PACIFIC SALMON FISHERIES: CLIMATE, INFORMATION AND ADAPTATION IN A CONFLICT-RIDDEN CONTEXT

KATHLEEN A. MILLER

Environmental and Societal Impacts Group, National Center for Atmospheric Research, P.O. Box 3000, Boulder, CO 80307 - 3000, U.S.A.

Abstract: Pacific Salmon are anadromous fish that cross state and international boundaries in their oceanic migrations. Fish spawned in the rivers of one jurisdiction are vulnerable to harvest in other jurisdictions. The rocky history of attempts by the United States and Canada to cooperatively manage their respective salmon harvests suggests that such shared resources may present difficult challenges for effective adaptation to climate change. On June 30, 1999, the two nations signed an agreement which, if successfully implemented, may end several years of rancorous conflict. For the previous six years, they had been unable to agree on a full set of salmon "fishing regimes" under the terms of the Pacific Salmon Treaty. This conflict was sparked by strongly divergent trends in the abundance of northern and southern salmon stocks, and a consequent change in the balance of each nation's interceptions of salmon spawned in the other nation's rivers. The trends are attributable, in part, to the effects of large-scale climatic fluctuations. This case demonstrates that it may not be a simple matter to respond effectively to a climate change. Adaptation is difficult when a resource is exploited by multiple competing users who possess incomplete information. If, in addition, their incentives to cooperate are disrupted by the impacts of the climatic variation, dysfunctional breakdowns in management rather than efficient adaptation may ensue. Institutional factors will determine the extent to which the management of such resources can adapt effectively to climate variability or long-term climate change.

1. Introduction

Climatic variations and climate change may affect the abundance, availability and even the continued existence of a wide range of natural resources. Many of these resources are not owned and controlled as private property. Rather, they are common or public property resources that are managed with varying degrees of effectiveness by local, national or international public authorities. Marine fisheries, particularly those exploited by more than one nation, are notable examples of climate-sensitive resources whose management is complicated by the difficulty of defining and enforcing exclusive rights to the resource.

The Pacific salmon stocks of North America are transboundary resources in that they cross state and international boundaries in their oceanic migrations. There are five species of Pacific salmon (chinook, coho, sockeye, pink and chum), with a multitude of distinct breeding populations. While the various species, and even different stocks of the same species, follow somewhat different life histories, all Pacific salmon are anadromous. In other words, they spawn in freshwater streams. The juveniles migrate to the ocean where they often traverse enormous distances as they feed and mature. Mature salmon then return to their natal streams to spawn and die. Their anadromous nature makes salmon sensitive to changes both in the ocean and stream environments. It also creates a perplexing set of difficulties for effective management.

The United States and Canada have a long and rocky history of alternating between cooperating on joint management of Pacific salmon harvests and squabbling over their respective shares of the catch. The most recent breakdown in cooperation began in 1993, when the two nations became embroiled in an extended dispute that left them unable to agree on a full set of salmon "fishing regimes" under the terms of the Pacific Salmon Treaty. A new Agreement, signed on June 30, 1999, may end the conflict, but it is too early to judge its likelihood of success. The Canadians remain bitterly divided over the merits of the Agreement, which has been labeled a "sellout" by Canadian fishing interests, and the arrangement is still contingent on U.S. Congressional approval of $140 million for two jointly managed endowment funds to be used for scientific cooperation, stock enhancement and habitat restoration (Culbert and Beatty, 1999). The Agreement is also contingent on a U.S. Federal Government determination, by December 31,1999, that the Agreement satisfies the legal requirements of the Endangered Species Act (U.S. Department of State, 1999).

The recent acrimony began when northern salmon runs increased dramatically while southern runs declined, leading to a change in the overall balance of "interceptions " between the U.S. and Canada. These trends appear to be influenced by the effects of climatic variations on the ocean and stream environments, but climate is not the only source of harvest variability. Because it is difficult to disentangle natural and anthropogenic sources of variability, the negotiation process has been complicated by differences of opinion over the biological "facts". When marine survival rates for chinook and coho salmon originating in Washington, Oregon and British Columbia declined sharply during the early 1990s, the Parties proved unable to quickly and effectively constrain harvests (PSC-JCTC, 1994; PSC, 1995; 1996; *Confederated Tribes and Bands v. Baldridge* [W.D. Wash. September 7, 1995]). This almost certainly contributed to the current imperiled state of some of these stocks, culminating in recent listings of some Columbia Basin and Puget Sound chinook stocks under the Endangered Species Act (Shaffer, 1998; Whitman, 1999).

The complex role of an extended climatic regime-shift (Hare and Francis, 1995; Mantua et al., 1997) in this dispute suggests that future efforts to adapt to greenhouse gas-induced climate change may encounter analogous pitfalls. A better understanding of the role of unanticipated climatic trends or shifts in current resource-management disputes may help to smooth the path of adaptation, for example, by encouraging the development of more flexible allocation rules. Accordingly, this paper has two goals. The first is to summarize the nature of the possible impacts of anthropogenic climate change on Pacific salmon. The second is to draw lessons from the Treaty dispute regarding the process of adaptation in the case of transboundary fishery resources.

2. Salmon Biology, Abundance and the Role of Climate

Pacific salmon lay their eggs in the gravel of cold fast-moving streams. After hatching, the juvenile salmon remain in the freshwater environment for a period of weeks to years, depending on species and stock, and then migrate downstream and disperse into the coastal ocean. Some salmon stocks remain in coastal areas throughout their lives, while others spend a year or more in a long-distance migration across the feeding grounds of the subarctic Pacific before returning to their natal streams to spawn and die (Pearcy, 1992). The five salmon species vary in relative abundance along the west coast of North America. All species are present from Washington state northward, while in Oregon and California only chinook and coho spawn in significant numbers.

Most rivers along the Pacific coast of North America from California's Central Valley northward once supported salmon runs. Where streams have been heavily modified by human activities, some wild salmon runs have disappeared, while others have diminished in size. In many rivers, wild runs have been supplemented and/or supplanted by hatchery production.

Prior to its development, the Columbia River system had been the major source of salmon south of the Canadian border. Over the course of the twentieth century, a series of dams harnessed the Columbia and its major tributary, the Snake River, to provide most of the region's hydroelectric power as well as irrigation water and navigation benefits. The dams have had well-documented adverse impacts on salmon survival (Volkman, 1997). In particular, those stocks that must traverse several dam sites lose a significant fraction of the out-migrating juveniles to turbine-caused mortality. As a result, natural salmon stocks in the Columbia system declined and were largely replaced by hatchery production located in the lower part of the basin. Several Columbia and Snake River wild salmon stocks are now listed as threatened or endangered under the Endangered Species Act. Northward from Washington state, the degree of human interference with salmon streams diminishes. In addition, the natural variety and abundance of salmon populations increases.

Climatic variations can affect salmon at several life stages. In the streams in which Pacific salmon spawn, reductions in summer flows, increased winter flooding, changes in the timing of spring freshets, increased water temperatures or increased sedimentation are among the hydrologic changes that could result from global warming. Such changes could be highly detrimental to salmon productivity by interfering with adult migration and spawning success, as well as egg-to-smolt survival and juvenile outmigration (Chatters et al., 1991; Levy, 1994). Warming might also result in poorer feeding conditions in lakes that are critical rearing habitat for young sockeye (Henderson et al., 1992).

In the Columbia system, the projected impacts of global warming (warmer water temperatures and earlier seasonal peak flows) in some ways resemble the effects of development of the system for hydropower and other purposes (Lettenmaier et al., 1996; Snover, 1997; Hamlet et al., 1997; Lettenmaier and Hamlet, 1998). Over the past few decades, construction and operation of water storage capacity on the Columbia system led to a significant "flattening out" of the annual hydrograph at the Dalles (U.S. Dept. of Energy-Bonneville Power Administration et al., 1991). This has contributed to high rates of smolt mortality at the dams, as a result of both slower movement down the river, resulting in increased losses to predation, and damage and disorientation as many smolts are forced to pass through the turbines rather than over the spillways (Volkman 1997). Further evidence for the possible impacts of a warmer climate on Columbia Basin salmon is provided by Chatters et al. (1991), who used paleohydrologic evidence to develop a scenario of the effects of a warmer climate on streamflows, water temperatures and salmon habitat for theYakima Basin (a Columbia tributary). Geological and archaeological evidence from a previous warm period suggests that stream flows were less than 70% of modern; many small, low elevation, perennial streams became intermittent (dry during part of the year); streams had finer bed loads (greater sedimentation); water temperatures were higher; and the spring peak flow (freshet) ended three to four weeks earlier than it does today. Incorporating these hydrologic changes in a salmon production model resulted in large projected declines in the number of returning adult spring chinook salmon.

Stream temperatures are especially critical for adult salmon as they ascend the rivers to spawn. They may die before spawning if water temperatures are too warm. During the summer of 1998, high water temperatures in the Fraser River led to high pre-spawn mortality of adult sockeye, necessitating emergency closures in the fishery (Hansen, 1998). High water temperatures in the Columbia River also raised concerns for salmon spawning there.

The period immediately after salmon smolts enter the marine environment is particularly critical, and survival in that period contributes importantly to subsequent cohort size (Pearcy, 1992, 1997; Downton and Miller, 1998). Variations in both feeding conditions and predation at that life stage may account for much of the interannual variability in stock size (Bakun, 1996; Pearcy, 1997). Returning adult salmon also can be affected by poor feeding conditions in the marine environment, as evidenced by the small size and poor condition of coho returning to west coast streams during the 1983 El Niño event (Miller and Fluharty, 1992).

In the mid-1970s, ocean conditions in the North Pacific changed dramatically, as an extended period of cool coastal sea surface temperatures (SSTs) gave way to much warmer conditions along the west coast of North America. This shift may be part of a long-term pattern of interdecadal oscillation in the climate of the North Pacific (Zhang et al., 1996; Latif and Barnett, 1996). The Pacific Decadal Oscillation (PDO) is characterized by alternation between a pattern of warm SSTs along the west coast of North America coupled with a large area of anomalously cool water in the western and central North Pacific, and an opposite pattern of cool coastal conditions and anomalous warmth in the western and central North Pacific. The coastal warm phase is associated with intensification of the winter Aleutian low pressure system. Some analysts identify a shift to the cool coastal pattern in the mid-1940s, and back to the warm coastal pattern after 1977 (Mantua et al., 1997).

The North Pacific also is influenced by the El Niño/Southern Oscillation (ENSO) phenomenon (Kiladis and Diaz, 1989). ENSO warm events (El Niños) intermittently warm the eastern and central equatorial Pacific, with effects often propagating northward. The effects of El Niño in the North Pacific closely resemble the PDO warm phase, with warming along the west coast of North America, cooling in the central North Pacific, and a tendency for an eastward shift and intensification of the winter Aleutian low (Trenberth and Hurrell, 1994). An unusual sequence of closely-spaced ENSO warm events has occurred since 1977, and these events have tended to reinforce the decadal-scale shift to warmer coastal SSTs and cooler SSTs in the central North Pacific (Trenberth and Hurrell, 1994; Trenberth and Hoar, 1996). To the extent that the changes in ocean conditions during the recent period of coastal warming resemble the changes that may occur under global warming, the impacts on salmon may be similar.

Throughout this century, Alaska has accounted for a major proportion of the total North American commercial harvest of Pacific salmon. More important, however, is the fact that Alaska's dominance has mushroomed in recent years, with a nearly 10-fold increase in its commercial salmon harvest from a low of 22 million salmon (of all species) in 1974 to three successive record highs in 1993, 1994 and 1995 (Figure 1). At the 1995 peak, Alaska harvested a total of 217 million salmon. Despite a slight downturn since 1995, Alaskan harvests remain far above their historic levels.

British Columbia experienced a mixture of increasing and declining salmon runs during this period, with some northern stocks increasing, while commercial chinook harvests declined steadily. Southward, salmon harvests have been on a roller-coaster. Commercial chinook and coho catches in California, Oregon, and Washington dropped abruptly in the late 1970s, with extreme lows in 1983 and 1984 attributed to El Niño. There was a dramatic recovery in 1986 and 1987 followed by a precipitous decline to record low harvests in recent years (Figure 2). Production has declined to the point that some stocks in Washington, Oregon, California and Idaho are on the verge of extinction.

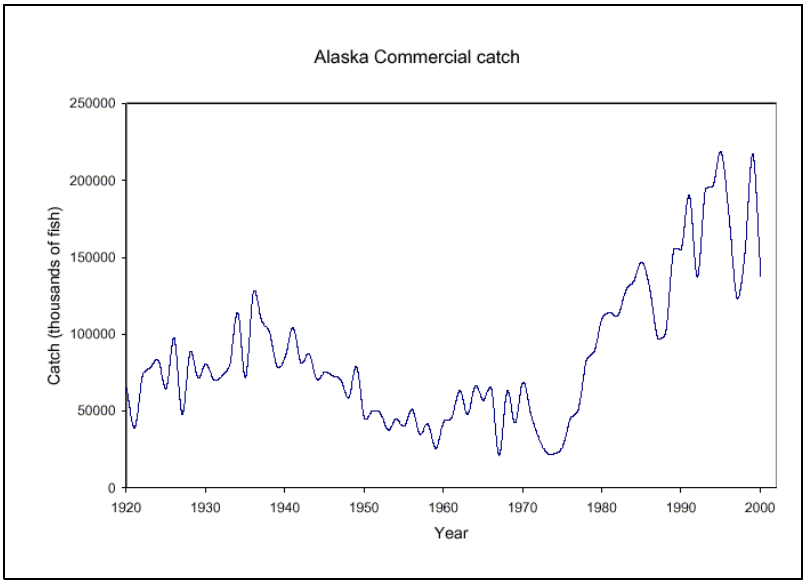

Figure 1. Alaskan commercial harvest of all salmon species - millions of fish.

The tendency for inverse fluctuations in Alaskan and southern salmon abundance can by seen by comparing harvests of a single species, coho (Figure 3). During the coastal cool period, immediately prior to the mid-1970s regime shift, west coast coho harvests far exceeded Alaskan harvests, while the opposite condition has prevailed since that time.

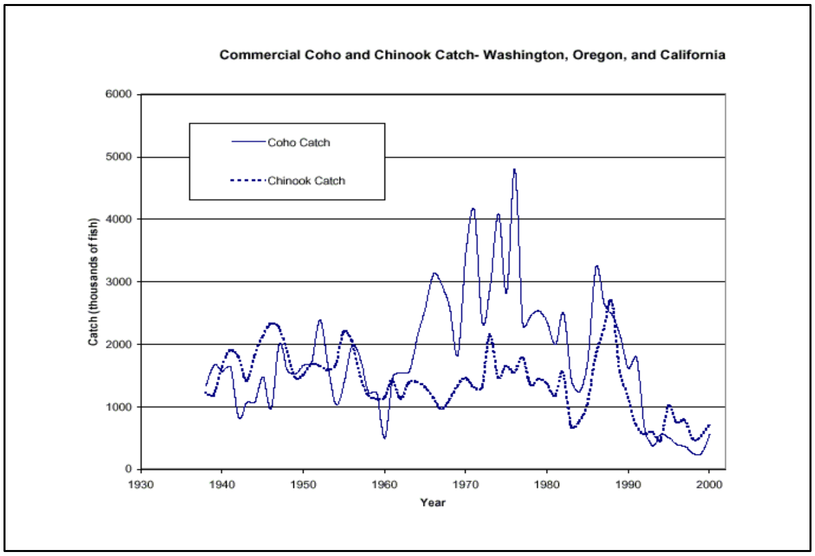

Figure 2. Total commercial harvest of coho and chinook in Washington, Oregon and California - millions of fish.

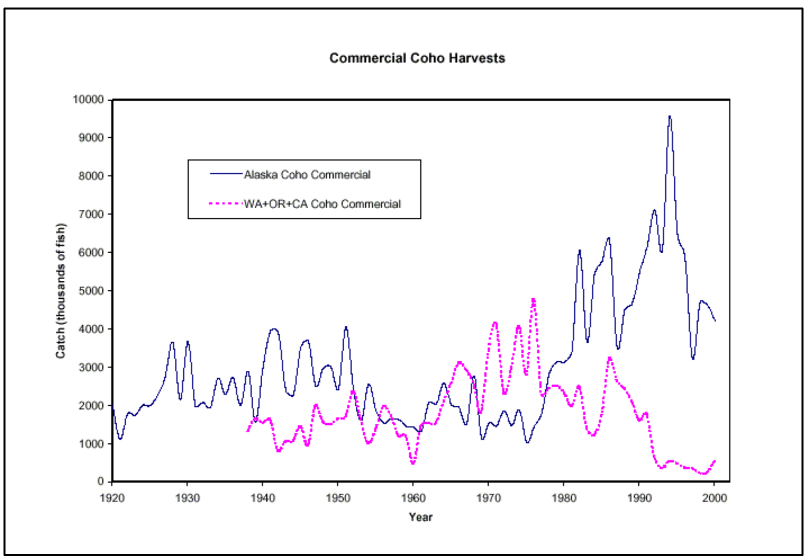

Figure 3. U.S. west coast and Alaskan commercial coho salmon harvests - millions of fish.

The above-described changes in ocean conditions, together with related changes in regional precipitation and streamflows, may have enhanced the productivity of Alaskan salmon runs while contributing to the decline of the southern stocks (Beamish and Bouillon, 1993; Hare and Francis, 1995; Pearcy, 1997; Mantua et al., 1997). Explanations for these opposite impacts have focused on improved food availability for Alaskan smolts, together with poorer feeding conditions and increased predatation in the southern areas. In the subarctic zone, the mixed layer has become shallower. This appears to have contributed to increased zooplankton biomass in the Gulf of Alaska (Polovina et al., 1995; Brodeur and Ware, 1992; Pearcy, 1992, 1997). From southern British Columbia southward, warm conditions have been associated with reduced upwelling and food abundance as well as changes in species composition, including increased abundance of jack mackerel and other species that prey on juvenile salmon (Pearcy, 1992, 1997). There is some evidence that hatchery smolts may be particularly vulnerable to such predation (Nickelson, 1986).

Climatic effects on salmon in their freshwater phase may have reinforced the trends. Alaska has experienced warmer and wetter winters during the past two decades (Mantua et al., 1997). Those changes may have contributed to favorable stream conditions for egg-to-smolt survival. On the other hand, recent droughts in California and the Pacific Northwest reduced spawning success and in-stream survival for some stocks.

It is difficult, however, to separate these climatic effects from the impacts of many other changes that have affected salmon harvests over the past two decades. In the south, dams, habitat degradation and poorly designed hatchery programs have been implicated in the decline of salmon populations. There is also widespread speculation that the rapid rebound of west coast sea lion populations following passage of the U.S. Marine Mammal Protection Act in 1972 may have hurt the southern salmon stocks because sea lions feed heavily on returning adult salmon (e.g., Meehan, 1998). Likewise, climate is only one of several factors contributing to Alaska's increased harvests. Alaska has protected its rivers from degradation, and has invested in both hatcheries and habitat improvement projects. In addition, they have significantly improved their harvest management programs to better match the spawning escapement for each stock to current scientific assessments of optimal escapement levels. Many Alaskans feel that these measures, rather than climate variations, account for much of the increase in their salmon runs (see e.g., Royce, 1988). Only partial evidence is available to evaluate that position. For example, estimates of the contributions of Alaska's hatcheries suggest that they account for less than 20 percent of the increase in statewide harvests up to the mid-1990s (ADFG, 1995). There also is evidence from international harvest records that passage of the Fishery Conservation and Management Act (Public Law 94-265) in 1976 and subsequent revisions of the North Pacific Treaty in 1978 and 1986 made a small contribution to the growth of

Alaskan salmon harvests by reducing interference from the Japanese high-seas mothership fishery (Harris, 1988; INPFC annual series, 1952-1990).

3. Marine Fisheries, Ownership and Adaptation

Marine fisheries exemplify several characteristics common to many publicly managed resources. The individual fish are highly mobile "fugitive" resources until they are captured, and fish populations are difficult to precisely count or monitor. The relatively high cost of controlling access to such resources historically precluded private ownership, favoring instead a gradual evolution from pure "open-access" to some form of common property or public control (Barzel, 1989; Eggertson, 1990; Ostrom, 1990). The fact that marine fish populations are subject to multiple sources of variability contributes to the difficulty of establishing and enforcing ownership rights to these resources (Barzel, 1989). Under open access, competition among harvesters tends to result in over-exploitation of fish populations and dissipation of the potential economic value of the fishery through excessive fishing effort (Gordon, 1954; Cheung, 1970). Economic overfishing often results in biological overfishing as well, in that a larger sustained yield could be obtained by curtailing effort and allowing the size of the breeding population to increase.

A variety of management regimes have arisen to control these tendencies. In a few cases, commercial harvesters have devised private methods of policing their own harvest rates (e.g., Acheson, 1988). In the more general case, however, public agencies have assumed the tasks of determining allowable harvests and creating and enforcing regulations to keep harvests within those limits. Most public fishery management schemes have emphasized biological conservation, although economic goals have received greater attention in recent decades. Achieving these goals often has proved to be quite difficult. Fish stocks tend to fluctuate widely from year to year for reasons unrelated to fishing pressure. Climate often plays a role in these natural fluctuations, although its role may be the complex product of cascading impacts through a chain of predator-prey relationships. These processes may result in multiple and lagged impacts on the abundance of a harvested species. Because it is difficult to identify and predict such effects, climate variability constitutes a significant source of uncertainty for fishery managers.

Traditional gear limits, designed to promote biological conservation, often conflict with economic efficiency, and economists have labeled such rules "irrational conservation " (Crutchfield and Pontecorvo, 1969). Harvesters are often rather ingenious in adjusting their technology to maintain and enhance their harvesting power despite regulations designed to limit capacity. This is true for seiners involved in the Pacific salmon fisheries.

> “Rules designed to limit seiners’ efficiency apply in both B.C. and Southeast (Alaska), but in each case fishermen and gear makers have outwitted the regulations. The ban on drums in Alaska and on skiffs in most of B.C. has driven innovations that allow both fleets to fish hard and fast; and despite their respective regulatory handicaps, they both perform with roughly equal, and impressive, efficiency” (Drouin, 1999, p. 39) .

However, such individually rational adjustments tend to thwart both the biological and economic objectives of the regulatory program.

An alternative approach to fisheries management, the use of individual transferable quotas (ITQs), has not been attempted for Pacific salmon. The difficulty of assessing run-size prior to the beginning of the fishing season and the numerous in-season adjustments that are needed to meet escapement goals may make ITQs impractical for many Pacific salmon stocks (Marinkovich, 1999). All jurisdictions have limited entry programs. Limitations on the number of vessels, together with area and time closures, and gear restrictions have been the major salmon harvest management tools. Where salmon fishing permits are transferable, as they are in Alaska, permit prices reflect the capitalized expected net return to participating in the fishery.

While it is a challenging task to achieve efficient management of a fishery that is confined to a single jurisdiction, further complications emerge when the targeted fish population migrates across international boundaries or straddles the boundary between a national jurisdiction and the international commons of the open ocean (e.g., Munro, 1987). In the case of a fish population that migrates across international boundaries, harvesting in each jurisdiction affects the availability of fish in the other jurisdiction (Criddle, 1996; Mckelvey, 1997a). If these nations harvest the shared stock competitively, they will tend to squander its potential value. Recognizing that possibility, they may attempt to work out a cooperative division of the harvest, but maintaining cooperation is difficult, and many international fishery agreements have degenerated into mutually destructive fish wars. This instability appears to result from changes over time in the parties' incentives to cooperate (McKelvey, 1997a; Miller, 1996). Uncertainty regarding the magnitude and sources of variations in fish stocks is another stumbling block to cooperative harvest management. The parties may have different information or beliefs about how the stock is changing, and they may have a strategic interest in concealing that information from one another, or in promoting a particular interest-laden interpretation of the biological facts.

The inherent difficulty of managing such resources suggests that adaptation to the effects of climate variability and climate change is likely to be less complete and effective than might be the case for resources that are controlled by private property owners. Furthermore, climatic variations may destabilize efforts to cooperatively manage resources that are shared among multiple jurisdictions.

4. The Case of the Pacific Salmon Treaty

North America's commercial Pacific salmon fisheries developed rapidly in the late nineteenth century, and the various jurisdictions soon created public agencies to control harvesting practices. These authorities never had full control over harvests of the salmon stocks within their purview, however, because many salmon could be caught as they passed through the waters of neighboring jurisdictions. Such "interceptions" became increasingly important over time as fishing effort expanded in offshore areas.

Early international tensions focused on U.S. harvests of sockeye originating in Canada's Fraser River. The mouth of the Fraser is very close to the border between British Columbia and Washington state. From the beginning of that fishery, Washington state harvesters had captured a sizeable portion of the Fraser River runs. Fishing interests in both nations were damaged when rock slides in 1913-1914 decimated the Fraser's salmon stocks by blocking access to a major part of their spawning habitat. Canada was unwilling to solely undertake the enormous costs of clearing the blockages and restoring the runs because the U.S. fleet could capture a large share of the benefits of any restoration effort (McKelvey, 1997b). In 1937, Canada and the U.S. ratified the *Convention for the Protection, Preservation and Extension of the Sockeye Salmon Fisheries in the Fraser River System*. That agreement divided the harvest of Fraser River sockeye salmon as well as management and restoration costs equally between the two nations (Munro and Stokes, 1989). The agreement, which was later extended to pink salmon, established a bi-national body, the International Pacific Salmon Fisheries Commission (IPSFC), to manage harvests within the convention area. The Convention operated well for many years, allowing substantial restoration of the runs and a relatively problem-free division of the catch. However, the Canadians became unhappy with the arrangement because they realized that by foregoing the opportunity to develop the Fraser River's hydropower potential, they were actually bearing more than half of the cost of maintaining its salmon resources. The U.S., on the other hand, had launched into a period of massive dam building on the Columbia and other important salmon streams in the Pacific Northwest.

At the same time, Alaskan interceptions of chinook spawned in the rivers of Washington and Oregon were creating tensions among the states, but much larger

Canadian troll interceptions of those stocks precluded an effective internal solution. In addition, mutual interceptions of salmon of Canadian and Alaskan origin were seen as a barrier to effective management in the northern area (Yanagida, 1987). Negotiations for a new agreement began in 1971. The talks dragged on for 14 years. During that time, British Columbia intentionally redirected its fisheries to put increasing pressure on U.S. chinook and coho migrating southward along the west coast of Vancouver Island to spawn in the Columbia and other U.S. rivers. As Washington and Oregon's coho and chinook harvests declined, particularly in the wake of the 1982-83 El Niño, Canada's "fish war" strategy succeeded in convincing the southern U.S. parties to support the proposed treaty (Munro and Stokes, 1989; Munro et al., 1998). Alaska, however, showed little interest in reaching an agreement. Alaska is in a unique position because many salmon stocks migrate northward as juveniles to feed and mature in the Gulf of Alaska (Pearcy, 1992). This migratory pattern gives Alaska a natural advantage in intercepting salmon originating elsewhere, while only a small part of Alaska's own salmon stocks are vulnerable to Canadian interception.

In 1980, the Pacific Northwest Treaty Tribes sued to extend the 50-50 sharing rule established by the landmark Boldt decision (*United States v. Washington* [W.D. Wash. 1974]) to restrict Alaskan harvests of chinook originating in the rivers of the Pacific Northwest (*Confederated Tribes and Bands v. Baldridge* [W.D. Wash. September 7, 1995]; Yanagida, 1987; Munro et al., 1998). A side-agreement between Alaska and the tribes in *Confederated Tribes and Bands v. Baldridge* (W.D. Wash. 1985) broke the impasse. Under the settlement, the tribes agreed to give up their right to litigate north/south chinook allocations in exchange for a voice in the Treaty fishing regime-setting process. The Pacific Salmon Treaty went into effect in 1985.

The Treaty created the Pacific Salmon Commission and empowered it to develop and recommend "fishing regimes" to be used by the governments in setting conservation and sharing arrangements for: (i) salmon spawning in the transboundary rivers of British Columbia and the Alaskan panhandle; (ii) salmon from areas around the disputed maritime boundary between Alaska and British Columbia; (iii) Fraser River sockeye and pink salmon; (iv) chinook; (v) southern coho; and (vi) southern chum. The Commission’s major task has been to periodically renegotiate these regimes as they expire. The body of the Treaty lays out a set of general principles to guide the Commission in this task. Of central importance are the equity and conservation objectives, which the Treaty expresses as follows:

> *"...each Party shall conduct its fisheries and its salmon enhancement programs so as to:*

a) prevent overfishing and provide for optimum production; and

b) provide for each Party to receive benefits equivalent to the production of salmon originating in its waters" (*Pacific Salmon Treaty*, Article III).

The treaty then advises the Parties to consider the following factors: the desirability of reducing interceptions, the desirability of avoiding disruption of existing fisheries and annual variations in abundances of the stocks. These considerations are somewhat mutually inconsistent because many of the existing fisheries relied heavily on interceptions.

Until the June 1999 amendments to the Treaty, the fishing regimes were effective for only a few years. Negotiations for new regimes were to follow a consensus rule, but that allowed any of the Parties to veto proposed fishing regimes seen as contrary to its constituent's interests (Yanagida, 1987; Miller, 1996; Schmidt, 1996; Munro et al., 1998). The relevant parties in this context are Canada and the three voting U.S. Commissioners – representing Alaska, Washington/Oregon, and twenty four treaty tribes located in Washington, Oregon and Idaho. While the Canadian federal government has primary authority on the Canadian side, the B.C. Provincial Government often differs vociferously with federal policies. Those internal differences frequently have colored the course of the negotiations.

When the parties failed to agree on fishing regimes, regulatory authority reverted to the appropriate state or federal jurisdiction. In the U.S., the states have authority within three nautical miles of the coast and federal jurisdiction extends from 3 to 200 miles offshore.

Another major feature of the 1985 Treaty was a commitment to rebuild naturally spawning chinook stocks from the area extending from Southeastern Alaska to Oregon by the year 1998. The parties agreed to a program of harvest restrictions to achieve that goal. In addition, the Treaty provided that each party should receive the benefits of its own enhancement investments (Munro and Stokes, 1989; *Pacific Salmon Treaty*, Articles III and V). The parties expected that this protection would eventually result in larger harvests of all species by encouraging hatchery investments and other restoration efforts.

4.1. THE COLLAPSE OF COOPERATION

The recent breakdown in efforts to renegotiate the expired fishing regimes revolved around two issues. The first was a long-standing dispute over the meaning and enforcement of the Treaty's equity provisions. The second was disagreement regarding actions required to meet the goal of rebuilding chinook stocks. When the Treaty went into effect, the Parties recognized that interceptions could not be reduced to zero and that the interception balance would vary from year to year. They also recognized that the balance would tend to favor either the U.S. or Canada in each of the covered fisheries. The Canadians hoped, however, that the Treaty would lead to a rough balance in total interceptions. In particular, they expected that their own interceptions of U.S. coho and chinook would roughly offset the value of U.S. interceptions of Fraser River salmon (Munro and Stokes, 1989; Munro et al., 1998). The Parties also expected that the harvest restrictions would halt the chinook declines.

Nature and the actions of each Party thwarted these expectations. Until the new agreement was signed in June 1999, the fishing regimes consisted primarily of harvest ceilings for specific locations, species, and portions of the fishing season. That approach, however, proved to be both ineffective and dangerous in the presence of significant changes in abundance. In Southeast Alaska, for example, where Canadian sockeye are highly intermingled with Alaskan pink salmon, the ceilings could not be tailored to prevent increased interceptions when abundance increased, without imposing significant costs on the Alaskan fishery. Canada complained that Alaska's refusal to agree to more stringent ceilings allowed its interceptions of Canadian salmon to increase significantly. Canada also found that it was unable to redress the imbalance because declining southern coho and chinook stocks prevented Canadian harvesters from reaching the agreed-upon ceilings for harvests of those stocks along the west coast of Vancouver Island. At the same time, fishing interests along the U.S. West Coast claimed that Canada's efforts to reach the ceilings resulted in overharvesting of those fragile stocks. In addition, while Alaska's chinook harvests remained roughly constant, with slight decreases over the past few years, declining runs in British Columbia and the southern U.S. jurisdictions pushed the chinook rebuilding goal further out of reach.

4.1.1. *Chronology*

Negotiations first began to break down in 1993 when the parties failed to reach agreement on some expired fishing regimes. The dispute escalated the following year when the Canadian delegation broke off the negotiations, charging that the growing interceptions imbalance violated Canada's interpretation of the Treaty's equity provisions. Soon afterwards, Canadian authorities temporarily imposed a substantial fee on U.S. fishing vessels using the Inside Passage to travel from Washington ports to fishing grounds in Alaska, and urged Canadian harvesters to fish aggressively in order to intercept Fraser River sockeye before they entered U.S. waters. In addition, the Canadians also continued to harvest fragile coho and chinook stocks heading south to spawn in U.S. rivers despite the fact that

Washington and Oregon had closed their own offshore coho and chinook fisheries for the first time ever, due to the imperiled state of those runs.

Canada's aggressive fishing policy backfired. Warm water conditions in 1994 caused an unexpectedly large proportion of the Fraser River sockeye to approach the river via the northern route, through the Johnstone Strait, rather than through the Strait of Juan de Fuca. Resulting misjudgments regarding run size and total harvests contributed to dangerous overharvesting of part of the Fraser River's sockeye stocks by the Canadian fleet (Fraser River Sockeye Public Review Board, 1995).

That experience and mounting concern over the state of the southern coho and chinook stocks induced British Columbia and the southern U.S. interests to agree on a set of harvesting regimes for the Fraser River and southern coho and chinook fisheries for 1995. Alaska, on the other hand, not only remained unwilling to make concessions on its harvests, but actually rejected the substantial conservation-based chinook harvest reductions recommended by the Chinook Technical Committee (CTC) of the Pacific Salmon Commission for the 1995 season. Instead, Alaska used its own model to support a decision to allow a harvest of 230,000 chinook in Southeastern Alaska. Alaska's action caused tensions on the U.S. side to reach a boiling point. The Northwest treaty tribes and the states of Washington and Oregon sued Alaska and won an injunction that closed the Southeastern Alaska chinook fishery for the remainder of the 1995 season (*Confederated Tribes and Bands v. Baldridge* [W.D. Wash. September 7, 1995]). British Columbia supported the southern interests by entering the case as a "friend of the court."

At the end of the 1995 season, the parties hired a New Zealand diplomat, Ambassador Beeby, to act as a mediator (Reuters, 1995). His non-binding recommendations were to be kept secret if they were rejected by either side. The U.S. rejected Beeby's 1996 report, but its "secret" contents (favoring Canada's position on the equity dispute) eventually appeared in the region's newspapers (Westneat, 1997).

The flickers of good will in the south proved unable to withstand the stress of continuing Canadian unhappiness over progress on the equity issue. By the summer of 1997, the salmon war had flared to a new fever-pitch. When huge pink and sockeye runs in the Alaska Panhandle region contributed to a much larger Alaskan sockeye harvest in the border region than would have been allowed under the expired Treaty fishing regime, angry Canadian harvesters reacted by holding the Alaska Ferry hostage in the port of Prince Rupert for three days (D'oro, 1997; Hogben et al., 1997). British Columbia's Premier, Glen Clark, called U.S. harvesters "pirates", threatened to close a torpedo testing range used by the U.S., and initiated a lawsuit against Alaska, Washington state and the U.S.

federal government seeking approximately $235 million in damages for the accumulated harvest imbalance (Klass, 1997; Lee and Hogben, 1997; May, 1997). Even before the ferry crisis, the Canadian Fisheries Minister and Premier Clark announced intentions to pursue an aggressive "put Canada first" fishing strategy designed to cut U.S. access to the Fraser River runs, which were expected to be unusually large (Connelly, 1997).

In late August, with angry rhetoric flying on all sides and suits and counter-suits pending in both countries, the two national governments appointed special envoys to recommend an appropriate course of action. The envoys, William Ruckelshaus, former U.S. EPA Administrator, and David Strangway, former President of the University of British Columbia, recommended that the governments adopt a two-year interim agreement and undertake a comprehensive review of the Pacific Salmon Commission to improve its effectiveness. In addition, they advised both sides to compromise and suggested that any agreement would have to involve "movement of fish to Canada and a willingness on the part of Canada to agree that not all the fish they deemed to be theirs would be returned" (Strangway and Ruckelshaus, 1998, pp. 5-6). The 1999 Agreement is the ultimate product of their recommendations.

4.1.2. *Analysis of the Dispute*

The Canadians have long argued that the Treaty principle that each party should receive "benefits equivalent to the production of salmon originating in its waters" (*Pacific Salmon Treaty*, Article III, para. 1) should be interpreted literally as a dollar-for-dollar balancing of the value of a nation's total harvest with the total harvested value of the salmon spawned in its rivers. That interpretation is equivalent to defining national "property rights" to the fish solely on the basis of where they were spawned. According to Canadian calculations, the U.S. would now owe Canada a considerable debt under that approach. The U.S. delegation never favored a quantitative approach, arguing instead that: "[A]n effort to create an accounting scheme would invite costly, and perhaps divisive and inconclusive debate over biological and economic variables" (Yanagida, 1987, p. 591). U.S. officials are quick to point out that slightly different biological assumptions and valuation rules can give vastly different results regarding amounts owed and even the direction of the equity imbalance. In particular, commercially caught salmon may be worth much less than fish caught by recreational anglers, and salmon from endangered runs are far more valuable if they are allowed to spawn rather than being caught and sold (Westneat, 1997).

Munro et al. (1998) note that the intent of the 1985 Treaty had been to allow each party to continue receiving its "baseline" benefits plus any increments arising from its post-Treaty enhancement efforts. They argue that much of the recent conflict relates to the fact that the parties never clearly agreed on the size and nature of their respective baselines. It may be helpful to recognize that each baseline really never was a "line" at all. Rather, it was a dynamic set of opportunities to exploit the stocks accessible to each party's fleet. The ability to respond quickly and equitably to changing opportunities was a quality missing from the ceiling-based approach to negotiating fishing regimes. Where stocks were increasing, harvest ceilings proved to be onerous, and thus prone to being ignored. Where stocks were declining, harvest ceilings resulted in dangerous overharvesting. Although the Treaty advised the Commission to take into account "annual variations in abundances of the stocks" (*Pacific Salmon Treaty*, Article III), it provided no guidance as to *how* to do so.

There also was disagreement about the exact meaning of the phase "...originating in its waters." Canadians argue that salmon are "produced" where they are spawned. To support this interpretation, they cite Article 66 of the 1982 U.N. Convention on the Law of the Sea, which declares that: "states in whose rivers anadromous stocks originate shall have primary responsibility for such stocks." The Alaskans point out that they contribute to the production of all salmon that migrate to feed in Alaskan coastal waters by maintaining the near-shore environment in good condition. They further argue that Article 66 protects the rights of coastal nations against harvesting on the high seas, but does not restrict harvests within the territorial waters of a neighboring nation (Shelton and Koenings, 1995). Because Canadian and other U.S. salmon "graze" on the Alaskan "pasture," they may compete with Alaskan origin salmon or may in other ways impose costs on the Alaskan fishery. As a result, Alaska feels that it should have a right to some of those fish.

U.S. negotiators also stressed that the equity provision was only one of the principles to be used in determining the division of the harvest. Envoys Strangway and Ruckelshaus (1998, p. 4) describe the U.S. position as follows: "The U.S. contends that all the principles in Article III must be read together, and that whether an "equity" imbalance exists or interceptions need to be reduced in any particular situation, require consideration of a number of factors, including annual variations in the abundance of stocks, conservation and avoiding undue disruption of existing fisheries."

Taken together, all of this suggests that the difficulty of identifying which fish "belong" to whom, and what they are worth has been a central part of the problem. Information costs thus contributed to the conflict, but it was the growing interceptions imbalance that destabilized the Treaty regime negotiation process. The recent inverse trends in northern and southern salmon stocks may have aggravated the break-down in cooperation in two ways: 1) by making it more difficult to achieve the Treaty's conservation and equity objectives and 2) by altering the Parties' incentives to cooperate in setting harvest allocations under the Treaty.

Cooperation can "pay" in an international fishery because the size of the pie is not fixed. This year's harvesting activities affect both net returns this year and the size of potential harvests in future years. If cooperation leads to better conservation and/or lower harvesting costs, all parties can benefit. Cooperation may dissolve, however, if the players' expected payoffs change.

In the Pacific Salmon Treaty case, Alaska's unwillingness to make concessions on fishing regimes contributed to the breakdown in cooperation. The concessions requested by B.C. and the southern U.S. parties made little sense from Alaska's standpoint because they would impose costs on Alaska without commensurate benefits. To agree to the terms of the Treaty, Alaska had to expect that it would be left at least as well off as before the Treaty (Munro et al., 1998). However, apart from avoiding threatened litigation over Native American fishing rights, Alaska never had much to gain from participating in the Pacific Salmon Treaty (Schmidt, 1996). Alaska’s interceptions of salmon originating elsewhere could be reduced if harvesting were allowed only in rivers, estuaries and marine areas close to river mouths, and began somewhat later in the season when the stocks have separated and are ready to begin their upriver migrations. However, that would increase Alaska’s harvesting and monitoring costs substantially, and would make it more difficult to maintain well-distributed escapements of pink salmon to the numerous spawning streams in Southeast Alaska (ADFG, 1994). In addition, it would reduce the average quality and value of the harvested fish because many salmon begin to deteriorate rapidly as they approach their spawning streams.

Any increase in the costs imposed by the Treaty on Alaska could only increase the likelihood of Alaska's defection from the agreement. The recent trends in stock abundance may have made it more expensive for Alaska to restrict its interceptions of fish spawned in Canada and the west coast states (Miller, 1996). In addition to the benefits they would lose by refraining from the harvest of the foreign-origin fish, the Alaskans argue that the increase in the size of the Alaskan runs has made it impossible to avoid increased interceptions unless they allow a larger number of their own fish to escape harvesting in the prime offshore areas. With spawning escapements already strong, and markets glutted with lower valued "canning quality" salmon, Alaska finds that option unattractive.

The analysis by Munro et al. (1998) supports this view, concluding that: "The Salmon Treaty in its present form has evolved into an almost textbook example of a cooperative game devoid of a core." Because Alaska appeared to have nothing to gain from cooperation, they predicted that the impasse would continue unless the scope of bargaining could be widened beyond the balancing of fish-for-fish.

They argued that serious consideration should be given to the introduction of monetary side-payments.

Side-payments need not be in monetary form. The literature on interconnected games suggests that parties can sometimes resolve bargaining problems by negotiating on several issues at once, explicitly allowing tradeoffs across issues (Folmer et al., 1993). Schmidt (1996), for example, concluded that the 1985 Treaty's inflexibility and inability to provide Alaska with incentives to cooperate were serious weaknesses, and argued that side-payments could take the form of concessions on other non-fishery issues. He examined the option of removing the veto power of the three voting members of the U.S. section, but concluded that doing so would reduce the overall bargaining leverage of the U.S. and allow Canada to capture a larger share of the potential gains from cooperation. As an alternative, he supported allowing internal side payments among the members of the U.S. section, with payments from southern interests to Alaska to secure its cooperation.

4.2. CURRENT AGREEMENT AND PROSPECTS FOR THE FUTURE

The 1999 Agreement represents a dramatic break from the previous approach. Rather than relying on short-lived, ceiling-based regimes whose frequent renegotiation provided ample opportunity for disagreement and brinkmanship, the new Agreement establishes a long-term commitment to define harvest shares as a function of the abundance of each salmon species in the areas covered by the Treaty. For example, for the next 12 years, the U.S. share of Fraser River sockeye will be fixed at 16.5% of the annual harvest. This represents a decrease from the post-1985 average U.S. share of 20.5%, but an increase relative to the share actually attained by the U.S. fleet during the 1992-1997 salmon war period (DFO, 1999; O'Neil, 1999a). This percentage approach allows the number of Fraser River sockeye harvested by the U.S. fleet to increase in years of high sockeye abundance while requiring reduced harvests when abundance is depressed. In contrast, in the 1985 Treaty, U.S. harvests of Fraser sockeye were to be held to a cap of 7 million fish over each of two successive 4 year periods (*Pacific Salmon Treaty, Annex 4)*.

The new arrangements for chinook, which will be in effect for ten years, take account of the fact that the various fisheries along the coast differ considerably in the extent to which they rely on healthy or depressed chinook stocks (U.S. Department of State, 1999). Accordingly, the Agreement designates two types of fisheries: 1) abundance-based management (AABM) fisheries will be managed based on indices of the aggregate abundance of chinook present in the fishery; 2) individual stock-based management (ISBM) fisheries, which are primarily located in inside fishing areas, will be managed based on the status of individual stocks or groups of stocks (e.g., on the basis of the evolving status of currently endangered or threatened stocks). An initial schedule relating harvest rates to abundance indices for each AABM fishery is laid out in the new Agreement, together with provisions describing how the Chinook Technical Committee (CTC) is to compute the indices. For ISBM fisheries, Canada has agreed to a "general obligation" to reduce fishing mortality by at least 36.5% relative to a 1979-82 base period, while the U.S. has agreed to a 40% reduction relative to the same base period. Where those reductions are insufficient to achieve escapement objectives for natural stocks, the Agreement specifies additional measures. The Agreement further specifies that chinook are to be managed on the basis of "total fishing mortality" (i.e., accounting for mortality of fish caught and released or otherwise incidentally killed by fishing activities). Because there is not yet an adequate scientific basis for that approach, the CTC is to apply interim indices of total mortality until improved estimates are available.

For the Southeastern Alaska and Northern British Columbia fisheries, the Agreement outlines how the Annual Allowable Harvests (AAH) of Nass and Skeena sockeye and Southeastern Alaska pink are to be calculated. It then specifies the shares of these AAHs allowed to Alaska or Canada in each of several fisheries, and provides for joint accounting for overages and underages to be used as the basis for subsequent "payback."

Another major feature of the Agreement is its provision for two endowment funds. Initial funding is to be provided entirely by the U.S., but either Party may make additional contributions, and even third parties may contribute, with the agreement of the Parties. The annual investment earnings on the Northern Boundary and Transboundary Rivers Restoration and Enhancement Fund (Northern Fund), and Southern Boundary Restoration and Enhancement Fund (Southern Fund) are to be used to support scientific research, habitat restoration and enhancement of wild stock production in their respective areas. The funds are to be managed by committees composed of representatives appointed by the federal governments of Canada and the United States. The entire deal is contingent upon U.S. Congressional approval of initial U.S. contributions of $75 million for the Northern Fund and $65million for the Southern Fund. These funds appear to be intended to serve as the type of side-payment suggested by Munro et al. (1998) and by Schmidt (1996), although their yield will be far smaller than the debt that Canada had claimed that it was owed for the accumulated harvest imbalance. The Northern Fund may also be aimed at "sweetening the pot" for Alaska because a portion of the available money will be spent in support of Alaskan research and enhancement (O'Neil, 1999b).

The Agreement also provides for improved scientific cooperation by establishing a new bilateral Committee on Scientific Cooperation and by articulating a commitment to enhanced cooperation on data exchange and development of common assessment models. Finally, the Parties have agreed to protect spawning habitat, and have instructed the Commission to report annually on non-fishing factors affecting the health of the stocks subject to the Treaty.

The new Agreement is a promising step, but its success is not assured. It will require better science to provide more timely and accurate assessments of abundances and the stock composition of harvests in many separate fisheries. As such, it will place a greater burden on data and modeling than the ceiling-based approach. As with any cooperative venture, the success of the new arrangements will also depend on the continued good will of those involved. That may be difficult to maintain because many Canadians remain convinced that Canada will lose under the arrangement. While the ink is still drying on the Parties' mutual statement that adherence to the Agreement shall be deemed to satisfy the terms of Article III of the *Treaty* (U.S. Department of State, 1999), a vigorous opposition by some B.C. interests is being fueled by fears that the abundance-based approach will do little to change the interceptions imbalance (Culbert and Beatty, 1999).

5. Conclusion

The Pacific salmon case demonstrates that the impacts of climate variations on a natural resource may be intricately entwined with the effects of other sources of variability, both natural and anthropogenic. The case further demonstrates that societal responses to variations in resource abundance or availability are often a complex product of institutional factors and economic motivations operating in a context of incomplete information. In this case, the Parties needed to come to grips with the fact that there may be long term natural trends in abundance that have nothing to do with their previous management actions. It took the accumulated evidence of several years of unusual ocean conditions coupled with sustained changes in patterns of salmon abundance to convince all of the Parties that no sustainable agreement was possible unless it explicitly accommodated such changes (DFO, 1999).

For many natural resources, a variety of users compete to derive benefits from the resource. Institutions typically develop over time to manage such competition, but they may be either well or poorly suited to adapting to the effects of climate variability and climate change. Climatic variations can disrupt cooperative resource management arrangements by upsetting expectations, altering incentives to cooperate or by contributing to misjudgments regarding the state of the resource or the actions of other parties. Accurate scientific assessments of climatic impacts might contribute to more effective adaptation, but they are likely to be only part of the solution. We also need to better understand how to design agreements and enforcement mechanisms to maintain cooperation and prevent destructive disputes when there are difficult-to-forecast or totally unanticipated changes in the condition of a shared natural resource.

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