THE 1999 PACIFIC SALMON AGREEMENT: A SUSTAINABLE SOLUTION?

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I. INTRODUCTION

When Canada and the United States signed the Pacific Salmon Agreement on June 30, 1999, they hoped that it would put an end to the pattern of bickering, failed negotiations, conservation-threatening harvest practices, and blame-laying that had prevailed over the previous six years. The agreement does not replace the 1985 Pacific Salmon Treaty, but rather puts additional obligations on the parties and replaces the expired short-term harvest management regimes, contained in an annex to the treaty, with new longer-term arrangements. The two nations thereby consented to temporarily set aside a long-smoldering dispute about the equitable division of the harvest and to focus instead on implementing multi-year, abundance-based harvesting regimes that would foster conservation and restoration of depressed salmon stocks. The agreement has been

*A list of acronyms used in this article is provided on page 58.

in place now for two full fishing seasons, and at the time of this writing the two nations are in the midst of a third year of coordinated management under the new regime.

While the ultimate success of the new agreement is yet to be determined, sufficient time has passed to allow a preliminary assessment of its performance as well as an enumeration of the challenges that may lie ahead. Success can be gauged by the extent to which the agreement facilitates stable cooperation while promoting such diverse goals as preservation and restoration of salmon resources, efficient management of fisheries, and a mutual perception that the distribution of the benefits is equitable.

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Is the 1999 agreement designed for success? What other changes might be needed to ensure continued bi-national cooperation on Pacific salmon management? To address these questions, we begin by briefly reviewing previous analyses of the breakdown of cooperation under the 1985 Pacific Salmon Treaty (Huppert, 1995; McDorman, 1995; Miller, 1996; Munro *et al.*, 1998; McDorman, 1998a). We then examine the negotiation process which led to the new agreement, evaluate the differences between the new and old approaches, and draw upon both game-theoretic analysis and actual experience to assess the extent to which the 1999 agreement is likely to succeed.

Our analysis suggests that real progress has been made. Specifically, the abundance-based rules appear to be much better suited to effective management of harvesting effort when there are sustained natural changes in salmon abundance. In addition, the new agreement opens the door to using enhancement projects funded through newly established endowment funds both to facilitate restoration of depleted stocks and to provide the parties with incentives to continue cooperating. Cooperation also may be supported by the growing significance of conservation concerns in Canada and U.S. Pacific northwest. These concerns have been fueled by the severely depleted state of some Canadian coho and chinook stocks, and recent listings of several salmon stocks in the U.S. Pacific northwest as threatened under the Endangered Species Act (ESA--see National Marine Fisheries Service, 1999; U.S. Federal Register, 2000). However, sustained cooperation is not ensured. In particular, difficulties in forecasting and measuring the abundance of the numerous salmon stocks subject to the agreement may prove to be a stumbling block. We conclude by drawing upon our analysis as well as experiences in other fisheries to suggest further options that could be pursued to maintain positive momentum toward achieving the promise of sustained, mutually beneficial cooperation.

II. THE HARVEST MANAGEMENT GAME

Pacific salmon are anadromous fish. The juveniles emerge from the freshwater environment where they were born, feed and mature in the ocean, and then return to their natal streams to spawn and die. Many of the salmon stocks originating in the rivers of western North America are inherently bi-national resources because they cross international boundaries during their oceanic migrations. The need for cooperative management arises because harvesters in one jurisdiction can intercept salmon heading to spawn in the rivers of the other jurisdiction. As is so often the case with such fisheries, it has been difficult for Canada and the U.S. to attain and maintain cooperation, and their efforts have been marked by alternating periods of harmony and discord.

Cooperation can pay in an international fishery because it can dramatically expand the long-term size, value, and stability of harvest yields. This year's harvesting activities affect both net returns for this year and the size of potential harvests in future years. If cooperation leads to better conservation, a more highly valued allocation of the fish, and/or lower harvesting costs, all parties can benefit. The existence of such potential gains drives efforts to negotiate cooperative management agreements, but the way in which those gains are divided is critical in determining the willingness of the parties to participate.

Game theory provides an analytical framework that sheds considerable light on the question of why negotiations sometimes lead to stable cooperative agreements and why they fail at other times. Game theory is designed to analyze strategic interactions among independent, self-interested players, in which any agreement results from hard bargaining. 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. 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.

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). One can model the process of negotiating harvest allocation agreements under the Pacific Salmon Treaty as a dynamic cooperative game.

A cooperative 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, in which case cooperation would be predicted to fail. 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).

Individual rationality is central to the success of any agreement, and it must be honored if cooperation is to be sustained. An agreement will remain viable only so long as each party perceives some benefit to continued cooperation. Incentives to cooperate, however, are not necessarily stable. If conditions controlling either the productivity of a shared resource or its value change over time, the parties' estimates of the benefits of cooperation versus going it alone may also change. Cooperation is likely to break down if changing circumstances cause one or more of the parties to believe that it can do better outside of the agreement. A sustainable agreement, therefore, not only must accommodate the initial individual rationality positions of the participants, but it must also be "time consistent" (Munro, 2000). That is to say, it must be sufficiently flexible to accommodate unexpected changes in surrounding conditions. Among other things, it must be sufficiently flexible to adjust the division of benefits as the players' competitive power and interests shift with changing natural conditions and market circumstances. One way to provide such flexibility is to allow the parties to make "side payments"(i.e., transfers) to one another when there is no other convenient way to simultaneously satisfy individual rationality and capture the potential gains from cooperation. In some instances, it may not be possible to satisfy the players' multiple objectives by simply re-allocating the benefits of the harvest. In such cases, sustained cooperation would require supporting side payments with value injected from outside the fishery. For example, one of the two governments might transfer resources to the other through disproportionate contributions to a joint project or through concessions on a non-fishery matter.

Unfortunately, throughout the history of U.S.–Canadian negotiations regarding Pacific salmon management, there has been scant attention to the significance of individual rationality. In addition, the bargaining framework established by the 1985 Pacific Salmon Treaty provided little latitude for accommodating changes in the parties' interests over time. Until recently, the question of providing side payments was never "on the bargaining table." However, as will be detailed below, shifts in the interests and competitive power of these parties have played a large role in the historical ebb and flow of bi-national cooperation in this arena.

Before proceeding further, we should digress by asking what the consequences are of failure to cooperate. Models of "non-cooperative" fisheries games yield firm and consistent predictions (see, for example, Clark, 1980; Levhari and Mirman, 1980). These models predict that non-cooperation will, except under very special circumstances, result in overexploitation of the fishery resource. The "non-cooperative" fishery game is an example of the classic "non-cooperative" game, "The Prisoner's Dilemma," in which the players are driven inexorably to adopt strategies that they know to be harmful and destructive.

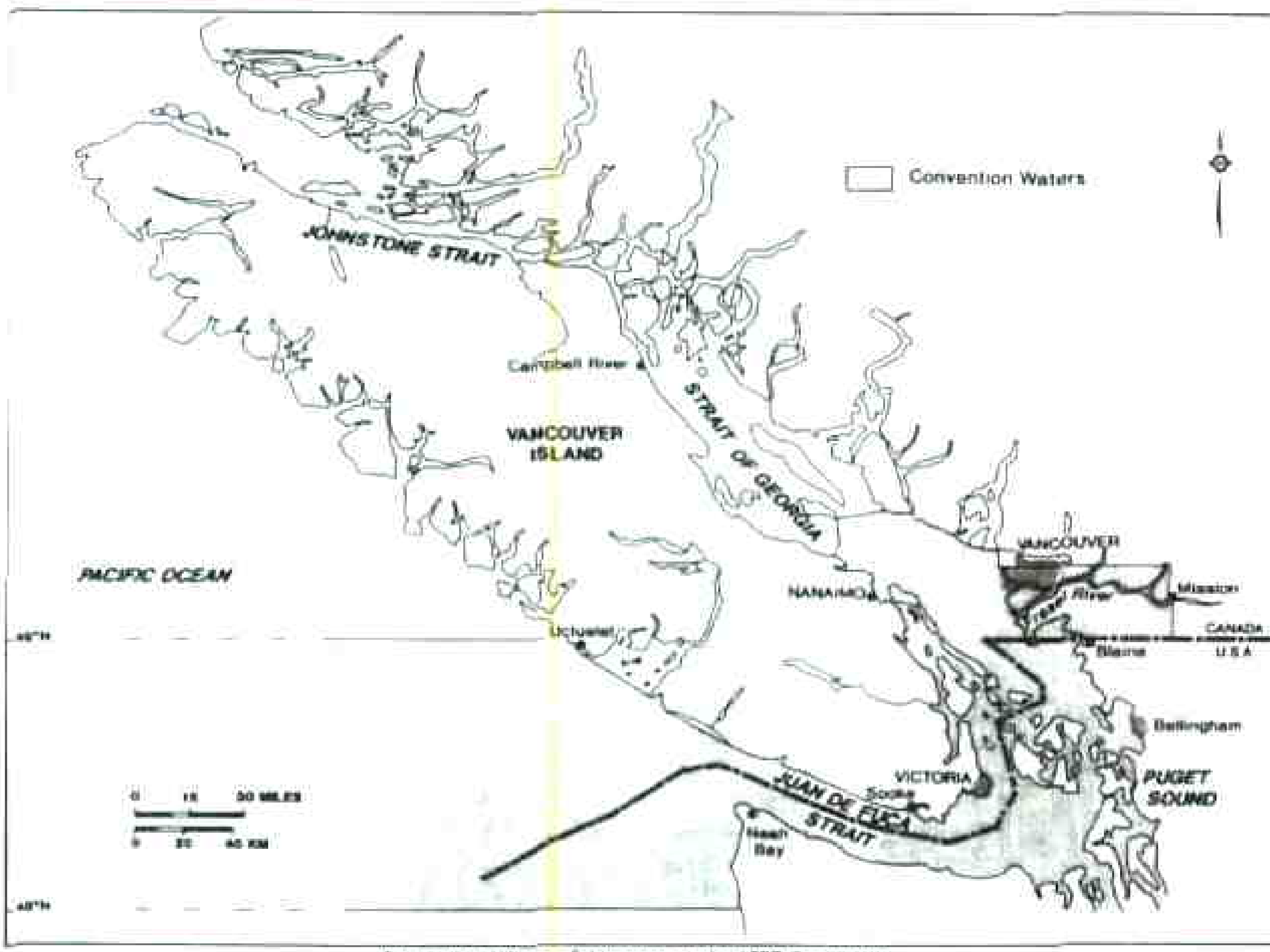
III. THE HISTORICAL CONTEXT

The 1985 Pacific Salmon Treaty and the recent period of discord have been described in detail elsewhere (Yanagida, 1987; Munro and Stokes, 1989; Huppert, 1995; McDorman, 1995; Munro *et al.*, 1998). Here, just a brief historical sketch will enable us to put the 1999 agreement in context.

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).

The first significant international agreement on salmon harvests was the Fraser River Convention between the United States and Canada, signed in 1930 and ratified in 1937.[1] 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). It was later extended to Fraser River pink salmon, a less valuable species. Under the convention, the International Pacific

Salmon Fishery Commission (IPSFC) regulated harvests of the Fraser River stocks within an area designated as "the Convention Waters" which encompassed the traditional fishing grounds for those stocks (Figure 1). 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 clearly had a joint interest in removing the blockage and restoring the runs.



Conventional Waters fishing area under 1937 Convention

Fig. 1: Convention Waters Fishing Area Under 1937 Convention
Source: Adapted from Roos, J.E., 1996, p. 60.

Support for the Fraser River 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 hydro-power dams on the Fraser, Canada was effectively bearing more than half of the cost of maintaining those runs. Canadian harvesters also had discovered that they could circumvent the IPSFC regulations by fishing for Fraser sockeye, outside of the convention waters in Georgia Strait. This was made increasingly possible and profitable by a change in the migratory habits of the returning Fraser sockeye.

In the early years, most of the harvest occurred within convention waters. Each year, however, some of the Fraser sockeye take a more northerly route, returning by way of Johnstone Strait. The portion taking the Johnstone Strait route could easily be harvested by the Canadian fleet outside of the Convention waters, and thus outside of IPSFC regulation (Figure 2a). The Johnstone Strait diversion rate varies from year to year in response to changing ocean conditions. A climatic regime shift in 1977 contributed to a marked increase in the average Johnstone Strait diversion rate. In the period 1953–1976, the diversion rate averaged 16.4 percent. From 1977 through 1985, the average rate jumped to 46 percent,[2] surely strengthening Canada's hand in the negotiations leading to the 1985 treaty. In fact, Canada clearly took advantage of unusually high diversion rates in 1978, 1980, 1981, and 1983 to concentrate harvesting efforts outside of Convention waters, thereby increasing its overall share of the harvest. For example, in 1983 (an El Niño year), the Canadians took advantage of an 80 percent Johnstone diversion rate to increase their overall harvest share to 89 percent (Figure 2b).

In addition to that pressure tactic, Canadian harvesting effort also intensified off the west coast of Vancouver Island, leading to increased interceptions of U.S. origin coho and chinook salmon heading south to spawn in the Columbia River system and other west coast streams. Alaskan interceptions of those same stocks were already a source of tension between Washington/Oregon and Alaska, and by the time that negotiations for the Pacific Salmon Treaty began in 1971, Alaska and British Columbia intercepted significant numbers of each other's salmon in the northern boundary area. These facts made it clear that a comprehensive agreement was needed that would cover all of the salmon stocks subject to significant interceptions.

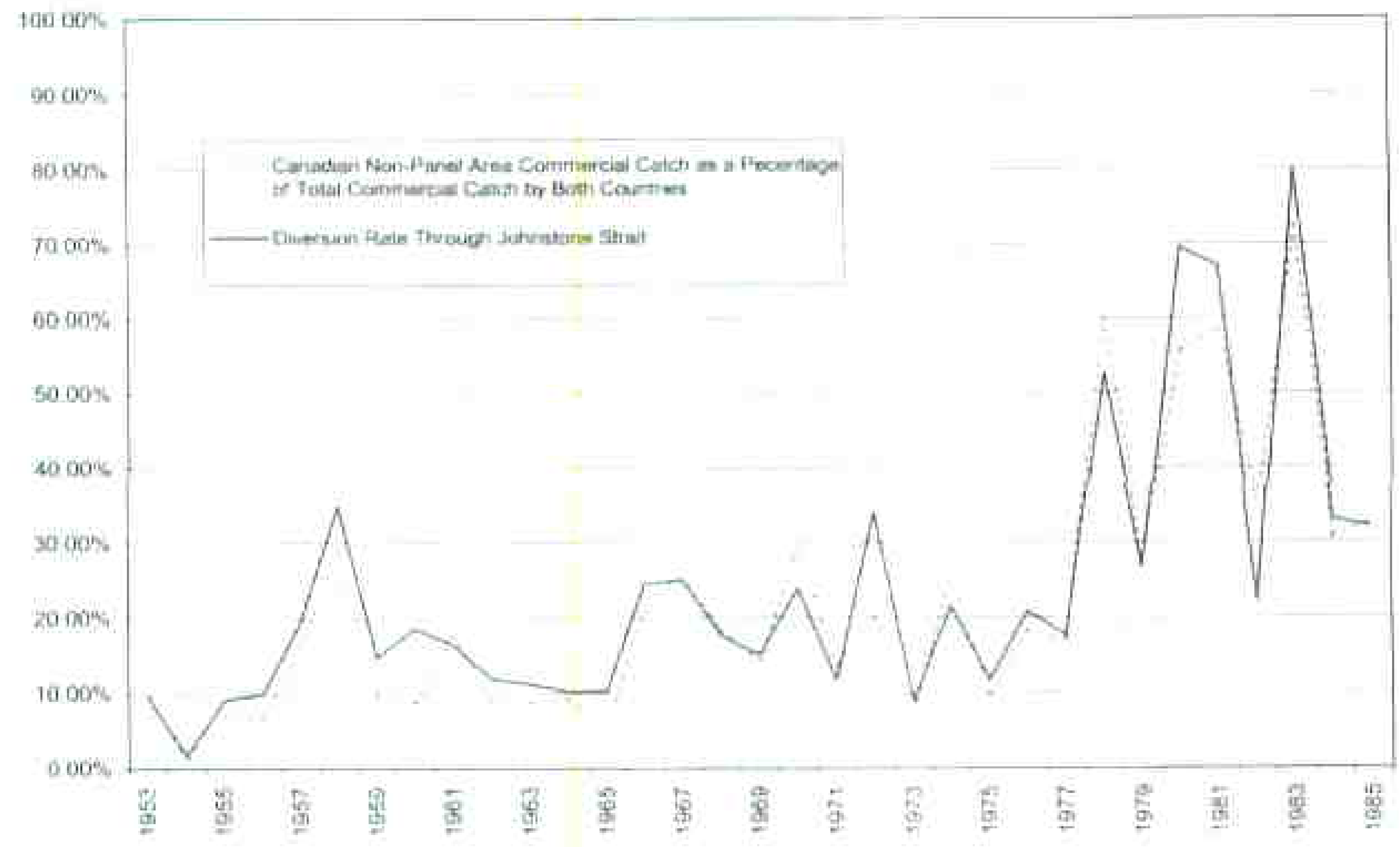


Fig. 2a: How Diversion Rate Affects Where Canada Harvests Fraser Sockeye
Data Source: Courtesy of James Woodey, Pacific Salmon Comm., May 2000.

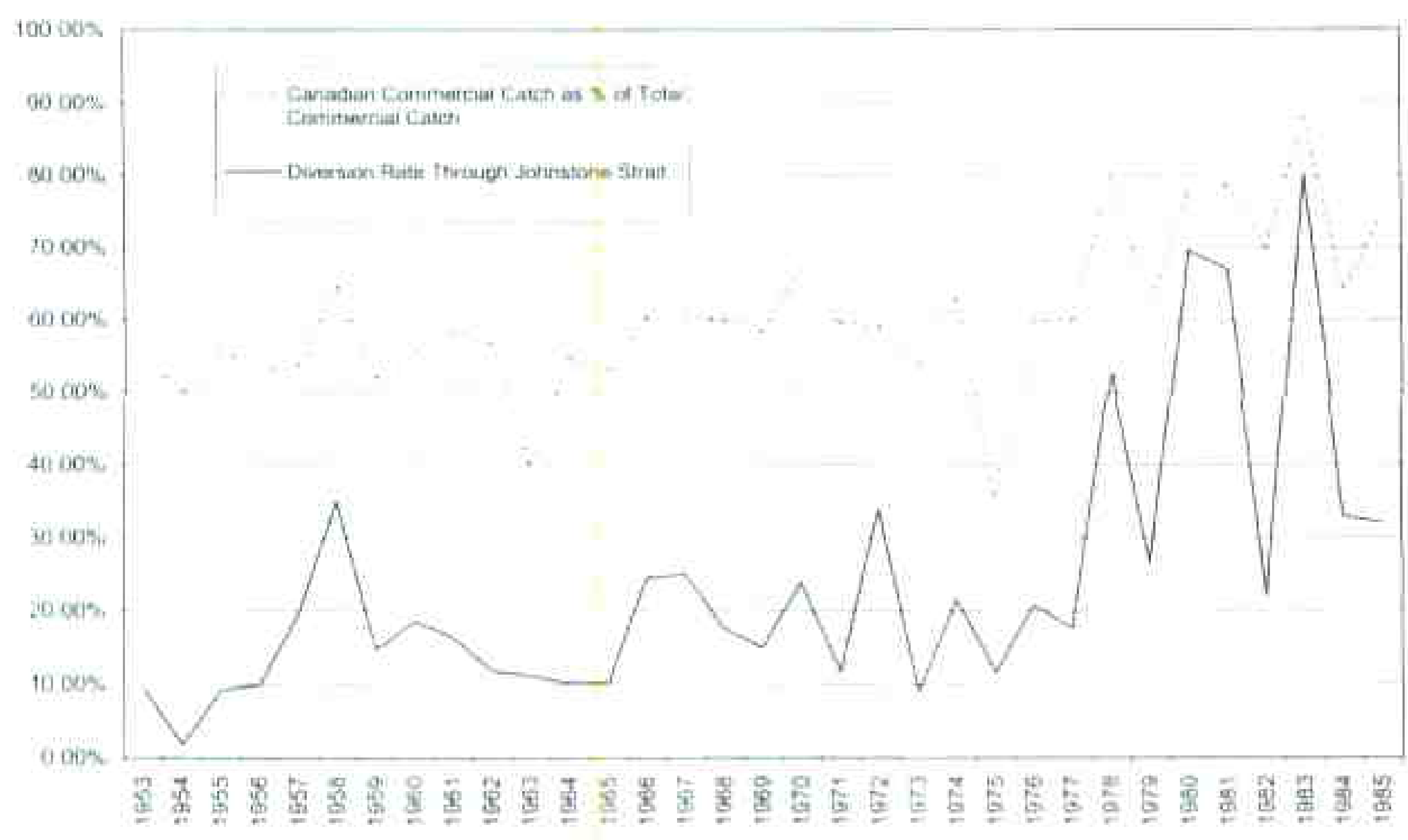


Fig. 2b: Canadian Commercial Catch of Fraser Sockeye in Relation to the Diversion of Fish Through Johnstone Strait
Data Source: Courtesy of James Woodey, Pacific Salmon Comm., May 2000.

It took 14 years to negotiate the 1985 Pacific Salmon Treaty (For accounts of that period see: Yanagida, 1987; Munro and Stokes, 1989; Roos, 1996). It established a tenuous balance among competing interests and conflicting objectives that relied on optimistic assumptions regarding increases in salmon abundance from anticipated enhancement projects that had been held back by the competitive atmosphere of the pre-treaty period. If the optimistic assumptions had proved correct, the treaty in all likelihood would have functioned to everyone's satisfaction. However, the expected surge in salmon abundance never materialized in the south. The same climate regime shift that had strengthened Canada's hand in the negotiations played a role in the treaty's undoing because it altered the abundance of northern and southern salmon stocks in ways that had not been foreseen. (Miller, 1996). Ultimately, the treaty proved unable to withstand the pressure of changing circumstances (Munro *et al.*, 1998; McDorman, 1998a).

The 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 principles to guide the commission in this task. Of central importance are the conservation and equity objectives or principles, which the treaty expresses as follows:

> *...each Party shall conduct its fisheries and its salmon enhancement programs so as to:*
>
> *a) prevent over-fishing 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).*[3]

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

The bargaining framework implemented in 1985 called for frequent re-negotiation of the fishing regimes. Negotiations were to follow a consensus rule in that the Canadian and American delegations were to agree on new regimes. Pursuant to the U.S. legislation implementing the 1985 treaty, the American delegation was composed of three voting commissioners representing Alaska, Washington/Oregon and the Treaty Indian Nations, and a fourth non-voting commissioner from the U.S. federal government (U.S. Senate, 1985; Yanagida, 1987; Schmidt, 1996). The federal government had not delegated either its treaty-making or treaty-maintenance authority to the commissioners and could step in when the 1985 treaty was being breached. Nevertheless, through the implementing legislation, the federal government had given to the three voting commissioners the authority to agree upon new regimes under the 1985 treaty. One effect of these arrangements was that the three voting commissioners were independent from the U.S. federal government, and effectively any one of them had a veto over the work of the Pacific Salmon Commission in developing new regimes. When the parties failed to agree on new fishing regimes, the appropriate state or federal authority would implement its own management regime independent of the other party. In the U.S., the states have authority within three nautical miles of the coast and federal jurisdiction (exercised by regional management commissions) extends from three to 200 n. miles offshore, as well as within three nautical miles where the fisheries in question are predominantly located outside three miles. In Canada, the federal government exercises authority respecting fisheries.

A central weakness of the bargaining framework under the 1985 treaty was that it did not enable the parties to resolve major tensions between individual rationality and strongly held perceptions of equity. From the beginning, there were fundamental differences of opinion regarding the meaning of the so-called equity clause [Article III (1) (b)] and whether it contained a principle (obligation) as opposed to an objective and, as a consequence, whether or not it should take precedence over objectives and factors expressed in the language of the treaty.

The background for the equity provision can be traced, in part, to the negotiations leading to the 1982 United Nations Convention on the Law of the Sea[4] (LOS Convention), which were largely contemporaneous with the negotiations leading to the 1985 Pacific Salmon Treaty. Although neither Canada nor the United States are parties to the LOS Convention, both vigorously participated in the negotiations and broadly accept its provisions regarding the international law applicable to anadromous species. Article 66(1) of the LOS

Convention directs that "[s]tates in whose rivers anadromous stocks originate shall have the primary interest in and responsibility for such stocks."[5] The primary purpose of Article 66, strongly supported by both Canada and the U.S., is to eliminate high seas fishing for salmon and other anadromous fish.

The case in which salmon originating in the rivers of one state migrate into another state's waters is covered by other provisions in Article 66 and elsewhere in the convention. Article 66(4) provides that where salmon originating in the rivers of one country migrate into or through the waters of a neighboring state, the neighboring state "shall cooperate with the State of origin with regard to the conservation and management of such stocks."[6] Article 66(2) allows a state of origin, after consulting with the neighboring state, to establish the total allowable catch (TAC) for salmon originating in its rivers, but does not allow the state of origin to enforce that TAC in the neighboring state's waters.[7] Rather, Article 56(1) grants exclusive sovereignty to each coastal state over the living and non-living resources found within its 200-n.mile exclusive economic zone (EEZ),[8] and Article 61(1) gives each coastal state the right to establish the TAC for marine living resources within its EEZ. Article 56(2), however, directs each state to give "due regard to the rights and duties of other states."[9]

The Law of the Sea Convention neither creates sole ownership of salmon originating within a country's rivers nor clear limitations on the jurisdiction of a neighboring state into whose waters the salmon migrate. Rather, the LOS Convention envisions cooperation between state-of-origin rights and coastal state sovereignty. This requires the sharing of transmigrating anadromous fish to be negotiated on a case-by-case basis (McDorman, 1998a), and the 1985 Pacific Salmon Treaty was to provide the framework for U.S./Canadian sharing.

In the case of the Pacific Salmon Treaty, some have argued that the equity clause was intended to establish state of origin "ownership" of the salmon (Shepard and Argue, 1998). However, interceptions were not prohibited, but rather the benefits accruing to each nation were to be commensurate with the value of salmon originating in its waters. Perhaps, at most, "...the equity provision creates a national ownership right that provides to the state of origin a right to "benefits equivalent" to the salmon intercepted" (McDorman, 1998a, p.89). On the other hand, U.S. negotiators have typically maintained that equity was merely one of the agreed-upon objectives guiding the actions of the states (Yanagida, 1987; Strangway and Ruckelshaus, 1998; McDorman, 1998a). Indeed, the U.S. had consistently opposed including the equity provision in the treaty and yielded only under intense pressure from Canada (Yanagida, 1987; Munro and Stokes, 1989).

U.S. opposition to the equity language derived, in part, from the difficulty of quantifying an overall interceptions balance, and partly from the fact that some segments of the U.S. salmon fishing industry could only be hurt by the restrictions that might be necessary to bring about such a balance. Alaska, in particular, was likely to be hurt by such a provision. Given a general north-to-south migration pattern for returning salmon stocks, Alaskan fisheries are in a natural position to intercept many Canadian and some southern U.S. salmon, while few Alaskan stocks are vulnerable to Canadian interception. Hence Alaska was wary of interception restrictions that might entail significant changes in Alaskan fishing operations.

The task of quantifying the interceptions balance is complicated by the fact that commercial harvest value is only one possible measure of the value of a salmon. And it is certainly not the most important measure in cases where individual stocks are threatened with extinction, support highly valued sports fisheries, or have significant cultural value to native communities that have relied on those stocks since time immemorial. Even commercial value varies considerably depending on species, location of harvest, and condition of the fish when delivered to the dock. Thus, while all interests recognized that the equity principle was meant to reflect economic values and did not amount to a simple fish-for-fish balancing rule, they could legitimately disagree on how the balance was to be measured.

In order to reach agreement in 1985, the parties chose to finesse the equity point by putting off any decision on measurement. In a Memorandum of Understanding attached to the treaty, they acknowledged that "... it will be some time before the Commission can develop programs to implement the provisions of Article III paragraph 1(b) in a complete and comprehensive manner."[10] They nevertheless agreed that the commission should take the equity principle into account when establishing annual fishing regimes, and they expressed an expectation that if an imbalance occurred, there would be a "phased program to eliminate the inequity."[11] However, the parties established no specific time frame for such a phased program, nor any deadline for establishing an operational definition of an equitable balance. Their failure to firmly establish the content and role of the equity clause allowed it to become a major bone of contention when incentives to continue cooperation shifted.

For the first few years, the commission was able to side-step the equity issue because Canada remained satisfied that interceptions were roughly in balance. Attention focused, instead, on designing regimes that would encourage enhancement and conservation efforts by guaranteeing that the party making the investment would be able to reap the rewards from the *expected* subsequent increase in production. The regimes established by the commission relied heavily on the use of "ceilings." For example, the initial agreement specified that the Washington State harvest of Fraser sockeye was to be capped at 7 million fish over each of two successive four-year periods (Pacific Salmon Treaty, Annex IV, Chapter 4). This approach was based on the notion that capping harvests in the intercepting fishery would allow any increase in run strength to primarily benefit the nation of origin whose hatchery or habitat restoration investments had presumably caused the increase.

Prior to the conclusion of the 1985 treaty negotiations, it was believed (as has already been indicated) that the absence of a cooperative management arrangement had served to stall the implementation of enhancement projects, and other conservation initiatives, on both sides of the border. Each country feared that the other would "free ride" on the benefits arising from enhancement/conservation initiatives. This was one manifestation of the "Prisoner's Dilemma" (Munro and Stokes, 1989).

Thus the ceilings were seen as necessary to open the floodgates of enhancement and conservation. One interpretation of the equity principle, at least from the Canadian perspective, was that it would strengthen the needed assurance that those investing in the resource would enjoy the benefits of the investment. Shepard and Argue state that "the ...[equity] principle reflected the need to ensure that the country making sacrifices and expenditures to conserve its salmon would reap the benefits of its own efforts" (Shepard and Argue, 1998, p.2).

Munro and Stokes (1989) make a distinction between "baseline benefits" and "post-Treaty benefits." The former refer to economic benefits that would arise from the salmon fisheries in the absence of treaty-induced enhancement and conservation measures; the latter to economic benefits arising from those treaty-induced enhancement and conservation measures. The hope existed among the treaty negotiators that the latter would overwhelm the former (Munro and Stokes, 1989).

Nature, however, threw a monkey wrench into this scheme. While enhancement and restoration efforts certainly can increase the number of salmon available for harvest, the effects of such actions easily can be dwarfed by the impacts of natural environmental fluctuations. Survival and growth rates may vary considerably both over time and across areas due to variations in food availability, predation rates, and in-stream conditions. The feeding conditions and predation rates encountered during the first few weeks in the marine environment appear to be especially critical in determining the ultimate production of adult salmon from a given juvenile cohort (Pearcy, 1992).

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 later difficulties. In the mid-1970s, ocean*

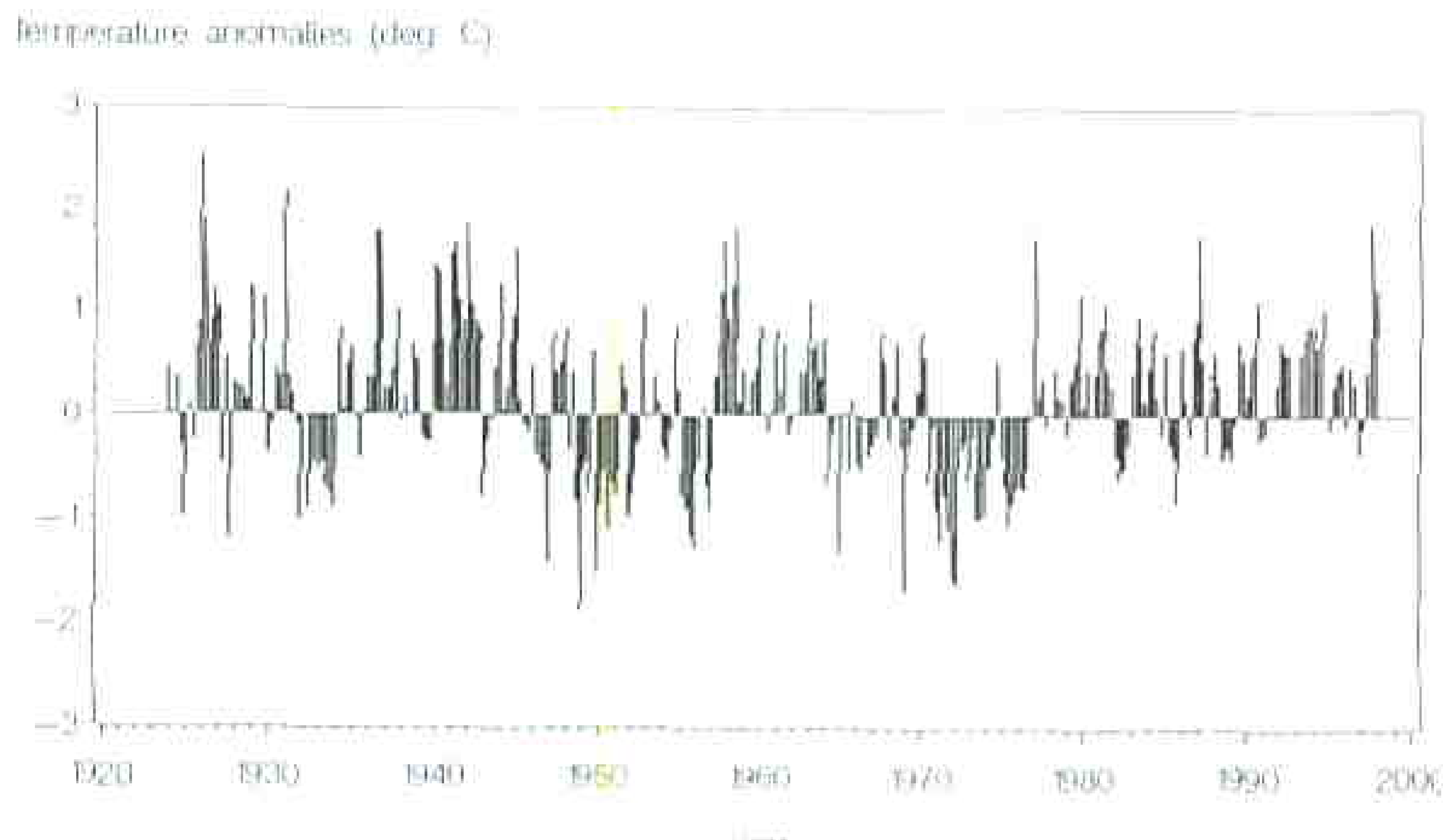


Fig. 3: Sea Surface Temperature Anomalies (deg. C)—Gulf of Alaska and B.C. Coast
Source: Courtesy of Mary Downton, National Center for Atmospheric Research, data set described in Downton and Miller, 1998.

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 (Figure 3). This shift may be part of a long-term pattern of inter-decade 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 (El Niño-Southern Oscillation) 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 ocean 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 British Columbia salmon smolts by increasing zooplankton productivity and, therefore, food abundance for juvenile salmon (Polovina *et al.*, 1995; Brodeur and Ware, 1992). Figure 4 displays the major currents and physical/biological domains of the northeast Pacific (Pearcy, 1997).

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, droughts in California and the Pacific northwest 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.

In the south, the natural sources of low salmon survival and stock productivity were compounded by other stresses, including habitat degradation, mortality at dams, water diversions, and questionable hatchery practices. The cumulative effects of all of these stresses severely weakened several Pacific northwest salmon stocks. In 1998 and early 1999, the U.S. National Marine Fisheries Service

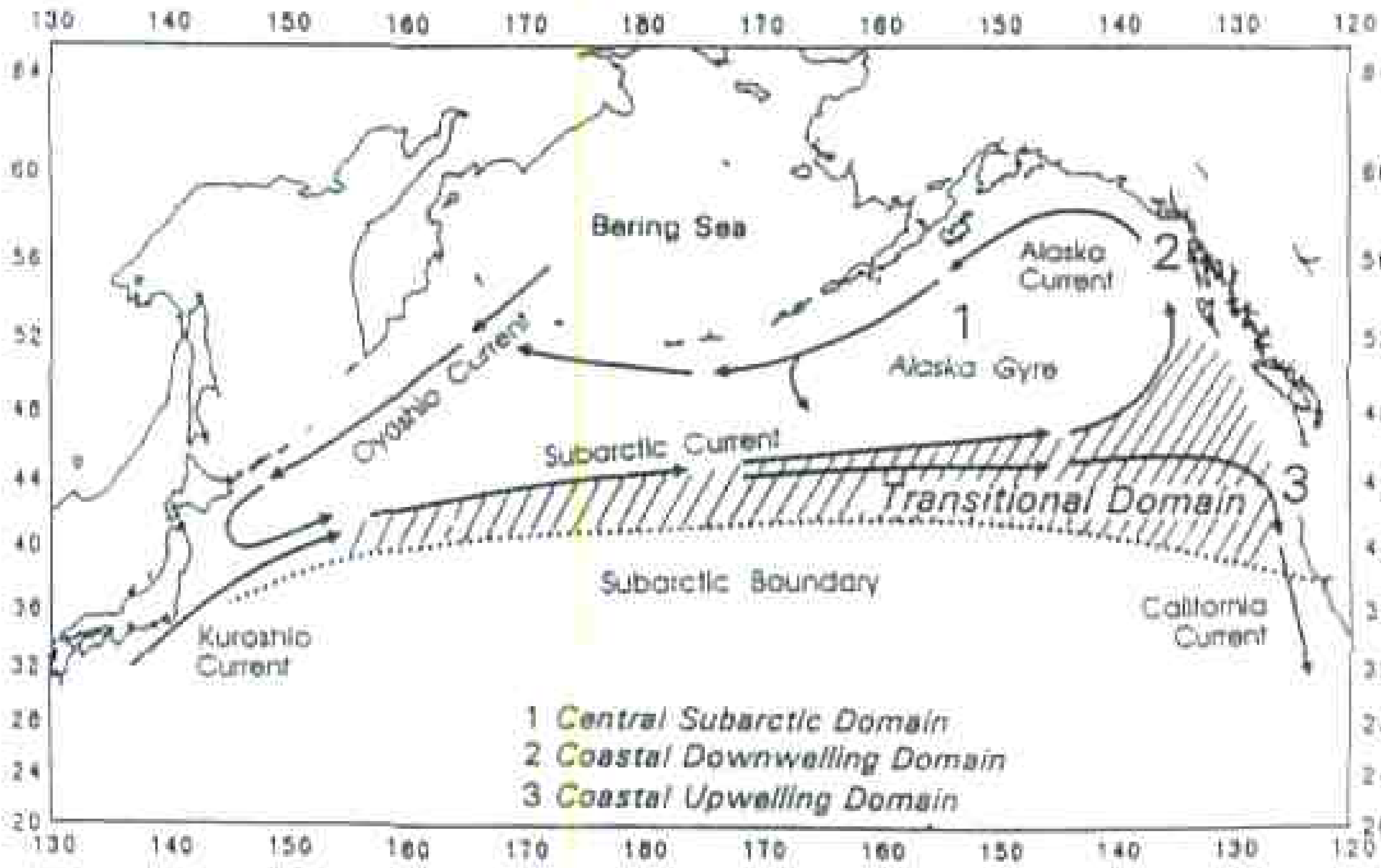


Fig. 4: *General Circulation and Salmonid Domains of the Northeast Pacific.* Source: Reprinted with permission from Pearcy (1997). The primary ocean feeding grounds for Pacific salmon are located in the CentralSubarctic Domain (where salmon are the dominant predators), and in the Transitional Domain (where they compete with several other species). The Coastal Downwelling Domain is the primary migration corridor for many juvenile salmon stocks. In the Coastal Upwelling Domain, the California current is a biologically rich system, but Pacific salmon are not a major component of the fish communities there.

substantially expanded the number of these stocks listed as "threatened" under the Endangered Species Act (U.S. Federal Register, 2000). The listings surely heightened the urgency of the negotiations that led to the 1999 agreement. Shortly after the apparent mid-1970s climatic regime shift, Alaskan salmon harvests entered a period of dramatic increase, rising nearly ten-fold from fewer than 22 million salmon (of all species) in 1974 to three successive record highs in 1993, 1994, and 1995 (Figure 5). At the 1995 peak, Alaska harvested close to 218 million salmon. Another high was attained in 1999 when Alaska harvested almost 217 million salmon (the second-largest harvest on record). Harvests of most salmon species in northern British Columbia also fared well through the mid-1990s, although British Columbia's chinook harvests have declined steadily (Hare *et al.*, 1999; PSC Joint Chinook Technical Committee, 1999), and by the late 1990s it had become apparent that many of British Columbia's southern and interior coho stocks were severely depleted (Pacific

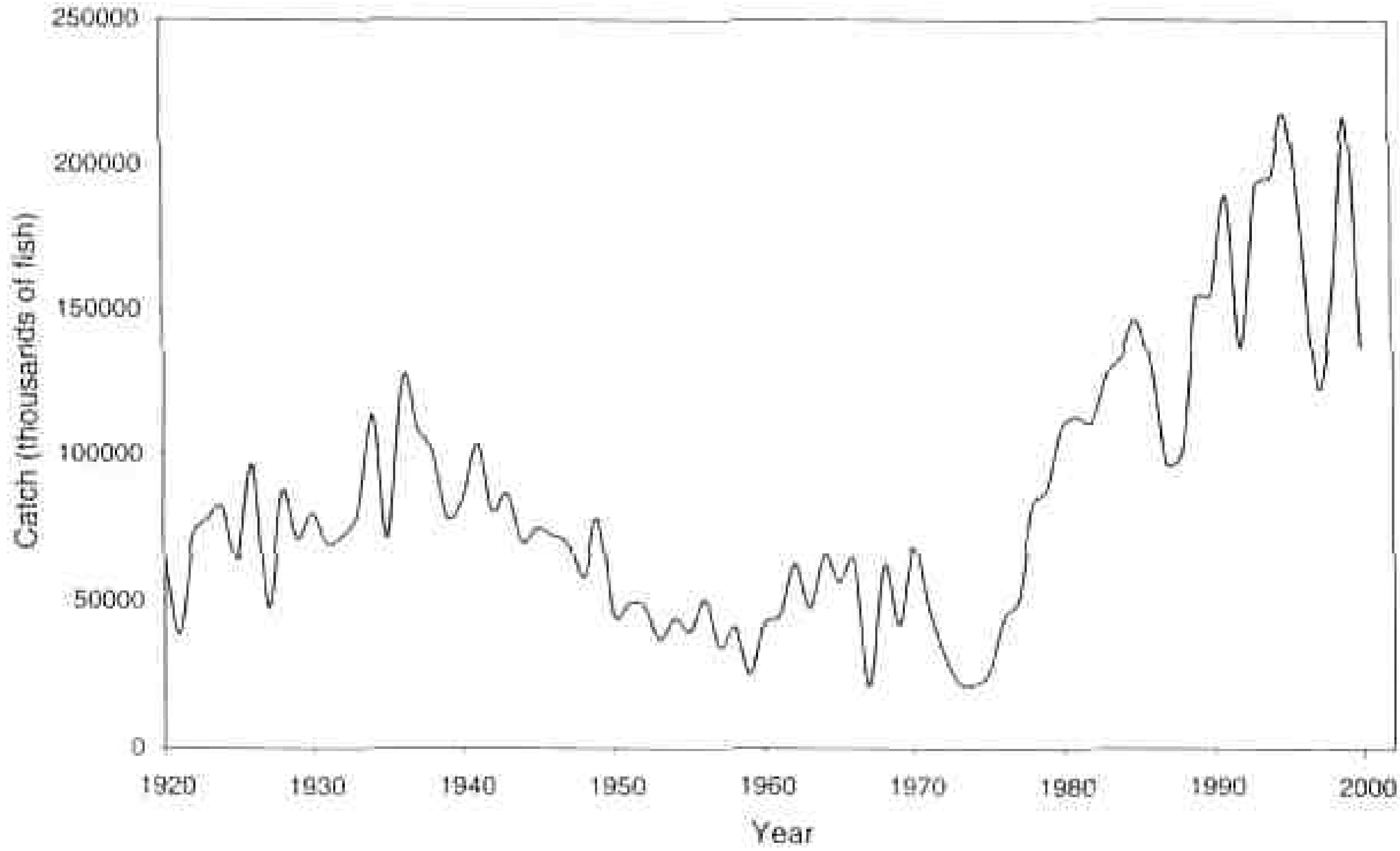


Fig. 5: Alaska Commercial Catch
Data Sources: http://www.cf.adfg.state.ak.us; NPFC, 1997-99; INPFC, annual series 1952-1992; Rigby *et al.*, 1991.

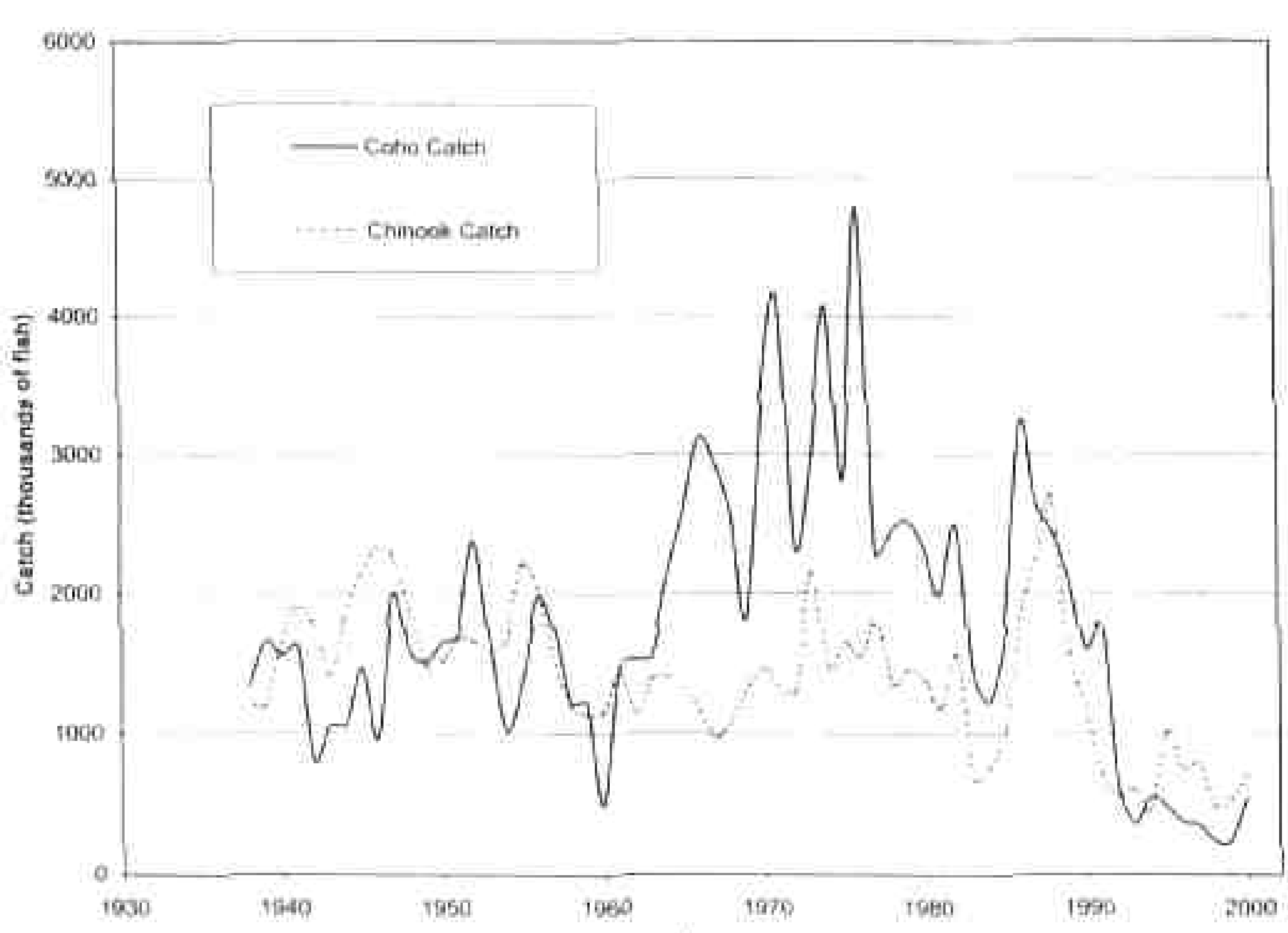


Fig. 6: Commercial Coho and Chinook Catch– Washington, Oregon, and California.
Data Sources: NPFC, 1997-1999; INPFC, annual series 1952-1992; INPFC, 1979; *Pacific Fishing*, Annual Yearbooks 1996-2000.

Fisheries Resource Conservation Council, 1999). Southward, 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 6). 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 7). 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.

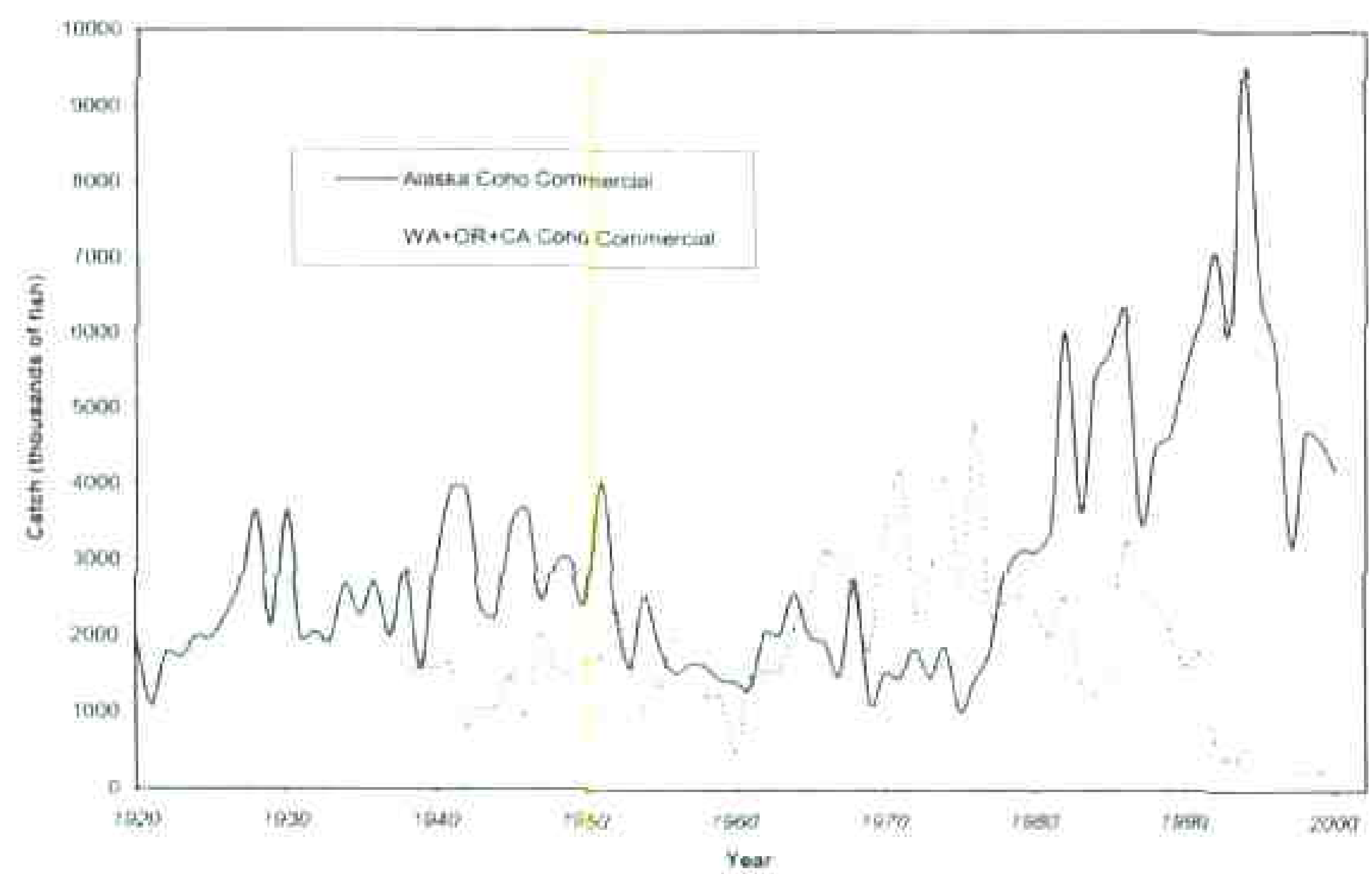


Fig. 7: Commercial Coho Harvests.
Data Sources: Alaska Dept. of Fish and Game data available at HtmlResAnchor http://www.cf.adfg.state.ak.us; *Pacific Fishing*, Annual Yearbooks 1996-2000; NPFC, 1997-1999; INPFC, Annual Series 1952-1992; INPFC, 1979.

The period of high productivity in Alaska induced Alaskan harvesters to fish harder in areas where British Columbian 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 British Columbia rivers.[12] 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.

The shift in the relative abundance of northern and southern salmon stocks made it increasingly difficult to satisfy the treaty's equity and conservation objectives while meeting each party's expectations regarding the benefits that it should be able to derive from its salmon fisheries. From Canada's perspective, there appeared to be a mounting interceptions imbalance in favor of the U.S., but little willingness on their part to make concessions to redress the imbalance. From Alaska's perspective, the requested concessions appeared likely to impose uncompensated costs on Alaska. While the southern U.S. jurisdictions demonstrated a willingness to make further concessions on their harvests of Fraser River salmon in exchange for reduced Canadian harvesting pressure on southward-bound coho and chinook, they really had few bargaining chips to bring to the table.

By 1993, the growing frustrations caused cooperation to collapse when the parties proved unable to agree on a full set of fishing regimes. The dispute escalated the following year when the Canadian delegation broke off the negotiations, charging that the growing interceptions imbalance was inconsistent with Canada's interpretation of the treaty's equity provisions and that the United States was not negotiating seriously. As the treaty dispute escalated, the Canadians, with little leverage over the U.S. parties, employed a variety of desperate tactics in an effort to force the U.S. back to the bargaining table. For example, in 1994, Canada tried to pressure the southern U.S. parties by pursuing an "aggressive fishing strategy." That effort 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 angry about increasing Alaskan harvests of B.C. sockeye 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).

The two federal governments made several efforts to resolve the impasse. These included enlisting a neutral third-party diplomat, Christopher Beebe of New Zealand, in a failed attempt to mediate the dispute; an attempt by Canada to use the scientific dispute settlement provisions in the 1985 treaty, which was rebuffed by the United States; a stakeholder process in which fishing interests on both sides of the border met to discuss options; and a joint report by two eminent individuals from each nation, David Strangway of Canada and William Ruckelshaus of the U.S., on the sources of the dispute and potential remedies. The Strangway and Ruckelshaus Report concluded that both sides would need to make concessions in order to restore cooperation, and that the parties should concentrate their efforts on developing a "practical framework for implementing Article III of the treaty [the Principles Article] leading to the establishment of longer-term fishing arrangements."[13] The report also advised the governments to undertake a comprehensive review of the Pacific Salmon Commission in order to make it "a functional institution for the preservation and management of the Pacific Salmon."[14]

As the dispute continued to fester, the condition of Canada's own fall chinook and coho stocks deteriorated (Pacific Fisheries Resource Conservation Council, 1999). This led Canada's Department of Fisheries and Oceans (DFO), the agency charged with managing Canada's fisheries, to impose stringent domestic controls on harvesting levels and methods. Canadian chinook harvests were scaled back sharply in 1995 and 1996; beginning in 1997, the DFO introduced radical changes in fishing regulations aimed at limiting further damage to a number of seriously depleted coho stocks. In 1998 the DFO established a zero-mortality goal for the stocks of greatest concern (Thompson River coho in southern B.C. and upper Skeena coho in northern B.C.) and required significant changes in fishing practices in all salmon fisheries where those stocks might be encountered (DFO, 1998a). At the same time, the agency announced an expanded fleet restructuring program to reduce the number of commercial fishing vessels relying on Pacific salmon (DFO, 1998b).

These actions also signaled a significant change in Canadian bargaining objectives with respect to bi-national harvest management. The Canadian focus shifted radically from insistence on an equitable interceptions balance to the need to tailor harvesting efforts to protect the stocks that had become severely depleted. The ESA listings in the Pacific Northwest most likely colored the positions of the southern U.S. participants in the negotiations as well.

If the equity principle was seen, in part, as being designed to ensure that the benefits from conservation and enhancement were properly apportioned, and if the reverse problem – resource depletion – had in fact become paramount, then the need for "equity" was obviously diminished. In any event, this shift in focus was instrumental in breaking the previous deadlock. Throughout 1998 and early 1999 federal negotiators from both sides worked to hammer out the details of the agreement adopted on June 30, 1999.

Prior to examining the details of this accord, it is worth re-emphasizing just how dangerous the situation had become before the signing, and how severe the consequences of failing to achieve an agreement might have been. Whatever the limitations we may point to in the following discussion, we would insist that the negotiators on both sides are to be strongly commended for having achieved the agreement. At an absolute minimum, it "bought time," allowing for the construction of a truly stable long-term cooperative management arrangement. The task at hand is to ensure that this opportunity is not squandered.

IV. WHAT HAS CHANGED?

In some respects, the 1999 agreement represents a dramatic break from the approach to negotiating harvest allocations embedded in the 1985 treaty. 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 12 years beginning in 1999, the U.S. share of Fraser River sockeye will be fixed at 16.5 percent of the TAC (total allowable catch). This represents a decrease from the post-1985 average U.S. share of 20.5 percent 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 aggregate abundance is depressed.[15]

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) aggregate abundance-based management (AABM) fisheries will be based on indices of the aggregate abundance of chinook present in the fishery, without specific reference to any individual stock; 2) individual stock-based management (ISBM) fisheries, which are primarily located in fishing areas near the spawning rivers, will be 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 was 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 two states. 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 agreement is contingent upon 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 U.S. installments have been approved. Canada also has made small contributions to the funds. Since the funds (at this stage) come overwhelmingly from the U.S., they can be viewed as implicit side payments.

The funds are to be managed by committees composed of representatives appointed by the federal governments of Canada and the United States. Both governments have made appointments, and preliminary meetings have focused on developing investment strategies for the funds. The role of the fund management committees in determining the allocation of fund proceeds will be relatively minor until significant investment earnings are realized. Therefore, it will likely be several years before the effectiveness of their operations can be fully evaluated.

A more immediate issue will be the extent to which the parties succeed in implementing effective abundance-based management regimes. By moving to the abundance-based approach, they have acknowledged the need to take natural changes in stock abundance into account when dividing the available harvest. Under the ceiling-based approach, the nation of origin either reaped the reward or bore the brunt of any natural fluctuations in abundance. The approach was asymmetric in terms of its effectiveness. It worked well when stocks were increasing. It worked badly when stocks were declining. When the stocks were declining, those upon whom the ceilings had been imposed saw no reason to fish below the ceilings, particularly since they anticipated no rewards for such sacrifices.

Under abundance-based management, the risk is to be shared according to the agreed-upon formulas. The risk-sharing arrangement, which carries with it the promise of reward from sacrifice to both parties, will hopefully prove to be symmetrically effective in times of decreasing or increasing abundance, thereby lessening interception pressure on depressed stocks. While abundance-based management is a relatively new philosophy in the context of international salmon harvest allocation, all jurisdictions have experience in basing at least part of their internal harvest regulations on indicators of abundance. In the international context, however, significant challenges will be posed by the general lack of timely and accurate abundance indicators to which all participants can agree.

The difficulty of forecasting run strength and accounting for changes over time in the stock composition of harvests will likely be the most challenging technical problems for implementation of abundance-based management. In anticipation of those challenges, the agreement identifies improved scientific cooperation as an important goal. To that end, it calls for enhanced exchange of information and scientific cooperation and requests that the Pacific Salmon Commission establish a committee on scientific cooperation to monitor progress and to provide guidance on the distinction between technical and policy issues.

While the equity issue has not entirely disappeared, it has been placed on a "back burner." In the letter of conveyance attached to the new agreement, the chief negotiators proposed that "...compliance with this Agreement shall constitute compliance by the Parties with their obligations under Article III of the Treaty."[16] This means that if abundance-based regimes are implemented in a manner deemed to be consistent with the spirit of the agreement, then the ensuing division of the harvest shall be considered as satisfying the treaty's equity language.

V. GOALS, GAMES, AND SHIFTS IN COMPETITIVE ADVANTAGE

Before proceeding to evaluate the new agreement's prospects for success, let us return to the discussion of game theoretic concepts and their application to Pacific salmon management. We have noted that both individual rationality and notions of equity will affect the strategies of parties bargaining over the management of transboundary resources, and that incentives to cooperate can shift over time. Here, we shall use a comparative-static graphical analysis to investigate the effects of shifts in competitive advantage and the significance of tensions between competitive advantage (individual rationality) and notions of equity. (Compare Munro *et al*, 1998, and McKelvey and Miller, 2001.) We shall then turn to an examination of the destabilizing effects of random environmental fluctuations, including unanticipated regime shifts, especially when managers' forecasting ability is limited (Golubstov and McKelvey, in preparation; McKelvey, 2001; McKelvey and Cripe, 2001).

A centrally important point that is often missed or misunderstood in discussions of international fishery treaties is that *cooperation is not a zero-sum game. Not only can cooperative management* result in larger sustained yields, but changing the allocation of fish among the parties also can be beneficial. To understand why the allocation problem is not zero sum, one must realize that the value of an additional fish to either party is not constant. Rather, the first increments allocated to either party are likely to be used to serve important conservation, cultural, and recreational uses. As more fish become available, the value of each additional fish declines.

Figure 8 illustrates a simple two-party game. The curved line in this figure is the Pareto boundary, which describes a set of harvest allocations satisfying the Pareto condition discussed above, in the case in which there are no side payments. The Pareto boundary has a convex shape (i.e., bulging upward at its center). Near the upper-left-hand 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 value to party 2 grows, more than offsetting the former's decline. The total payoff to the binational community, U_1+U_2, will be maximized at some cooperative mix of shared landings.

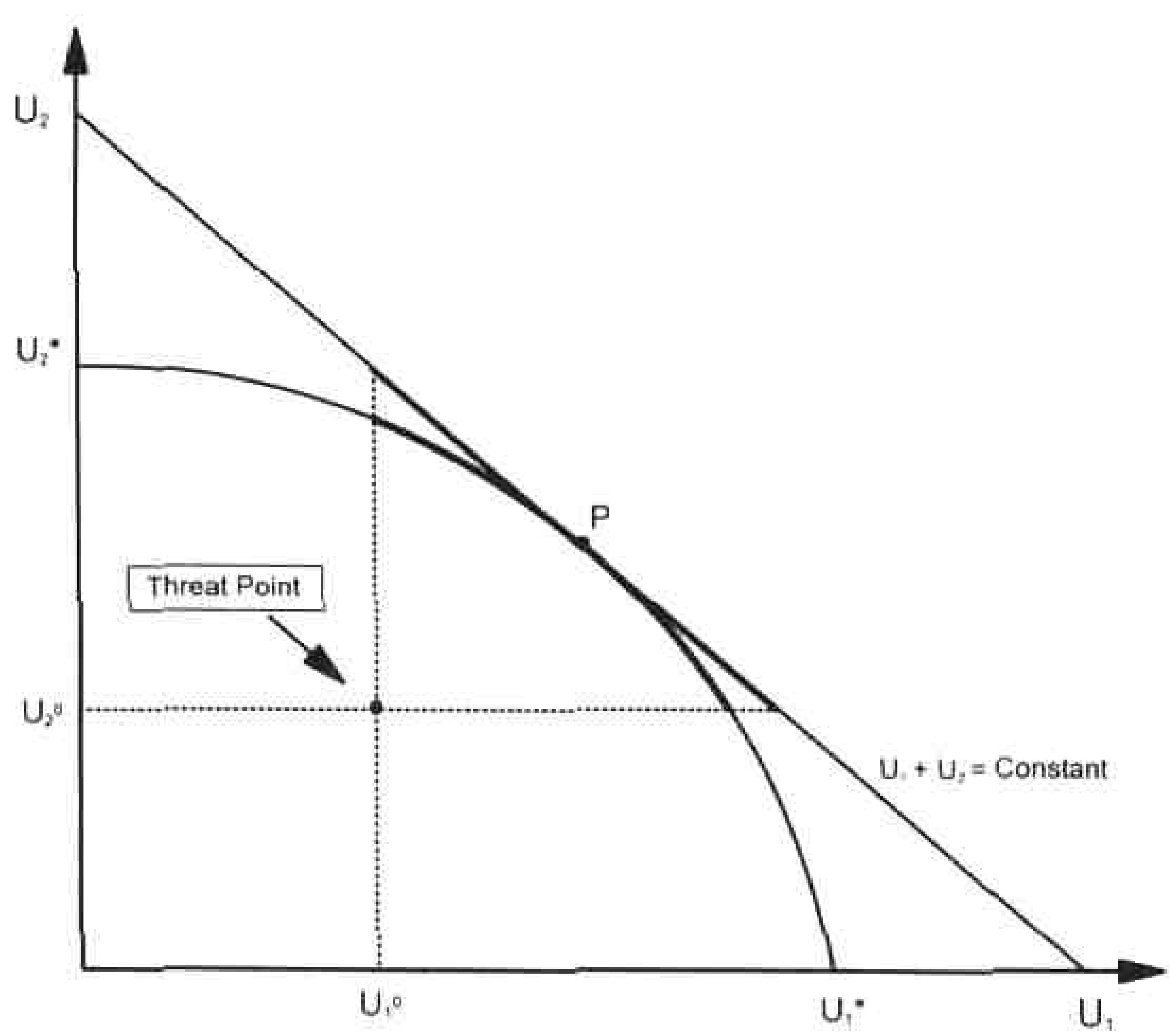


Fig. 8: Two-Party Fisheries Game

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.

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, suggesting the existence of many joint harvesting arrangements that are preferable to the non-cooperative threat point. Second, if the parties' levels of well-being $[U_{1}, U_{2}]$ are given equal weight, then there is one coordinated management arrangement which maximizes total community utility (well-being). 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 to 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' levels of well-being and satisfy their individual rationality. Until recently, U.S. and Canadian negotiators only considered options in which the benefits accruing to each nation depended on its own harvests, thus effectively constraining the bargaining set to a subset of the possible arrangements.

Now we 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 9. For simplicity assume that side payments are not considered within the bargaining framework (as has been the historical case for the Pacific Salmon Treaty). Suppose that the threat point is initially at T^0 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

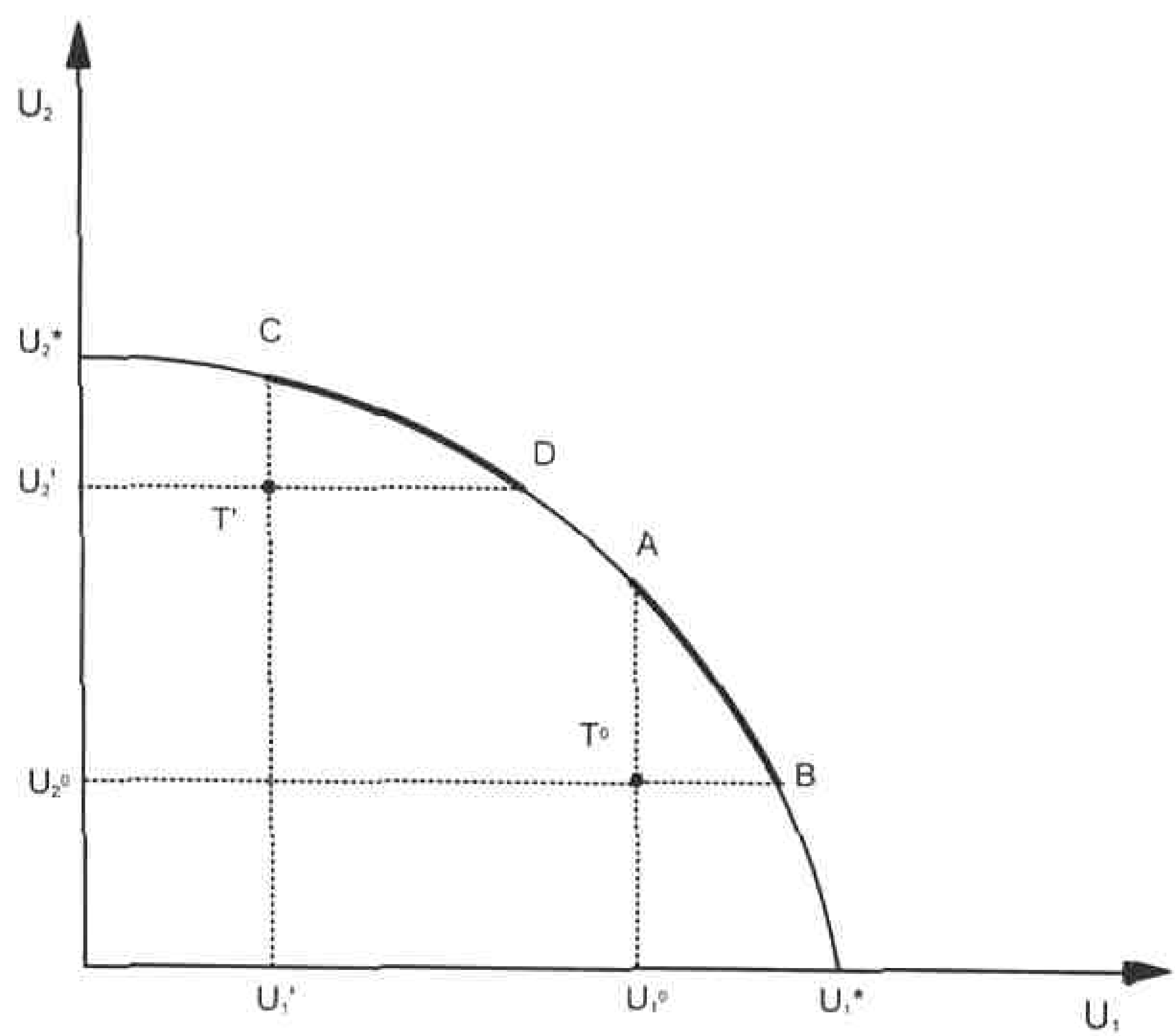


Fig. 9: Game with Shift in Threat Point and No Side Payments

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 (i.e., to the new threat point). 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 would occur.

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

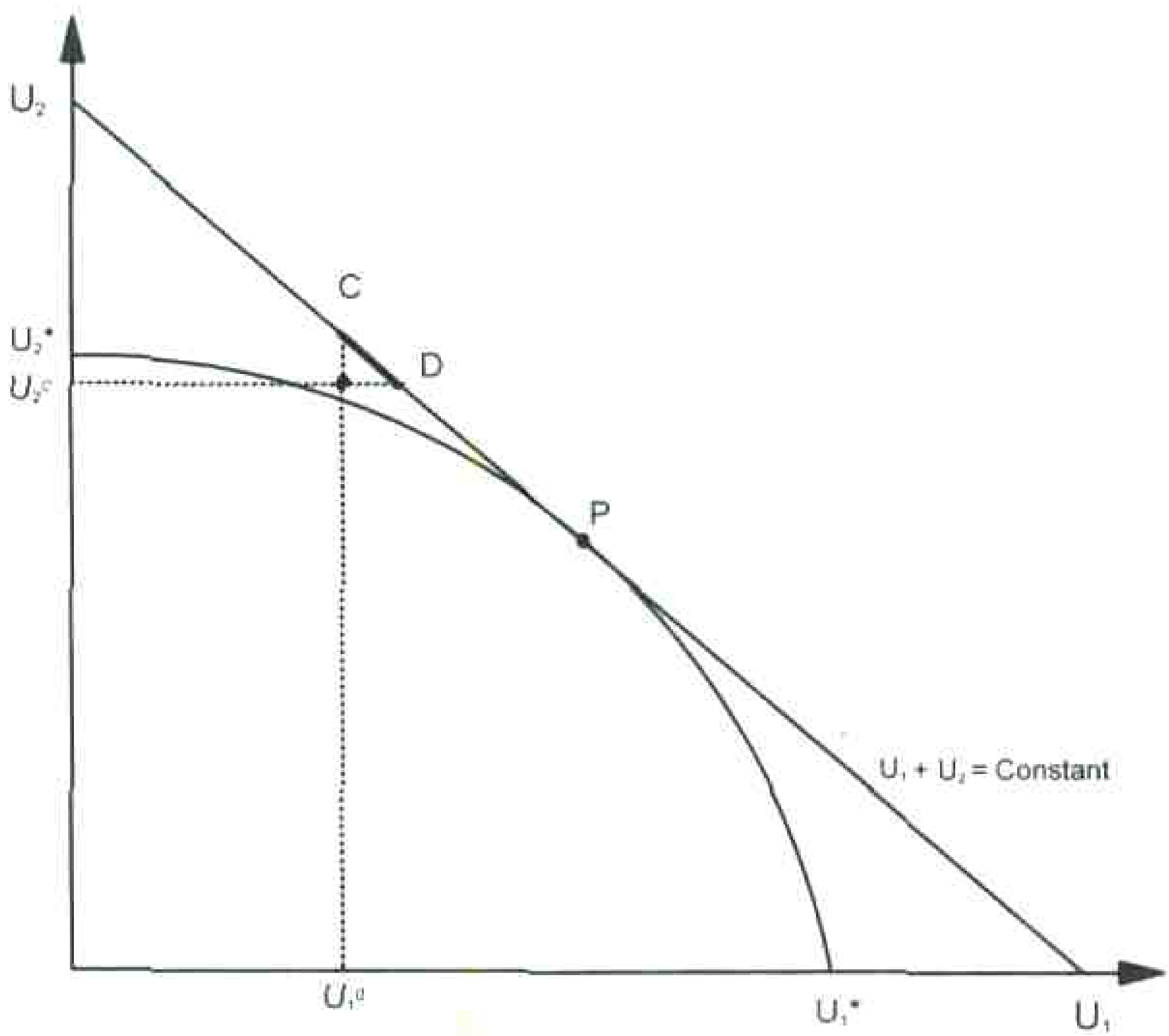


Fig. 10: Game in which Cooperation Requires Side Payments

harvest agreement, the new threat point could lie above the Pareto frontier, as depicted in Figure 10. 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 $[U^{a}_{1}, U^{a}_{2}]$ in Figure 8. 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" and the others collectively as "party 1," this situation would be analogous to a shift in the threat point from a position like T^0 to T^1 in Figure 9 or perhaps even to a point such as that depicted in Figure 10.

Canada's bargaining position *vis-à-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 have enhanced British Columbia'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 ignored was a central feature of the recent dispute.

When the parties signed the 1985 treaty, Canada implicitly assumed that it would be able to balance Canadian harvest of Pacific northwest chinook and coho against the U.S. 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, and by the lack of flexibility in the existing treaty arrangements. It would have been easier to maintain the intended equity balance if side payments (monetary or in-kind) or cross-border access arrangements had been considered.

Now let us turn to the effects of uncertainty in such a bargaining situation. Neither party can perfectly foresee future environmental changes affecting stock productivity or return migration paths. Decisions, thus, are based on partial information and a limited ability to forecast the consequences of current actions. In this context, the amount of information available can make a big difference for the sustained health of the resource and economic returns to the competing fleets. Who has the information also matters, and situations where the parties possess different kinds or levels of information (situations of "asymmetric information") are of particular interest.

Up to now, the effects of uncertainty on transboundary fisheries management have been relatively little studied empirically. However, some interesting insights into the management of uncertainty can be gleaned from recent theoretical studies of an idealized model, the so-called Competitive Split-Stream Model (McKelvey, 2001; McKelvey and Cripe, 2001). This is a stochastic dynamic model, (i.e., the resource changes over time in response to previous harvests and random environmental variability) based loosely on the characteristics of the Fraser River sockeye fishery. It is intended to capture the mechanisms of competitive harvest decision-making under circumstances of uncertainty similar to those present in the 1994 Fraser sockeye fishery. That year, Canada returned to an aggressive fishing strategy in an effort to limit U.S. access to the Fraser sockeye stocks, but misapprehended the strength of the Johnstone Strait diversion, leading to serious over-harvesting of the late run of Adams River sockeye (Fraser River Sockeye Public Review Board, 1995). In fact, the split-stream model seems quite robust and thus relevant to any number of competitive harvesting situations under circumstances of incomplete and asymmetric information.

The stochastic split-stream fishery model is explicitly dynamic and examines the idealized population dynamics of a harvested anadromous fish stock. In each harvest season, the mature fish stock (constituting the "recruitment" to the fishery) returns to the nursery stream to spawn, while being harvested along the way. More specifically the fish run, returning to the river-of-spawn, splits into two parallel streams, each accessible to harvest by only one of two competing fishing fleets. Following their separate harvests, the residual stock runs once again merge (to form the "escapement") and then finally spawn. The young (offspring) generation subsequently migrates back to the sea, eventually forming a new season's recruitment. The size of this offspring recruitment depends on both the size of the parental spawning-stock escapement and also on the oceanic survival of the young. It is expressed through a "stock-recruitment relation" which incorporates both. Following recruitment, the cycle repeats.

During a fishing season each fleet is modeled as choosing a level of harvest that is designed to optimize its expected long-run payoff from the fishery, given the likely actions of the other fleet. This requires achieving an appropriate balance between the fleet's immediate harvest and the expected contribution of its escapement to subsequent recruitment. In making its harvest decision each fleet must also form an expectation of its competitor's harvest policy and of the total escapement that will thus result.

In this stochastic model, the proportions of the run entering each stream and the specific stock recruitment relation will change annually, their fluctuations being dependent on oceanic environmental conditions. Furthermore, the harvesting fleets have only limited ability to predict these randomly varying phenomena. For example, though a fleet may observe the size of the partial stock run in its own exclusive-harvest stream, it may not have the information necessary to infer the separate factors – the total recruitment and stream-split proportions – which have led to it. Thus the fleet has only an uncertain estimate of the overall escapement that its policy, together with that of its competitor, might achieve. Miscalculations in choosing harvest levels may easily lead to a significant overharvest of potential spawners and hence to a severe depression in the stock size of the offspring generation. From this illustration it might appear that increasing the level of environmental information should increase the precision of harvest decisions, and that this would contribute to the profitability of the fishery. Indeed, this is always true in a fully cooperative fishery.

The value of forecast information in a competitive fishery is much less clear. It can go either way, in the sense that the additional information may be beneficial, *or* it may be harmful (Golubtsov and McKelvey, in preparation). In some cases – for example when there is great inter-annual variability in the "split" – the payoffs to equally informed competitors may increase when more information becomes available. The explanation lies perhaps in the fact that blunders by either party can harm the resource to the detriment of both parties in the long term. In such a case, information transparency, including cooperative research to improve forecasts of abundance or migratory behavior, could be mutually beneficial even in the absence of full cooperation. On the other hand, there are cases in which additional information will simply intensify the destructive competition, with the consequence that the payoffs to both players will be reduced (Golubtsov and McKelvey, in preparation). This outcome may be thought of as yet another dimension of the ubiquitous open access tragedy of the common.

The case of asymmetric information is even more complex, and clear predictions of the effects of improved information cannot be made. Rather, outcomes will depend on the values of the parameters describing the behavior of the resource and variations in the characteristics of the competitors themselves (e.g. levels of risk aversion, preferences for future as opposed to current returns, sensitivity of harvesting costs to changes in abundance).

In many cases, when one party has more information than the other, that privately held information can powerfully increase the favored fleet's competitive advantage over its rival (and thus its bargaining strength in negotiations over terms of potential cooperation). The more knowledgeable fleet can often use its private information to leverage advantages of other sorts (e.g., if the run-split normally favors it). In this case, that fleet will have a strong incentive to withhold its private information from its rival, or to exact a sizeable price for making it public. If the rival has equity rights to the stock, institutional arrangements can be designed to minimize the cost of making public this private information. (See McKelvey, 1997, for an illustration involving private information of harvest costs.) Obviously, if the favored fleet receives additional information, which it is able to keep private, the greater will be its advantage.

However, there also are cases in which the mistakes of an uninformed competitor may cause both parties to suffer when information is withheld. If that result is likely, a fleet with private information may well benefit by making its private information public! Clearly, if the favored fleet has more private information, the benefits it will enjoy by releasing hitherto private information to its competitor will be increased (McKelvey and Cripe, 2001).

Plainly, uncertainty and incomplete information – pervasive features of many fisheries – can vastly complicate and potentially destabilize arrangements for cooperative fishery management, essentially by altering the balance of competitive strengths. Thus the threat point in any negotiation for sustained cooperation can be expected to shift, and to do so repeatedly. The challenge, then, is to create institutional arrangements for cooperation that are flexible and robust against random regime shifts. In the following section we attempt to lay down some of the features that such an agreement must entail.

VI. DESIGNING AGREEMENTS FOR COOPERATIVE JOINT MANAGEMENT

These conceptual and mathematical models, together with other perspectives on competitive behavior (see e.g., Barzel, 1989; Eggertsson, 1990; Young, 1999) suggest a set of elements that should be incorporated in the design of transboundary fishery agreements:

- Both individual rationality and perceptions of equity must receive consideration in determining the initial distribution of benefits under an agreement.

- The scope for bargaining should be as broad as practicable. For example, it should be possible to consider values other than commercial harvests, and those broader interests should be integrated into efforts to achieve an acceptable bi-national balance of benefits.

- An agreement must reward participation so that no party is asked to make uncompensated sacrifices.

- The agreement should separate the distribution of benefits from current harvest decisions.

- The agreement should reward investment in the resource by basing adjustments in long-term "ownership" shares on demonstrated beneficial impacts of such investment.

- The agreement should maintain flexibility to alter harvesting patterns quickly in response to new information about the state of the shared resources.

- The allocation of current benefits should not be sensitive to uncertainties regarding stock assessments. In other words, neither party should be able to gain by hiding information, delaying a determination of stock abundance, or by disputing the estimates.

- The cost of fishery management should be reasonably small relative to the value of the fishery.

VII. SUCCESS OR FAILURE?

The 1999 Pacific Salmon Agreement represents a "re-framing" of the bi-national fishery management problem. Conservation concerns have jumped to the forefront, while allocation issues have faded into the background (Waldeck and Buck, 1999; McDorman, 2000). In many respects, this shift in focus was a natural outcome of concerns that had been mounting domestically on both sides of the border. In another respect, the shift was strategically necessary to break the previous impasse.

One way to think about the prospects of the new agreement is to consider the extent to which this apparent change of heart is real, permanent, and broadly shared. If so, how well does abundance-based management serve the conservation agenda? If payoffs to the commercial fishing sector are still a central goal lurking behind the conservation veneer, will the new abundance-based approach lead to harvest allocations that participants will view as "fair"? In either case, can this new agreement achieve the kind of balance between individual rationality and notions of entitlement that our analysis suggests will be needed?

While abundance-based management is meant to respond to the problem of fluctuating stock abundance, the formulas appear to be designed primarily for biological conservation. As such, the problem of instability in incentives to cooperate does not appear to have been much affected. This might be a small problem if the two nations really have changed their minds about the kinds of benefits that they want to derive from their salmon resources.

Certainly, in the U.S. Pacific Northwest, the aesthetic and cultural value of salmon returning to spawn in their natural habitats, and vibrant sport fisheries, are now widely viewed as more important than maintaining commercial harvests. A similar shift in attitudes appears to have occurred in parts of British Columbia. Furthermore, in the U.S. Pacific Northwest, the legal mandate to protect and restore salmon populations listed as threatened or endangered under the Endangered Species Act will continue to play a powerful role in shaping fishery management practices and bargaining objectives.

In both British Columbia and the Pacific Northwest, efforts to protect or increase aboriginal harvests are also playing a role in redefining the objectives of fisheries management. In British Columbia, the reallocation of harvest share to aboriginal communities appears to serve several objectives. In addition to redressing past injustices, moving a portion of the Canadian harvest from the offshore commercial fleet to in-river aboriginal fisheries may increase the net economic value of the harvest by reducing harvesting and monitoring costs, while promoting conservation of weak stocks and reducing Canadian interceptions of U.S. stocks (Schwindt, 1995; Link and English, 1998). If so, it would appear to be in the interest of both nations to encourage this Canadian domestic reallocation.

The objectives of Canada and the southern U.S. parties in the international bargaining arena appear to reflect these shifting domestic agendas. In Alaska, on the other hand, the commercial fishing sector is still the dominant concern. Alaska's fishery managers and representatives on the Pacific Salmon Commission and its panels remain focused on protecting the interests of Alaska's commercial salmon harvesters.

These divergent objectives are, to some extent, accommodated under the 1999 agreement. For example, under the chinook abundance-based regimes, allocations for Alaska's commercial troll fishery and northern B.C. commercial fisheries depend on aggregate measures of abundance, while the ISBM rules applied to more southerly fisheries are tailored to promote conservation of weak and endangered stocks. This accommodation can be viewed as an effort to balance Alaska's individual rationality position against evolving concepts of the equity positions of the other parties.

For coho fisheries, on the other hand, there has been little progress to date on developing a mutually acceptable set of abundance-based regimes. Since the coho fisheries in B.C. and the southern U.S. jurisdictions remain largely closed, the only current tensions are in the northern area, where joint coho management is complicated by the fact that most of Alaska's coho stocks are healthy and able to withstand higher exploitation rates than some of the intermingled B.C. stocks. While most of Alaska's coho do not have to traverse long distances in the freshwater to spawn, many of the weaker B.C. stocks spawn far inland and consequently have lower inherent productivity rates due to in-river mortality. So for coho, divergent conservation versus harvest goals still present challenges to effective joint management.

There is language in the new regimes for the Transboundary Rivers and Northern Boundary area that is intended to clarify accounting of the harvest balance and its relationship to domestic conservation measures.[17] The Northern Boundary regime calls for cumulative accounting and payback of "overages" and "underages", with balances to be carried forward in the event of failure to renew the regime at its expiration. The Transboundary Rivers regime further specifies that "if a shortfall in the actual catch of a party is caused by the management action of that Party, no compensation shall be made"(Annex IV, Ch.1, para. 4). This particular provision appears to address Alaskan charges that part of the alleged interceptions imbalance had been due to inept Canadian efforts to manage Canadian harvests of weak stocks intermingled with abundant stocks.

The shift in focus toward conservation has not eliminated competition over harvests, but it does represent a broadening in the scope for bargaining. Although the treaty language always promoted conservation, until recently it appeared that the implicit goal of conservation was solely to enhance future commercial salmon harvests. There now appears to have been a fundamental redefinition of the purpose of conservation: it has ascended to the position of a goal in its own right, serving species preservation, biological diversity, and maintenance of cultural and aesthetic values. Attention to these values allowed the scope of bargaining to extend beyond the previous focus primarily on payoffs to the commercial (and to a lesser extent, sport) fishing sectors.

The Endowment Funds also may serve to expand the scope for bargaining. In addition, they may provide a vehicle to reward cooperation and to separate the division of benefits from the division of the harvest. By calling on the United States to provide the initial capitalization of the Endowment Funds, the 1999 agreement implicitly treats them as a type of side payment from the U.S. to Canada. 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).

The amount of money currently committed to the funds is quite small in relation to the overall value of the fishery, and their annual yields will be small in relation to the debt that some Canadians claimed should be paid by the U.S. for accumulated harvest imbalances. Nevertheless, this vehicle should be considered as a positive first step. At the very least, the side-payment aspect of the Endowment Funds sets a precedent that may work to overcome a long standing resistance on the part of many Canadians toward taking monetary payments in lieu of fish to achieve an equitable balance of fishery benefits.

The principle that investment in the resource should be rewarded is partially addressed by the new agreement because, if an investment results in increased future abundance, all participants will benefit. In the short term, such benefits would be shared according to the abundance-based formulas rather than being reserved exclusively for the home nation. This had been the case under the previous ceiling-based approach. Over the longer term, it should be possible to revise the abundance-based formulas to reward investments that demonstrate sustained positive impacts on stock levels. In addition, the abundance-based formulas themselves could be "tilted" to favor the home country when abundance increases, thus providing an incentive to maintain and improve spawning habitat. Because not all of the formulas have been worked out in detail, the extent to which the allocation rules will reward investment is not yet clear.

As an aside, it can also be noted that abundance-based management could be expected to lead to cross-border resource investment. If Americans (Canadians) stand to benefit from resource investment in Canada (U.S.), then incentive for such investment will obviously be there. Cross-border resource investment carries with it the flavor of the original Fraser River Convention. It is true that the Convention fell into disfavor in Canada in the 1960s. The problem was not that the principle of cross-border resource investment was inherently flawed; it was, rather, that the division of the benefits was perceived as being "unfair."

Given that conservation is the central thrust of the 1999 agreement, its ultimate success will hinge largely on the extent to which the parties can effectively implement the abundance-based regimes that already have been worked out, and on whether or not they succeed in devising workable arrangements for coho. Effective implementation of the regimes will require agreement on abundance measures and accounting methods as well as the ability and willingness to adjust fishing efforts in response to new information regarding abundance and actual harvests. Some "bumps in the road" seem inevitable because forecasts of abundance are imprecise, and it is difficult to tailor fishing openings and regulations to achieve precise harvest targets. Provisions in the agreement for making up overages and underages in subsequent years are meant to address some of this imprecision, but the general lack of specific deadlines for eliminating imbalances provides an opening for abuse.

Larger problems may arise if there is failure to come to consensus on the actual measures of abundance (McDorman, 1998b). Already, there have been some disagreements between Alaska and the Chinook Technical Committee (CTC) regarding the abundance estimates to be applied in determining allowable chinook harvests (ADF&G, 2000). The abundance estimates generated by the CTC's chinook model are very sensitive to the data used to calibrate the model, and when a recalibration alters the abundance indices, catch limits are to be adjusted accordingly.[18] Last year (2000), Alaskan officials disputed the results of a recalibration that would have called for significant reductions in Alaskan harvests. Efforts are under way to re-assess and improve the forecasting model. However, for chinook, as for all of the other salmon species, the ability to forecast abundance and the stock composition of the fish harvested in any particular area is hampered by data inadequacies and by the uncertain and uneven impacts of variable marine and river conditions. Therefore, precise estimates are likely to remain an elusive goal. The best that reasonably can be expected should be mutual willingness to accommodate uncertainty and to share the risks arising from imprecise abundance estimates. However, given that the incentive structure remains basically unaltered, scientific uncertainties may loom larger than ever as a source of conflict.

Data inadequacies are also the primary impediment to developing abundance-based regimes for coho. In Canada, active coho management only began within the past few years, and the data and models that would be needed for workable abundance-based formulas are generally lacking. An alternate approach may be to forego the development of precise allocation rules and to agree instead on statements of management intent. These would define the types of actions to be taken by each party as a function of the available information on stock status.

Abundance-based management will be data intensive. As such, it is not likely to provide a path to low-cost joint management. This aspect of the agreement is troublesome because, by some estimates, the costs of administering some of the commercial fisheries for Pacific salmon are already very high relative to the value of the commercial catch (Schwindt *et al.*, 2000).

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 relatively little to resolve long-standing differences over the division of benefits. In fact, some Canadians continue to worry that Canada will come out short under this agreement, and they have labeled it "profoundly disappointing" (Culbert and Beatty, 1999). 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. In addition, the greater need for scientific consensus implied by this approach either could prove to be a serious stumbling block or an avenue to a clearer joint vision of appropriate harvesting patterns.

The vagaries of nature and of the market for commercially caught salmon might work either to soften or exaggerate the remaining tensions. If recent trends in stock productivity are reversed, the abundance-based regimes may allow rapid rebuilding of the currently depleted stocks and lead to an interceptions balance satisfactory to even the most skeptical Canadian observers. If not, or if the north/south contrast in stock productivity worsens, the results of this experiment may prove to be disappointing.

In addition, the impacts of two decades of explosive growth in farmed salmon production on the prices for marine-caught salmon might hasten the decline of commercial harvesting in all but the most productive areas, perhaps further altering the management objectives of the parties to the treaty. Munro *et al.* (1998) discussed the growth of salmon aquaculture production and its implications for marine-caught fishery salmon production. On the basis of then-

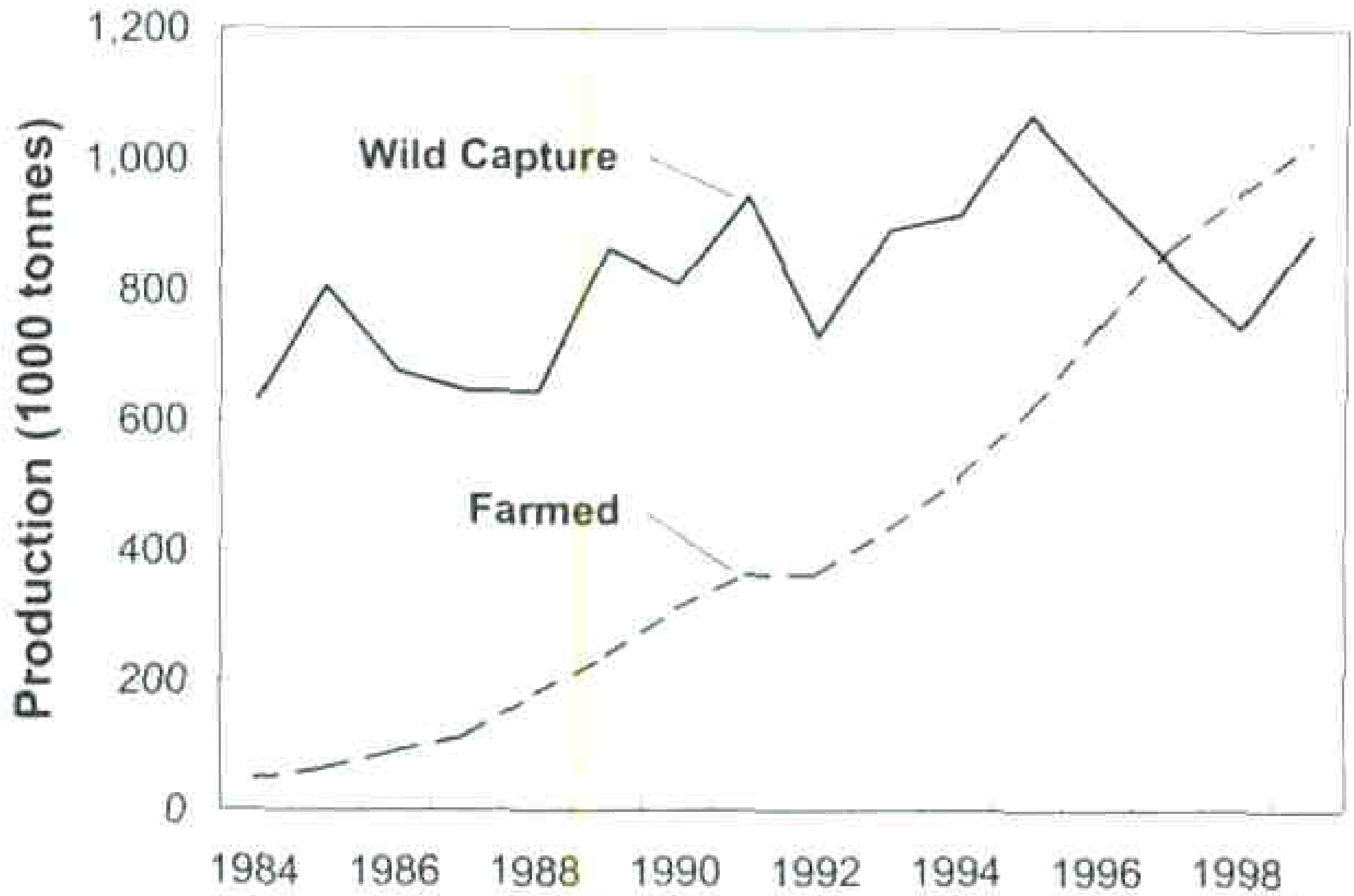


Fig. 11: World Salmon Capture Fisheries Landings and Marine-Based Farmed Salmonid Production
Data Sources: FAO data files downloadable from http:///www.fao.org/fi/statist/fisoft/fishplus.asp. Real price of frozen U.S. sockeye in the Japanese market derived from data reported in the FAO salmon commodity update of September, 2000, available at http:///www.globefish.org.

available data, they made projections of future marine-caught fishery and aquaculture production of salmon worldwide. These projections led them to predict that aquaculture production would surpass marine-caught fishery production between 2005 and 2010. Figure 11 reveals that the Munro *et al.* projections were far, far too conservative. The salmon production "crossover" had actually occurred *before* Munro *et al.* was published in 1998!

Figure 12 shows the steady increase in world salmon production over the past decade and a half, an increase due very largely to aquaculture (Figure 11). Figure 12 shows, as well, that the increase in salmon production has been accompanied by generally declining prices for frozen wild-caught sockeye in Japan (the principal market for those fish). Reports for the 2001 fishing season indicate that prices for wild-caught Pacific salmon are continuing to plummet (Warren and Chambers, 2001). A recent study confirms that there is a high

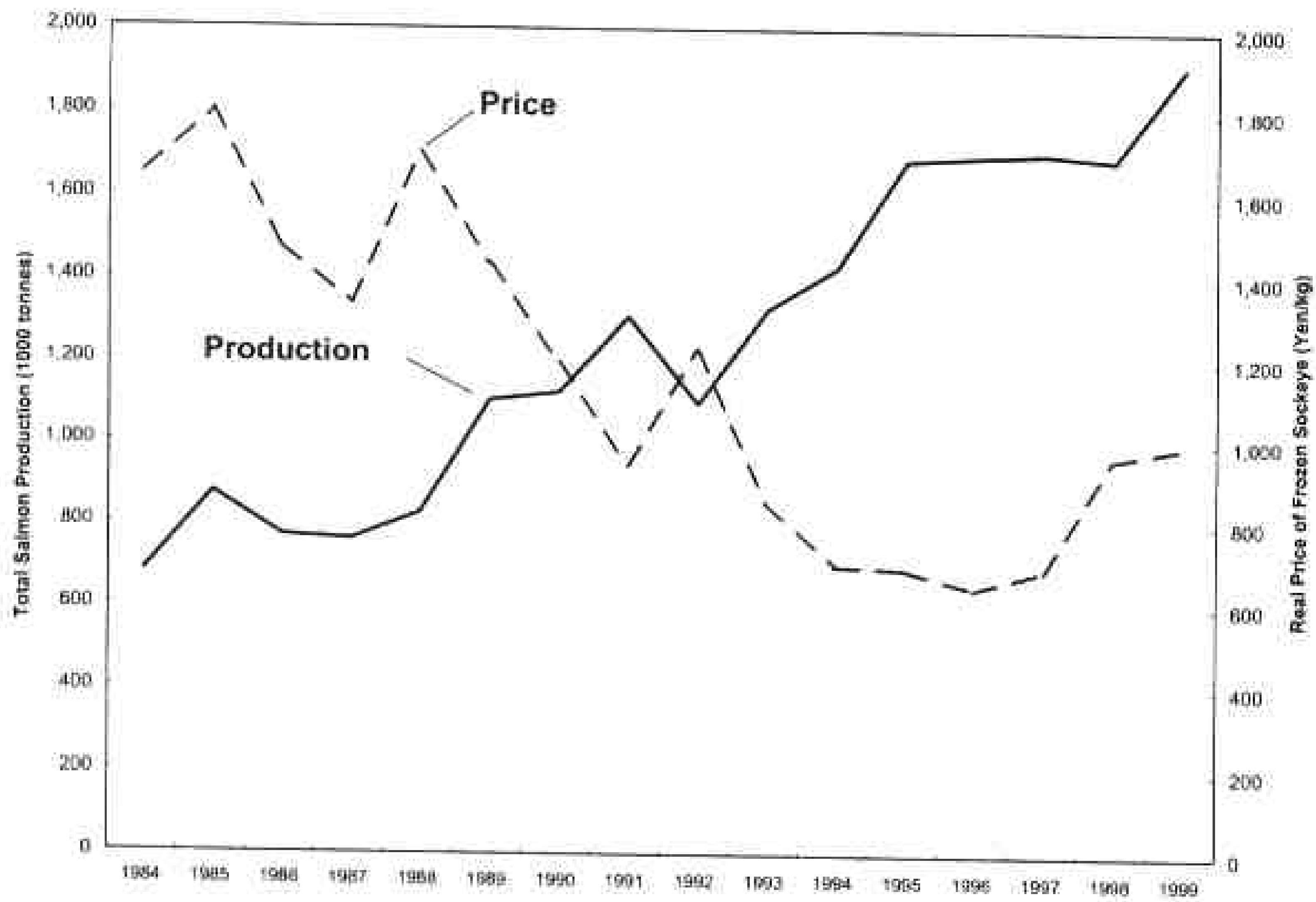


Fig. 12: Total World Salmon Production and Real (1995) Yen Price of Frozen Alaskan Sockeye
Data Sources: FAO datafiles downloadable from http://www.fao.org/fi/statist/fisoft/fishplus.asp. Real price of frozen U.S. sockeye in the Japanese market derived from data reported in the FAO salmon commodity update of September 2000, available at http://www.globefish.org

degree of substitutability between aquaculture products and wild salmon products (except canned salmon), which leaves us in no doubt about the impact of the growth of salmon aquaculture upon the prices of wild salmon harvests (Asche *et al.*, 2001). The study also shows that unit production costs of salmon aquaculture production in Norway (the lead aquaculture salmon producer) have steadily declined since the mid-1980s. Such costs in real terms in 1999 were less than one-quarter of what they had been in 1986. The decline in costs has, of course, brought forth expanded output. There are no signs that the falling trend in production costs is abating (Asche *et al.*, 2001).

As prices have declined, so too have harvesters' incomes. Declining profit expectations are reflected in the prices at which Alaska's transferable fishing permits are being traded. As recently as 1991, the average price for an Alaskan power gurdy salmon troll permit peaked at $36,800. By 2001, the inflation-adjusted price for those permits had declined to just half that level.

VIII. SUSTAINING COOPERATION

It is important at this juncture to consider what else could be done to maintain positive momentum and to short-circuit any tendencies to slide backwards into aggressively competitive positions. The 1999 agreement became possible because several of the players in this multi-player game made significant concessions. Notably, Canada softened its position on equity. The spirit of cooperation that allowed such concessions can best be sustained by continuing to build confidence through incremental reforms that provide rewards for continued cooperation. Our analysis above implies that side payments (perhaps coming from outside of the fishery sector) and access agreements can be useful tools to sustain cooperation.

The Endowment Funds and vessel buy-back programs in Washington State and B.C. are a useful start, but such efforts could go much further. In particular, the high cost of current efforts to maintain and restore ailing salmon populations in Puget Sound, along the Oregon coast and in the Columbia Basin, suggests that there is room to buy some additional harvest reductions, particularly if the affected power, forestry, water-use, and development interests are allowed to look across borders to compensate Canadian (and perhaps Alaskan) harvesters for taking actions to further reduce harvest pressures on sensitive stocks (Shaffer and Associates Ltd., 1998). The relative impacts of exploitation versus improved in-river survival rates are subject to debate. However, there may be cases in which beneficial reductions in harvest pressure could be purchased cheaply enough to make such efforts a valuable component of an overall restoration program. One possible use of Trust Fund resources would be to make a comprehensive assessment of the marginal trade-offs between marine conservation and river enhancement projects. The funds also could be used to leverage expenditures by public or private entities who are faced with legal requirements to make salmon-restoration investments. For example, cooperative joint ventures might be negotiated that could entail mixtures of stream-restoration projects and further harvest reductions.

The potential effectiveness of side payments in fisheries, along with some of their possible pitfalls, are illustrated by recent historical developments in the commercial mixed-stock fishery for Atlantic salmon. Throughout their native range, Atlantic salmon are a highly prized commercial and recreational game fish. Historically, most Atlantic salmon fishing was conducted by salmon "producing" nations on stocks primarily of domestic origin. This pattern of predominantly terminal exploitation changed, however, when fisheries targeting over-wintering stocks of salmon from around the North Atlantic began in the waters off Greenland and the Faroe Islands in the 1960s. To the consternation of most Atlantic salmon-producing countries, these high seas, mixed-stock interception fisheries grew rapidly. In response to this growing international harvest allocation issue and other management challenges, in 1983 the North Atlantic Salmon Conservation Organization (NASCO) was established with representation from almost all Atlantic salmon producing and fishing nations.

Since its inception, delegates to NASCO have negotiated a maximum annual quota that can be taken in the waters off Greenland and the Faroe Islands that attempts to balance the interests of these fishing jurisdictions with those of the major salmon-producing countries. However, for many individuals and organizations within continental Europe, the United Kingdom, and North America, there is a strong belief that the continued execution of any commercial interception fishery for Atlantic salmon represents economic waste. Specifically, many argue that the conservation and recreational angling value of an Atlantic salmon returning to its home waters far exceeds its commercial landed value. Consequently, beginning in 1991, and continuing each year since then, the Iceland-based, and largely privately supported North Atlantic Salmon Fund (NASF) has been paying commercial Atlantic salmon fishermen in the Faroe Islands not to fish their NASCO allocated quota. Similarly, in both 1993 and 1994, the NASF reached a comparable agreement with the commercial salmon fishermen of Greenland. Practically, this has meant that in years in which a successful agreement was reached with either Greenland or the Faroese, the NASF paid an amount equal to approximately 25 percent of the total potential landed value of each jurisdiction's quota to an organization representing all licensed salmon fishermen. These organizations then, in turn, made payments to individual license-holders that they represent based on a previously arranged internal allocation scheme. From the fishermen's perspective, the financial benefits of this arrangement clearly exceeded their reasonable expected returns from fishing. Similarly, for the NASF and its supporters, the perceived benefits – namely, improving recreational angling and stock conservation opportunities in the countries and rivers to which the salmon are destined to return – have outweighed the cost of paying fishermen not to fish.

Given the uncertainty regarding the number of Atlantic salmon that actually would have been caught had the Greenland and Faroese quota buy-outs not occurred, it is difficult to assess the efficacy of the NASF's activities. However, a conservative analysis by Potter (1996) suggests that over the course of the first four years of the Faroese buy-out, together with the 1993 and 1994 Greenland buy-out, almost 400,000 additional salmon were returned to their home waters in Europe and North America as a result of NASF activities.

While seemingly effective, the approach taken by the NASF to reduce harvest levels has not been without its detractors. One criticism is that by routinely buying out only annual quotas, as opposed to retiring licenses permanently, the NASF functions as an on-going private "subsidy" to the commercial fishers of the Faroe Islands. While the critics may view this situation as inappropriate, we would emphasize that the arrangement honors the individual rationality position of the Faroese and thus maintains their cooperation.

In the case of the North American Pacific salmon fisheries, access agreements could encourage more effective conservation efforts by allowing more efficient deployment of the bi-national fleet. Conservation efforts can have disproportionate impacts on the various fleets engaged in harvesting salmon. Historically, such uneven impacts tended to weaken the resolve of fishery managers in pursuing aggressive conservation. An underlying problem is the comparative immobility of the fishing fleets relative to unrestricted natural fluctuations in stock productivity. Recent trends toward area licensing have further restricted fleet mobility. While the uneven impacts of conservation-oriented regulations could be mitigated by monetary side payments, in many cases idle harvesters would prefer compensation in fish – or at least in opportunities to catch fish.

An obvious remedy would be to give harvesters more mobility across jurisdictional lines, including national boundaries. Any scheme to do this on a grand scale (e.g., making the fleets fully bi-national and giving the commission the powers of an international authority) seems to be out of the question for now. However, small-scale regional adjustments might be workable. For example, there are transferable license programs in all of the Alaskan fisheries governed by the treaty. One option would be for the U.S. government to buy some of these licenses and to make them available (perhaps for rent) to Canadian vessels in years when an imbalance has accumulated. The Canadian vessels would then be allowed to fish in Alaskan waters with their harvest credited to the Canadian "account." A complementary idea was proposed by Walters (1998), who suggested that individual fishery rights could be denominated in terms of exclusive rights to fish at a particular time and place (rather than as individual quotas). He further proposed that the "access cards" be made freely transferable and that compliance be monitored by satellite surveillance and mandatory vessel location transponders. If such a system could work for a domestic fishery, there would be no particular technical barrier to extending it to allow transfers of access rights across the border.

Indeed, there are precedents for cross-boundary access agreements in other parts of the world, one example being provided by the Barents Sea. There, Norway and Russia share an important cod resource, Arcto-Norwegian cod, along with haddock and capelin. The two countries have had a very successful cooperative resource management arrangement extending back to the mid–1970s (Munro, 2000). The arrangement prospered in spite of the Cold War (Norway was a member in good standing of NATO) and the turmoil of the last fifteen years in the Soviet Union/Russia. A central pillar was, and is, *the Mutual Access Agreement of 1976, which enables each country to* take parts of its quotas in the other country's EEZ. For example, the agreement allows the Soviets/Russians to take a substantial portion of their cod quota in the Norwegian zone. The cod migrating between the Russian and Norwegian zones tend to spend their juvenile life stages in the former zone, and their adult life stages in the latter zone. It makes eminently good economic sense for the cod to be harvested as adults (Stokke *et al.*, 1999). As well as making good economic sense, the Mutual Access Agreement *paved the way for quota trades. Thus,* for example, Norway has obtained more than its allocated cod quota by "buying" cod quota from the Soviets/Russians, in exchange for redfish, blue whiting, and other species quota (Stokke *et al.*, 1999). These quota trades fall within all but the narrowest definition of side payments. There can be little doubt that the Mutual Access Agreement has greatly enhanced the flexibility of the Barents Seas cooperative fisheries management.

In the Pacific salmon case, one of the most pressing needs will be to find a way to keep the parties from turning the abundance estimates into tools of combat. The Russian/Norwegian cooperative framework in the Barents Sea provides guidance there as well. Bilateral scientific cooperation has been facilitated through an independent *scientific organization* ICES (the International Council for the Exploration of the Sea). The two nations actively contribute to the research efforts of this multinational organization and rely on the ICES Advisory Committee on Fishery Management for stock assessments and recommendations regarding harvest levels and practices. ICES provides scientific information and advice in support of other international fishery agreements as well, notably in the Baltic and North Atlantic. Its broad base and independence from direct government *control allows the recommendations coming from ICES to be* viewed as credible and impartial.

There is a similar scientific organization in the Pacific called PICES (the North Pacific Marine Science Organization). It is a much younger organization[19] that has not yet assumed a prominent role in providing scientific advice to fishery managers, but it is serving to coordinate international research efforts on such topics as atmosphere/ocean/ecosystem interactions and specifically the ocean ecol*ogy of salmon populations. It seems possible that PICES could grow* into the role of an independent (and neutral) provider of timely management-oriented stock assessments, if the parties to the Pacific Salmon Treaty were willing to encourage and finance that development. At the very least, the engagement of such an organization in the ongoing assessment efforts of the commission and the relevant fishery agencies could serve to enhance transparency and to curtail unproductive disagreements about abundance indicators.

IX. CONCLUSION

The jury is still out regarding the likely success of the 1999 Pacific Salmon Agreement. It clearly represents a step forward, but it certainly does not lay all sources of conflict to rest, nor does it close all easy avenues for the dissenter's mischief. Will we continue to limp along from one unstable agreement to another, or will the parties find the political will to establish a more robust cooperative regime? Their approach to the work ahead could be either haphazard or purposeful.

If the haphazard path is chosen, nature might "keep up the pressure" and thus enhance the need for long-term resolution of the issues left unaddressed. On the other hand, a climatic regime shift favorable to Canada and the south might allay potential dissatisfaction, allowing the current arrangement to survive as "good enough" until it is again destabilized by future changes in natural or market conditions.

A more purposeful approach would be to address the remaining weaknesses in the current agreement in an effort to make continued cooperation resilient to a wide range of possible changes in biological or economic factors. Our analysis suggests that to sustain cooperation, the parties will need to continue to work on enhancing the flexibility of the agreement. They also will need to pay particular attention to managing the impacts of scientific uncertainties. Simply conducting more research, taking more precise measurements and constructing more elaborate forecasting models is likely to be an expensive endeavor that is not guaranteed to lead to the desired payoff of a self-sustaining, mutually satisfactory agreement. Rather, what is needed is a workable framework for allocating the risks arising from imperfect ability to forecast and account for variations in abundance, coupled with agreed-upon procedures to curtail quibbling about the estimates.

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REFERENCES

ADF&G (Alaska Department of Fish and Game), 1994. *Alaska's District 104 Purse Seine Fishery.* ADF&G, Juneau.

ADF&G (Alaska Department of Fish and Game), 2000. *Statement of Work Improving the Pacific Salmon Commission's Chinook Model Abundance Index*, available on World Wide Web, Oct. 2000, at: wysiwyg://34/http://www.state.ak.us/adfg/geninfo/special/recovery/chinkmdl.htm.

Asche, Frank, Trond Bjorndal and James A. Young, 2001. Market Interactions for Aquaculture Products. Bergen, Norwegian School of Economics and Business Administration.

Barzel, Y.,1989. *Economic Analysis of Property Rights*, Cambridge University Press, Cambridge, U.K.

Brodeur, R. D. and D. M. Ware, 1992. Long-term variability in zooplankton biomass in the subarctic Pacific Ocean. *Fish. Oceanography*, 1: 32-38.

Clark, Colin W., 1980. "Restricted Access to Common Property Fishery Resources: A Game Theoretic Analysis," in P. Liu (ed.), *Dynamic Optimization and Mathematical Economics*, New York, Plenum Press: 117-132.

Culbert, L., and Beatty, J., 1999. Salmon pact "disappointing", *Vancouver Sun*, June 4, Final ed., A1.

DFO (Department of Fisheries and Oceans, Government of Canada),1998a. Canada's Coho Recovery Plan, *Backgrounder*, June 1998.
http//www.dfo-mpo.gc.ca/communic/backgroun/1998/1906_e2.htm

DFO (Department of Fisheries and Oceans, Government of Canada),1998b. The Pacific Salmon Fishery: A 15-Year Perspective, *Backgrounder*, June 1998.
http//www.dfo-mpo.gc.ca/communic/backgroun/1998/1906_e9.htm

DFO (Department of Fisheries and Oceans, Government of Canada),1999. Canada and U.S. reach a comprehensive agreement under the Pacific Salmon Treaty, *Press Release, and Backgrounders*, June 3. http:// www.ncr.dfo.ca/

D'oro, R., 1997. Judge orders end to blockade Alaska officials attempt to end ferry standoff, *Anchorage Daily News*. July 21, Final ed., A1.

Downton, M. W. and K. A. Miller, 1998. Relationships Between Salmon Catch and North Pacific Climate on Interannual and Decadal Time Scales, *Canadian Journal of Fisheries and Aquatic Sciences* 55: 2255-2265.

Eggertsson, T., 1990. *Economic Behavior and Institutions*, Cambridge University Press, Cambridge, U.K.

Fraser River Sockeye Public Review Board, 1995. *Fraser River Sockeye 1994: Problems and Discrepancies.* Canada Communication Group - Publishing, Ottawa.

Golubtsov, P. and R. McKelvey, In Preparation. The Impact of Information Asymmetries on the Competitive Harvesting of Common Property Biological Resources.

Hare, S. R., N. J. Mantua and R. C. Francis, 1999. Inverse Production Regimes: Alaska and West Coast Pacific Salmon. *Fisheries*, 24(1): 6-14.

Hogben, D., D. Rinehart and J. Beatty, 1997. Prince Rupert fish boats end blockade of Alaskan ferry: Ringleaders comply with injunction after meeting late Monday evening with federal fisheries minister David Anderson, and the ferry steams away. *Vancouver Sun*. July 22, Final ed., A1.

Huppert, Daniel D., 1995. *Why the Pacific Salmon Treaty Failed to End the Salmon Wars*, School of Marine Affairs, University of Washington, SMA 95-1, Seattle.

INPFC (International North Pacific Fisheries Commission), annual series, 1952-1990. *Statistical Yearbook*. INPFC, Vancouver, B.C.

INPFC (International North Pacific Fisheries Commission), 1979. *Historical Catch Statistics for Salmon of the North Pacific Ocean*, Bulletin No. 39, INPFC, Vancouver, B.C.

Latif, M., and Barnett, T. P., 1996. Decadal climate variability over the North Pacific and North America: Dynamics and predictability, *Journal of Climate* 9: 2407-2423.

Levhari, D. and L.J. Mirman, 1980. The Great Fish War: An Example Using a Dynamic Courant-Nash Solution. *Bell Journal of Economics*, 11: 649-661.

Link, M. R and K. K. English, 1998. "Aboriginal fisheries and a sustainable future: a case study from an agreement with the Nisga'a nation in British Columbia," in T. J. Pitcher, P. J. B. Hart and D. Pauly (eds.), *Reinventing Fisheries Management*. Kluwer Academic Publishers, Dordrecht, 149-161.

Mantua, N. J., S. R. Hare, Y. Zhang, J. M. Wallace and R. C. Francis, 1997. A Pacific Interdecadal Climate Oscillation with Impacts on Salmon Production. *Bulletin of the American Meteorological Society*, 78(6): 1069-1079.

McDorman, T. L., 1995. The West Coast Salmon Dispute: A Canadian View of the Breakdown of the 1985 Treaty and the Transit License Measure, *Loyola of Los Angeles International and Comparative Law Journal*, 17: 477-506.

McDorman, T. L., 1998a. A Canadian View of the Canada-United States Pacific Salmon Treaty: The International Legal Context (I), *Willamette Journal of International Law and Dispute Resolution* 6: 79-98.

McDorman, T. L., 1998b. A Canadian View of the 1999 Canada-United States Pacific Salmon Agreement: A Positive Turning Point? (II) *Willamette Journal of International Law and Dispute Resolution* 6: 99-112.

McDorman, T. L., 2000. The Canada-United States Pacific Salmon Agreement: Resolved and Unresolved Issues, *Journal of Environmental Law and Litigation* 15: 1-20.

McKelvey, R., 1997. Game-Theoretic Insights into the International Management of Fisheries . *Natural Resource Modeling* 10: 129-171.

McKelvey, R., 2001. *The Split-Stream Harvesting Game I: Mathematical Analysis*, NCAR Technical Report, NCAR/TN-449+STR - Part I.

McKelvey, R., and G. Cripe, 2001. *The Split-Stream Harvesting Game II: Numerical and Simulation Studies*, NCAR Technical Report, NCAR/TN-449+STR - Part II.

McKelvey, R., and K.A. Miller, 2001. "The Pacific Salmon Dispute: Rationalizing a Dysfunctual Joint Venture", in *Sustaining North American Salmon: Perspectives across Regions and Disciplines,* Kristine D. Lynch and Michael L. Jones, (eds.) American Fisheries Society, Bethesda MD. (In Press)

Miller, K. A., 1996. Salmon stock variability and the political economy of the Pacific Salmon Treaty, *Contemporary Economic Policy* 14(3):112-129.

Munro, G.R., 2000. On the Economic Management of "Shared Fishery Resources," in A. Hatcher and D. Tingley (eds.), *International Relations and the Common Fisheries Policy*, Portsmouth, Centre for the Economics and Management of Aquatic Resources, University of Portsmouth, 149-167.

Munro, G. R. and R. L. Stokes, 1989. "The Canada-United States Pacific Salmon Treaty," in D. McRae and G. Monro, (eds.), *Canadian Oceans Policy: National Strategies and the New Law of the Sea*, University of British Columbia Press, Vancouver, 17-35.

Munro, G. R., T. McDorman and R. McKelvey, 1998. Transboundary fishery resources and the Canada-United States Pacific Salmon Treaty, *Occasional Papers: Canadian - American Public Policy*, No. 33, Canadian - American Center, University of Maine, Orono.

National Marine Fisheries Service (NMFS), 1999. *Biological Opinion: Approval of the Pacific Salmon Treaty by the U.S. Department of State and Management of the Southeast Alaska Salmon Fisheries Subject to the Pacific Salmon Treaty.* Endangered Species Act – Reinitiated Section 7 Consultation, November 18, 1999. NMFS, Northwest Region, Seattle.

NPFAC (North Pacific Anadromous Fish Commission, 1997 - 1999. *Statistical Yearbooks, 1993 -1995.* Vancouver, B.C.

O'Neil, P., 1999a, Taking stock of the Salmon Treaty, *Vancouver Sun*, July 5, Final ed., A1.

O'Neil, P. 1999b. Conservation card played key role in salmon deal. Vancouver Sun, June 5, Final ed., A1.

Pacific Fisheries Resource Conservation Council, 1999. *1998-1999 Annual Report.* PFRCC, Vancouver, B.C.

Pacific Fishing. Yearbook Issues, March 1996 – March 2000.

Pearcy, W. G., 1992. *Ocean Ecology of North Pacific Salmonids.* Univ. of Washington Press, Seattle.

Pearcy, W. G., 1997. "Salmon Production in Changing Ocean Domains," in D. J. Stouder, P. A. Bisson and R. J. Naiman, (eds.), *Pacific Salmon and Their Ecosystems: Status and Future Options.* Chapman and Hall, New York, 331-352.

Polovina, J. J., Mitchum, G. T., and Evans, G. T., 1995. Decadal and basin-scale variation in mixed layer depth and the impact on biological production in the Central and North Pacific, 1960-88, *Deep Sea Research* 42: 1701-1716.

Potter, E.C.E, 1996. "Increases in the returns of salmon to homewaters following the reduction in fishing at Faroes and Greenland," in D. Mills (ed.), *Enhancement of Spring Salmon* Proceedings of Atlantic Salmon Trust Conference, London, January 1996. AST, Pitlochry.

PSC (Pacific Salmon Commission), 1998. 1997/98 Thirteenth Annual Report. Pacific Salmon Commission, Vancouver, B.C.

PSC-JCTC (Pacific Salmon Commission - Joint Chinook Technical Committee), 1999. *Preliminary Retrospective Analysis of the U.S. and Canadian Proposals for Abundance-based Regimes for Chinook Fisheries.* TCCHINOOK (99)-1. Pacific Salmon Commission, Vancouver, B.C.

Rigby, P., McConnaughey, J., and Savikko, H., 1991. *Alaska Commercial Salmon Catches, 1878-1991.* Reg. Info. Rep. No. 5J91-16. Alaska Department of Fish and Game, Juneau.

Roos, J. E., 1996. *Restoring Fraser River Salmon: A History of the International Pacific Salmon Fisheries Commission 1937-1985.* Pacific Salmon Commission, Vancouver, B.C.

Schelle, K. and B.Muse, 1986. "Efficiency and distributional aspects of Alaska's limited entry program." In N. Mollett (ed.), *Fishery Access Control Programs Worldwide: Proceedings of the Workshop on Management Options for the North Pacific Longline Fisheries.* Alaska Sea Grant Report No. 86-4. University of Alaska Press, Fairbanks, 317- 352.

Schmidt, R. J., Jr., 1996. International negotiations paralyzed by domestic politics: two-level game theory and the problem of the Pacific Salmon Commission, *Environmental Law* 26: 95-139.

Schwindt, R., 1995. "The Case for an Expanded Indian Salmon Fishery: Efficiency, Fairness, and History," in H. Drost, B. L. Crowley and R. Schwindt (eds.), *Market Solutions for Native Poverty.* Renouf Publishing Co. Ltd., Ottawa, 98-152.

Schwindt, R., A. R. Vining and S. Globerman, 2000. Net Loss: A Cost-Benefit Analysis of the Canadian Pacific Salmon Fishery, *Journal of Policy Analysis and Management* 19(1): 23-45.

Shaffer, M. and Associates Ltd, 1998. *Pacific Northwest Salmon Recovery Efforts and the Pacific Salmon Treaty.* Report prepared for the Departments of Fisheries and Oceans and Foreign Affairs and International Trade of the Government of Canada, dated December 31, 1998.

Shepard, M. P., and A.W. Argue, 1998. Ocean Pasturage in the Pacific Salmon Treaty Fact or Fiction? Canadian Industry Report of Fisheries and Aquatic Science 242. Department of Fisheries and Oceans Canada, Vancouver, B.C.

State of Alaska Commercial Fisheries Entry Commission, 2000. Annual Report, Juneau.

Stokke, O. S., L. G. Anderson and N. Mirovitskaya, 1999. "The Barents Sea Fisheries," in O. Young (ed.), *The Effectiveness of International Environmental Regimes: Causal Connections and Behavioral Mechanisms.* The MIT Press, Cambridge, MA, 91-154.

Strangway, D. W. and W. D. Ruckelshaus, 1998. *Pacific Salmon: Report to the Prime Minister of Canada and the President of the United States.* January 12.

Trenberth, K. E., and Hoar, T. J., 1996. The 1990-1995 El Niño-Southern Oscillation event: Longest on record, *Geophysical Research Letters* 23(1): 57-60.

Trenberth, K. E., and Hurrell, J. W., 1994. Decadal atmosphere-ocean variations in the Pacific, *Climate Dynamics* 9: 303-319.

United Nations, 1982. *Convention on the Law of the Sea.* Signed at Montego Bay, Jamaica, December 10, 1982.

U. S. Department of State, 1999. *Diplomatic Note No. 0225 from Canada to the United States; reply; attached Agreement*, June 30. http://www.state.gov..

U. S. Federal Register, 2000. Department of Commerce, National Oceanic and Atmospheric Administration, 50 CFR Part 223 (Docket No. 991207323-9323-01; I.D. No. 092199A) RIN 0648-AM59. *Endangered and Threatened Species; Proposed Rule Governing Take of Seven Threatened Evolutionarily Significant Units (ESUs) of West Coast Salmonids: Oregon Coast Coho; Puget Sound, Lower Columbia and Upper Willamette Chinook; Hood Canal Summer-run and Columbia River Chum; and Ozette Lake Sockeye.* Federal Register, Vol. 65, No. 1, Monday January 3, 2000, Proposed Rules, pp. 170-196.

U.S. Senate, 1985. Pacific Salmon Treaty Act of 1985, Pub. Law no. 99-5, 99 Stat. 7.

Van Alen, B. 2000. "Status and Stewardship of Salmon Stocks in Southeast Alaska," in Knudsen et al. (eds.), *Sustainable Fisheries Management: Pacific Salmon.* CRC Press – Lewis Publishers, Boca Raton, FL, 161-193.

Waldeck, D. A. and E. H. Buck, 1999. *The Pacific Salmon Treaty: The 1999 Agreement in Historical Perspective.* U.S. Congressional Research Service Report for Congress, June 18, 1999.

Walters, C., 1998. "Desiging fisheries management systems that do not depend upon accurate stock assessment," pp.279-288 in T. J. Pitcher, P. J. B. Hart and D. Pauly (eds.), *Reinventing Fisheries Management.* Kluwer Academic Publishers, Dordrecht.

Warren, B. and S. Chambers, 2001. Seafood Report. *Pacific Fishing*, 22(8): 8-10.

Yanagida, J. A., 1987. The Pacific Salmon Treaty. *The American Journal of International Law*, 81: 577-592.

Young, O. (ed.), 1999. *The Effectiveness of International Environmental Regimes: Causal Connections and Behavioral Mechanisms*. The MIT Press, Cambridge, MA.

Zhang, Y., Wallace, J. M., and Iwasaka, N., 1996. Is climate variability over the North Pacific a linear response to ENSO? *Journal of Climate* 9: 1468-1478.

ACRONYMS

AABM	aggregate abundance-based management
CTC	Chinook Technical Committee
DFO	Department of fisheries and Oceans (Canada)
EEZ	exclusive economic zone
ENSO	El Niño-Southern Oscillation
ESA	Endangered Species Act (U.S.)
ICES	International Council for the Exploration of the Sea
IPSFC	International Pacific Salmon Fishery Commission
ISBM	individual stock-based management
LOS	Law of the Sea
NASCO	North Atlantic Salmon Conservation Organization
NASF	North Atlantic Salmon Fund
PSC	Pacific Salmon Commission
PICES	North Pacific Marine Science Organization
SSTs	sea surface temperatures
TAC	total allowable catch

NOTES

[1] Convention for the Protection, Preservation and Extension of the Sockeye Salmon Fishery in the Fraser River System, May 26, 1930, U.S.-Can., 8 U.S.T. 1058.

[2] During the post-Treaty period, it has continued to be higher than the previous norm. The average diversion rate for 1977-1998 has been 48.2%.

[3] *Pacific Salmon Treaty, March 18, 1985, U.S.-Can., 99 Stat. 7 [codified* at 16 U.S.C. 3631-3644 (1997)].

[4] U.N. Law of the Sea Convention, December 10, 1982.

[5] *Id.* at art. 66(1).

[6] *Id.* at art. 66(4).

[7] *Id.* at art. 66(2).

[8] *Id. at art. 56(1)(a).*

[9] *Id.* at art. 56(2)

[10] Memorandum of Understanding to the Pacific Salmon Treaty, *supra,* note 3.

[11] *Id.*

[12] For example, dramatic increases in the abundance of pink salmon in Southeast Alaska led to increased fishing effort in Alaska's District 104 Purse Seine Fishery (measured in terms of the number of boat-days). The Treaty regimes have restricted Alaskan effort in this area *through roughly the third week in July (statistical week 30 in Treaty* parlance) to control Alaskan interceptions of Nass and Skeena River sockeye. However, the regimes provided for no restrictions later in the season, even though some Canadian sockeye would still be intermingled with the later-migrating Alaskan pinks. Therefore, most of the increased effort (and increased interceptions) occurred the period after Statistical week 30 (ADF&G, 1994; PSC, 1998). In the Southeast Alaska fisheries targeting pink and coho salmon, high-

abundance years during the 1980s and 1990s generally allowed both catch per unit of effort and spawning escapements to increase (ADF&G,1994; Van Alen, 2000). Alaska has a limited entry / transferable permit system for its salmon fisheries that was passed into law in 1973 (Schelle and Muse, 1986; State of Alaska Commercial Fisheries Entry Commission, 2000). The limits appear to have prevented excessive increases in effort in response to the expanded fishing opportunities.

[13] Strangeway and Ruckelshaus, 1998, p. 8.

[14] *Id.* at p. 8.

[15] It should be noted that for the Fraser stocks, these abundance-based rules are not completely novel. The management regime incorporated in the original annex to the 1985 Treaty called for the U.S. harvest to be reduced below the levels implied by the 4-year caps during periods of low abundance. Pacific Salmon Treaty, March 18, 1985, U.S.-Can., 99 Stat. 7, Annex IV, Chapter 4 [codified at 16 U.S.C. 3631-3644 (1997)].

[16] Letter of Donald McRae and James Pipkin to Lloyd Axworthy, David Anderson and Madeleine Albright, dated June 23, 1999.

[17] U.S. - Canada Agreement Relating to the Pacific Salmon Treaty, June 30, 1999, Annex IV, Chapters 1 and 2.

[18] *Id.* at Chapter 3, section 6.

[19] PICES is only 10 years old, while ICES is close to 100 years old.