Status, Constraints, and Opportunities for Salmon Culture in the United States: A Review

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Introduction

One might expect that the United States would be a leader in the production of farmed salmon since much of the technology for raising salmon was developed many decades ago in North America (Bardach et al., 1972). This, however, is not the case. Although the United States has open net-pen farms and ocean ranching operations for several salmonids including Atlantic salmon, *Salmo salar*; coho salmon, *Oncorhynchus kisutch*; chinook salmon, *O. tshawytscha*; and rainbow trout, *O. mykiss*, production in 1988 and 1989 was on the order of 2–3% of the total world farmed production (FAO, 1989; WSDF, 1989–91; Bettencourt and Anderson, 1990). Some of the reasons for this low contribution of U.S. production will be addressed in this paper.

Throughout the 1980's, the salmon culture industry has attracted considerable interest from potential investors, governments, and entrepreneurs worldwide. Through 1991, production was still expanding in many countries such as Norway, Scotland, Ireland, Faroe Islands, Chile, Canada, Japan, and the United States. More recently, production in Norway, Scotland, and Ireland has begun to decline or level off. To understand some of the economic factors which have stimulated this industry's rapid growth, it is valuable to consider first the fundamental trends in the seafood sector which helped create much optimism about salmon culture.

United States seafood consumption increased by 24% from 1980 to 1990 (from 12.5 pounds per capita to 15.5 pounds per capita) (USDC, 1991)[1]. This occurred despite the fact that the consumer price index (CPI) for fish increased 68% during that period, while the CPI for all food increased 52% (USDA, 1992; PCEA, 1990; Fig. 1). Thus, fish prices increased nearly 30% faster than other food products, indicating an expansion in seafood demand. Among the factors that may have contributed to this increase are: 1) A shift in consumption away from red meat and toward white meat and fish, motivated by health concerns; 2) the aging of the U.S. population[2]; and 3) the

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ABSTRACT—This paper reviews and analyzes the major factors constraining the development of salmon culture in the United States. A brief review of economic factors in the seafood sector contributing to the industry's recent growth is offered, and the present status of the major producing regions is summarized. The major constraints, which include marketing problems, policy and regulatory constraints, production costs, disease, financing, and environmental uncertainty, are discussed, followed by recommendations for improving the industry's development.

[1]It should be noted, however, that the rate of increase for consumption of products such as poultry has exceeded the growth in seafood consumption.

[2]A household survey conducted in 1989 in major U.S. metropolitan areas revealed that the highest proportion of seafood consumers was among respondents over 60 years of age, followed by the 30–39 and the 40–49 year groups (Egan and Gislason, 1989).

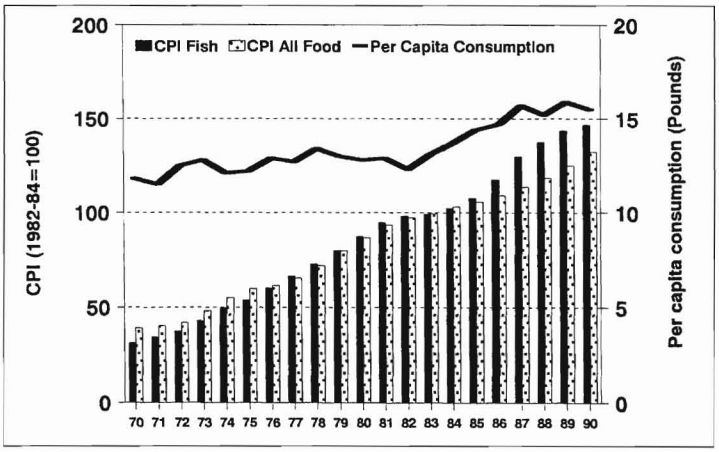

Figure 1.—U.S. consumer price index for fish and all food products and per capita consumption of seafood. Sources for CPI Fish (1970–79): Putnam (1989), USDA (1992). CPI Food: PCEA (1991). Per Capita Consumption: USDC (1991).

gradual increase in the proportion of certain ethnic groups, such as Asians, which traditionally consume large amounts of seafood (USDA, 1990).

The high U.S. dependence on imports of fishery products is another factor which has stimulated the development of U.S. salmon culture (Fig. 2). Over the past 10 years, fishery product imports have been in the range of 50% of total supply (in round weight terms), but have dropped recently to the lowest level in more than a decade to 41.7% in 1990[3] (USDC, 1991). In 1990, imports of fishery products amounted to over $9 billion, of which edible fishery products comprised $5.2 billion and nonedible products about $3.8 billion (USDC, 1990; Fig. 3)[4].

With large import levels of fishery products and the increasing demand for seafood that prevailed during the 1980's (especially during 1985–88), hopes were raised that the emerging U.S. salmon culture industry would find a profitable presence in the market to meet demand and to reduce imports. Until recent years, the profitability of farmed salmon sold in the U.S. market had been positive for many producers, especially those from Norway, raising expectations for prospective U.S. farmers.

The world supply of farmed salmon increased at an exponential rate (Fig. 4), from an insignificant level in 1980 to an estimated production of 279,000 metric tons (t) in 1990, a 27.5% increase over the 1989 level of 218,800 t (FAO, 1989). Continued growth is expected for the near future, although at a slower rate (Talley, 1991). For excellent reviews of salmon aquaculture on a country by country basis, readers should refer to McFeeters (1991) and OIA, 1992.

Most of the farmed production consists of Atlantic salmon, with the majority produced in Norway. It is startling to consider the contribution of

[3]This includes edible and industrial commercial fishery products.

[4]Note that the U.S. Department of Commerce classifies some imports which are ultimately used in the food system, such as live trout, kelp, vitamins, fish oils, and other products along these lines, as nonedible fishery products.

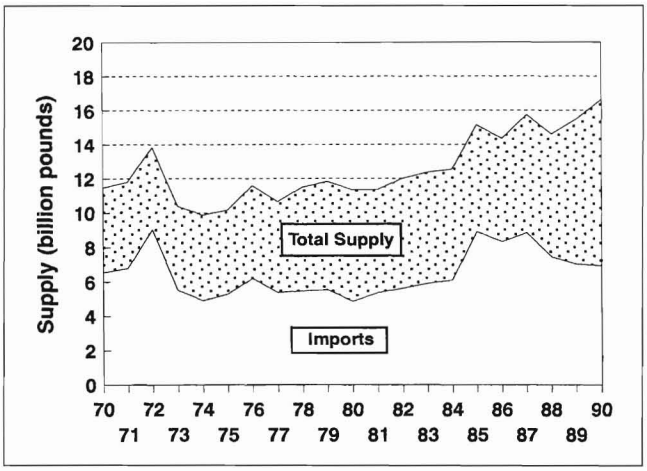

Figure 2.—U.S. supply of edible and industrial fishery products (share of imports, 1970–90). Source: USDC (1971–91).

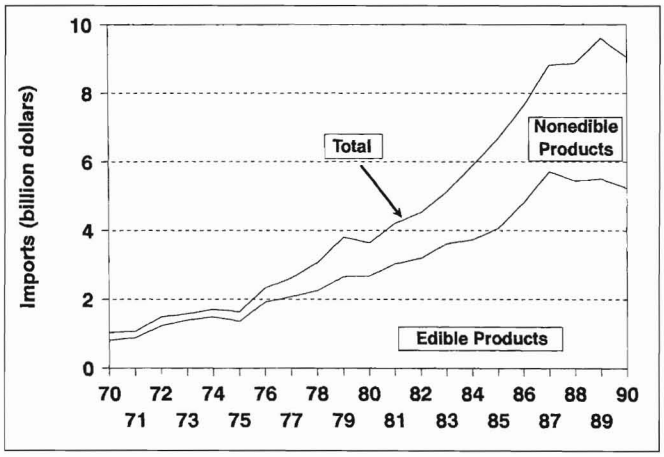

Figure 3.—Total U.S. fishery imports edible and nonedible products, 1970–90. Source: USDC (1971–91).

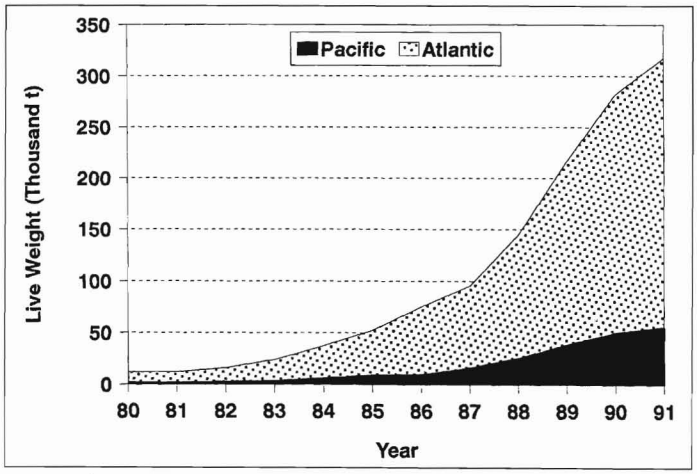

Figure 4.—World supply of farmed Atlantic and Pacific salmon. Sources: McFeeters (1991); FAO (1992); OIA (1992). Live weight for 1991 was estimated.

farmed salmon to the total world supply, traditionally dominated by wild-caught Pacific salmon species. From a negligible contribution in 1980, farmed supplies rose to over 10% of world production in 1986, attaining a share of nearly 29% in 1990 (ASMI, 1991). The share of farmed salmon products is expected to increase, but at a decreasing rate, in the future. It is unlikely that wild harvest will increase substantially, and although production in Norway and Scotland will likely decline in 1993, total aquaculture production should increase somewhat.

Much of the fresh salmon consumed in the United States is imported, despite the fact that the United States is the largest producer of salmon in the world, contributing, in 1989, about 48% (357,000 t) of the total world supply of wild-caught salmon (USDC, 1990). This is essentially because U.S. wild salmon are caught during a limited season (primarily summer), and thus are not available year-round in a fresh form. In fact, imported fresh salmon, available year round, has largely displaced much of the wild, U.S.-caught salmon from markets in the U.S. northeast.

Until 1989, Norway was the dominant supplier of fresh salmon to the United States, followed by Canada, Chile, and the United Kingdom (Fig. 5). (Note: Prior to harmonization, 2/89, imports were not broken down by species.) Before 1989, most fresh imports were farmed coho, chinook, and Atlantic salmon. However, some sockeye and pink salmon may be included in imports from Canada. In 1989, Canada displaced Norway as the leading supplier to the United States. Up until 1989, virtually all of the U.S. imports of fresh salmon were from farmed sources. In 1989, as much as 38% of the fresh Canadian salmon exported into the United States was wild caught. This increase in imports of whole, fresh, wild-caught salmon from Canada was largely a consequence of the liberalization of trade between the United States and Canada. In terms of farmed fresh whole salmon, Canadian imports into the United States of 11,470 t, were approximately equal to Norwegian imports of 11,509 t (Kenney[5]). By the end of 1990, Norwegian exports to the United States had decreased significantly, having been replaced largely by exports from Chile and Canada. Norway was essentially out of the U.S. market by 1991. This was largely a consequence of the Norwegian exporters' reaction to the countervailing duty and anti-dumping case brought against them in February of 1990 by the Coalition for Fair Atlantic Salmon Trade (as discussed later) (USITC, 1991).

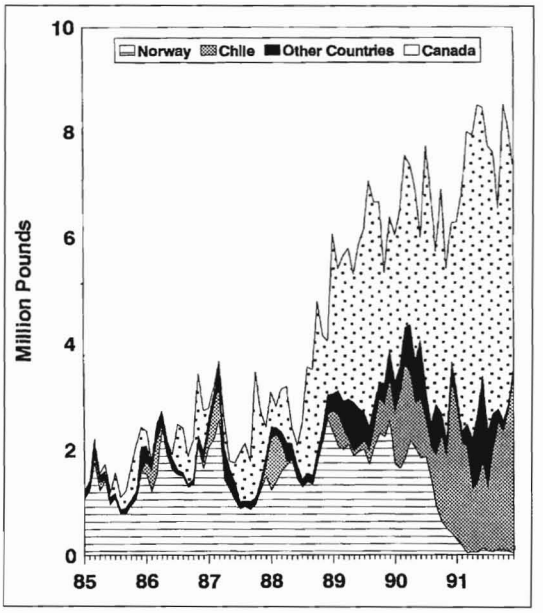

Figure 5.—Monthly U.S. imports of fresh and chilled Atlantic, coho, and chinook salmon, January 1985–December 1991. Source: USDC data.

U.S. Salmon Farming

Significant amounts of Atlantic, coho, and chinook salmon, and rainbow trout are raised in ocean net-pen systems in the Pacific Northwest (primarily Washington), whereas only Atlantic salmon and rainbow trout are raised in significant quantities in the Northeast (primarily Maine). Besides commercial enterprises, there are aquaculture programs in the form of public enhancement of salmon stocks (also known as salmon ranching) in the states of California, Oregon, Idaho, Washington, Alaska, and the Great Lakes states. There are also restoration programs for Atlantic salmon in New England, as well as private nonprofit salmon hatchery operations in Alaska oriented towards fisheries enhancement.

The principal U.S. commercial salmon farming activities involve pen-raised salmon in Washington and Maine. A land-based system also exists in Hawaii, which pumps cool ocean water inland to provide the proper temperature for salmon rearing. There is also some limited private salmon culture in California and Idaho (mostly rainbow [steelhead] trout and pan-sized coho). During the 1980's, there were a few private ocean ranching operations in Oregon, however, none are currently operating. There are also a few small operations (primarily hatcheries) based in the northeastern states, and one private (freshwater) chinook pen-operation in a quarry in Minnesota (ASMI, 1991; Chew and Toba, 1991; Horrex, 1991). There are some trout operations involved to a very limited degree with freshwater rearing of salmon in other

[5]Kenney, A. 1991. British Columbia Salmon Farmers Assoc. Personal commun., April.

Table 1.—Status of the salmon farming industry in Washington (1989).

Item	Production (t) 1988[1]	1989[1]	1990[1]
Production level	2,718	2,306	1,525
Atlantic salmon	912	1,103	650
Pacific salmon[2]	1,647	1,005	706
Coho	1,647	612	205
Chinook	0.02	393	501
Trout[3]	159	198	169
Rainbow trout	159	198	170
Other trout	0.03	0	0.01

[1]Washington Department of Fisheries. 1989–1991. Fisheries Statistical Report. Washington Department of Fisheries, Olympia, Washington. This includes only market-sized fish.
[2]Includes coho and chinook salmon.
[3]Includes all trout.

states as well. In addition, a proposal is under consideration to install a pen culture facility 27 miles off the coast of Massachusetts, which, if feasible, would be one of the largest of its kind in the world (Bettencourt and Anderson, 1990). The prospects for commercial salmon culture development in Alaska have been curbed by the permanent moratorium passed by the state legislature in 1990 on private, profit-oriented, pen-raised salmonid culture (Painter, 1990). The moratorium was strongly supported by the fishing industry which was concerned with both the environmental and economic implications of aquaculture development.

The main characteristics of the two primary pen-culture production areas, Washington and Maine, are depicted in Tables 1 and 2. In Washington (Table 1), salmon farming is concentrated in Puget Sound, where it started in 1969 with experiments conducted by the National Marine Fisheries Service (NMFS), followed by experiments with coho and chinook pen culture carried out by Ocean Systems, Inc.[6] (which later became Domsea, Inc.) (Weston, 1986; Sylvia, 1989). Commercial sales of farmed salmon are believed to have started in 1971 (Sylvia, 1989). Following a period of slow expansion during the 1970's (production estimated at 179 t in 1976 and 391 t in 1980), output grew to about 1,305 t in 1986 and 2,718 t in 1988 (Washington Department of Fisheries, 1989–1991). Since 1988, production has been declining. An estimated 1,525 t (2,306 t in 1989) of market-sized fish were produced in 1990, consisting roughly of 650 t (1103 t in 1989) of Atlantic salmon, 205 t (612 t in 1989) of coho, 501 t (393 t in 1989) of chinook salmon, and 169 t (198 t in 1989) of rainbow trout.[7] Washington production has been shifting away from coho and towards chinook and Atlantic salmon, which, respectively, accounted for 33 and 43% of the total production of market-sized salmonids in 1990.

Table 2.—Status of the northeastern U.S. salmon farming industry (1989), with 15 operational firms[1]. Source: Bettencourt and Anderson (1990).

Item	No. or amt.
Direct employment in the industry	290
Full-time	220
Part-Time	70
Total number of hatcheries[2]	10
Operational hatcheries[3]	9
In Maine	7
In New Hampshire[4]	2
Total number of commercial leases issued[5]	37
In Maine	36
In Massachusetts[6]	1
Total number of leased grow-out sites[7]	32
Operational sites[8]	18
Total number of pens installed[9]	355
Production level (1988–89)[10]	605 t
Atlantic salmon	400 t
Rainbow trout	205 t
Production level (1989–90)[11]	1,540 t
Atlantic salmon	1,420 t
Rainbow trout	120 t
Production level (1990–91)[12]	4,530 t
Atlantic salmon	4,530 t
Rainbow trout	180 t

[1]Companies operating commercial salmonid pen mariculture operations, or hatcheries fully linked with the salmonid pen culture industry as of summer 1989.
[2]Includes only commercial operations exclusively or primarily serving the pen-culture industry.
[3]Hatcheries that had live fish in the water as of summer 1989.
[4]Includes an egg-incubating facility and a parr-smolt facility.
[5]Commercial leases granted by the Maine Department of Marine Resources or equivalent state permits.
[6]This permit was under appeal as of fall 1989. Permits for an additional offshore operation were being considered.
[7]The number of grow-out sites is smaller than the number of leases because several leases issued pertain to adjacent tracts of water, considered as a single production site.
[8]Defined as a production site with fish (smolts or adults) in the water as of summer 1989.
[9]Estimated.
[10]Producers' estimates as of summer 1989; pertains to 1988–89 production year.
[11]Estimate based on producers' forecasts made as of summer 1989; pertains to 1989–90 production year
[12]Estimate based on producers' forecasts made as of summer 1989; pertains to 1990–91 production year

The number of salmon farming operations in Washington has expanded slowly, curbed by regulatory and political constraints. As of 1986 there were 9 commercial grow-out sites in Puget Sound, in addition to several research and public operations[8]; as of 1990, a total of 13 sites were operational, and another 16 sites were in the process of obtaining legal permits (Pitts[9]). Among the major constraints faced by the industry were regulatory barriers based on concerns about the environmental impact of the pen sites and political opposition coming especially from commercial fishermen and nearby landowners concerned with the loss of aesthetic value of waterfront property (Sylvia, 1989).

On the U.S. east coast, commercial salmonid farming started in the early 1970's with a few private operations which raised coho salmon and rainbow trout. Problems with extreme temperature variation, lack of infrastructural support, and marketing and financial constraints contributed to the failure of these early operations. The industry resurfaced in the mid-1980's in the Cobscook Bay region (northeastern Maine) led by Ocean Products, Inc., benefiting from excellent environmental conditions and from the close geographical proximity with the fast-growing New Brunswick salmon farming industry.

The status of salmon farming in the U.S. northeast in 1989 is summarized in Table 2. As of that summer, there were a total of 15 aquaculture firms in the region operating 18 marine grow-out sites (all in Maine's inshore waters) and 9 hatcheries (2 in New Hampshire and 7 in Maine)[10]. A total of 37

[6]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

[7]Washington State Department of Fisheries (WSDF, 1990 and 1991).

[8]In addition to these, another 13 facilities were operated by Native tribes and sportsmen's groups for stock enhancement (Weston, 1986).
[9]Pitts, J. 1990. State of Washington, Department of Agriculture. Personal commun., October.
[10]This number does not include hatcheries that supply smolts to the grow-out sites on a sporadic basis only.

leases for marine salmonid pen-culture had been issued in the region, including one in Massachusetts and 36 in Maine. In this same time period, roughly 355 net-pens were installed, and direct industry employment at the hatcheries and grow-out sites was estimated at about 220, with additional part-time employment estimated at around 70. Based on farmers' projections, the estimated production for 1988–89 (most harvest occurs from November through March) was 605 t of market-sized fish, including 400 t of Atlantic salmon and 205 t of rainbow trout; for 1989–90, the estimated production was 1,540 t of market-sized fish, including 1,420 t of Atlantic salmon and about 120 t of rainbow trout. Based on the number of smolts stocked at sea in 1989–90 (close to 2 million sea-run Atlantic salmon smolts), and farmers' and processors' estimates, in 1990–91 the region should have produced about 4,530 t of pen-raised salmonids, including 4,350 t of Atlantic salmon and 180 t of rainbow trout. These estimates compare favorably with calendar year estimates from the Division of Marine Resources in Maine (Churchill, 1992) which indicate 905 t in 1989, 208 t in 1990, and 4,715 t in 1991. The large growth in production between 1989–90 and 1990–91 is due, for most part, to the first-time harvest of several new firms which began operating in 1987 (Bettencourt and Anderson, 1990). Based on industry projections of hatchery capacity, site capacity, and expansion plans, the production of Atlantic salmon in Maine has the capacity to increase to a level of 12–15,000 t by 1995. Other expected advancements in the region are the development of the culture of Arctic char and nonsalmonids (Bettencourt and Anderson, 1990).

Primary Constraints on U.S. Salmon Culture

At this point the reader may be led to believe that the outlook for the United States salmon industry is positive. However, global competition, recent stability in seafood consumption per capita, poor marketing, the regulatory environment, cost uncertainties, disease, environmental constraints, financing, and recent general economic conditions have made development of the salmon farming industry difficult. Relatively slow development of the U.S. industry, in contrast to increases in worldwide production, has caused the price of fresh salmon to drop considerably, especially from mid-1988 through early 1990 when many U.S. producers were just getting started. Nominal prices of Norwegian salmon sold in the United States dropped from highs of nearly $5.50/pound in 1987 to lows of around $3.00/pound in 1990 (UBSPC, 1985–90). In real terms, the price decline was even more severe (Fig. 6). Wholesale prices for farmed Atlantic salmon of approximately $3.00/pound, and under $3.00/pound for farmed chinook salmon, are a cause for concern, since current estimated baseline production costs range between $2.10 to $3.00/pound for Atlantic salmon in Maine[11] and are about $2.40/pound for chinook salmon cultivated in British Columbia (Bettencourt and Anderson, 1990; BCMAF, 1990).

In addition to foreign competition and rapid increase in supply, marketing is another major problem facing the United States salmon industry. Most farmed salmon has been sold as whole, fresh, premium product primarily to the "white tablecloth" restaurant segment and to specialty seafood retail outlets. The common viewpoint is that the presence of salmon in the "white tablecloth" restaurant market segment is relatively established and there is a need to expand the market of farmed salmon to the mid-price range restaurant and supermarket segments. To penetrate these segments to a significant degree, either price needs to remain relatively low (at least for the supermarket segment) or new products need to be developed which meet the convenience needs of the chefs in the moderately priced restaurants, as well as those of both the managers of the retail outlets and the consumers. Neither private nor cooperative marketing efforts within North America have been developed much beyond price-oriented commodity marketing.

Through personal interviews conducted with salmon farmers in Maine in 1989, industry respondents indicated that regulatory constraints were the dominant factors restricting the development of aquaculture throughout most of the 1980's. The bureaucratic process was described as unwieldy, including multiple regulatory agencies at both the Federal and state levels. In 1989, an average of ten different permits were

[11]Most production cost estimates are on the high side of the range (Bettencourt and Anderson, 1990).

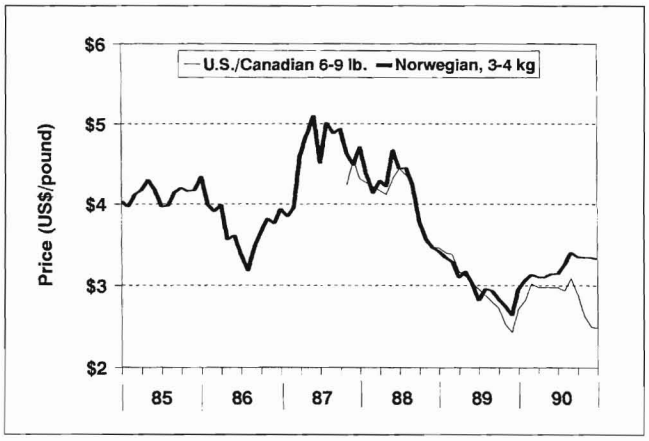

Figure 6.—Real price variation of fresh Norwegian and U.S./Canadian Atlantic salmon (nominal prices adjusted by CPI (1982–84=100). Mid-Atlantic, sales by first receivers—fresh, farmed, whole, head-on. Source: Prices from UBSPC (1985–90); CPI from President's Council of Economic Advisors (1990).

required for obtaining leases, constructing the site, transporting smolts, and marketing. Several additional permits were under consideration (Bettencourt and Anderson, 1990). Based on industry opinions, with the notable exception of the Maine Department of Marine Resources (DMR), the agency responsible for granting aquaculture permits in the state, most agencies and regulatory bodies did not seem to have a clear understanding of how to regulate or grant permits to aquaculture operations. This often resulted in unnecessary delays and regulatory overlaps. The process is gradually becoming more streamlined, especially in Maine, where plans are being developed to standardize the permit application process under the leadership of the DMR (Plante, 1990a), but there is still a long way to go. The U.S. Army Corps of Engineers (COE), in particular, which requires a permit for aquaculture sites under the Rivers and Harbors Act of 1899, has been severely criticized by the farmers for bureaucratic delays in granting the permits (an average of 2 years, according to the producers). Another source of concern for farmers in 1989 was a possible requirement by the Environmental Protection Agency (EPA) that the pen site operations qualify for a pollution discharge elimination permit, under the National Pollutant Discharge Elimination System (NPDES) enacted by the Clean Water Act of 1972. Both the COE and the EPA have been accused of failing to conduct adequate research on the potential costs of the regulatory requirements to the industry, and of failing to set environmental monitoring guidelines for use in ocean systems. As a consequence, producers in Maine estimate that the cost of obtaining a lease site, acquiring the appropriate permits, and paying for consulting and legal fees alone, could easily exceed $100,000 under current regulations (Bettencourt and Anderson, 1990) before normal operational start up costs are incurred.

Regulatory constraints are also a major problem curbing the development of the west coast industry. In Washington, in addition to an operation plan and a site characterization survey submitted to the Department of Natural Resources, a firm may be required to perform a full environmental impact statement (EIS) that may last up to 1 year (TCEDC, 1987). In addition, once the major state, Federal, and county permits are secured, applicants may be required to conduct a benthic baseline survey[12], and an annual environmental survey[13] (SAIC, 1986; TCEDC, 1987). As of 1987, the normal regulatory costs incurred by new entrants ranged between $50,000 and $125,000, with no guarantees of success and before any pens could be placed in the water. For all practical purposes, these initial costs, which can be as high as 50 percent of the total start-up costs of a small operation, have contributed to preventing small operators from entering the industry (TCEDC, 1987). The resulting problems facing salmon growers are not unlike those which faced, and still retard, coastal aquaculture in California as is thoroughly discussed in Bowden (1981). More recently, a broad discussion of regulatory limitation can be found in NRC (1992).

[12]Required for operations with production levels exceeding 100,000 pounds/year.

[13]A diving survey is required for operations with production levels exceeding 20,000 pounds/year. For operations exceeding 100,000 pounds/year, full water quality sampling and hydrographic surveys, in addition to the benthic baseline survey, are required.

Another constraint for U.S. salmon culture relates to production costs, and in particular feed costs. Approximately 60% of a typical salmon feed is composed of fishmeal (Jackson, 1988), which has prices that are extremely volatile as they depend largely on the unpredictable yearly catches of herring (Fig. 7) and the price of substitute products such as soybean meal. In Maine, feed accounts for 30–50% of all operational costs of a salmon farm (Bettencourt and Anderson, 1990; Fig. 8). This introduces an important element of uncertainty on cost prediction for salmon farmers.

Cost uncertainty is further intensified by the occurrence of unpredictable environmental conditions and disease. Several environmental factors can play a significant role in production success. Toxic algal blooms, for example, have reportedly caused problems for some western U.S. salmon operations. To date, no problems of this type have been reported in Maine. Most of Maine's inshore waters, however, are susceptible to the occurrence of superchilled waters, which can cause severe mortality in the pens. This risk factor is a major reason explaining the concentration of the east coast salmon industry in the Cobscook Bay area of Maine which, with its strong currents (3 knots) and high tides (14–15 feet),

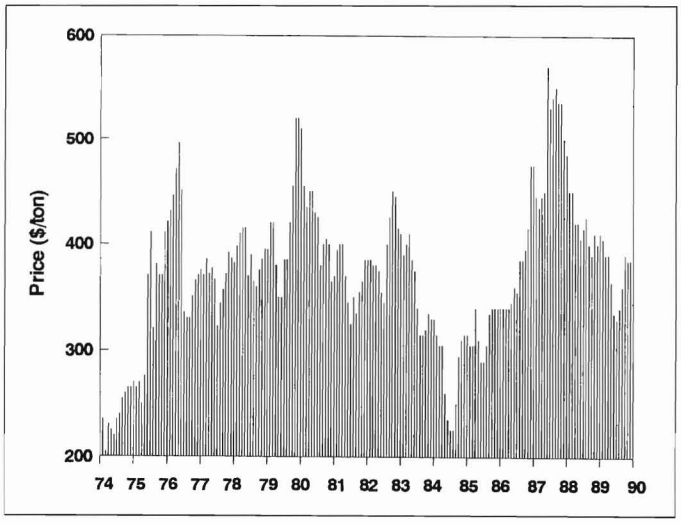

Figure 7.—Fish meal cash prices (Atlanta), 1974–90. Source: Feedstuffs (1974–91).

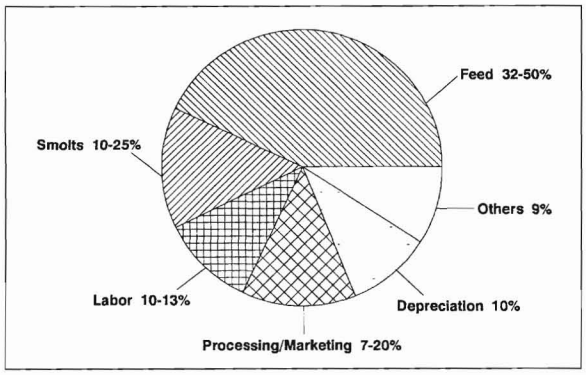

Figure 8.—Salmonid pen culture in northeastern United States: Operational costs as reported by grow-out operators, summer 1989. Source: Bettencourt and Anderson (1990).

is favored with an excellent water flow and vertical mixing of water layers that protect it from superficial chilling during the winter (Sylvia, 1989). Other environmental factors which can affect the aquaculture operations are storms and severe weather conditions, as well as extreme tides, which can hinder access to the sites and induce stress in the fish. Additionally, sea birds and marine mammals (principally seals) can kill or injure fish despite the widespread use of predator nets.

Diseases such as vibriosis (*Vibrio* spp.) and furunculosis have been reported on both the east (Bettencourt and Anderson, 1990) and the west coasts (Weston, 1986). Outbreaks of these diseases are relatively common, but others, such as the reported occurrence of a virus resembling viral hemorrhagic septicemia (VHS) on eggs and adults from government growing facilities on the west coast[14], and the occurrence of infectious hematopoietic necrosis on trout (Weston, 1986), can lead to high mortalities. In addition to disease, birds, seals, otters, and other animals can have serious impacts on mortality levels.

The uncertain nature of the market and of the regulatory environment, and the unpredictable nature of operating costs, has contributed to financing becoming a serious problem for the U.S. salmon culture industry. Since most of the U.S. industry began producing salmon in significant quantities only since 1989, thus starting harvest at a time when prices were declining and supply was abundant, banks and venture capitalists became extremely cautious of investing in the industry. One of the most striking examples was the withdrawal of investor support for the largest Atlantic salmon farm in North America, Ocean Products, Inc. of Eastport, Maine, which resulted in the sale of the company to a Canadian company, Connors Brothers, in September 1990 (Plante, 1990b). Additionally, several farms have had difficulty in acquiring loans to meet their operational expenses.

Given the state of the U.S. economy and the current conservative nature of banking policy, it is not likely that this problem will be resolved in the near future. An additional factor that contributes to the uncertain financial climate is the long life cycle of salmon; in particular for firms that are vertically integrated and operate their own hatchery as well as grow-out sites, production strategies have to be formulated 3 years before the projected harvest[15]. This poses an extreme financial burden on most investors concerned with the volatility of the marketing conditions within the 3-year horizon.

The final issue regarding the recent development of salmon culture relates to foreign ownership and consolidation within the industry. The lack of financing from U.S. sources has contributed to significant foreign investment in the U.S. aquaculture industry (primarily Canadian and Norwegian). The dominant operations in Washington and Maine are at least partially owned by Canadian and Norwegian interests, and the salmon operation in Hawaii is owned primarily by Japanese investors. In Maine, the degree of foreign ownership has intensified as financial constraints and regulatory difficulties have begun taking their toll. Thus, several small local operations that were able to secure permits for their sites at a time when the regulatory climate was more favorable (i.e., prior to 1988–89), have entered into aquaculture agreements with large new firms owned partially or entirely by foreign interests, which, in turn, avoid the high costs of securing new leases (Bettencourt and Anderson, 1990). The unfavorable financial and political climate facing the industry has thus contributed to its consolidation and vertical integration, as well as to an increasing dependence on foreign capital. While the precise degree of foreign ownership is uncertain, controversies are likely to arise regarding foreign investment in salmon culture operations which requires access to common property resources.

Options for the Industry and Government

Several options are available to improve the climate for the U.S. salmon industry. First and foremost, regulatory and permitting procedures (including related costs) need to be, at the minimum, streamlined and standardized, so prospective farmers can adequately judge whether or not to attempt to enter the industry. In Maine, for example, some of the information regarding siting required by the Corps of Engineers for its permits overlaps with information that needs to be provided by farmers for the state aquaculture permits which are generally obtained earlier. A standardization of the permitting re-

[14]WSDF. 1989. Draft news release on new virus isolation. Wash. State Dep. Fish., Draft Rep., Olympia.

[15]Including an average of 1.5 years for the egg-smolt phase (hatchery stage) and another 1.5 years for the smolt-adult phase (grow-out stage).

quirements is warranted, perhaps under the control of a leading regulatory agency as suggested for the region (MSPO, 1990). This may considerably lower the costs resulting from misinformation and delays. A reduction in the permitting and regulatory costs could also encourage the emergence of small local operations in economically depressed areas such as northeastern Maine.

In contrast to aquaculture policies and regulation, U.S. trade law was used by the industry to insulate itself somewhat from foreign competition. The price decline in 1989 precipitated the formation of the Coalition for Fair Atlantic Salmon Trade which alleged that Norwegian salmon production was being unfairly subsidized and that Norwegian traders had been dumping Atlantic salmon in the U.S. market, reportedly selling below cost. The U.S. International Trade Commission (USITC) in June 1990 ruled that Norwegian producers received countervailable subsidies at a rate of 2.27% and, in October 1990, determined that Norwegian companies were dumping salmon, selling at between 15.65 and 31.81% below cost. The ITC also determined in February 1991 that the U.S. industry had been damaged by the Norwegian production subsidies, and imposed tariffs proportional to the estimated dumping margins on fresh, whole Atlantic salmon from Norway (USITC, 1991). The threat and eventual imposition of these duties contributed to the rapid withdrawal of Norwegian salmon from the U.S. market. However, Norway's position was rapidly filled by Canada, Chile, and others (Fig. 5). This type of legal action is expensive and not particularly efficient.

Besides improving the regulatory constraints, there is also a need to reduce production uncertainty. This can be achieved through better disease control, improved farm management, improved feeds, and selective breeding of fish which are disease resistant, fast growing, or possess attributes which are appealing to the market. Research is currently underway to develop techniques that allow for better control of the production cycle, especially the timing of stocking of smolts (typically done in the spring) and their size at stocking time, to enable farmers to extend the harvesting season beyond the traditional winter harvest (Bettencourt and Anderson, 1990). These experiments, if successful, will enable farmed salmon supplies to respond more readily to marketing needs in terms of both quantity and size of fish at harvest. Capital costs need to be reduced as well by developing systems which are fundamentally inexpensive, uncomplicated, and durable.

Marketing strategies and techniques also need refinement and improvement. Competition is strong among U.S. farms, between U.S. farms and other producers of farmed salmon outside the country, and with some components of the wild fishery. Some of this competition is not in the best interest of the industry, as it hinders information flow on such aspects as production techniques as well as marketing. Development of a more efficient product flow from the production to market stages needs to be established, including innovative new product development. Many value added and partially processed salmon products are currently moving into the market, and one should expect to see in the near future an expansion in the supply of products such as salmon steaks, fillets, salmon medallions, roasts and pâtés, and other products prepared with different sauces and herbs, as well as a variety of smoked salmon preparations. An expansion in salmon gift packs is also expected (Marris, 1991; Friedman, 1991).

Norwegian exports to the United States are also widely expected to diversify into value-added products which are not subjected to the tariffs imposed on fresh, whole Norwegian salmon as previously discussed. Despite these recent developments, however, that market development has lagged behind growth in production. Both generic marketing programs and firm-level promotion need more attention. This variety of value-added products ranging from simple fillets to smoked products and a variety of mid-range, convenience-oriented salmon meals implies a need for improvement in packaging and shipping technologies for cultured fish products.

Another critical area which needs improvement is waste disposal technology, including, in particular, the disposal of dead fish as well as the management of effluents from both hatchery and ocean sites. Reduction of mortality and effluent control could be achieved through improved nutrition, better management practices, better site selection, and through new technologies to process wastes and dead fish. As technology for waste disposal and effluent control is refined and improved, regulatory barriers may also diminish.

Another aspect to improving the current status of the U.S. salmon culture industry involves better information flow between researchers at public and private institutions and producers, investors, regulators, and industry supporting agencies. At this stage, most farmers feel that they do not have adequate access to information on aspects such as disease control, management practices, prices, costs, potential profitability, and marketing. This information is also frequently not available to regulatory agencies. In Maine, farmers often expressed the need for a research and development institute capable of meeting some of the information needs, such as the Salmonid Demonstration and Development Farm located in New Brunswick, Canada. Continued and improved communication and collaboration between producers and agencies such as the USDA-supported Regional Aquaculture Centers is also needed.

Greater attention should be focused on market research and development. The serious problems that confronted the industry in recent years were largely a consequence of poor planning, with production strategies being decided at a time when prices were still high (1987). With smolts already in the water, farmers could not avert a large harvest in 1989, when prices declined. This miscalculation could perhaps have been avoided had adequate marketing forecasts reached the producers. Hopefully, as the relatively new "Aquaculture Situation and Outlook Report," produced

by the Economic Research Series of the USDA, improves and broadens its information base, this will help industry participants develop better plans.

In conclusion, worldwide salmon culture is certainly here for the foreseeable future. United States salmon farming, however, is still in its infancy and faces several obstacles that can only be overcome by a closer cooperation between farmers and governmental agencies. The industry's close geographical proximity with the United States market is a potential advantage that is yet to be fully explored. If the regulatory constraints are lifted and the information flow is improved, the industry should be expected to overcome some of its present problems and become a significant contributor to the U.S. supply of fresh salmon. In addition, it could become a building block for other marine finfish aquaculture as it has globally, where salmon aquaculturists are diversifying into cod, turbot, sea bream, halibut, and other species.

Acknowledgments

This work was partially funded by the Northeastern Regional Aquaculture Center and the Rhode Island Agriculture Experiment Station. The authors would like to thank Joan Gray Anderson and Barbara Gardiner for comments and editorial review.

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