
Oyster and trout farming have a much longer history, but it is salmon farming that has raised the profile of aquaculture on the West Coast. Salmon farming has had a brief but dramatic history. In 1971 the first salmon farm license was issued in B.C. Today there are more than 100 companies with 130 operating marine sites, and many more are under investigative permit or being developed (see Table 1).

Companies now in the salmon farming business range in size from 40 tonne family operations to very large vertically integrated companies with annual fish production in the range of 1000 tonnes.
addition, licenses have been issued for 34 private hatcheries, more than a dozen of them large production facilities. What was an uncertain cottage venture for more than a decade has, in just a few years, been transformed into a large and prominent coastal industry with total investment estimated between 150 and 200 million dollars.

This dramatic change in British Columbia salmon farming was not due to R&D breakthroughs or to sudden shifts in economic factors. Rather, the examples of salmon farming in Norway and Scotland were finally noticed by Canadian politicians and bureaucrats and by the business communities of both Canada and Europe. Some skillful promoting was behind this awareness, but farming salmon on an industrial scale in B.C.'s marine waters was an idea that was ready for exploitation. Investment dollars became available both from within and outside Canada, and salmon farms began to appear by the dozen overnight.

The first area of intense development was in the Sunshine Coast region in the vicinity of Sechelt (see map) where there are now over 40 companies, some with several sites. the West Coast of Vancouver Island has developed more slowly but now has over 20 sites, and the inlet waters near the northeastern shores of Vancouver Island (Campbell River, Port McNeil areas) have seen the most intense recent development. This region may well become the focus of industry development over the next few years.

Exploitation further north has been slower with a few developed sites in the Prince Rupert area and some investigative permits on the Queen Charlotte Islands. Much of B.C.'s immense coastline lies north of Vancouver Island and eventually these regions will be developed by marine farms. However, the costs of transportation and lack of general infrastructure will delay them relative to the southern regions.

Right now the future economic structure of the industry is far from clear. As noted above, there are many smaller farms, usually with one marine site and no hatchery, often owned by a single family or a small number of investors. Depending on farm size and equipment, $300,000 to $2 million or more in investment may be required from start-up to stable production. Most of these farms aim at producing 75 to 200 tonnes of fish annually. It must be noted, however, that these are generalized statistics and there is considerable variation among farms.
Many of the larger salmon farming companies are partially financed by public offerings and many have financial backing from large Canadian or European parent companies as well. There are also two co-operatives, one sponsored by a commercial fishing co-op and the other an organization of five smaller companies. The larger companies or co-ops may own their own hatcheries, processing plants, and transportation, operate their own veterinary and marketing systems, and engage in significant R&D programs.

The final shape of the industry in terms of company ownership, size and geographical distribution will not be apparent for several years. Ninety percent of the industry as it now stands is less than four years old and it is definitely changing more rapidly than data can be acquired. The extraordinary growth of the last three years is slowing somewhat in terms of the formation of new companies, but in terms of live fish biomass it is still increasing rapidly. Several years of consolidation will follow and it will be accompanied by a steady growth with expansion into new regions.

SPECIES AND STRATEGIES

Coho and chinook

Coho and chinook are the main species reared in B.C.'s farms. Chinook is currently the preferred fish because of its late maturation (3 and 4 years), easy smolt production (normally a fresh water fry period of only 3-4 months) and a good reputation in the North American market.

Coho have a normal fry rearing period of about one year. They can be accelerated by manipulating temperature and photoperiod and smolts can be produced in less than a year ("0+ smolts") for introduction to sea water during their first summer, although under production conditions these methods have not been universally successful. Coho will normally
mature after 18 months at sea (second ocean autumn) but they will not be large enough to sell in the second spring before B.C.'s commercial fishery begins. By the time this fishery has ended the maturing coho are beginning to darken. Coho may also undergo precocial maturation (so-called "jacks"), and for all of these reasons are less popular than chinook.

The eggs of coho and chinook used on B.C. farms originally came from DFO's Salmon Enhancement hatcheries as production in excess of enhancement requirements. Coho eggs are plentiful but chinook eggs are usually scarce because this species is generally in decline along the West Coast and has a high priority for enhancement. Private chinook broodstock programs have tried to bridge the gap between demand and supply of chinook eggs but due to the rapid increase in industry demand this has not been possible. The yield of private chinook eggs this year may be as high as 15 million (compared to 3 million supplied by DFO), and by next year the industry could be self-sufficient.

Atlantic salmon were introduced into BC in 1985 under stringent quarantine. Several companies have imported Atlantic salmon eggs from Scotland and the first farm egg production of this species occurred this year (about 300,000 eggs). Importations are scheduled to stop in a few years, by which time broodstock will be producing on coastal farms. To date the growth and survival of Atlantic salmon looks favorable, although there have been a few problems associated with smolting. Work with Atlantics in Washington State suggests that it is a very promising species for the West Coast.
Rainbow trout

Domesticated rainbow trout from established trout farms have been successfully introduced to seawater sites as large fry and have grown well. Enthusiasm for this fish as a second crop was high until a series of plankton blooms (Chaetoceros) revealed the rainbow's sensitivity to plankton and raised doubts concerning its value at many sites. This trout, sometimes called the "salmon trout," does not command the price of true salmon (Oncorhynchus and Salmo), and in the light of algal problems seems to be less favored by the industry at present.

Steelhead trout from BC's anadromous wild stocks are being investigated on several farms, but it is not clear whether they will be more resistant to algae than the domestic rainbows.

Pink, chum, sockeye

Pink, chum and sockeye salmon have been studied at the experimental fish farm at DFO's Pacific Biological Station, but high losses to diseases during marine growout made these species unattractive. This could change with advances in disease management, and BC, with its array of salmonid species, may pioneer new candidates for marine sea pen culture.

The sockeye, despite many inherent problems, could be an interesting fish for future trials. In addition the Arctic char could be introduced and studied in BC where the temperature and salinity ranges are different from those on the East Coast where these fish have been difficult to rear in sea pens.

The B.C. salmonids comprise a large number of biologically distinct fish stocks (or strains)
throughout the province. Preliminary trials with coho suggest that growth characteristics vary little between stocks, but chinook have a more complicated and variable life history and there may be superior stocks with regard to survival, growth, grilseing rates and other qualities.

**TABLE 1.**

<table>
<thead>
<tr>
<th></th>
<th>1984</th>
<th>1987a</th>
<th>1990b</th>
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<tr>
<td>Marine sites</td>
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<td></td>
</tr>
<tr>
<td>with equipment</td>
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<td>113</td>
<td>255</td>
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<tr>
<td>and fish in the</td>
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<td>water</td>
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<tr>
<td>Active applications</td>
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<tr>
<td>for finfish leases</td>
<td>n/a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>and licenses</td>
<td></td>
<td>279</td>
<td></td>
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<tr>
<td>Privately owned</td>
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<tr>
<td>hatcheries in</td>
<td>5</td>
<td>34d</td>
<td></td>
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<tr>
<td>operation</td>
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</tbody>
</table>

"139 additional tenures had been approved by 15 November 1987. An unknown number of these will become operational farms.

A conservative estimated of 25% would result in 70 additional farms within the next 14-24 months.

Private hatchery capacity is currently estimated at more than 40 million eggs.

Source: BC Salmon Farmers Assoc.

To investigate this possibility the Provincial Ministry of Agriculture and Fisheries, the Department of Fisheries and Oceans and the BC Salmon Farmers Association have begun an ambitious broodstock comparison program in which chinook from ten wild stocks are being rigorously compared at both family and stock levels on thirty farm sites. Important stocks may be identified in this study, and much genetic diversity will have been brought into the industry which has so far relied principally on chinook from only two hatchery stocks.

For all species reared on BC salmon farms the goal is to produce a "salmon-sized fish" that weighs more than four pounds dressed. These will be sold during the off season for the commercial fishery. It is expected that competition between farmed and wild salmon will diminish as marketing channels develop for the farmed product, almost all of which is sold fresh to the United States.

The arrival of Chilean coho on the American market will be an equally important consideration in the coming years. Some farms are considering producing still larger fish, but size at harvest is determined by factors such as mortality and growth patterns, cash flow requirements and the species on hand.

As noted above, coho create problems in the timing of sales. Several companies are experimenting with the larger 1+ coho smolts which can be placed in salt water early in the spring and which may attain a marketable size twelve months later. The problem of grilseing (jacking) may increase with this strategy, but the production of coho "mono-milt" (sperm from females) by DFO’s West Vancouver Laboratory will offer a solution to this problem as it has for chinook, where grilseing is also a cause of lost revenue and a fish culture problem. Chinook mono-milt has been successfully produced by DFO for several seasons, and the industry is now developing its own broodstocks to produce this milt.

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Residence at remote sea cage site (top). Competition for top-quality staff has been intense, especially for remote locations, and many companies are now providing excellent accommodation for workers. (Bottom): net repair at a remote site on the west coast of Vancouver Island. Salmon farming contributes to the economy of many small B.C. communities.
Variation in sea cage size and configuration. (Top): a pair of 10,000 ft² (100 x 100 ft) cages. (Bottom): wooden cages of varying size and configuration. This type is much less expensive but must be protected from wave action. The industry is experimenting with cage types and sizes, and some growers think that both pen volume and loading density affect fish health and rate of growth.

William Pennell photo
Some of the modern cage systems will support a small truck on the gangway (top). Early systems were predominantly of European origin, but local companies now compete successfully in cage design. More and more cage sites are locating in exposed areas in deep water. The Underton cage system (bottom) has been engineered to withstand the high waves found in such locations.
CONTRIBUTIONS TO THE COASTAL ECONOMY

There have been many discussions on the extent to which salmon farming contributes to coastal communities and to the BC economy in general. It has been projected that by 1990 over 2500 full time jobs will have been created on salmon farms and in hatcheries, and a further substantial amount of employment will be generated indirectly.

Much of the economic benefit of this industry is felt in the remote coastal communities where reductions in forestry production and centralization of commercial fishing has created high rates of unemployment. Salmon farming is a decentralized activity that is located in remote inlets and bays near these communities, where it becomes a sustaining force.

Secondary industries have been formed to make fish feeds (three large plants are now operating in BC) and equipment such as nets and float systems, and to provide services such as veterinary, processing, and marine transportation. There is also a significant industry specializing in the transportation of smolts and larger fish, the former to the farms from the hatcheries and the latter from the farms to the processors.

TECHNICAL PROBLEMS

Despite 17 years of salmon farming experience in BC and an excellent tradition for fisheries research, most of the problems faced by the pioneer industry a decade ago are still with the new and much larger industry of today. Research work over the decade has not focused on sea pen culture which, until recently, was seen as an experimental venture unlikely to succeed in the face of the commercial salmon fishery. All this has changed but research programs need time to develop and research on biological problems yields its results slowly. Consequently many unsolved problems have increased in scale with the industry. Although the research needs discussed below are directed at serious problems, it must be emphasized that the industry will overcome these to achieve more efficient and cost effective production.

In 1987 the BC Salmon Farmers Association (see sidebar) conducted a study on the research needs of the industry. Farmers were in agreement on the primary needs: in order of priority these were: (1) disease control (with emphasis on Bacterial Kidney Disease, or BKD); (2) genetics and breeding; and (3) nutrition.

There were also a number of smaller problems that needed attention, including some aspects of farm equipment, smolt production, product quality and predator control. These problems are discussed here only briefly. The full report can be obtained from the BCSFA.
**BKD**

In the early days of salmon farming, *Vibrio* was a serious threat to fish in sea pens. New vaccines and more effective use of antibiotics have nearly brought this disease under control. Today the problem is BKD (Bacterial Kidney Disease). BKD is a significant problem in fresh water hatcheries and has proven resistant to most attempts at control. *Onchorynchus* seem particularly susceptible to it, and in marine sea cage culture it may cause heavy losses. There are indications that a combination of husbandry techniques, subtle changes in diet formulation and carefully timed administration of antibiotics can reduce the seriousness of this disease, but work is needed on vaccines. A meeting to establish research directions on BKD was held in Vancouver on 15–16 October, 1987, and the details of needed research were discussed by fish disease specialists from Europe and North America.

**Genetics**

Fish genetics and breeding is a complicated subject. The large companies have started their own private broodstock programs, and these range from informal selection of survivors to elaborate family separation schemes and the use of modern tagging techniques to identify individual fish in sea pens.

The companies doing the more advanced work feel that fish breeding programs should be left to the private sector where healthy competition will create superior smolts. Others feel that no single company can afford the scale of work needed for rapid selection of superior domesticated fish. This is an academic point at present since there is no large government program that would assist in this area.
There are other areas related to genetics which are important to salmon farming. These include control over sexual development and the production of sterile fish through triploidy or hormone application, the production of genetically female sperm, andro- and gynogenesis, and perhaps the ultimate in fish biotechnology - the implanting of genes to create transgenic fish. All of these areas have been pioneered by scientists at DFO's West Vancouver Laboratory under the direction of Dr. Edward Donaldson. This institution, with recently expanded facilities, has done a great deal for the industry.

### TABLE 2.

<table>
<thead>
<tr>
<th>Year</th>
<th>Direct Capital Investment in Marine Sites and Private Hatcherries ($ millions)</th>
<th>Person Years of Direct Employment at Marine Sites and Private Hatcherries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984</td>
<td>5</td>
<td>Full time 60, Part time n/a, Totals 60</td>
</tr>
<tr>
<td>1987</td>
<td>125</td>
<td>Full time 607, Part time 25, Totals 632</td>
</tr>
<tr>
<td>1990</td>
<td>250</td>
<td>Full time 2000, Part time 700, Totals 2700</td>
</tr>
</tbody>
</table>

Average wage data for farm and hatchery employees have not been developed because of widely varying skill-related rates of pay. A conservative average salary of $18,000 would generate a full-time payroll of $11 million for 1987. For 1990, an average salary of $20,000 would generate a full-time payroll of $40 million.

Source: BC Salmon Farmers Assoc.

### Transportation

Transportation of smolts to remote farm sites by helicopter. In addition to helicopters, fixed-wing aircraft, tanker trucks and special well boats are used.

### Nutrition

So much needs to be done in salmon nutrition that it is difficult to identify one area as more vital than another. The basic nutritional requirements of Pacific salmon, especially at larger sizes and in salt water, are not well known. This knowledge would allow healthier, more efficient diets to be formulated with less risk of deficiency or negative component interactions. This is a long term project but a necessary one. The history of the poultry industry indicates that as fish become more domesticated and as diets improve, the cost of production will be greatly reduced.

Other aspects of nutrition which need attention include: a) studies
on dietary components and resistance to BKD; b) the development of better broodstock diets to promote higher domestic egg quality, and c) research on finishing diets to economically produce fish with texture, color and characteristics associated with human health such as fatty acid and lipoprotein compositions similar or superior to those of wild fish.

Phytoplankton

Other important areas of research include the development of a non-invasive fish inventory system, fine tuning of fish transportation techniques, and the development of a phytoplankton warning and prediction system. Plankton outbreaks have caused significant damage in the last two years and relatively little is known about the conditions that contribute to blooms, their geographical distribution, or what to do about them. The many farms scattered throughout the southern coast provide an opportunity for oceanographic research that includes plankton occurrence and distribution.

As increased quantities of farmed salmon arrive on the world market, competition will increase and product quality will become increasingly important. Quality includes the texture, color and taste of the flesh as well as the presence of deleterious substances such as antibiotic residues for which testing protocols and clearance times are poorly established. Here there are problems of jurisdiction. DFO has not done this type of testing and, although Agriculture Canada does, it has no mandate to test fish. Recent difficulties with Canadian tuna and mussels demonstrate the importance of quality control and inspection in the seafood industry.

Electric fence around net pens (arrows) discourages predators (according to one farm manager, the predators learn faster than the workers). The feed bucket is state-of-the-art; waist high, wind and scavenger proof, dry, easily filled.

The research needs discussed here will entail far more projects than can be done under present levels of support or with existing facilities and manpower. Research dollars must be carefully spent and the efforts of DFO, MAF, the
universities, BC Research and other groups will have to be coordinated. There must also be an effort to increase the profile of aquaculture research requirements and stimulate government to spend more money on this expanding industry.

In addition to controlled research under laboratory conditions there is a need for research under production conditions in sea water net pens. In BC there are few facilities for this type of research. The small research farm at

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**PERMITS, LICENSES AND OTHER DOCUMENTATION REQUIRED FOR THE OPERATION OF A SALMON FARM IN BRITISH COLUMBIA**

An aquaculture operation requires a municipal or provincial business license and must conform with any municipal zoning regulations. It should also be registered with the provincial Registrar of Companies, Ministry of Finance and Corporate Relations.

If fish are to be transported more than 50 kilometres from a hatchery the operator must obtain approval from the federal-provincial Transplant Committee. Fish farms may also require a Pollution Control Permit from the Waste Management Branch of the Ministry of Environment and Parks, and a federal Aquaculture Permit from the Department of Fisheries and Oceans (usually not issued until all other documentation is in place). The required documentation can be summarized as follows:

**SUMMARY OF DOCUMENTATION REQUIRED FOR SALMON FARMING**

<table>
<thead>
<tr>
<th>Zoning Compliance</th>
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</thead>
<tbody>
<tr>
<td>Business License</td>
</tr>
<tr>
<td>Registration - Registrar of Companies</td>
</tr>
<tr>
<td>Aquaculture Development Plan</td>
</tr>
<tr>
<td>Business Plan</td>
</tr>
<tr>
<td>Transplant Approval - Fisheries Branch, DFO</td>
</tr>
<tr>
<td>Aquatic Land Lease - Ministry of Forests and Lands</td>
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<tr>
<td>Pollution Control Permit - Waste Management Branch</td>
</tr>
<tr>
<td>Navigation Compliance - Transport Canada</td>
</tr>
<tr>
<td>Water License - Water Management Branch (hatcheries)</td>
</tr>
<tr>
<td>Fish Culture Permit - Fisheries Branch (hatcheries)</td>
</tr>
<tr>
<td>Aquaculture Permit - Department of Fisheries &amp; Oceans</td>
</tr>
</tbody>
</table>

THE B.C. SALMON FARMERS ASSOCIATION

The B.C.S.F.A is a group of salmon farmers committed to establishing a foundation for British Columbia's newest and strongest growth industry.

Incorporated with nine charter members on 11 July 1984 under the Societies Act of British Columbia, the Association's membership on 1 October 1987 was 85, representing more than 95% of the salmon farmers in B.C.

The membership at large elects a 10 member Board of Directors, of which five are elected each year. Factors such as size of farming operation and geographic location are considered when nominating Directors to ensure that the Board represents a cross-section of the industry. The Directors elect four Officers from among the Board members.

A full-time staff of six implements policies developed by the Board of Directors and administers Association programs and day to day operations.

the Pacific Biological Station is at its limit of use and experience has shown that many types of research are difficult or impossible on commercial farms. Dedicated sea pen research facilities, such as the Salmonid Demonstration and Development Farm on the East Coast (see Bulletin 87-3) are urgently needed.

Research is not the only answer to industry problems. To be of value, research information must be transferred to the industry. Often there is a bottleneck between researcher and grower and valuable information languishes. Occasionally a valuable piece of research is left in a form that can not be used by farm production managers. In other instances a newly researched process may not have been tested adequately under production conditions. This constriction in technology transfer highlights the need of industry for extension services which include education and on-farm work. The Ministry of Agriculture and Fisheries is taking the lead in establishing extension services in BC (see sidebar), with complementary activities on the part of the BC Salmon Farmers Association, Community Colleges, universities and DFO.

Conflicts and environmental concerns

The rapid growth of salmon farms throughout the southern part of the province has created public opposition. Environmental groups have become concerned with both local and regional water quality, the salmon fishing industry has voiced concerns for wild stocks and markets, and upland residents have become upset over visual changes. A year ago all of these concerns stimulated a temporary provincial government moratorium on new farms and the formation of the Gillespie Commission (3), which recommended a series of steps for the rational expansion of the industry.

Most of the concerns that have been posed by the public and special interest groups were addressed by the commission. Farm applications now go through an elaborate referral procedure, extensive
CONCLUSIONS

Although the salmon farming industry in BC has undergone 15 years of pioneering work, it is still a new industry. Growth in recent years has been extraordinarily rapid and although there is a strong investment base and a commitment by government to see the new industry thrive, there are also many problems to overcome. Many of these problems require research beyond the capacity of established research units.

Individual farms will have their own management and financial problems. Some sites will prove better than others and luck, both good and bad, will play a role in company success.

The next few years will see many internal adjustments as the new farms fine-tune their husbandry strategies and consolidate their resources, but the salmon industry is here to stay and will continue to grow.

The support of government and a strong growers' association will be vital during this phase of development. The economic support provided to coastal communities by the industry will help maintain the political will that is so important during this development period. The realization that an annual $200 million industry is a reasonable expectation for BC is an excellent incentive for this support.

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