Climate, Uncertainty and the Pacific Salmon Treaty: Insights on the Harvest Management Game

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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 environmental variability may complicate the management of such shared resources. In recent years, an extended breakdown in cooperation was fueled by strongly divergent trends in Alaskan and southern salmon abundance, and a consequent change in the balance of each nation's interceptions of salmon spawned in the other nation's rivers. While several natural and anthropogenic factors contributed to these trends, there is considerable evidence that changing ocean conditions played a significant role. The period of high productivity in Alaska contributed to increased Alaskan interceptions of B.C. salmon at a time when Pacific Northwest coho and chinook could least withstand retaliatory actions on the part of the Canadian fleet. Only recently, has the mounting crisis led to a fundamental shift in the approach taken by the two nations to determine their respective salmon-harvest shares. On June 30, 1999, Canada and the U.S. signed an agreement which, if successfully implemented, may lay the groundwork for a more sustainable cooperative management regime. However, there are many unanswered questions regarding the viability and sustainability of the new Pacific Salmon Treaty Agreement. This paper draws lessons from the recent period of turmoil to identify strengths and weaknesses in the new abundance-based management approach, and to suggest avenues for further negotiations to secure more rational management of Pacific salmon resources.

1. INTRODUCTION

Pacific salmon are anadromous fish. In other words, they migrate from the ocean to spawn in rivers and streams. After hatching, the juveniles spend a period of weeks to years in the freshwater (depending on species and stock), then disperse into the ocean environment where they feed and mature before returning to their natal streams to spawn and die (Pearcy, 1992). While some salmon stocks remain in coastal areas throughout their lives, many others spend a year or more in a long-distance migration across the feeding grounds of the subarctic Pacific. As they migrate across state and international boundaries, salmon may be subject to fishing pressure in multiple jurisdictions.

Their anadromous nature makes salmon populations vulnerable to environmental variability and disturbance in both the freshwater and marine environments. Salmon are not unique in their sensitivity to climatic variations. Climate variations often affect the abundance, location or migratory patterns of fish populations. Even when a fishery is entirely contained within a single jurisdiction, such climate impacts complicate the difficult task of maintaining economically efficient and biologically sound harvest management while balancing the interests of competing harvesters. When fish stocks are harvested by more than one nation, or when they cross internal jurisdictional boundaries, the management task is further complicated by the efforts of each nation or jurisdiction to promote the interests of its own harvesters.

The United States and Canada harvest their Pacific Salmon resources in several interrelated commercial and sport fisheries. The links among fisheries arise because many of the salmon that could be harvested close to their spawning grounds are intercepted earlier, in areas where they are intermingled with fish from other rivers. These two nations have a long and rocky history of alternating between cooperation on salmon management and predatory grabs at one another's returning adult salmon. Their faltering attempts to cooperate illustrate the fragile nature of such cooperation and the destabilizing role that climate variations can play.

The most recent breakdown in cooperation began in 1993. For six years, the U.S. and Canada were unable to agree on a full set of salmon "fishing regimes" under the terms of the Pacific Salmon Treaty. The 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. Alaska's salmon harvests (i.e., northern) have experienced a remarkable sustained increase over the past two decades, while harvests of some salmon stocks in British Columbia, and chinook and coho harvests in Washington, Oregon and California (i.e., southern) have fared poorly. These opposite trends allowed Alaska's interceptions of B.C. salmon to increase while B.C.'s interceptions of U.S. salmon declined. This destabilized cooperation by interfering with the Parties' ability to achieve a mutually acceptable interceptions balance.

Several natural and anthropogenic factors contributed to the opposite trends in salmon abundance. Habitat loss, hydropower development, over-harvesting of weak stocks and poorly-designed hatchery programs have all been cited as contributing to the decline of salmon stocks along the U.S. west coast and in parts of British Columbia. However, there also is considerable evidence that changing ocean conditions and climate-related changes in freshwater environments played a significant role in these declines, as well as in the dramatic increase in Alaskan salmon abundance (Hare et al., 1999).

The six-year breakdown in efforts to renegotiate fishing regimes under the terms of the Pacific Salmon Treaty may have further jeopardized the troubled southern salmon stocks. Only recently, has the mounting crisis led to a fundamental shift in the approach taken by the two nations to determine their respective salmon-harvest shares. On June 30, 1999, Canada and the U.S. signed an agreement which, if successfully implemented, may lay the groundwork for a more sustainable cooperative management regime. However, there are many unanswered questions regarding the viability and sustainability of the new Pacific Salmon Treaty Agreement. Lessons from the recent period of turmoil may help to identify strengths and weaknesses in the new abundance-based management approach, and may suggest avenues for further negotiations to secure more rational management of Pacific salmon resources.

This paper begins with an analysis of the failure of the previous regime-negotiation process, focusing on the roles played by changing salmon abundance and uncertainty regarding the causes and magnitude of those changes. We employ a simple game-theoretic model to show how climate-related changes in salmon abundance, coupled with differing interpretations of the Treaty's provisions, led to the collapse in cooperation. The paper discusses the effects of changing ocean conditions and the Treaty impasse on harvesting patterns.

We then examine the new Agreement, using insights from the game-theoretic model to evaluate the benefits and potential pitfalls of the new approach. We also address concerns that have been raised by the salmon managers who must implement its provisions. Finally, we identify potential opportunities for side-deals to enhance the recovery prospects for southern salmon populations as well as the stability of the new Agreement itself.

2. EVOLUTION OF INTERNATIONAL MANAGEMENT

North America's commercial fisheries exploit five species of Pacific salmon: chinook *(Oncorhynchus tshawytscha)*, coho *(O. kisutch)*, sockeye *(O. nerka)*, pink *(O. gorbuscha)*, and chum *(O. keta)*. All five species are harvested in Alaska, British Columbia and Washington State, while only coho and chinook are harvested in significant numbers in Oregon and California. Sport fisheries for coho and chinook have grown in the post World War II era, and now account for a sizeable share of the harvest of these species outside of Alaska (see e.g., NPAFC, 1999). Steelhead *(O. mykiss)* is a related species that is important to in-river sports fisheries, but it is neither commercially targeted nor significantly affected by marine fisheries, and thus is not subject to international management.

When the rapid growth of commercial harvests in the late 19^{th} and early 20^{th} centuries threatened to deplete salmon runs, all jurisdictions created agencies to regulate gear and fishing seasons. However, these authorities could never fully control harvests of the salmon stocks within their purview, because many salmon could be caught as they passed through the waters of neighboring jurisdictions on their return migration. Such "interceptions" became increasingly important over time as fishing effort expanded in offshore areas.

The first significant international agreement on salmon harvests was a Convention between the United States and Canada, signed in 1930 and ratified in 1937. 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 was later extended to Fraser River pink salmon. Under that Convention, the International Pacific Salmon Fishery Commission (IPSFC) regulated harvests of the Fraser River stocks. Although the Fraser River lies entirely in Canada, a large portion of the salmon spawning in that drainage typically approach the river through the Strait of Juan de Fuca where, historically, they had been harvested by Washington State fishing vessels. When rock slides blocked access to part of their spawning habitat, and sent the Fraser's salmon resources into decline, the U.S. and Canada had a clear joint interest in removing the blockage and restoring the runs.

Support for the Convention began to evaporate during the 1960s. The Canadians had become increasingly unhappy about their agreement to share one half of the Fraser River salmon with the U.S. because, by foregoing construction of hydropower dams on the Fraser, Canada was effectively bearing more than half of the cost of maintaining those runs. Developments in international law arising from the United Nations Conference on the Law of the Sea (UNCLOS) also perhaps contributed to Canadian perceptions that a 50-50 split of the Fraser harvest was an inequitable arrangement. By the mid-1970s, the international community had articulated a principle of management preeminence for the nation of origin of anadromous stocks (Shepard and Argue, 1998). This was expressed in Article 66 of the United Nations Convention on the Law of the Sea as follows:

> *States in whose rivers anadromous stocks originate shall have the primary interest in and responsibility for such stocks.* (United Nations, 1982).

Another inadequacy of the Fraser River agreement was that it covered only a portion of the salmon runs jointly exploited by the U.S. and Canada. When negotiations for the Pacific Salmon Treaty began in 1971, Alaskan interceptions of salmon spawned in the rivers of Washington and Oregon were creating tensions among the states while increasing Canadian troll harvests 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). While negotiations for the new Treaty proceeded over the next 14 years, British Columbia maintained intense pressure on the southward-bound U.S. coho and chinook stocks. As Washington and Oregon's harvests of these species 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 until the Pacific Northwest Treaty Tribes filed suit 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 (Yanagida, 1987; Munro et al., 1998). Language in the U.S. Senate's implementation act (1985) and 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, Alaska, the Northwest states, and the tribes obtained representation and a veto within the U.S. delegation to the joint Commission, and the tribes agreed to give up their right to litigate north/south chinook allocations (Stevens, 1986; Yanagida, 1987).

The 1985 Pacific Salmon Treaty created the Pacific Salmon Commission whose primary task was to develop and recommend "fishing regimes" intended to govern the overall harvest and allocation of the salmon stocks jointly exploited by the U.S. and Canada. 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.

The bargaining framework implemented in 1985 called for frequent renegotiation of these fishing regimes. Negotiations for new regimes were to follow a consensus rule. That rule gave an effective veto over proposed fishing regimes to the Canadian delegation, as well as to any of the three voting U.S. Commissioners — representing Alaska, Washington/Oregon, and the Treaty Indian Nations (Yanagida, 1987; Miller, 1996; Schmidt, 1996; Munro et al., 1998; McDorman, 1998a). 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 (exercised by regional management councils) extends from 3 to 200 miles offshore.

Until the June 1999 amendments to the Treaty, the fishing regimes consisted primarily of harvest ceilings for specific locations and species. For example, in 1985 and 1986, the annual all-gear harvest of chinook in northern and central British Columbia and southeast Alaska was to be limited to 526,000 fish divided equally between the parties (*Pacific Salmon Treaty,* Annex IV, Chapter 3). In the South, the U.S. harvest of Fraser sockeye was to be held to a cap of 7 million fish over each of two successive 4 year periods (*Pacific Salmon Treaty,* Annex IV, Chapter 4).

Although the intent of the Treaty was to control interceptions of fish produced in other jurisdictions, the difficulty of identifying the true origins of fish taken in an ongoing mixed-stock fishery led to the harvest ceiling approach as a proxy method for balancing interceptions. In addition, harvest ceilings may have been viewed as a tool for reconciling the apparently conflicting goals of the treaty. In the absence of major environmental changes, ceilings could both reward enhancement investments on the part of the nation of origin and avoid disruption of existing fisheries. The Fraser River cap did indeed "avoid disruption" of the existing U.S. Fraser harvest, while protecting the benefits to Canada from its investments in enhancement.

However, under the Treaty's equity clause, the Canadians expected that the right of the U.S. to continue harvesting Fraser River salmon would be contingent upon equivalent Canadian harvests of U.S. salmon stocks. In particular, they expected that Canadian vessels operating along the west coast of Vancouver Island would be able to capture sufficient coho and chinook of Washington and Oregon origin to roughly offset U.S. harvests of the Fraser River stocks. Initially, this arrangement appeared satisfactory, but within a few years, Pacific Northwest coho and chinook stocks declined precipitously. It soon became apparent that the U.S. could no longer pay for its allocation of the Fraser harvest in this way.

During the long period of negotiation leading to the 1985 Treaty, changes were already apparent in the ocean environment that would contribute to the Treaty's undoing. In the mid-1970s, ocean conditions in the North Pacific changed dramatically. An extended period of cool coastal sea surface temperatures (SSTs), that had been favorable to U.S. west coast salmon production, 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 (Mantua et al., 1997; Zhang et al., 1996; Latif and Barnett, 1996). An unusual sequence of closely-spaced ENSO warm events from 1977 to 1998 reinforced the decadal-scale shift to warmer coastal SSTs and cooler SSTs in the central north Pacific and contributed to a pattern of intensified winter Aleutian lows (Trenberth and Hurrell 1994; Trenberth and Hoar 1996). These changes in the ocean environment appear to have had positive effects on salmon abundance in the Gulf of Alaska, but negative effects on stocks that spend a portion of their lives in the California Current (Pearcy 1992; Hare et al., 1999). In the subarctic zone, the mixed layer became shallower. This may have enhanced the survival of Alaskan and Northern B.C. salmon smolts by increasing zooplankton productivity and, therefore, food abundance for juvenile salmon (Polovina et al. 1995; Brodeur and Ware 1992). A general pattern of winter warming and increased winter precipitation in Alaska (Mantua et al., 1997) also may have contributed to favorable stream conditions for egg-to-smolt survival. From southern British Columbia southward, El Niño events have been associated with poor feeding conditions for maturing salmon, and changes in species composition, including increased abundance of some species that prey on juvenile salmon (Pearcy, 1992). In addition, recent droughts in California and the Pacific Northwest have resulted in poor conditions for spawning and migration in the salmon's freshwater phase. Changes in ocean temperatures and circulation, and associated changes in stream conditions, thus appear to have contributed to the opposite trends in northern and southern salmon abundance.

Shortly after the apparent mid-1970s climatic regime-shift, Alaskan salmon harvests entered a period of dramatic increase, rising nearly ten-fold 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. Harvests of most salmon species in northern British Columbia also fared well during this period, although B.C.'s chinook harvests have declined steadily (Hare et al., 1999; PSC Chinook Technical Committee, 1999), and by the late 1990s it had become apparent that many of B.C.'s southern and interior coho stocks were severely depleted (Pacific Fisheries Resource Conservation Council, 1999). 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, hitting El Niño-related lows in 1983 and 1984. A dramatic but brief recovery in 1986 and 1987 then gave way to a precipitous decline to record low harvests in recent years (Figure 2). Abundance has declined to the point that some stocks are on the verge of extinction.

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

The period of high productivity in Alaska induced Alaskan harvesters to fish harder in areas where B.C. salmon are intermingled with Alaskan fish. In particular, the dramatic increase in pink salmon abundance in southeastern Alaska led to increased interceptions of Canadian sockeye from the Skeena, Nass and other northern B.C. rivers. Alaskan officials argued that they could not avoid increased interceptions of Canadian salmon without foregoing efficient harvest of Alaska's own salmon.

The Canadians, however, found themselves unable to redress the growing interceptions 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 over harvesting of those fragile stocks.

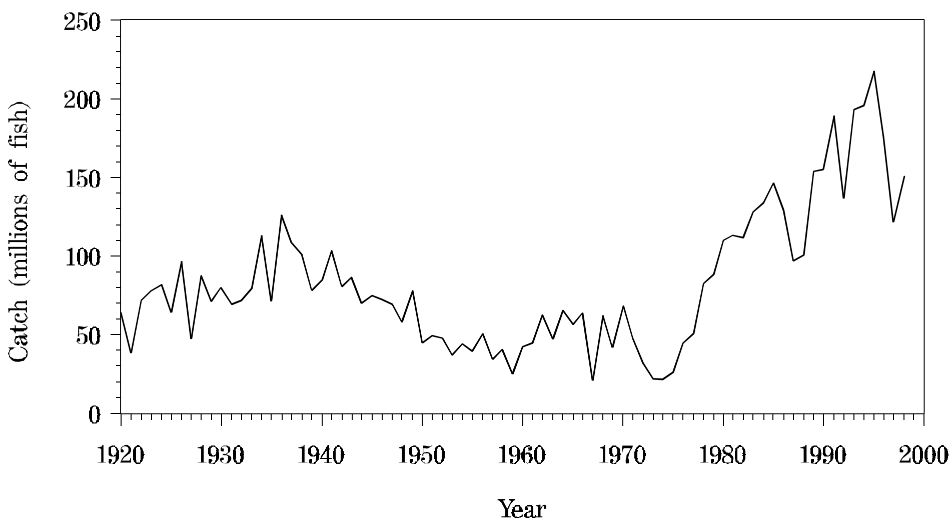

Figure 1: Alaskan Commercial Harvest - All Salmon Species

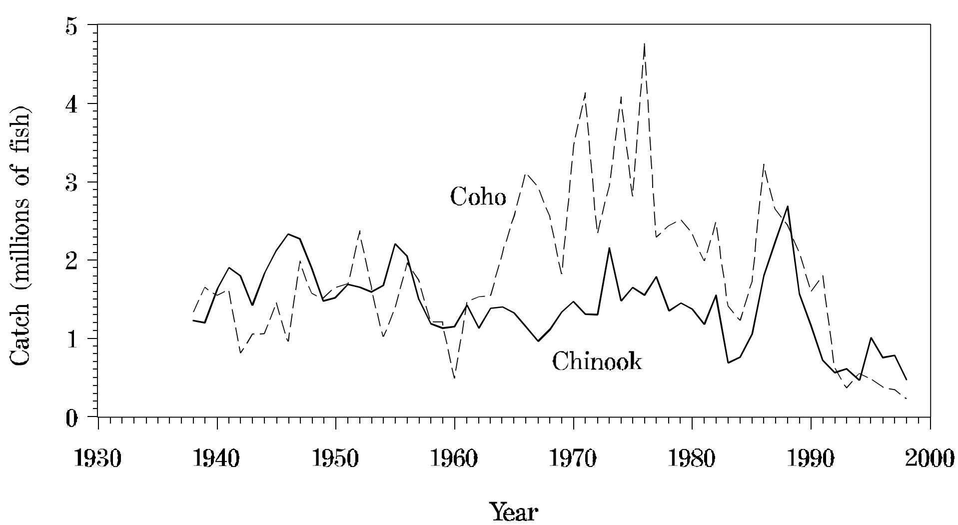

Figure 2: Commercial Coho & Chinook Harvest-Washington, Oregon, & California

In addition, the generally warmer coastal SSTs since the mid-1970s appear to have contributed to an increase in the proportion of Fraser River sockeye returning via the northern route, through Johnstone Strait rather than through the Strait of Juan de Fuca, which is shared with Washington State. This change in migratory behavior has tended to limit

U.S. access to those stocks and favor Canadian harvest. While the estimated Johnstone diversion rate averaged 19.5% during the 1960s and 1970s, it has averaged 50.7% during the past two decades (Data supplied by Jim Woodey, PSC). As can be seen in Figure 4, SSTs were much warmer in the Gulf of Alaska and along the B.C. coast in the latter period than in the former.

Negotiations first began to break down in 1993 when the parties failed to renew 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. As the Treaty dispute escalated, the Canadians employed a variety

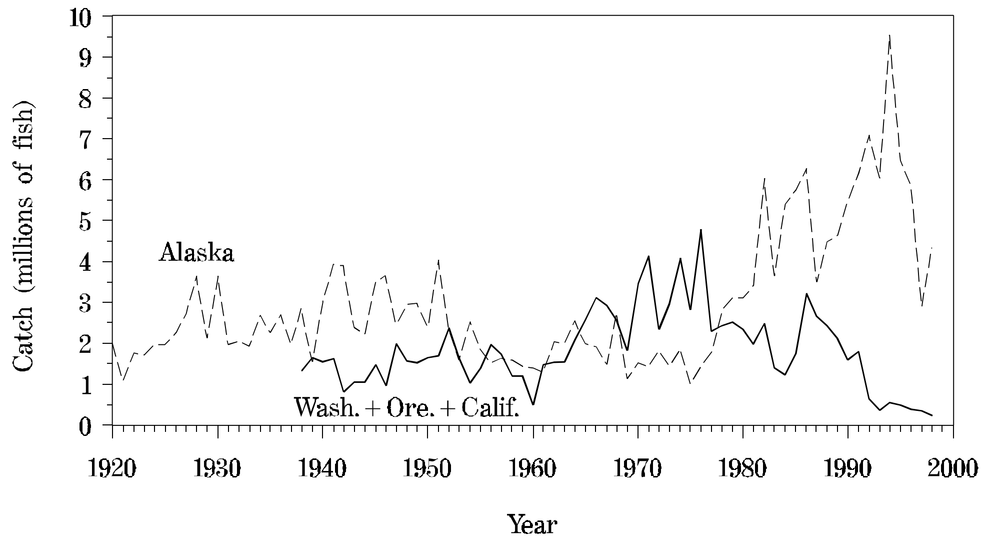

Figure 3: Commercial Coho Harvests

of desperate tactics in an effort to force the U.S. back to the bargaining table. For example, in 1994, British Columbia tried to pressure the southern U.S. parties by pursuing an "aggressive fishing strategy". That strategy failed to win any concessions and resulted in dangerous overharvesting of part of the Fraser River sockeye run 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 led to a partial agreement between Canada and the southern U.S. Parties in 1995, but Alaska remained outside the agreement and the truce proved to be temporary. By the summer of 1997, British Columbia's salmon harvesters had become so frustrated that approximately 150 fishing vessels participated in a blockade that held the Alaska Ferry hostage in the Canadian port of Prince Rupert for three days (Hogben et al., 1997; D'oro, 1997). Canadian frustration was fueled by Alaska's unwillingness to take actions to reduce the interceptions imbalance. Such concessions made little sense from Alaska's standpoint because they would impose costs on Alaska without commensurate benefits.

The dispute festered until the new Agreement was signed in 1999. Even now, it is unclear whether this Agreement will prove to be yet another temporary truce or a first step to lasting cooperative management.

3. GAME THEORETIC INSIGHTS ON INTERNATIONAL HARVEST ALLOCATIONS

In order to better understand why it has been so difficult to achieve and maintain cooperation in this case, it is helpful to formally model the bargaining process among the Parties to the Treaty. The theory of games is a particularly valuable tool in this context.

Game theory is designed to analyze strategic interactions among independent, self-interested players. The players are modeled as rationally choosing a strategy on the basis of expected payoffs, given the likely actions of the other players over the entire sequence of play. Interactions among the players can be modeled as occurring only once or repeated many times; and as involving different levels of information and communication among the players. A repeated game is "dynamic" if the initial conditions and expected payoffs at the start of each period of play change as a result of the players' past actions. A game also can be "stochastic" if exogenous variability (e.g. environmental factors) affect starting conditions and payoffs. The two main categories of games "cooperative" and "non-cooperative" differ in that the players in a cooperative game are assumed to be able to communicate freely, while communication is faulty or non-existent in "non-cooperative" games. A game is said to have a "solution" if the players' interactions result in a stable outcome. However, many games do not have such a solution.

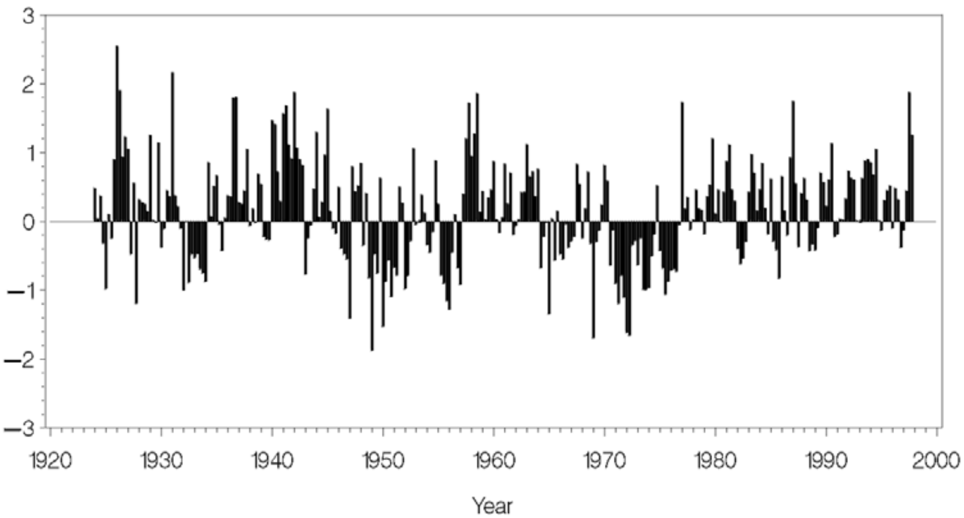

Figure 4: Gulf of Alaska and B.C. Coast. Temparature anomalies (deg. C)

When applied to international fisheries, the "players" in the game are the respective national authorities who either choose to set independent policies governing harvests by their respective fleets, or to negotiate coordinated fishing policies with the other national authority(ies). In a game theoretic model, any agreement on harvest allocations results from hard bargaining among these players.

One can model the regime-setting process under the Pacific Salmon Treaty as a dynamic cooperative game. Such games may or may not result in a cooperative agreement regarding division of the harvest. If cooperation is achieved, it is not motivated by altruism, but by the possibility that all parties can gain by avoiding the destructive consequences of non-cooperation. To be stable and efficient, a cooperative solution must satisfy the following conditions: 1) the solution must be "Pareto optimal," which means that it must not be possible to make one player better off without harming the other(s) and 2) the individual rationality constraint for each player must be met, which means that it must not be possible for any player to do better by refusing to cooperate (Munro et al., 1998).

Figure 5 illustrates a simple two party game. The curved line in this figure is the Pareto boundary that satisfies condition (1) above. There is a "threat-point" [U^o_1, U^o_2] which represents the payoffs available to parties 1 and 2 when their fleets fall back to a narrowly self-interested (and mutually destructive) competition. Neither fleet will agree to accept less from a cooperative arrangement than it could achieve unilaterally (the "principle of individual rationality"). Therefore, in the absence of side-payments, the "bargaining set" effectively would be confined to that (darkened) segment of the Pareto boundary which lies between the horizontal and vertical lines passing through the threat point.

Cooperation can "pay" in an international fishery because it can dramatically expand the overall size and sustainability of the harvest. 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. In addition, the total value of the harvest depends on how it is allocated among the nations exploiting the fish stock. The allocation problem is not a zero-sum game because the marginal utility to either party of a change in its share of the total salmon run is not constant. Rather, the first increments allocated to either party are likely to be used to serve important conservation, cultural and recreational uses. This is represented in Figure 5 by the convex shape of the Pareto boundary—i.e. bulging upward at its center. Near the northwest corner of the Pareto boundary, the value to party 1 of an increment in its share of the run may be very high, but that marginal value would tend to decline as one moves downward and to the right along the frontier. Simultaneously the marginal utility to party 2 grows, more than offsetting the former's decline. The convexity feature affirms that there is substantial added utility to be achieved through cooperation—a bonus beyond the purely biological consequence of enhanced stock productivity. Therefore, the total payoff to the binational community, U_1+U_2, will be maximized at some cooperative mix of shared landings.

This very simple model can be used to make several points relevant to the Pacific salmon management problem. First, the bargaining set depicted in this figure is fairly large,

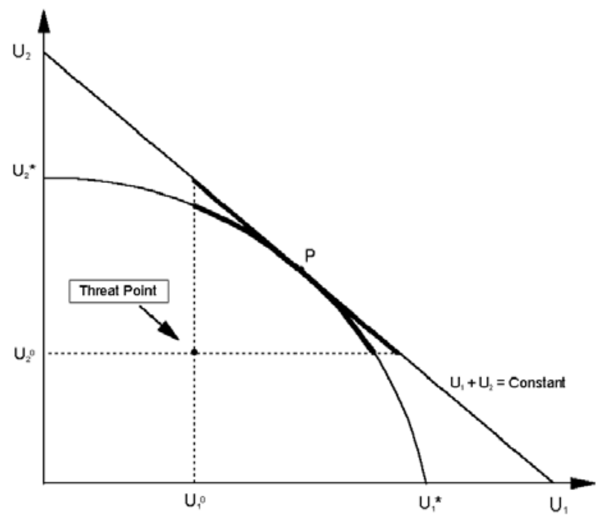

Figure 5

suggesting the existence of many joint harvesting arrangements that are preferable to the non-cooperative threat point. Second, if the parties' utilities are given equal weight, then there is one coordinated management arrangement which maximizes total community utility. This corresponds to the point P—the point of tangency of the Pareto boundary of the feasibility set with a 45 degree line.

If the scope of bargaining is confined to arrangements in which each party benefits only from its own harvests, then the set of possible outcomes is limited to those shown by the darkened segment of the convex Pareto boundary. However, if the parties are also willing to allow other payments change hands, then they could achieve an expanded bargaining set. Efficient harvesting at point P, coupled with side payments, would cause the 45 degree line to become the expanded Pareto boundary. With this expanded bargaining set, the benefits of efficient harvesting could be allocated between the parties through the use of side payments (monetary or in-kind), or by allowing the nationals of one jurisdiction to participate in the fishery located in the other jurisdiction (i.e., an access agreement). Any point within the darkened segment of the 45 degree line would both maximize the sum of the players utilities and satisfy their individual rationality.

However, throughout the history of U.S./Canadian Pacific Salmon negotiations, the allocation of benefits never has been decoupled from the allocation of the harvest in this way. Rather, the only options that have been considered are those in which the benefits accruing to each nation depend on its own harvests. In effect, this has constrained the bargaining set to a subset of the possible arrangements.

We now can examine how climatic shifts may have affected cooperation between the two nations. By altering the spatial distribution of salmon abundance, a climatic regime shift changes the relative payoffs to non-cooperative versus cooperative behavior. In other words, the position of the threat point is sensitive to a change in climatic conditions affecting salmon survival rates.

One possible outcome is simply a change in the relative strength of the parties' bargaining positions. Such a situation is depicted in Figure 6. For simplicity assume that side payments are not considered within bargaining framework (as has been the historical case for the Pacific Salmon Treaty). Suppose that the threat point is initially at T^o and the parties have struck an agreement within the bargaining set A-B. A climatic shift then occurs which favors party 2's stocks and changes the position of the threat point to T^1. There is still plenty of room for mutually advantageous cooperation within the new bargaining set C-D, but the original deal no longer will be acceptable to party 2. Party 2, in fact, now can do better by refusing to cooperate than by adhering to the original agreement. In such a situation, renegotiation of the terms of cooperation will be necessary to avoid a retreat to mutually destructive competition. If the other party misjudges the change in circumstances and insists on clinging to the original agreement, or if the negotiation process is excessively slow and costly, a breakdown in cooperation could occur.

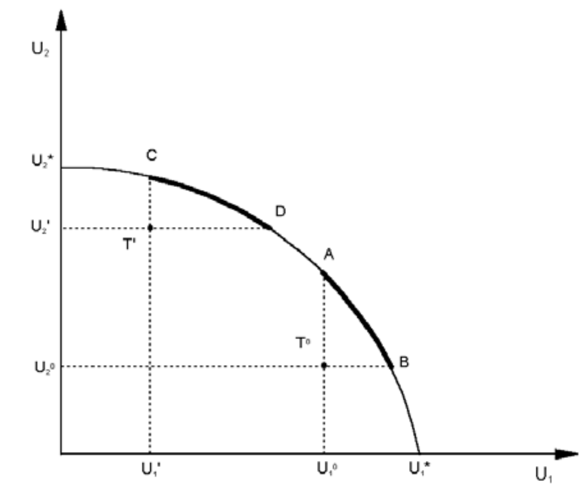

Figure 6

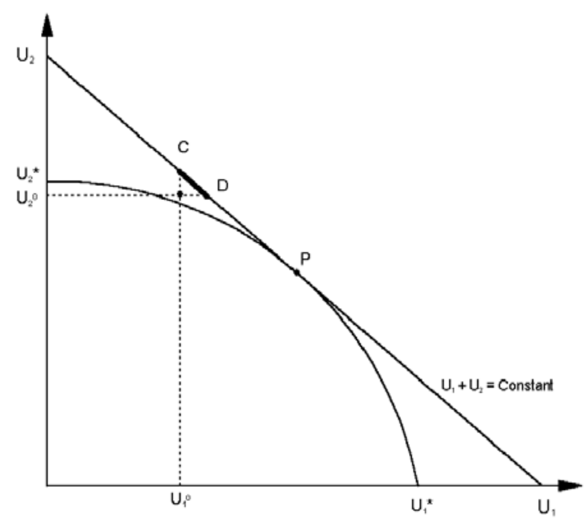

Figure 7

Another possibility is that a change in abundance patterns may so advantage one of the players that cooperation no longer pays from that party's perspective. If it is costly to negotiate and enforce a harvest agreement, the new threat point could lie above the Pareto frontier, as depicted in Figure 7. In that case, the only way to achieve cooperation would be to use side payments to induce that party to cooperate. Cooperation in such a case would likely collapse if the parties failed to consider side-payment or access agreement options, insisting instead that the distribution of benefits remain strictly tied to the distribution of the harvest.

We might suppose that when the Pacific Salmon Treaty was signed in 1985, the parties perceived the threat point as lying in a position analogous to $[U^o_1, U^o_2]$ in Figure 5. Given that, they were able to agree to a pattern of harvesting that roughly satisfied individual rationality and their notions of a "fair" distribution of the harvest based on the equity principle articulated in the Treaty.

In actuality, Alaska never had much to gain by participating in the Pacific Salmon Treaty. Salmon migration patterns give Alaska a natural advantage in exploiting chinook salmon from the southern U.S. jurisdictions and certain Canadian stocks while Alaskan-origin salmon are less vulnerable to interception. When climatic conditions increasingly favored Alaskan salmon, Alaska had even less to gain by cooperating with Canadian and southern U.S. interests. If we think of Alaska as "party 2," this situation would be analogous to a shift in the threat point from a position like T^0 to T^1 in Figure 6 or perhaps even to a point such as that depicted in Figure 7.

Canada's bargaining position vis á vis the southern U.S. parties was similarly strengthened by the effects of the climatic regime shift. The high Johnstone Strait diversion rates in recent years has enhanced B.C.'s ability to increase its share of that fishery.

Our discussion, thus far, has focused on shifts in the balance of competitive advantage. We have largely abstracted from notions of stock ownership or "equity" as described in Article III of the Treaty. Indeed, from an "equity" standpoint, the notion of rewarding the party whose competitive position has improved might appear objectionable. However, this analysis suggests that if one ignores the reality of individual rationality, and the instability of incentives to cooperate, it may be impossible to maintain cooperation. It would be equally dangerous to ignore notions of "fairness." Indeed, Canada's claim that the Treaty's equity provisions were being violated was a central feature of the recent dispute.

"Equity" involves a question of ownership—the principle that a nation should be able to capture the benefits arising from harvest of the salmon originating in its waters. To examine the significance of ownership using our simple diagrams, consider the extreme case depicted in Figure 8. Here, suppose that only one stock is involved, and that stock is the acknowledged property of party 2. In that case, a distribution of benefits within the line segment EF would both recognize party 2's undisputed ownership of the stock and satisfy the individual rationality of both parties. To achieve such a point, the value of part of the harvest taken in the fisheries of jurisdiction 1 would have to be reallocated to party 2. Again, that could be accomplished through monetary payments, payments in kind, or an access agreement.

There also might be circumstances in which one party is in a very powerful position with respect to its ability to intercept the salmon returning to spawn in the other jurisdiction. In that case, the added value achieved by operating the fishery at point P would be sufficient to achieve EITHER fleet 1's individual rationality OR fleet 2's full equity rights—*but not both simultaneously*. The only way to accomplish that is to inject value from outside of this single-stock fishery. This case is depicted in Figure 9— where party 2 is the owner of the stock while party 1 could easily intercept a large fraction of the run in a competitive fishery. Any agreement in this case would involve either balancing the division of benefits in this fishery against the division in another, or side-payments from outside the fishery sector.

Both countries seem to have recognized this problem, and agree that equity claims need only be balanced in the aggregate. To this we would add that individual rationality claims need also to be adjusted, but that this too needs only to be achieved in the aggregate. As an example, when the parties signed the 1985 Treaty, Canada implicitly assumed that it would balance Canadian harvest of Pacific Northwest chinook and coho against the US harvest of Fraser sockeye. It appears that they hoped to meet equity and individual rationality requirements simultaneously by pairing two groups of transboundary stocks which are separately targeted and have different countries of origin. As we have seen, that hope was thwarted by the subsequent changes in stock abundance.

4. 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)*.

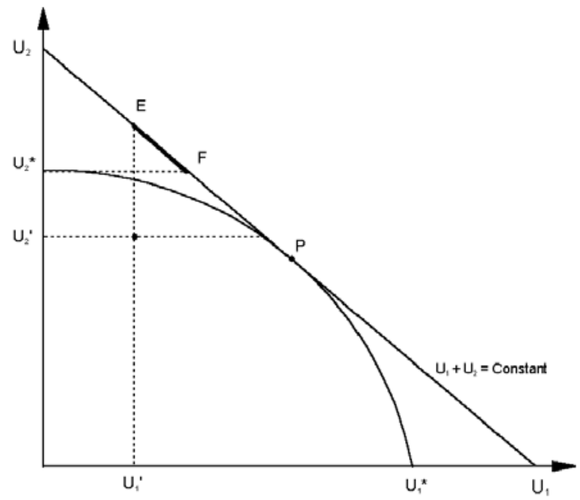

Figure 8

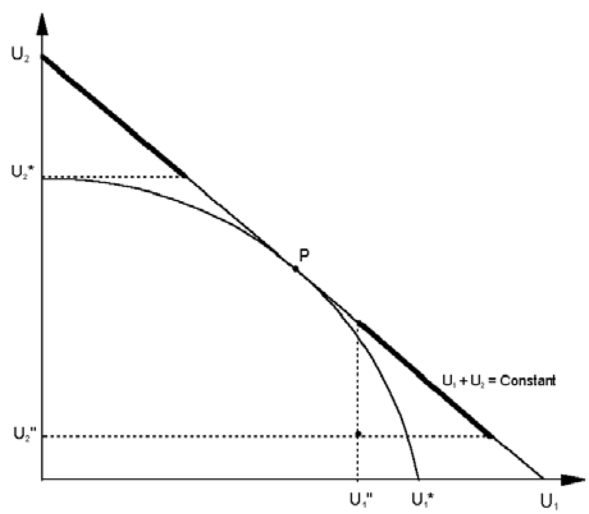

Figure 9

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). Abundance-based allocation rules for coho have not yet been developed, but the Agreement instructs the Parties to jointly develop such a management approach, and specifies various deadlines for the accomplishment of particular tasks.

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 Agreement is contingent upon U.S. Congressional approval of U.S. contributions of $75 million for the Northern Fund and $65 million for the Southern Fund over a four-year period. The first installments have been approved. These funds appear to be intended to serve as the type of side-payment suggested above, 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 also may 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).

At the very least, the side-payment aspect of the Endowment Funds sets a precedent that may work to overcome a long standing prejudice on the part of many Canadians against taking monetary payments in lieu of fish to achieve an equitable balance of fishery benefits.

While their initial yield will be quite small, the Endowment Funds may constitute a vehicle for more extensive future side-payments. The provision allowing third parties to contribute to the funds raises numerous possibilities for efficiency-enhancing side deals. For example, it might be possible for a coalition of Pacific Northwest hydropower, environmental and development interests to use the Endowment Funds to compensate Alaskan and B.C. harvesters in order to secure "safe-passage" for endangered Columbia Basin and Puget Sound chinook. Future work on this project will investigate the feasibility of such arrangements. Such privately funded payments to reduce ocean harvesting of salmon have been pioneered in the North Atlantic, where the North Atlantic Salmon Fund (NASF) has coordinated the buy-out of ocean commercial fishing for salmon in Greenland, Icelandland, The Faroes and Wales (NASF, 2000).

Most observers agree that the 1999 Agreement is better than limping along from year to year without an agreement, but it is not yet clear if the new abundance-based management approach will provide a path to sustainable cooperation. While the focus on conservation will tend to protect some of the weak stocks that were jeopardized by the recent turmoil, the new Agreement does little to resolve long-standing differences over the division of benefits. In particular, many Canadians remain convinced that Canada will come out "short" under this Agreement, and they have labeled it "profoundly disappointing" (Culbert and Beatty, 1999). In fact, the Canadian government effectively agreed to temporarily suspend the argument about equity by agreeing that: "...compliance with this Agreement shall constitute compliance by the Parties with their obligations under Article III of the Treaty"(McRae and Pipkin, 1999).

Some Canadians are unhappy about the long-term implications of the Agreement because they feel that it risks committing them to an unsatisfactory arrangement for many years. In fact, the Canadian delegation had unsuccessfully argued for a shorter term. Although the Parties have formally stipulated that compliance with the terms of the new Agreement shall be deemed to fulfill the requirements of Article III of the Treaty, the stipulation applies only for the duration of the current agreement. If Canadians continue to feel that their interests have been compromised, there may be renewed turmoil when this Agreement expires.

Abundance-based management also will place a greater burden on fishery scientists to develop accurate and timely estimates of abundance. Given inevitable uncertainties, there will continue to be considerable scope for disagreements regarding these projections. McDorman (1998b) notes for example that:

> The potential for scientific and data disagreements is simply too overwhelming to expect complete harmony. In the event of non-agreement on management measures within the Pacific Salmon Commission, it can be expected that each country will proceed with its own management plans declaring itself to be consistent with the complexities of the 1999 Agreement. (p. 112).

He worries that this could simply leave the parties exactly where they were before: "...where the two states and their representatives found disharmony to be in their national interest."(McDorman, 1998b, p. 112). At this point, we would have to agree with McDorman's conclusion. "It is too soon to tell whether the 1999 Agreement is a continuation of the past or whether it represents a turning point for the future."(p.112).

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