these constraints are long term, such as those resulting from the need to protect species listed as endangered under the ESA. Other constraints address short-term survival or annual abundance problems. Central California ocean fisheries are regulated for concerns for impacts on the endangered Sacramento winter chinook salmon run. Fisheries off northern California and Central Oregon are managed to constrain impacts on Klamath River fall chinook salmon. Fisheries from Washington to California are evaluated based on their impacts on the endangered Snake River fall chinook salmon stock. Chinook and coho salmon fisheries in the Strait of Georgia are constrained due to concerns for local stocks. West coast Vancouver Island and North/Central B.C. fisheries have been curtailed to address serious conservation problems for west coast Vancouver Island chinook salmon. Fisheries in Puget Sound, the Columbia River, and along the Washington coast are restricted to meet stock-specific escapement objectives. The ESA has affected Alaskan fisheries to a lesser degree than several other U.S. fisheries, but Alaskan impacts on listed stocks are still taken into consideration and harvests are still subject to incidental take permits under biological opinions issued by the National Marine Fisheries Service.

Confronted with the continuing decline of certain salmon stocks, primarily caused by habitat degradation and low ocean survival, managers are faced with increasing requirements to address the needs of individual stocks by regulating ocean fisheries. Managers have turned to a variety of tools to constrain impacts, most commonly seasons, catch ceilings, and size limits, all directed

toward achieving spawner escapement objectives. Regardless of the methods, the ultimate result has been a quantum leap in regulatory complexity and demands for more information.

THE SITUATION TODAY

Unprecedented challenges currently confront ocean trollers, sportsmen, and fishery managers. For example, fisheries exploiting highly complex stock mixtures must be managed on a stock-by-stock basis to meet legal obligations stemming from reserved tribal rights and the ESA. The salmon resource has declined in response to continuing degradation of freshwater and estuarine habitats and poor marine survival conditions. Large sums of public funds are expended to support hatcheries and to maintain the management and information systems required to contend with difficult technical challenges. Ready supplies of fresh salmon from aquaculture operations in Norway, Chile, New Zealand, and Canada are making major inroads into markets once dominated by the troll industry, calling into question the wisdom and need to continue hunting for salmon on the high seas. Societal attitudes are rapidly changing from consumption and commercialization of naturally produced salmon toward recreation and preservation.

Today, managers of ocean salmon fisheries are in a quandary. They are struggling to make do with diminishing fiscal resources while trying to develop strategies for making scientifically supportable decisions in the face of uncertainty, to devise strategies for avoiding mistakes that can have far-reaching consequences for the salmon resource base, and to find defensible and effective means to meet their legal obligations. Three basic alternatives are currently under political and management consideration: (1) approaches that evade accountability by delaying implementation of unpopular management decisions affecting fisheries and habitat; (2) approaches that are less information-demanding, less risky, and more conservative, but which still do not address, in detail, problems of declining salmon abundance on a stock-by-stock basis; or (3) improved technology coupled with significantly increased critical stock data to do a better job.

Delaying implementation of necessary corrective management measures appears to be popular on several fronts. Some of this is understandable because the limited political tenure of elected officials and top fisheries administrators allows them to escape accountability. By the time the consequences of decisions become evident, either the cause has been forgotten or the decision-makers have moved on. A plethora of interests seek to evade responsibility by accusing each other of being the real cause of the salmon problem. Politicians, administrators, loggers, farmers, ranchers, irrigators, developers, power companies, and competing groups of fishermen, among many, have managed to entangle issues in copious rhetoric and blame. Few solutions have emerged. Indeed, conflict and controversy have forced fishery managers to divert resources from their clear responsibility: to manage fisheries and hatcheries, and to try to halt degradation of the habitat necessary for the salmon to exist.

The option to implement management strategies that are less information-demanding provides a means of managing fisheries in recognition of uncertainty. This option employs heuristic decision rules, based on general stock status indicators, to establish allowable harvest levels for broad geographic regions. Costs of implementation would be lower and would result in more realistic expectations by taking into account the uncertainty surrounding abundance forecasts and projected fishing patterns. This type of approach contrasts markedly with the current management practice in the Pacific Northwest, where complex time-area fishing regimes are devised to find every fishing opportunity.

The search for management approaches that are less information-demanding is also leading to consideration of other strategies. Managers of ocean fisheries have not given up the search for an elusive magic bullet that will resolve their problems quickly and easily. Presently, this magic bullet appears to be manifesting itself as a push for selective fisheries (e.g., Lawson and Comstock 2000). The superficial appeal of fisheries that selectively harvest hatchery fish while releasing wild fish makes this approach a modern-day Siren's song. Instead of basing decisions on scientifically supportable analyses, managers are turning to assumption and presumption that selective fisheries will resolve resource conservation and utilization problems. Selective fisheries strive to improve economic benefits from hatchery fish, particularly for certain recreational fisheries, but they are also likely to diminish stock assessment and management capabilities because they may obscure the true mortality imparted on wild stocks, increase the uncertainty as to impacts of fisheries, require the expenditure of scarce funds to mark fish and modify CWT sampling programs, and undermine the data collection and analysis systems required for management. Fears have also been expressed that selective fisheries for hatchery fish may undermine the political support needed to protect habitats for production of wild fish. There are many operational problems, including impacts on other stocks and species, which need to be resolved before the role of selective fisheries in protecting and restoring salmon stocks can be scientifically evaluated.

New technology has allowed management of Pacific Northwest ocean salmon fisheries to become information-intensive. Ocean fishery managers have invested considerable funds to collect the necessary stock data and develop the needed computer models to more effectively manage salmon. In response to increasing demands for stock-specific information on impacts of ocean fisheries, affected constituents have raised numerous questions regarding the validity of management models while at the same time insisting on ever more complex and sophisticated analyses. The thirst for more and perfect information seems insatiable, driving decision-makers to seek answers that go far beyond the limits supportable by available scientific information. Then, when results based on scientific data and information are unwelcome, some managers choose to ignore or discount them as being inconclusive. Although data are adequate to document the declines of some salmon stocks, some management entities dispute the scientific data in order to delay measures needed to successfully rebuild depleted stocks. As a consequence, substantial funds are being diverted from important management programs to support research, studies, and analysis before decisions can be made through political processes of fisheries regulation. The consequence of course is that the resource bears the burden of uncertainty. Impacts continue unabated and the inexorable loss of less productive stocks further depletes the diversity and resiliency of the resource base. Such problems are by no means unique to salmon fisheries. Similar experiences prompted the United Nations to adopt a draft agreement in 1995 containing the precautionary management principle that: "States shall be more cautious when information is uncertain, unreliable or inadequate. The absence of adequate scientific information shall not be used as a reason for postponing or failing to take conservation and management measures."

The public may not continue to support funding to obtain, analyze, and utilize the data necessary for information-intensive management of ocean fisheries. The challenge is to utilize existing information for decision-making within the context of uncertainty and implications for error while studies continue to improve knowledge for future decisions.

CURRENT APPROACHES SUPPORTING OCEAN FISHERIES SUSTAINABILITY

Other alternative approaches for management of ocean salmon fisheries are now coming into focus as deliberations over sustainability continue. Chan and Fujita (1994), among others, have made suggestions for reforming ocean salmon fisheries. In general, alternatives that appear to be gaining support can be characterized as being adaptive, collaborative, or risk averse.

Adaptive management is in vogue (Lee 1993). The idea is relatively appealing because it does not lock decision-makers into a course of action. It is not new and exotic, but is simply muddling, trial and error. It can produce needed data in a relatively short time, data that might be years in obtaining under normal conditions. Since the ecological and economic system for salmon management is extremely complex, this management strategy perturbs the system and evaluates its response. This approach will likely falter because: 1) the political environment staunchly resists the perturbation of ocean fisheries to the degree necessary to conduct scientific and sociological experiments on a scale required to cover the migratory range of the salmon; and 2) it is unlikely that the mood of fiscal austerity will provide the resources necessary to monitor and evaluate results.

Collaboration, or the voluntary imposition of management measures to protect depressed salmon stocks, has been attempted in the past. This approach is still being pursued, in part because of its simplicity, by assuming that the managers who impact stocks throughout their migratory ranges will "do the right thing." The stark reality, however, is that there is an overriding temptation to shift responsibility to someone else. For example, Washington and Oregon's repeated cries for help from Canada to address growing concerns for chinook and coho salmon generally have gone unheeded. Now Canada has its turn to ask Alaska to reduce harvests to help conserve its chinook and coho salmon stocks. Unless managers can agree on common goals and their respective responsibilities for resource conservation, collaboration will likely fall by the wayside.

Another disturbing development that will interfere with a collaborative approach is the tendency to question the minutiae of the technical basis for management — in some forums, every assumption, goal, data value, and analysis method comes under intense scrutiny. Management models, while providing the capacity to conveniently evaluate the impacts of alternative regulatory regimes, make fertile ground for conflict and controversy. In the Columbia River for example, policy issues are debated and buttressed by battling models that rely upon different assumptions and data. While we recognize the value of a good dose of skepticism and the need for scrutiny of models and data, the tactic too often has not been to improve the scientific basis for management, but rather to delay and increase uncertainty so that important decisions are not made. Thus, the status quo is preserved and only minor perturbations that can easily be accommodated are possible. The problem is that time is of the essence; delayed decisions to conserve the resource can have serious long-term consequences.

Even where competition between models is not a factor, the issue of compatibility between models surfaces. In evaluating impacts of regulations affecting chinook salmon, for instance, the Salmon Technical Team of the PFMC must interpret, consolidate, and reconcile the results of four distinct models that involve different stocks, effort measures, and time frames. Greater collaboration on modeling is needed to alleviate confusion, conflict, and redundancy.

Of the three strategies for ocean salmon fisheries management looming on the horizon, risk aversion holds the most promise (e.g., Hilborn et al. 1994). Increasing attention has recently been paid to the explicit consideration of uncertainty and incorporation of risk-averse strategies into harvest regulation. Risk aversion can take a variety of forms. For ocean fisheries, risk-averse strategies could employ conservative estimates of abundance projections and/or consideration of impacts at the upper end of an anticipated range or could involve less information-intensive approaches such as those described earlier. Risk-averse strategies have already been implemented for some ocean salmon fisheries. For example, the allowable harvest of chinook salmon produced by Southeast Alaskan hatchery facilities reflected a policy decision that there would not be more than a 5% chance that the actual harvest of hatchery fish would exceed the inseason projection. This approach was risk averse in that it attempted to avoid pushing the limits of resource sustainability and was acceptable to certain constituencies.

Risk-averse strategies, however, can have adverse consequences, principal among them being reduction in the short-term yield from fisheries. Because risk aversion would err on the side of the resource, fewer fish would be available for harvest and fishing opportunity would be reduced in anticipation of larger catches in the future. To minimize undesirable adverse economic impacts, there is likely to be a strong tendency to push decision-making beyond the limits supportable by science, to demand more precision in management, particularly in the areas of stock identification and abundance estimation. Political pressures will likely keep the economic cost of risk aversion to a minimum and ignore the variability in the data and the analyses.

CAN OCEAN SALMON FISHERIES BE SUCCESSFULLY MANAGED FOR SUSTAINABILITY?

Changes in the political climate have set the stage for deliberations over the sustainability of ocean salmon fisheries. Institutions and boundaries are forming with the establishment of regional fishery management councils, court rulings regarding joint tribal and state management authorities and specific tribal entitlements, the ratification of the Pacific Salmon Treaty, and the implementation of the ESA. In the face of the ESA, adverse consequences of management error are becoming increasingly severe and unacceptable. New management tools, like computerized simulation models, have emerged to help regulators contend with technological challenges. However, the fundamental, daunting complexity that characterizes ocean salmon fisheries still remains. Ocean salmon fisheries exploit dynamic mixtures of natural and hatchery stocks with vastly different productivities, migration routes, and exploitation patterns. These stocks originate over an extensive geographic range and have high interannual variability in survival, growth, and distribution.

Ocean salmon fisheries can be managed for sustainability, despite this complexity, if that is what society desires. Sustainability can take many different faces — from protecting productivity and diversity of the various salmon runs to stability of the fisheries in terms of season structure, catch, or opportunity. In the years ahead, management of ocean salmon fisheries will certainly undergo changes, some of them likely to be drastic. Even now, commercial trolling along the Washington coast is rapidly waning and ocean sport fishing is barely holding on. There is no sense in longing for the return of unfettered fisheries that gave trollers and sportsmen the freedom of less than two decades ago to hunt the high seas for as many salmon as they could catch. The days of the last frontier have come and gone. Ultimately, the form of sustainability that will evolve for ocean fisheries will depend upon the needs and objectives spawned and dictated by societal values.

In many ways, the sustainability of ocean fisheries will depend upon the willingness and ability of managers to maintain a viable information base to evaluate impacts on the resource. Managers must be willing to make substantial investments in the development of common data systems, methodologies, and sophisticated computer models. The viability of the coastwide system for collecting CWT data must be preserved. Abundance, age, and maturity data for both catch and escapement are vitally important for stock assessments and the establishment of scientifically supported spawning escapement goals. The degree to which exploitation patterns of hatchery stocks are representative of wild stocks must be determined. Finally, the relationship between production, fishery impacts, and habitat must be demonstrated and quantified. Proper management of ocean salmon fisheries will necessitate collecting detailed, stock-specific data and substantial investments in predictive information, such as effort response, migration routes, and timing, so that models can accurately estimate the expected impacts of various management options and reflect uncertainty. At the same time, a new management paradigm is needed to overcome the variability in the data and the environment. Therefore, the development of approaches that are less information-demanding and more risk averse will be critical to future decisions regarding sustainability of ocean salmon fisheries and the stocks upon which those fisheries depend.

Despite these technical challenges, the foremost hurdles that must be overcome to sustain ocean fisheries are fundamentally political (Netboy 1973). Because coho and chinook salmon, the primary species harvested by ocean fisheries, can be caught several months before maturity in places far distant from their natal rivers, extraordinary efforts will be required among interjurisdictional managers to achieve the degree of coordination necessary to protect the resource. The involvement of multiple political jurisdictions that affect harvest and habitat create the necessity to integrate disparate types and qualities of information on abundance, spawning escapements, and biological characteristics and the need to accommodate uncertain impacts by fisheries. Managers must, therefore, be willing to forego some of the flexibility they have become accustomed to exercising. Instead, multi-jurisdictional approaches to planning and management must become the norm. Each management entity must recognize the necessity of regulating its own fisheries in full consideration and appreciation of other entities that affect the resource throughout its migratory range. Sustainability of ocean salmon fisheries ultimately rests upon sustainability of the salmon populations. That can only be assured if cumulative impacts of all fisheries are considered and accommodated within the populations' productive capacity.

With ocean salmon fisheries, future decisions will be less concerned with salmon biology or coordination of harvest management than with the resolution of issues that pit diverse economic interests against strongly held moral and ethical values. Already the flavor of the debate raging among politicians and their constituencies over salmon and salmon fisheries has involved profound questions of social policy. Can society afford to spend hundreds of millions of taxpayer dollars to pay for complex management systems and hatcheries to subsidize fishing for salmon? To preserve inefficient fisheries to catch wild salmon when aquaculture operations can provide high quality fresh fish for consumption? To curtail or forego economic development and growth to protect and maintain salmon habitats? To protect every remnant run of salmon?

Managing ocean salmon fisheries for sustainability requires that political leaders confront all these issues and more in a way that assures the viability of the salmon populations. This will be a formidable task. Given the reluctance of decision-makers to take responsibility for divisive decisions that affect their constituencies, there is considerable doubt as to whether many natural salmon stocks can be sufficiently productive to support viable ocean fisheries, or even to simply survive. The focus of the debate over sustainability needs to change from the fisheries to the fish. If the resource succumbs, the fisheries will too.

ACKNOWLEDGMENTS

We thank P. Dygert, L. Rutter, and several anonymous reviewers for their thorough reviews of the manuscript.

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