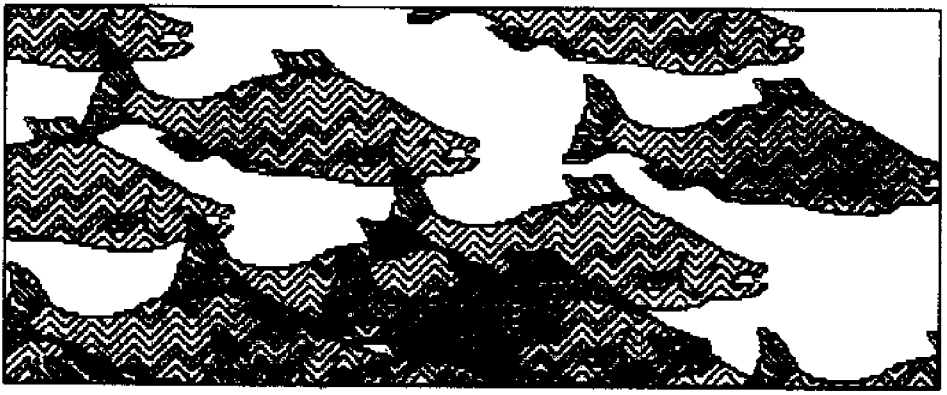
# WORLD SALMON FARMING:
## AN OVERVIEW WITH EMPHASIS ON POSSIBILITIES AND PROBLEMS IN ALASKA



by Curt Kerns



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"Spurred by the chic, up-scale mystique of seafood, more and more consumers want fresh seafood."

(Martin 1985)

# INTRODUCTION

## OVERVIEW

Whenever a plant or animal species with high market acceptability is brought under domestic cultivation, the year-round availability of superior quality, fresh product creates new market opportunities for both farmed and wild products. The phenomenal production increases of farmed salmon may well become analogous to what has happened with the poultry industry. When reliable mass-production techniques for chickens, turkeys, and ducks were developed in the 1940s and 1950s, consumers responded by buying poultry in vast quantities. As increasing health awareness causes consumers to move away from red meat, the production of farmed salmon will become the basis of a large industry (SCC 1985).

## EUROPEAN AQUACULTURE DEVELOPMENT

Many observers feel that the development of saltwater salmon and trout farming in Norway is the most significant event in the history of European aquaculture (NMFS 1984a). The Foreign Fisheries Analysis Branch of the National Marine Fisheries Service (NMFS) predicted that the 1983 output of farmed Norwegian salmon would double by 1990. They missed it by five years. Production doubled in just two years. Between January and December of 1984, NMFS raised their 1990 predictions of Norway's output from 30,000 mt to 80,000 mt (NMFS 1984a, 1984b). The explosive growth in Norway's farmed salmon output is due to export gains, expanding first to other European countries and now to the world's largest market for farmed salmon, the United States.

## NORWEGIAN PRODUCTION

In 1985, Norwegian fish farmers produced a total amount of saltwater farmed salmonids (salmon and trout) equal to the 1979 to 1983 average total United States commercial harvest of king and silver salmon. Norway's output was 32,700 mt while the average U.S. production of king and silver salmon was 32,263 mt (NMFS 1985a).

## IMPORTS OF PEN-CULTURED SALMONIDS

Farmed salmon import is one of the most rapidly growing segments of the U.S. fish markets, second only to surimi analogs. Atlantic salmon imports into the United States are growing even faster than increases in world output. Starting with a nominal amount in 1981, 42,000 lbs (Ford 1984), imports have increased dramatically. In 1985, despite excellent supplies of domestic salmon and Alaska's all-time record harvest, imports of Atlantic salmon have grown to about 16 million lbs, valued at more than $50 million. That is a tripling in just three years (see Table 1). That amount is greater than the total U.S. troll-caught harvest of all species, 95 percent of which was marketed frozen (*Seafood Business Report* 1986).

The United States, the world's largest salmon exporter, was a net salmon importer between January and May of 1984. Although there are no figures available to support this contention, Alaska, with the largest supply of salmon in the world, is probably a net importer during the winter period.

## CONSUMER PREFERENCES

With their increased sensitivity to nutrition and health, U.S. consumers are demanding fresh, very high quality fish, year-round (ASMI 1983, NMFS 1985b). Unfortunately, the traditional domestic salmon fishery only supplies fresh salmon during about one-half of the year. In the rush of having to make a year's profit in just a few weeks, not all fish are treated as well as they could be. Fish farmers from other nations are happy to supply fresh, very high quality fish not only during winter, but increasingly during the summer as well (see Figure 1).

## NEW MARKET NICHE

Handled with the utmost care, delivered to major U.S. markets fresh, oftentimes within 24 hours of harvest, 2 to 5 kg sized, farm-raised Atlantic salmon have found an unfilled market niche, a niche that can possibly be occupied by North American producers.



Table 1. Imports of fresh, farmed salmon into the United States 1983-1985

| Country | 1983 Lbs | 1983 Dollars (US 1,000) | 1984 Lbs | 1984 Dollars (US 1,000) | 1985 Lbs | 1985 Dollars (US 1,000) |
|---|---|---|---|---|---|---|
| Norway | 3,897 | 12,781 | 8,572 | 28,344 | 13,798 | 46,256 |
| United Kingdom | 9 | 33 | 229 | 813 | 865 | 3,003 |
| New Zealand | 7 | 18 | 21 | 58 | 216 | 546 |
| Chile | 0 | 0 | 71 | 144 | 319 | 610 |
| France | 0 | 0 | 2 | 9 | 72 | 275 |
| Finland | 10 | 32 | 181 | 579 | 100 | 268 |
| Ireland | 0 | 0 | 0 | 1 | 30 | 108 |
| Sweden | 3 | 9 | 4 | 16 | 18 | 53 |
| Canada | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. |
| Iceland | 1 | 2 | 12 | 30 | 11 | 34 |
| Denmark | 1 | 1 | 18 | 60 | 2 | 8 |
| West Germany | 0 | 0 | 2 | 4 | 0 | 0 |
| *Other | N.A. | N.A. | 373 | 1,333 | 625 | 1,239 |
| Totals | 3,928 | 12,876 | 9,485 | 31,391 | 16,056 | 52,400 |

*Produced in above countries but shipped through other nations.

Source: U.S. Bureau of the Census, unpublished, and extrapolations from NMFS Fishery Market News, 2/24/86, page 3.

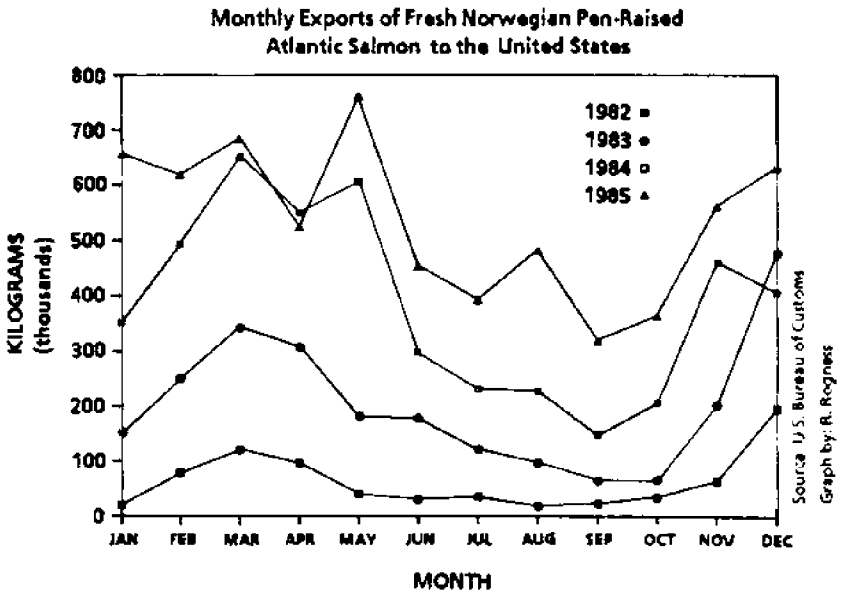


Figure 1. Monthly exports of fresh Norwegian pen-raised Atlantic salmon to the United States.



# HISTORY

## EUROPEAN

Northern Europe has long had fish farms. Carp culture began in Austria in 1227 (Bardach, Ryther, and McLarney 1972). Carp farms spread to Norway during the Middle Ages (IFE 1972). Salmonid culture began in Europe when Stephen Ludwig Jocobi established the first trout hatchery in Germany in 1741 (Bardach, Ryther, and McLarney 1972). Culture of sea trout (brown trout in North America, *Salmo trutta*) and Atlantic salmon (*S. salar*) and hybrids between brown trout and arctic char (*Salvelinus alpinus*) in marine enclosures occurred as early as 1870 (Naevdal 1978). Soon afterward, raising trout for market began on the Atlantic coast of North America (Klontz and King 1975).

### *Rainbow Trout Farming*

Rainbow trout (*S. gairdneri*), which are indigenous to the western drainage of North America from Baja California to Alaska, were introduced into the eastern United States in the 1880s. The culture of rainbow trout spread to Denmark by 1890. Introduction of rainbow trout from North America sped development of trout farming because these fish were much easier to culture than the indigenous brown trout (Sedgwick 1976). Production grew slowly, however, until the late 1960s.

### *Recent History*

One of the first instances in the recent spate of culture projects using marine enclosures was at a public aquarium in Norway in 1958, by Mr. Fritjof Wiese-Hansen.[1] The fish did not fare well, suffering an outbreak of what was thought to be vibriosis (F. Wiese-Hansen, 1986 personal communication). Bardach, Ryther, and McLarney (1972) report that both Japan and Denmark had marine pen culture enterprises by the late 1960s. In 1967, a fenced area in a Norwegian fjord was used, with the first sea pens following in 1969 (Lindgren, Sewell, and Peterson 1985).

[1]Wiese-Hansen is now president of TECS, Inc., of Bergen, Norway. One subsidiary is Scan-Am Fish Farms of Anacortes, Washington.

### NATIONAL MARINE FISHERIES SERVICE MANCHESTER FIELD STATION

In 1969, the National Marine Fisheries Service established the Manchester Field Station to develop the art and science of salmonid pen culture. They too had problems with *Vibrio* spp., but developed a vaccine with the help of private companies and Oregon State University scientists. The vaccination technology was transferred to Northern Europe soon afterward. In the early 1970s, Norwegian salmon farming using net pens placed in marine waters began in earnest.

## METHODOLOGY

### PRESENT CULTURE METHODS

In the United States, salmonids have typically been cultured in fixed enclosures such as raceways, tanks, ponds, or silos at high water flow rates, up to four exchanges of the water volume per hour. Coastal and lakeside facilities are rare for several reasons. Most hatcheries are located away from salt water because coastal land is typically expensive. Lakes are not often used because in all but a few coastal areas with maritime climates, lakes will stratify. The resulting summer temperatures are hotter than those preferred by salmonids. (See Lietritz and Lewis 1980, for a detailed discussion of conventional methodology.)

Pen culture farms are analogous to beef cattle feedlots. Smolts, young salmon physiologically ready to enter seawater, are usually purchased from hatcheries. They are contained by pens placed in brackish to full-strength seawater (5 to 32 parts per thousand total salinity). Atlantic salmon smolts are stocked only in the spring, and Pacific salmon smolts are stocked in either the fall or spring. Their rations are largely made of fish or fish meal that contains 32 to 55 percent protein and 7 to 25 percent fat, depending upon the formulation. They are fed at a rate between 0.2 percent to 5 percent of body weight per day.

Atlantic, coho, and sockeye salmon, and rainbow trout have large smolts, 25 to 70 g, that are 12 to 18 months old (post-fertilization) when placed in salt water. These reach the desired 6 to 12 lb market size within two years. Chinook salmon smolts are placed in



seawater at a much smaller size, 4 to 8 g, at 6 to 10 months old (post-fertilization), and require three years to reach the desired size. In all, it takes 36 to 40 months from the time of egg fertilization for most strains of salmon and trout to reach harvest size of about 10 lbs. Certain domesticated strains of European Atlantic salmon and rainbow trout, however, can reach market size in as little as 22 months, post-fertilization.

### ECONOMICS OF PEN CULTURE

The main advantage pens have over conventional methods is that of low initial capital cost. They do not require dams, pipelines, pumps, or reservoirs. Tidal exchange suffices.

The comparative economics of catfish culture in cages, or pens, raceways, and enclosures have been reviewed; however, there has been no such comparison for salmonids. Collins and Delmendo (1979) reveal no important differences in relative costs of the three culture methods. Assuming water is available for each method, raceway culture has the cost advantage where abundant capital is available and labor is expensive. Cages have the edge if little capital is available and labor costs are moderate. Enclosures are used where capital availability is moderate and labor inexpensive.

"Assuming water is available" is the operative phrase. Water is seldom available in controllable amounts without investment. Canals and control structures are needed even for ponds that use tidal exchange. The tens of thousands of acres of tidal ponds used in tropical countries for milkfish (*Chanos chanos*) culture are often lined with mangroves for storm protection. For ponds in temperate climates, riprapped dikes for storm and flood protection may be necessary. For tidal ponds, ground level should be at an elevation between average higher high water (mean high water level at spring tide) and average lower high water (mean high water at neap tide) (Tang 1979a and 1979b).

### PUMPED SEA-WATER TANKS

Culturing fish in land-based tanks that use pumped seawater is receiving considerable attention in Europe. A 400 mt-per-yr pumped sea-water farm is being built on Vancouver Island in British Columbia. Several firms are investigating sites in Washington.

Higher capital and operational costs for these facilities are said to be overcome by increased control of environmental parameters and ease of fish handling.

## PRESENT STATUS OF SALMON FARMING

### UNITED STATES

*Washington*

Salmon farming in the Pacific Northwest using net pens in marine waters began in 1969 in Puget Sound at the NMFS Manchester Field Station. A joint pilot project was initiated by Domsea Farms, Inc., NMFS, and the University of Washington Sea Grant College Program to rear coho and chinook salmon. The emphasis was on pan-sized fish. Domsea first commercialized efforts in 1971. Soon afterward, Oregon Aqua-foods started another farm in southern Puget Sound. Several smaller companies began rearing pan-sized coho in other locations in Puget Sound.

There are presently six saltwater farms operating in Puget Sound. The three largest are Domsea, now owned by Campbell's Soup and subsidiaries of two Norwegian firms, and Scan-Am and Sea Farm of Norway, Inc., located near Port Angeles (Bill James, 1985 personal communication). About 3 million Atlantic salmon eggs will be used in 1985-86. About one-half were imported from Finland and Norway, and the rest came from the NMFS Manchester Field Station. Chinook eggs are not available because of Washington Department of Fisheries policy.

Opposition from local property owners and residents is the main reason that more farms have not been started. There are presently about seven freshwater farms raising pan-sized silver salmon, most in pumped groundwater.

Domsea produced nearly 4 million lbs of pan-sized, farmed coho salmon in 1985. The other seven freshwater farms produced another 1.5 million lbs (Arnie Einmo, 1985 personal communication).



*Oregon*

Oregon Aqua-foods in Springfield is the only farm operating in Oregon. They produced about 80,000 lbs of coho salmon in freshwater raceways. Started originally to ranch salmon (artificially spawn, rear until the fry are able to go to sea, release into rivers or estuaries, and recapture as returning adults), Oregon Aqua-foods facilities are currently for sale (Rosenberry 1986).

*Maine*

Atlantic salmon are being farmed in Cobscook Bay, near Eastport (Crowley 1983). A lack of suitable sites, warm Gulf Stream currents during the summers, very cold winters, and hurricanes will tend to limit the number of farms on the Atlantic Seaboard.

### CANADA

*British Columbia*

Explosive growth in number of farms, but not production, is occurring in British Columbia. A salmon farming industry is rapidly developing with help from northern European fish farmers, equipment suppliers, and financial institutions.

In 1975, Domsea formed a subsidiary, Apex Bio-Resources, that had pens located near Port Alberni on the west side of Vancouver Island. Unfortunately, Alberni Inlet is probably one of the few areas in British Columbia ill-suited for pen culture of salmonids as surface waters can reach 20°C (68°F) as early as April. By 1983, there were eight salmon farms producing pan-sized fish. In 1984, there were 12 permitted salmon farms. By June of 1986, there were 150 permits issued and more than 100 in process. Forty to 50 farms are expected to be operating in the spring of 1986.

In 1980, British Columbia produced 79.3 mt of trout, mostly from fresh water, and 146.5 mt of salmon, mostly from salt water. In 1984 production was 77.2 mt of trout, and 109.6 mt of salmon, a net decrease despite increased numbers of permitted trout farms from 46 to 107, and salmon farms from 3 to 12, 1980 to 1984, respectively. Most salmon farmers are not selling their chinook salmon, waiting rather for them to mature. Viable eggs from one

female chinook can be worth C$500 to C$1,000. Egg purchases, an indication of future production, were 1.4 million trout and 2.8 million salmon eggs in 1984 (B.C. Commercial Fish Farm Statistics, Ministry of Environment, Victoria, B.C.)

In 1985, nearly 20 million salmon eggs were purchased, enough to produce about 7,500 to 22,000 mt of fish. Present demand is about twice the available number of eggs. One smolt-producing company alone, Cockburn Bay Farms, is expected to produce more than 4 million smolts in 1986.

During 1986, 1.5 million Atlantic salmon eggs will be imported from Scotland into B.C.

Two companies have gone public, Seastar Resources and Pacific Aqua-foods. Another should soon be traded on the Vancouver Stock Exchange. Both stocks have risen dramatically in value.

The primary market for B.C. farmed salmon will be the U.S. The only specific subsidy is a government loan program for C$100,000 for equipment purchase, the Aquaculture Incentive Program. No interest accrues for three years and payback is required within five years. Aquaculturists are eligible for several other small business assistance programs.

*Maritime Provinces*

Salmon farming is also beginning on the Canadian east coast. Canada Packers, the largest food processor in Canada, (1985 sales C$3 billion) has formed a joint venture with Sea Farms of Norway, said to be the world's largest farmer of salmon. Two hatcheries will be built in New Brunswick, and fish raised in the Bay of Fundy. About $18 million will be invested. The primary market will be the U.S., according to a company spokesman (Nix 1985).

## OTHER PRODUCERS

*Norway*

Norway is the world's dominant producer of Atlantic salmon, accounting for about 70 percent of the total. Starting with harvests of 171 mt in 1973, Norway's 1985 production increased to about



27,200 mt of Atlantic salmon and 5,500 mt of rainbow trout. The industry is estimated to generate sales of $300 million per year, primarily as an export product.

By 1969, Norway had approximately 260 fish farms. Not until the early 1970s did marine pen culture become an important technique. Rainbow trout were the main species cultured until 1976, when Atlantic salmon became the main species (Gard 1984).

The rapid development of farm production (more than 600 are now operating with another 1,000 permits awaiting approval) reflects more than applying sound fish cultural practices. The process has involved many persons and institutions. Marketing, careful attention to industry structure and form, a long-term commitment to applied research, and the strong desire to produce the best-quality product have all been significant factors in the success story (Gordon 1984).

Norway is the seventh largest fishing nation in the world. Cod has a long history as its most valuable species produced, worth ex-vessel $100 to $200 million per year. Norway now produces a crop of farmed salmon that is more valuable than the cod catch.

The Norwegian government is actively involved in salmon farming. Loans to small growers are guaranteed through Regional Development Funds, and through the Agricultural Development Fund. Federal funding goes to research institutes. A national marketing board restrains production and sets quality standards. Farms constructed since 1974 can be no larger than 8,000 $m^3$, or about 50 to 80 mt per year production, in order to maximize the number of jobs created in rural areas. Restricting the volume as a way of limiting production is beginning to cause problems as farmers seek to maximize profitability by raising stocking densities.

*United Kingdom*

The U.K. has a strong, commercially successful Atlantic salmon farming industry, numerous freshwater trout and carp farms, as well as a very strong research infrastructure.

Most marine and net-pen farming is done in Scotland, adjacent to the Western Isles, and off the northwestern coast. Sheltered sites

are limited; however, 67 companies with 126 fresh and saltwater sites were in business in 1984. Output that year was nearly 4,000 mt. In 1985, production was 6,921 mt (*Fish Farming International* 1986). Four million smolts went into sea cages in 1984, which should translate to harvests of about 9,700 mt in 1986, with 1987 harvests predicted to be nearly 14,000 mt.

*Ireland*

Ireland does not have many sheltered saltwater sites. Output in 1990 is projected to be 2,000 mt of Atlantic salmon and 2,000 mt of rainbow trout, 50 percent pen reared.

*Denmark*

Trout farming in marine waters began in Denmark in 1974. By 1984, there were 17 sites. Nearly 50 are expected by 1987, with the number of land-based, pumped saltwater farms growing from the present seven to ten. The current output is about 25,000 mt of freshwater-raised and 2,500 mt of saltwater-cultured rainbow trout. Projected output is highly speculative; however, overall production is expected to grow to 50,000 mt by 1990. Eel and fish from families other than Salmonidae are expected to make up 10 to 15 percent of the total. Nearly 90 percent is exported, primarily within Europe (*Fish Farming International* Vols. 11, 12 and 13, various issues).

Strong government support is evident, particularly in the Faroe Islands. Subsidies include loans of up to 85 percent of project cost.

*New Zealand*

Pacific salmon from California and British Columbia were introduced into New Zealand in 1901 (Withler 1982). Chinook salmon (*Oncorhynchus tschawytscha*) reproduce naturally in several streams. Present production is on three main farms, with an output of 250 mt. Output is expected to grow to 2,000 mt by 1990 (*Fish Farming International* 1985a). In 1983, 90 percent of the farmed salmon was exported to the U.S. Pen culture of sockeye salmon (*O. nerka*) has also begun. The fish are reported free from IHNV (infectious hematopoietic necrosis virus), a potentially devastating disease, and have adapted to fresh water (kokanee). No special assistance is given other than the tax benefits all new industries receive.



*Finland*

Finland farmers mainly culture rainbow trout. Ironically, the fish are descendants of a domesticated strain developed at the University of Washington, and are being exported to the U.S. in growing quantities. The 1985 production was about 1,000 mt. Atlantic salmon are raised for smolt production and exported to northern Europe and North America.

*Iceland*

Salmon production is primarily from ocean ranching. Marine survivals range from 5 to 15 percent. The break-even point is 3.5 percent for a 1 million smolt-release hatchery. Over the past 20 years, the Icelandic government involvement has grown to include operation of about 40 salmon hatcheries and research stations. Two large private firms, joint ventures with a Norwegian and a U.S. firm, are in operation. Production is about 100 mt annually, expected to grow to around 5,000 mt by 1990. No financial incentives are reported.

*Japan*

Since 1978, saltwater pen-culture output has grown to about 7,000 mt in 1985 (Atkinson 1985a), with a projected 18 to 22 percent increase (8,500 to 9,000 mt) in 1986 (Atkinson 1986a). Almost all cultured fish are coho salmon although interest in sockeye salmon is high, and Nichiro has succeeded in raising chinook salmon. Nichiro Fisheries Company started the farms with Taiyo and Nichimo (other large trading companies) following their lead. The eggs come from Washington and Oregon hatcheries, typically in December. After hatching they are held in fresh water until the following October or November. By then the fry have grown to weigh between 100 and 250 g each. By the following July they weigh 2.5 to 3.5 kg each. The fish enter the markets when supplies are high. Consequently, they do not command the premium prices received in winter. Prices received for coho salmon range from $1.90 per lb to $2.36 per lb (Atkinson 1985b, 1985c). The average for 1985 was $2.13 per lb (Atkinson 1986a). The first trial production of chinook salmon sold for $3.21 to $4.01 per lb (Atkinson 1986b).

The main culturing location is in Miyagi Bay on the main island of Honshu, where water temperatures seldom drop below 10°C and can reach lethal levels in late summer. There are four egg importers, 34 freshwater hatcheries, and 224 growers. The fish produced are domestically consumed. In 1985, 2,000 mt were purchased by salt processors, another 500 tons were reportedly frozen, and the rest was sold fresh (Atkinson 1985a). No particular subsidies exist. However, as with many of Japan's fisheries, one must be a member of a cooperative to be a farmer.

*Chile*

Chilean salmon aquaculturists are attempting ocean cage culture and ocean ranching. Reports on ocean ranching of chum and silver salmon have not been encouraging. A number of chinook weighing more than 50 lbs have returned from a 1981 release (*Fish Farming International* 1985b). Nineteen new pen culture sites have been installed. Farmers expect production to be as high as 3,000 mt by 1990. Corporations and government agencies from Japan, the U.S., and Canada have joint aquaculture development projects in Chile. Nichiro has made test shipments of pen-reared coho to Japan at a selling price of $4.28 to $5.56 per lb. No direct financial incentives are reported.

*Sweden*

Most of the farmed salmon in Sweden is cultured in the warmer southern waters. Production in 1983 was 100 mt (NMFS 1984b). Few are exported to the U.S.

*Tasmania*

Atlantic salmon and brown trout eggs have recently been shipped to Tasmania from Europe. A joint venture has been formed with a local firm and Noraqua A/S, a subsidiary of a large Norwegian company, to do the investigation. Some believe that Tasmania is an excellent location for pen culture of salmonids, and hope to produce 2,500 mt per year within 10 to 15 years.



# THE POTENTIAL FOR PACIFIC NORTHWEST SALMON PRODUCTION

There is substantial biological and economic potential for salmon farming within the Pacific Northwest of North America, with British Columbia and Alaska having the most potential sites. California, Oregon, and Washington will have to rely on the development of pumped sea-water technology. Since water temperatures in the Gulf of Alaska do not vary much from those found from southeastern Alaska to Prince William Sound, Alaska has many potential sites, particularly if heavier-duty pens are used.

## SITE SELECTION

Experience taught the Norwegians to favor sites that are not too sheltered. Small bays with narrow entrances or shallow sites are not desirable. A good site will be somewhat protected from storm waves, yet have high water circulation rates. Pens developed in Norway routinely withstand 12-ft waves. Pens developed in Japan by the Bridgestone Rubber Company withstand much higher waves. Water depth should be at least 40 ft at a minus tide. Currents should not exceed 4 mph.

## ALASKA'S ADVANTAGES

Alaska has a number of advantages for pen culturing:

* Lower transportation costs to U.S. markets and shorter lead times for orders than any other location except Canada
* Large numbers of different chinook stocks, the favored fish of West Coast markets
* A plethora of pollution-free sites
* A population experienced in fish culture, fish handling, processing, transporting, and marketing
* Vast quantities of fish waste, the raw material for feed
* Processing plants and tenders with on-board fish pumps needing year-round employment

* The marketing advantage of "Buy American"

* No national barriers to cross in reaching the U.S., the largest market for farmed salmon in the world

*Transportation Costs*

The first air shipments of farmed salmon from Norway to the U.S. were sent on underused backhauls of air charter flights. Next, scheduled air passenger flights were used, followed by scheduled air freight.

The present air freight costs from northern Europe are about $0.60 per lb to the East Coast and about $0.80 per lb to the West Coast. Consequently, the advantage that Southeastern Alaska and South-central Alaska enjoy is $0.57 per lb and $0.62 per lb in freight cost, respectively. Industry sources indicate that the "pipeline" of fresh fish from Norway can only deliver about 200 mt per week due to limitations in air cargo capacity. During April of 1985, that quantity was approached (see Figure 1). If shipments are to exceed 200 mt per week, chartered flights are inevitable; Alaska will then have an advantage of nearly $1.50 per lb.

*Market Preference*

West Coast markets prefer king salmon. That preference is reflected in prices. F.O.B. Seattle prices for chinook run $0.40 to $0.60 per lb higher than for comparably sized Atlantic salmon, and about $1 per lb more than that for rainbow trout and silver salmon (see Table 2). In a recent survey, Rogness and Lin (1986) found that seafood wholesalers preferred Pacific salmon over that of Atlantic salmon for its superior flesh quality.

*National Interest*

There is a national interest served by domestically producing farmed salmon. A rapidly growing national balance of trade deficit can be slowed. Consumers will receive the benefits of additional choices of very high quality products. This national interest will serve domestic producers in their marketing strategies.



Table 2. Prices paid for farmed Atlantic salmon, 1984-1985.

The prices paid for farmed Atlantic salmon have been very consistent since they were first introduced to U.S. markets in 1981. The best prices are from late November to mid-May, when fresh, commercially caught salmon are virtually non-existent.

Wholesale prices per pound, F.O.B. Sea-Tac airport for farmed Atlantic salmon during the late fall, winter, and early spring of 1984-1985 were:

| Size class (lbs) | Price U.S. $ |
|---|---|
| 2-4 | $3.05 |
| 4-6 | $3.36-3.64 |
| 6-9 | $3.81-4.09 |
| 9-11 | $4.11-4.36 |
| 11-13 | $4.59 |

Chinook salmon reaching market during the winter brings approximately $0.50/lb more, and steelhead and coho grown in saltwater bring about $0.50/lb less.

Source: Mr. Arnie Einmo, President, Dory Seafoods, Bellevue, Washington

*Foreign Investors*

Alaska has no international borders to cross between its supply of farmed salmon and the large U.S. markets, an advantage that is not shared by other locations with a large number of sites. This factor has not escaped the attention of potential investors.

Discussions with industry and university faculty indicate that northern Europeans are now seeking to invest in Alaskan fish farming and will bring their technology and financing when allowed the opportunity. Increasing transportation costs have already led Norwegians to establish farms in Washington and on both the Atlantic and Pacific seaboards of Canada. Corporations from Scotland, Sweden, and other nations are seeking sites in British Columbia and Alaska. Their banks understand fish farming. It is not unusual for farms to be financed with 25 percent equity capital. The Norwe-

gians have particularly attractive export credit financing for equipment such as pen complexes.

*Present Alaskan Constraints*

Several major problems and a number of minor difficulties currently face would-be salmon farmers in Alaska. The legal framework is not established. Some commercial salmon fishermen oppose fish farming, believing it is incompatible with traditional fishing. There is a shortage of broodstock. Since salmon farming is animal husbandry, ongoing research and worker training will be necessary. There are no local supplies of economical, high-quality fish feeds. Disease and genetics policies were developed for salmon ranching, a much different endeavor, and should be widely discussed and perhaps revised for farming. An understanding of industry structure and form in competing countries is mandatory. Competition from other salmon farming countries will be intense. Because Alaska does not have a farming industry, questions of profitability are unanswered.

*Legal*

Alaska statutes do not specifically prohibit salmon farming; however, enabling statutes are lacking. Consequently, the Alaska Department of Fish and Game (ADF&G) has not directly encouraged fish farming, since no legislation has been enacted to set public policy guidelines.

Fish farming is mentioned in 16.05.340 (15) which discusses fish, fur, or game farming licenses, and again under 16.05.930, "...this chapter does not prohibit rearing and sale of fish from private ponds, the raising of wild animals in captivity for food...". And fish farming is clearly contemplated by existing definition in 16.05.940 (12).

*Attorney General's Opinion*

Two opinions on fish farming have been issued by the Alaska Attorney General's Office. File 366-187-84, December 13, 1984, concludes: "In summary, marine net pen salmon rearing is not prohibited by current fish and game statutes and regulations and would not constitute an exclusive right or special privilege of fishery."



The second, dated January 31, 1985, was more restrictive, and states: "In summary, marine net pen salmon rearing would not constitute an exclusive right or special privilege of fishery, but is not currently authorized by fish and game statutes and regulations." Additional legislation may be needed to outline how hatcheries could transfer smolts. (See OCFD, FRED 1985 for a copy of the Attorney General's opinions, or contact that office directly.)

*Political Incompatibility*

Political incompatibility is essentially a moot point in terms of market competition, as pointed out by a number of members of the Governor's Ad Hoc Aquaculture Advisory Committee, and by work commissioned by the Sealaska Corporation (OCFD, FRED 1985).

Whether Alaska has salmon farms is irrelevant to the world supply picture. Thirteen other nations are farming salmon. Farmed salmon production will continue to rise until the supply eventually meets demand regardless of what Alaska does. The real question is who will export and who will import.

Alaska currently imports fresh salmon during the fall, winter, and early spring, but it can potentially produce enough fresh salmon year-round to meet its own needs and develop a significant export market of both commercially harvested and commercially farmed salmon. Imports of farmed salmon already exceed the total U.S. troll harvest of all species. The United States can be a net importer of salmon during certain winter months or we can supply our own, and perhaps export as well. (The winter market for fresh red salmon in Japan is undoubtedly considerable. For example, the first red salmon harvested from the Copper River bring premium prices, up to $4.50 per lb, in Tokyo.)

The feeling in some sectors of the salmon fishing industry that "farmed salmon are taking our markets," is a misconception. Essentially, the North American commercial fishing industry is not supplying the product form preferred by U.S. white tablecloth restaurants and salmon farmers are taking advantage of those sales.

But goods and services are ultimately paid for by the consumer, not the seller; and the evidence suggests that in premium markets fresh

salmon of any origin is favored by customers over frozen salmon. Consequently, fresh salmon appears to occupy a slightly different market niche than frozen salmon.

Of the 15.5 million lbs of troll-caught salmon landed in Alaska, Washington, Oregon, and California in 1985, 95.7 percent was frozen (*Seafood Business Report* 1986). Rogness and Lin (1986) report that of the 63 seafood distributors who answered a survey, 79 percent stated that they did not consider frozen, wild Pacific salmon to be a substitute for fresh, pen-reared Atlantic salmon.

World supplies of salmon are dramatically increasing. As consumers have more choices, selling salmon in certain traditional ways is becoming more difficult.

Commercial fish harvesters could still fish during the summer and farm during the winter. Salmon farms could replace the rural livelihoods lost as limited entry permits have changed hands, moving from rural residents to those in cities and other states.

*Broodstock*

For salmon farming to have any chance to succeed in Alaska, we must have adequate broodstock.

The major problem facing Alaskan salmon farmers is a lack of sources of domesticated broodstock. In northern Europe the industry is established and domestication is better developed than in the U.S. Certain strains of coho from Washington and Oregon are somewhat accustomed to captivity as are a number of rainbow trout stocks. There are, however, no domesticated strains of chinook salmon. No North American stocks of Atlantic salmon have been selected for domesticated traits either. While NMFS's Manchester Field Station has held North American stocks in sea pens, some for a number of generations, they have not been rigorously selected for the traits compatible with production conditions: rapid growth rate, tolerance to overcrowding, adaptation to formulated rations with high feed conversions, disease resistance, and ease of handling.



*Species Preferences*

Nonetheless, Manchester Field Station personnel prefer to culture the Atlantic salmon instead of chinook (C. Manbun, 1985 personal communication). To date, Atlantic salmon have proven more suitable for raising to large sizes than have Pacific salmon. Rainbow trout have strong potential, although their lower market value is a negative factor.

There are no Alaskan salmonid stocks with a history of extensive use in pen culture.

*Priority Species*

Pacific Coast markets of North America, where Alaska will be the most competitive, prefer chinook salmon. That species should be given the highest long-term research priority. Unfortunately, the NMFS Manchester Research Station experience with king salmon has not been satisfactory (T. Novotny, 1985 personal communication). They suffer high mortality after the second year held in salt water. The NMFS Little Port Walter Field Station on Baranof Island in Southeastern Alaska, has also had mixed experience (Thrower *et al.* 1985). British Columbian experiences have also been problematic, although better than in Washington and Alaska. The one crop that Nichiro has raised from 1983 brood year chinook salmon originating in Washington has been encouraging, although mortalities were 20 percent during the six-month saltwater rearing phase. Whether the stress of captivity will prove extraordinary to chinook salmon, resulting in consistently high mortalities, is not known.

*Policy Questions*

Questions such as whether domesticated Atlantic salmon or rainbow trout should be brought in from outside the state must be discussed and policies must be developed. Domesticated fish strains are better adapted to the intensive conditions of production farms than are fish that have not been subjected to production conditions and rigorous genetic selection. If Alaskan salmon farmers are to compete with better established farms, difficult questions about importing non-indigenous stocks must be addressed and satisfactorily answered. If limited importation of domesticated stocks is allowed, policies, par-

ticularly those concerning disease, must be developed to insure that existing salmonid stocks are protected.

*Genetic policies.* Presently, Alaskan salmon ranching regulations restrict the distance allowed for transport. Stock importation is prohibited in order to protect both hatchery and non-hatchery fish that may intermingle with transplanted fish after release. While this does protect existing free-ranging salmonid stocks, it is a problem for salmon farmers and requires reevaluation. The closely controlled conditions of salmon farms are quite different from those of salmon ranches that release fish into common property pastures. Protecting free-ranging stocks must, of course, be of prime importance.

*Disease policies.* The transmittal of fish diseases is unacceptable and unnecessary both for free-ranging and closely controlled stocks, but particularly the latter. Disease can be more of a problem for farmed fish. Longer captivity, more frequent handling, higher densities, and oftentimes nutritionally less-complete feeds make all farmed animals more susceptible to disease than even the same species and stock if free-ranging.

Alaska has comprehensive, conservative disease policies and regulations. No known disease problems have been caused since their implementation. They may not, consequently, require change for intrastate movements. Hatchery practices used with fish destined for farms will need to be strengthened. Each female's eggs should be incubated separately until screened for disease. Eggs found with virtually any disease are terribly expensive in the long run. The Alaska Department of Fish and Game's pathology section will need to be strengthened. Again, protection of existing free-ranging stocks must be of prime consideration.

*Needed Policy Changes*

If, in order to be competitive, salmon farmers in Alaska must obtain carefully screened salmonid stocks from outside the state until suitable stocks of Alaskan chinook are found and developed, new policies and regulations are needed. Statutes may need to more clearly define the authority and role of the Commissioner of the Department of Fish and Game. The rigorous policies of British Columbia (DFO 1984) may well serve as a starting point for discussing changes to Alaska's statutes on fish transport from outside the



state. There are fish stocks available, long held in close captivity, with disease histories dating back as long as the science allows, that will provide a minimum of risk. These stocks are already being used in Washington.

## RESEARCH NEEDS

Virtually no aquatic organism has been domesticated during the latter portion of this century in developed nations without extensive and ongoing research and development efforts.

### WORLD FISHERIES SCIENCE RESEARCH

Of the more than 4,000 titles in fisheries science appearing in more than 400 scientific journals during 1984, 29 were on chinook salmon (Cvancara 1985). None of the articles were on chinook pen culture.

The only cultured chinook salmon comparable in size to the Atlantic salmon (3 to 5 kg) that are being imported to the U.S. are from British Columbia. The first 4-kg fish were produced there during the spring of 1985 for broodstock; consequently every care was lavished upon them.

*European Research*

There are a number of research centers in several European countries, and therefore an extensive literature base exists on the marine culture of rainbow (steelhead) trout and Atlantic salmon (Coche 1983).

*North American Research*

Research on net-pen culture of salmonids is presently under way on the Eastern Seaboard and at the NMFS Manchester Field Station with Atlantic salmon. The Pacific Biological Station, Nanaimo, B.C., is investigating pen culture of several salmonid species. There is little known about salmon farming in Alaska, however.

## ALASKAN RESEARCH

In a cooperative study, NMFS Auke Bay Laboratory and ADF&G are conducting preliminary trials of sea-pen culture of chinook salmon (Thrower *et al.* 1985). Problems requiring further work have been noted.

### *Variability Between Stocks*

Basic understanding of variability between Pacific salmon stocks is lacking. There is strong reason to expect variability between stocks of naturally spawned fish when they are introduced to domestication because they are adapted to different environments (Ricker 1972). Adaptation to differing environs results in salmonids with a wide range of individual stock characteristics. Kinghorn (1983) reviewed the literature on variability of genetically controlled production traits. Twelve studies of heritability have been performed on growth traits of rainbow trout, and five studies have been done on Atlantic salmon, but none have been done on Pacific salmon. A recent symposium (Wilkins and Gosling 1983) includes several papers on genetic variation of production traits between stocks of rainbow trout but none on Pacific salmon.

Alaska has from several hundred to more than 2,700 different stocks of Pacific salmon, depending on the criteria used. Rapid development of local stocks suitable for domestication will come only from testing under production conditions.

### *Short-Term Rearing Research*

Several studies on Pacific salmon held in sea pens for short-term rearing (holding fry and supplying feed during the first winter and/or spring for purpose of enhancing survival of salmon released into the ocean) have been done (Wertheimer and Martin 1984; Heard, Martin, and Wertheimer 1977). Very little has been reported; however, on long-term culture of salmonids in North America, Kennedy, Shoop, and Griffioen (1975) and Novotny (1975) report on the two main efforts.



## FEEDS

As with raising other domestic animals, feeding is the main expense. Consequently, nutritional studies are an ongoing undertaking. There is some understanding of the nutrient requirements of rainbow trout and salmon (NRC 1973, 1981). The adaptation of cultured fish to diet is complicated, however, by differences in environmental parameters such as temperature, light intensity, and the water chemistry in different locations (Cowey and Sargent 1979). Consequently, the nutritional response of a particular species to a specific practical ration can vary. Direct feeding trials are the only way to select the best ration. Feeding trials are also necessary to develop the most economical rations (dollars in, dollars out), and to test the use of new ingredients. Species differences will probably be reflected in slightly differing nutritional requirements. Kerns (1985b), for example, cites subtle differences in nutritional responses between post-larval pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon.

# TRAINING

## NEEDS

When salmon ranching began in Alaska during the mid-1970s, trained personnel had to be lured from outside the state. In order to insure that Alaskans benefit the most from salmon farming and other aquaculture endeavors, they will need training.

## LEVELS

Several different levels of training are required for the different jobs involved in salmon farming. As with most animal husbandry jobs, vocational education classes through high schools and continuing education programs will suffice for hatchery workers and those who feed and provide most of the care in pen culture operations. This training is best delivered using hands-on instruction coupled with classroom lecture and discussion. Instilling the necessary attitude is as vital, if not more so, as teaching technical skills.

A lead fish culturist would benefit from more thorough theoretical understanding and practical experience that a one- or two-year college level degree will convey.

A four-year college degree will be of value for persons involved with more technical matters such as disease diagnosis and treatment, or for business managers at larger farms. A bachelor's degree in fisheries science with a master's degree in business administration is appropriate for someone managing a complex of several farms. A bachelor's and master's degree are indicated for certain disease, genetic, and nutrition work.

Alaska's existing educational programs can provide all of the training necessary save the hands-on, practical experience. (The small number of Ph.D.s required for research already reside on staff of organizations, agencies, and firms in Alaska.)

### AQUACULTURE EXPERIMENT AND TRAINING STATION

An aquaculture experiment and training station, staffed with competent scientists, culturists, and motivated students is needed to answer questions on domestication and to transfer information, skills, and attitudes. Other possible culture species need work as well, for example, oysters, scallops, mussels, and marine algae.

To perform valid research, a production-sized farm will be necessary at an initial cost of about $500,000 per year for three to five years. Creating an aquaculture experiment and training station does not necessarily mean large, long-term state expenditures. Once the first crops are harvested, revenues from the sale of fish and of eyed eggs will make the station self-sufficient, or nearly so, depending on the amount of basic research being conducted and training duties. It is commonplace for faculty to be on staff for teaching, but it is required that outside funding be sought for research.

## COMPETITION

North American salmon farmers will be getting into a very competitive industry. If projections come even close there will be large quantities of similar or even identical product available from a growing list of foreign countries, some of which have a 15-year head start. Competing will require determination, a favorable regulatory climate, and ongoing research and development.



### PRICE INCREASES

Over time, the price received for farmed salmon will drop. While prices have been stable at about $4.20 per lb for 9- to 11-lb Atlantic salmon (F.O.B. Seattle) for the past five years, prices cannot be expected to hold (see Table 2 for 1985 F.O.B. Seattle prices). The rate of production growth is very high. Consequently, projections are for prices to soften by 1990 (NMFS 1985a).

Further credence is given to this contention by the present high profit margins. Industry sources indicate that the ex-farm breakeven point in Norway is somewhere between 11.25 and 13 Nkr ($1.25 to $1.50 per lb), dressed and packaged. Air freight adds another $0.60 to $0.80 per lb to the cost. Consequently, margins can shrink $1.90 to $2.35 per lb before losses occur.

If the cattle industry is an appropriate example, prices will eventually fall to the point of covering variable costs only. In such a competitive environment, the firms best able to produce top quality product at the lowest prices will survive.

### ALASKA'S COMPETITION

Alaska's main competitor will become British Columbia. They have a large number of sites, many indigenous chinook stocks, and share most of Alaska's advantages: experienced fisheries scientists, fish culturists, fish handlers, processors, and distributors. They also use a currency with a favorable exchange rate and are physically closer to the U.S. markets.

### U.S./CANADA TRADE BARRIERS

It is possible but not likely that trade barriers will be set up as they were for Canadian cod landed on the Atlantic coast. The tariffs (6.85 percent duty) imposed on Atlantic Seaboard imports were in reaction to fisheries subsidies, particularly the government assistance given to processors. Both the U.S. and Canada subsidize salmon similarly, with methods such as vessel loan programs, fisheries enhancement, and salmon aquaculture loan programs.

Despite well-publicized setbacks, efforts are presently under way to remove most trade barriers between Canada and the U.S. The trade

between the U.S. and Canada is the largest between any two countries in the world. U.S. companies sold $66 billion in goods to Canadians in 1984 and imported $112.5 billion (Clarke and Hryciuk 1986).

For Alaska to have a viable salmon farming industry it must be competitive with British Columbia over the long term.

### DISTANCE FACTORS

Many, if not the majority, of the sheltered sites in Alaska are some distance from road, ferry, and air freight service. Norway is served by hundreds of modern car ferries that service the entire coastline (Gjerset 1984). Many British Columbia farms are located on road systems.

Distances may not be all that important because of how salmon farming develops. Very few places contiguous with the Gulf of Alaska are further than 100 miles from a processing plant. Trout growers in other states advertise a delivery radius of 1500 miles. Moving live fish from farm to processing plant will not be that difficult. Unless salmon farming develops in Alaska much differently than in northern Europe, tenders will be used to haul live fish to holding pens adjacent to processing plants, the majority of which are served by airports.

If fast air service is reasonably close, the distance from Alaska to markets is considerably less than from any other potential supplier save Canada. If fresh fish can be air freighted from New Zealand to West Coast markets, it can certainly be air freighted from Alaska.

### SUPPLIES

Supplies and feed are likely to be brought in by barge or tenders, just as remote salmon hatcheries and processing plants now arrange. The supply problem is essentially the same as with all of the goods and services Alaska now imports. It raises the cost of doing business, just as it does in most other places where salmon are farmed, and will do so for the majority of fish farming sites in B.C.



### COST EFFECTIVENESS

The efforts revealed in the report commissioned by Sealaska Corporation (OCFD, FRED 1985) and by Kerns (in press 1986) indicate a favorable cost/price structure. The question of profitability will not be answered with certainty until a number of farms are in place.

## BENEFITS TO ALASKA

Alaska has much to gain by developing salmon farming:

* Market penetration and continuity of product supply
* Improvement of Alaska's image for fish quality
* Winter use of tenders and processing plants
* More complete use of fish and fish waste
* More year-round employment

### MARKET PENETRATION

Salmon farming in Alaska can increase market penetration and raise prices received for other Alaskan salmon. Premium quality farmed fish sold during the winter can earn an excellent reputation for Alaskan fish.[2] That reputation for quality can be shared by commercially caught salmon, particularly chinook, coho, and red salmon, if they are treated with care similar to that given to farmed fish. Economic rewards are created for both fishermen and processors to justify the extra care and expense required to produce a top-quality product.

The Prince Rupert Fisherman's Cooperative plans to add 100 salmon farms to its membership and has already started a hatchery. They want to process and market fresh fish all year.

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[2]Salmon farmers have little incentive to sell their product during the summer when most growth occurs and supply of commercially harvested salmon is high.

### WINTER EMPLOYMENT

Tendering, processing, transporting, and marketing of farmed salmonids will be done in the winter.[3] Tenders and processing plants are typically underused during the winter. One of the major factors in the high capital costs of Alaskan fisheries is not being able to spread cost over the entire year. Salmon farming will help spread costs into the winter.

### FEED PRODUCTION

Processors and fishermen stand to benefit substantially from fish feed production. For each unit of mass (expressed as wet weight) of farmed salmon produced, approximately two units of feed (expressed as dry weight) will be required. That translates to eight to ten units, depending upon quality of the dry ingredients added (expressed as wet weight) of fish and fish wastes required to produce each unit of farmed fish.

Feed production is a way to turn what is now a profit drain into a profit center. Vast quantities of underutilized fish wastes are produced in Alaska. Many processing plants have to pay for waste disposal, but some of that could be used to make fish feed. Processing plant operators will be able to market both fish wastes and complete feeds.

Participants in some fisheries will have new opportunities as well. By-catch that is presently discarded can be sold, and some marine organisms that now have no commercial value could be harvested. The only pelagic organisms that salmon do not eat are jellyfish. Virtually every other organism can be used as a feed ingredient. It must be understood, however, that feed ingredients are not high value.

The feed requirements for salmon farming are quite large. The 1983 imports of farmed salmon from Norway to the United States

[3]A certain percentage of salmonids become sexually mature at a younger age and smaller size than the average for each species. These "jacks" or "jills" will have to be sold prior to when spawning normally occurs for that particular stock.



represent 30 million to 40 million lbs per year of fish and fish wastes used for feeds. The requirement for Norway's 1983 production of Atlantic salmon and rainbow trout was about 200,000 mt of fish as feed ingredients. Assuming fish feed ingredients are 80 percent of fish origin, that is equivalent to nearly 46 percent of the round weight of all of the fish and shellfish processed by domestic processors in Alaska during 1983.

Providing more year-round employment could be one of the best ways to employ Alaskans in the state's fishing industry.

### WHO WILL BENEFIT?

Existing processors, tender operators, and commercial fishermen are in the best positions to benefit from salmon farming not only by providing feed, processing, tendering, and sale of by-catch but also because they have a familiarity with and access to the things required to farm fish: boats, motors, anchors, floats, experience with fish and fish handling, sites, and so forth. Others will benefit as well. For every job created on a Norwegian salmon farm, another job is created off the farm that is directly dependent on salmon farming. Webbing has to be hung into pens, floats constructed, smolts produced, feeds made, and fish transported, processed and delivered (Lindgren, Sewell, and Peterson 1985).

## POTENTIAL DISADVANTAGES TO ALASKA

### POLITICAL AND SOCIAL OPPOSITION

Political and social opposition is likely. Salmon farming means change, change that many don't want. Persons unwilling to alter lifestyles may not remain as competitive as those who do change. The potential for conflict exists between those who adapt new strategies and those who do not.

### LIMITED ENTRY PERMIT HOLDERS

Limited entry permit holders in salmon fisheries may perceive salmon farmers as a threat to livelihoods, and further resent non-entry permit holders being allowed to deal with fish. Certain gear-type groups may resent others seeking the reputation for the best quality of fish produced.

Out-of-state residents, a significant portion of limited entry permit holders, will be at an additional disadvantage over those who live here and may object.

### COMPETITION FOR STATE REVENUE

Within the state revenue allocation process, it is said that certain monies are "education" or "fish" or "mining" dollars, which are allocated by industry or endeavor. Salmon farmers and other aquaculturists will sooner or later become another interest group seeking state funds.

### DISEASE

No detection procedure can guarantee complete freedom from disease. Introducing more fish stocks will be a calculated risk. Fortunately the literature introducing new fish diseases, at least that of whirling disease to New Zealand, reveals little long-term risk to indigenous fish populations.

### TOURISM

Salmon farms alter the appearance of their locales. Some tourists may not care to see that alteration.

### STATE-CREATED WEALTH

Issuing permits and leases on state lands will, in effect, create wealth. A site with all necessary permits has considerable monetary value, reflecting the ability to earn profits. Some individuals may object.

## PROJECTIONS FOR THE FUTURE

The prognosis for salmonid farming worldwide is one of solid growth predominantly based on exports from producing to non-producing countries. Product diversification and value-added processing can be expected to increase as market growth slows.



### PRODUCTION

North Atlantic producers are projected to produce nearly 100,000 tons of pen-raised salmon in 1990, and Pacific growers about 13,000 tons (NMFS 1985b) valued in total at about $700 million (see Table 3). Estimates of world production in various issues of *Fish Farming International* add up to more than 130,000 mt. By comparison, the five-year average annual catch of all salmon in the U.S. from 1979 to 1984 is 276,000 tons, at an average ex-vessel value of about $350 million (NMFS 1985a).

By the year 2000, the Norwegian government anticipates their aquaculture industry will generate goods worth $3 billion per year, and will employ some 50,000 persons. Two-thirds of these jobs will depend on salmonid culture (SCC 1985).

### SALMON MARKETS

Salmon markets are quite diverse. Farmed salmon is unlikely to more than a fraction of the total market niches. Worldwide, 13 different species of salmonids are sold. Stock differentiation is common, as are prices paid and (less often) received for fish harvested by the four gear types.[4] Prices can be different for the same species, stock, and harvest method. The earlier portion of a run can bring a different price than other portions of that same run. Prices also vary for different-sized fishes that are otherwise the same. Different product forms bring different prices and occupy different market niches. In all, salmonids are differentiated into hundreds of overlapping market niches. It is unlikely that farmed salmon will ever compete directly with the high-volume, relatively low-valued fish destined to be canned or frozen, particularly in the round.

The high cost of farm production dictates that relatively high prices must be received. In the long run, prices will fall as more efficient husbandry techniques are developed and supply increases to meet, then exceed, supply.

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[4]Five gear types if you count the seine fish that are sold alive in floating pens such as with hatcheries; six or more if you differentiate among dry holds, iced, RSW, and so forth.

Table 3. World production of pen-farmed salmonids, 1981-1985, with projections for 1990

Atlantic Salmon (mt)

| Country | 1981 | 1982 | 1983 | 1984 | 1985 | 1990[a] |
|---|---|---|---|---|---|---|
| Norway | 8,907 | 10,226 | 17,016 | 22,196 | 27,200 | 80,000 |
| United Kingdom | 1,000 | 2,100 | 2,500 | 3,912 | 6,921 | 14,000 |
| Finland | 30 | 30 | 30 | 40 | 80 | 160 |
| Ireland | 80 | 103 | 256 | N.A. | N.A. | 2,000 |
| Sweden | 60[a] | 80[a] | 100[a] | N.A. | N.A. | N.A. |
| Canada | 35 | 140 | 180[a] | N.A. | N.A. | 1,000 |
| Iceland[b] | 20[a] | 30 | 50 | 60[a] | 100 | 5,000 |
| Denmark | 100[a] | 130 | 160 | N.A. | 250 | 1,000 |
| Totals | 10,232 | 12,839 | 20,292 | 26,148 | 34,451 | 103,160 |

Pacific Salmon (mt)

| Country | 1981 | 1982 | 1983 | 1984 | 1985 | 1990[a] |
|---|---|---|---|---|---|---|
| Japan | 1,150 | 2,112 | 2,900 | 4,600 | 7,000 | 14,000 |
| United States | 450[a] | 680 | 900 | 1,400 | 2,450 | 5,000 |
| Canada | 176 | 424 | 129 | 110 | N.A. | 15,000 |
| Chile | N.A. | N.A. | N.A. | 32 | 145 | 3,000 |
| New Zealand[b] | 2[a] | 5[a] | 10[a] | 12 | 250 | 2,000 |
| France | 60 | 80 | 80 | N.A. | N.A. | 500 |
| Totals | 1,838 | 3,301 | 4,019 | 6,154 | 9,845 | 39,500 |

[a] Estimated
[b] Includes ocean ranching

Sources: NMFS 1985b; B.C. Commercial Fish Farm Statistics 6/18/85; BANR Newsletter, various issues; Fish Farming International, various issues.



Although a small percentage is being frozen even now, most farmed fish will continue to be sold fresh in order to occupy the higher-priced market niches. Farmed salmon will probably never be canned, except for specialty items or as trim from filleting.

## CONCLUSIONS

Top quality fresh salmon and trout, whether commercially harvested or commercially grown, are destined to occupy much of the world's premium markets. Alaska cannot alter this.

In 1985, U.S. fresh salmon imports exceeded the total troll catch of all species in all states. With the very rapid increases in the volume of fresh salmon being produced around the world, any near-term damage to existing producers has already been done. We must avoid the damage that will occur if Alaska does not become involved in salmon farming.

Without a strong aquaculture program, Alaska's share of both the farmed and ranched salmon markets will drop over the long term. As advances in aquaculture technology reduce costs, Alaskan salmon will be continuously relegated to lower-priced market niches.

If we elect not to farm salmon, the Alaskan salmon fishing industry will probably continue to be highly seasonal, staffed by seasonal workers. Tendering, processing, and distribution facilities and personnel will continue to be underused during late fall, winter, and early spring.

One thing is clear: commercial salmon growing will not go away. It is permanently changing the shape, form, and substance of salmon production, marketing, distribution, and consumption.

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