ALASKA LEGISLATURE SPECIAL COMMITTEE/SUBJECT FILE 8672
1896 SCOMM 75: MARICULTURE (FISH FARMING), 1987-1990

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INTRODUCTION

Alaska's valuable salmon industry relies on production from wild systems and, increasingly, on fish produced by aquaculture programs. The importance of maintaining healthy wild stocks and implementing successful enhancement activities underlies the need for an effective genetic policy. The genetic guidelines created to steer Alaska's aquaculture efforts were established in the mid-70's and have been reviewed to ensure that they reflect current knowledge, and goals. A revised genetic policy has been established that contains guidelines, supporting information and recommendations.

The genetic policy contains restrictions that will serve to protect the genetic integrity of important wild stocks. Certainly in Alaska where wild stocks are the mainstay of the commercial fishery economy, it is necessary to protect these stocks through careful consideration of the impacts of enhancement activities. Another important aspect of the genetic policy is the orientation towards increasing the productivity of enhancement programs in the state. Adherence to the guidelines will help maintain adequate genetic variability ensuring that the enhanced stock will be able to adapt to changing environmental conditions. The policy also includes considerations for selective breeding for desirable characteristics.

Due to the limited amount of information available on the genetic impacts of salmon enhancement on wild stocks, much of the basis for these guidelines is theoretical or based on work done with other species. Consequently, the most important considerations used in writing the guidelines are presented as a mechanism for illustrating the intent of the policy. An understanding of the rationale behind the policy is imperative to its effective application to individual cases under the very diverse conditions found in Alaska.

The importance of the genetic guidelines will continue to increase as aquaculture activities expand their production. This policy represents a consensus of opinion and should continue to be periodically reviewed to ensure that the guidelines are consistent with current knowledge. By doing so, we will be able to meet the goal of greater fish production through enhancement while maintaining healthy wild stocks.

POLICY STATEMENT

I. Stock Transport

A. Interstate: Live salmonids, including gametes, will not be imported from sources outside the state. Exceptions may be allowed for trans-boundary rivers.

B. Inter-regional: Stocks will not be transported between major geographic areas: Southeast, Kodiak Island, Prince William Sound, Cook Inlet, Bristol Bay, AYK and Interior.

C. Regional: Acceptability of transport within regions will be judged on the following criteria.

1. Phenotypic characteristics of the donor stock must be shown to be appropriate for the proposed fish culture regions and the goals set in the management plan.

2. No distance is set or specified for transport within a region. It is recognized that transplants occurring over greater distances may result in increased straying and reduce the likelihood of a successful transplant. Although the risk of failure affects the agency transporting the fish, transplants with high probability of failure will be denied. Proposals for long distance transport should be accompanied by adequate justification for using nonlocal stock.

II. *Protection of Wild Stocks*

A. *Gene flow from hatchery fish straying and intermingling with wild stocks may have significant detrimental effects on wild stocks. First priority will be given to protection of wild stocks from possible harmful interactions with introduced stocks. Stocks cannot be introduced to sites where the introduced stock may have significant interaction or impact on significant or unique wild stocks.*

B. *Significant or unique wild stocks must be identified on a regional and species basis so as to define sensitive and nonsensitive areas for movement of stocks.*

C. *Stock Rehabilitation and Enhancement*

1. *A watershed with a significant wild stock can only be stocked with progeny from the indigenous stocks.*

2. *Gametes may be removed, placed in a hatchery, and subsequently returned to the donor system at the appropriate life history state (eyed egg, fry or fingerling). However, no more than one generation of separation from the donor system to stocking of the progeny will be allowed.*

D. *Drainages should be established as wild stock sanctuaries on a regional and species basis. These sanctuaries will be areas in which no enhancement activity is permitted except gamete removal for broodstock development. Use of such reservoirs for broodstock development should be considered on a case-by-case basis, and sliding egg take removal schedules applied to such systems should be conservative.*

E. *Fish releases at sites where no interaction with, or impact on significant or unique wild stocks will occur, and which are not for the purpose of developing, rehabilitation of, or enhancement of a stock (e.g., release for terminal harvest or in landlocked lakes) will not produce a detrimental genetic effect. Such releases need not be restricted by genetic concerns.*

III. *Maintenance of Genetic Variance*

A. *Genetic diversity among hatcheries*

1. *A single donor stock cannot be used to establish or contribute to more than three hatchery stocks.*

2. *Off-site releases for terminal harvest rather than development or enhancement of a stock need not be restricted by III.A.1, if such release sites are selected so that they do not impact significant wild stocks, wild stock sanctuaries, or other hatchery stocks.*

B. *Genetic diversity within hatcheries and from donor stocks*

1. *A minimum effective population (N_e) of 400 should be used for broodstock development and maintained in hatchery stocks. However, small population sizes may be unavoidable with chinook and steelhead.*

2. *To ensure all segm nts of the run have the opportunity to spawn, sliding egg take scales for donor stock transplants will not allocate more than 90% of any segment of the run for broodstock.*

GUIDELINES AND JUSTIFICATIONS

I. Stock Transport

A. Interstate: It is generally accepted that population of salmonids which have existed over many generations in a given watershed have evolved traits that make them best adapted for survival in that environment. The greater the distance that a population is transferred from its native environment or the greater the difference in environmental conditions between the donor and transplant stream, the less likely the genetic characteristics of the population will fit the new environment. If the fitness of the population is indeed reduced in the new environment, then the probability of the transplant succeeding would be affected. In addition, interbreeding of a transferred stock with indigenous stocks could transfer gene traits that would reduce the fitness of the native populations. In many states, discrete stocks cannot be identified because excessive movement and interbreeding have already occurred. The State of Alaska, therefore, desires to protect and develop local stocks by restricting the movement of live fish or eggs into the state. There are, however, several trans-boundary rivers penetrating British Columbia, Canada, that flow into the state of Alaska. In some instances, donors from these stocks might fit a well-designed management plan.

B. Inter-regional: The environment can vary greatly from one region to another in a state as large as Alaska. For similar reasons given in I.A. above, the transfer of fish from one region to another is restricted. Consideration may be given to regional border areas, especially when no suitable donor stock is available within a region.

C. Regional: Although it is recognized that indigenous stocks are best for donor stock development, there have been numerous successful transplants, especially if the environment at the new site is similar to that of the donor stock and distance between the sites is not great. There is insufficient scientific data to predict how far or how diverse the environment must be before a negative impact will occur. However, it is believed that within a region site matching opportunities may be available. As site matching characteristics decrease and transplant distance increases within the regional borders greater justification is required for the proposed transplant. The following should be considered when selecting a donor stock:

1. Matching: Phenotypic characteristics of the donor stock should be matched to the environment at the site and to the management goals. Water chemistry and temperature profiles should be considered. Island stocks should be matched to other islands or to short rivers of comparable characteristics where possible. Time of spawning and fry emergence should be matched or compensated with the hatchery temperature required. Any deviations should be addressed and justified in the permit application or the annual management plan.

2. Migration Routes: The probable migration routes and potential user groups should be identified. The applicant must determine a probable migration route based on the migration route of the proposed stock and characteristics (topography) of the transplant site. Coded wire tagging of hatchery releases can determine the accuracy of migration route predictions as well as assess possible impact on local stocks.

II. Protection of Wild Stocks

A. <u>Prevention of detrimental effects of gene flow from hatchery fish straying and interbreeding with wild fish</u>.

Straying of hatchery fish released at the hatchery or off-station can potentially impact the fitness of wild fish populations through interbreeding of wild and hatchery fish. This assumes that hatchery and wild fish are adapted to different environments and either would presumably be less fit in the environment of the other and that hybrids would be less fit for either environment. Wild stocks have presumably been rigorously adapted to their native environment. Because of the large number of loci involved in the adaptation, many "successful" combinations of genetic information are possible along with the enormous number of "unsuccessful" combinations. Hybridization between discrete populations may produce a stock that has reduced fitness and therefore reduced production. Hatchery fish have been subjected to selection pressure for survival within artificial culture regimes, and may also have been originally derived from another stock adapted to totally different conditions than the impacted wild stock. Continued influx of hatchery fish together with the return of hybrids may alter the wild gene pool, reduce stock fitness, and thus threaten the survival of the wild population.

An alternative perspective is that hatchery strays will have little genetic impact on wild stocks. The influx of new genetic material through straying is a natural process in the development and expansion of salmon populations. If adaptation of the natural population is indeed very specific and selection is intense, then selection will favor and maintain the genetic complex of the wild populations. If adaptation is less specific and less intensive, then the genetic impacts from gene flow are insignificant. It is true that some straying occurs among adjacent wild populations and in most cases has occurred for a long enough time that such populations are quite similar genetically. However, situations in which transplanted stocks are involved are not analogous, as transplanted stocks would be less similar and gene flow would have a more profound effect. It is also true that the impact of introgression into the wild gene pool of genes from fish transplanted from a radically different environment may be limited by natural selection. Again the situations of concern do not necessarily lie near this extreme; hybrids and strays may be fit enough to dilute or replace the wild genome. Inherent homeostatic mechanisms for gene expression may compensate for some genetic influx.

The magnitude of straying relative to the size of the wild run is the most important criterion, as massive spawning by hatchery strays may jeopardize a wild population by displacement on spawning habitat and superimposition of redds, as well as, genetic influx. A conservative management approach dictates avoiding release sites where large numbers of hatchery strays can be expected to interact with significant or unique wild stocks. This approach can be achieved by spatial or temporal isolation of the hatchery and wild stock.

B. Regional designation of significant and unique wild stocks.

The magnitude of salmon populations varies between watersheds from intermittent runs maintained by straying to hundreds of thousands of fish. In evaluating the impacts of salmon enhancement projects, consideration must be given to the potential of detrimental effects from straying and intermingling with wild populations and possible resultant loss of wild production. Such consideration must take into account the benefits of the enhancement activity and the significance of the wild stocks impacted. Designation of criteria for runs of fish that are considered significant would greatly expedite the evaluation process. However, "significance" must be defined not only by the magnitude of the run, but also in the context of local importance and utilization. A small sockeye salmon stock near a village in southeast Alaska may be "significant", whereas the same size population may be too small to be considered a manageable entity in Bristol Bay. Because local utilization is an important concern, a regional planning group such as the Salmon Enhancement Regional Planning Teams, should consider what criteria will be used to determine significant stocks within a region and recommend such stock designations.

C. <u>Stock rehabilitation and enhancement</u>.

1. A watershed with significant wild stocks can only be stocked with progeny from the indigenous stocks. Rehabilitation of a watershed implies that there is insufficient production in habitat that formerly maintained a stock of some magnitude. Unless the indigenous stock has gone to extinction, use of an exogenous stock has potential for genetic damage noted in II.A. This damage will be exacerbated by the imprinting and homing of the transplanted stock to the impacted watershed, and potential displacement of wild

juveniles by the exotics stocked in the rearing habitat.

Enhancement of habitat not naturally accessible to salmon involves stocking eyed eggs, fry, or fingerlings, thus gaining production from this unutilized habitat. Where the inaccessible habitat is located above barriers on watersheds that maintain significant natural populations, stocking nonindigenous populations again has potential for genetic impacts noted in II.A., exacerbated by imprinting and homing of the transplanted stock to the watershed. For both rehabilitation and above barrier stockings, use of the indigenous stock alleviates these concerns.

2. When enhancing a stream using the indigenous stock, the fish used for stocking shall not be removed from the wild system to a hatchery for more than one generation.

Hatchery incubation and rearing select for a limited set of biological and behavioral traits which are not necessarily the most suitable for survival in the wild environment. Because of this potential for such selection, the transfer of hatchery fish to rehabilitate or enhance stocks in depleted or underutilized watersheds runs the risk of altering the genetic character of the wild stock, even if the indigenous stock was the original donor stock for hatchery population. By restricting the separation between the transfer to the hatchery and the stocking to no more than one generation (e.g., eggs taken in a given year are cultured to fry or fingerling release at the hatchery; eggs or fish from the returns to the hatchery of this donor transplant are used for stocking), the risk of negative effects due to selection in the hatchery are minimized.

D. Establishment of wild stock sanctuaries.

As noted in preceding sections, there is concern that hatchery culture of salmon through their freshwater (and in some cases, initial estuarine) life history phases may select for a limited set of biological traits that are not suitable for wild populations. Loss of genetic variability through intensive inbreeding for domestication and desired traits has often resulted in detrimental genetic effects in agronomy and agriculture, such as reduced resistance to disease or adverse environmental conditions. Original wild strains can provide the genetic variability needed to outbreed domestics and alleviate inbreeding depression. Because there is potential for detrimental impacts due to reduction of genetic variability, there is a need to preserve a variety of wild types for future broodstock development and outbreeding for enhancement programs. Designation of watersheds where hatcheries or hatchery plants are not allowed would allow wild stocks within these watersheds to be subjected to natural selection only, within the life history phases cultured at hatcheries. These watersheds would be "gene banks" of wild-type genetic variability.

III. Maintenance of Genetic Variance

A. Genetic diversity among hatcheries.

There is general agreement that by introducing and maintaining a wide diversity of wild donor stock populations into the hatchery system that the prospects for long term success of the hatchery program in Alaska will be enhanced. Diversity tends to buffer biological systems against disaster, either natural or man-made. Developing and maintaining hatchery broodstock from a wide variety of donors will buffer the hatchery system against future catastrophes. Agricultural crop production in the U. S. provides a prime example of the dangers of genetic uniformity.

In an effort to increase yield, plant breeders have come to rely on a few highly productive strains. In 1970 approximately 15% of the corn production in the United States was lost to corn blight. The corn blight responsible, a mutant of the normal blight causing fungus, did not attack all strains. Only one strain of corn was vulnerable, but that strain of corn was grown by nearly every farmer in the country. Breeders were able to recover from the corn blight epidemic by replacing Texas cytoplasm with normal cytoplasm. Recovery was rapid because adequate genetic variability was available. There are other examples.

How does this relate to salmonid culture? Salmonid stocks apparently differ in levels of disease resistance, temperature tolerance, acid tolerance, and in their response to artificial selection. It seems imprudent to assume that conditions similar to those found in agriculture will not occur in aquaculture. In addition, the ability to genetically improve hatchery broodstock performance in the future will depend on the availability of genetic variability such as is found among wild salmonid stocks. A hatchery system with a variety of diverse broodstocks will be a valuable resource.

Genetic diversity does not guarantee protection from disaster, but uniformity seems to invite catastrophe. Local failures are inevitable within the hatchery system. It seems prudent to provide the system with a level of insurance by developing and preserving diversity among hatcheries.

Off-site releases for terminal harvest, whether for the commercial fishery or for a put and take sport fishery should have no adverse genetic effect if they are released at sites selected so that they do not impact significant wild stocks, wild stock sanctuaries or other hatchery stocks. The success of this type of release from a genetic standpoint depends on the ability to manage and harvest the return. If returns can not be harvested, increased straying may result which might lead to an impact on wild stocks at a greater than expected distance from the release site.

B. <u>Genetic diversity within hatcheries and from donor stocks</u>.

There is a general consensus among geneticists that fitness (reproductive potential) is enhanced by heterozygosity (genetic variability). Any loss of genetic variation will be accompanied by a concomitant reduction in fitness. Genetic variation allows a population to adapt to a changing environment or to adapt to and colonize a new environment. Available genetic variation determines how rapidly a population will respond to either artificial or natural selection. On the other hand, selection, inbreeding and random genetic drift will reduce genetic variability in a population.

Natural selection, that is selection for fitness, is a continuing process and should not be so intense that it has a significant effect in reduction of genetic variation, unless the population is in a new and quite different environment. Artificial selection on the other hand can be very intense, but can either be avoided or designed to assure that possible negative effects to fitness are offset by increased production efficiency due to the selection program, and by more efficient culture techniques. Inbreeding due to the deliberate mating of related individuals can be easily avoided in salmon hatcheries. Undoubtedly, in hatcheries and possibly in natural stocks the most important cause of loss of genetic variation is random genetic drift. In hatcheries reduction of genetic variation caused by inbreeding and genetic drift can easily be avoided by using adequate numbers of spawners.

Random genetic drift in general refers to fluctuations in gene frequency that occur as a result of chance. Such fluctuations occur, especially in small populations, as a result of random sampling among gametes. The amount of change but not the direction of change, can be predicted. The rate of this change is related inversely to effective population size (N_e). The smaller the effective population size the greater the fluctuation in gene frequencies. In small populations random genetic drift can result in inadvertent loss of genetic variability which may significantly reduce the fitness of the population.

Effective population size (N_e) is defined as the size of an idealized population that would lose genetic variability at the same rate as the sample population. An idealized population is one in which there is no mutation or selection, there are equal numbers of males and females, mating is random, etc. Obviously it is very unlikely that any natural population will meet all criteria for an idealized population.

Breeding structure of a population can profoundly affect the rate at which genetic variability is lost. However, we can determine the effective breeding size (N_e) for breeding structures and obtain the rate of inbreeding (ΔF) as

$$\Delta F = 1/2N_e$$

so the consequences of breeding structure can be related to the loss of variation.

Many breeding structure variations can influence the effective population size. Four seem likely to operate in a salmon hatchery population: (1) numbers of males and females in the breeding population; (2) unequal numbers in successive generations; (3) nonrandom distribution of offspring among families; and (4) overlapping generations. These are discussed in greater detail in Appendix A.

Any of these variations in breeding structure may have a marked effect on N_e. Although it may be impossible to control or even to measure variation in family size it is important to keep in mind the relationship to effective population size. Breeding plans that would aggravate or increase the variation of family size should be avoided. The effect of overlapping populations is to increase the effective population number, in that individuals mating in different years contribute to greater diversity. For example, it would take a larger number of pink salmon each year to maintain N_e = 400 than it would sockeye salmon.

The factor having the greatest potential effect in the hatchery and over which we have most control is sex ratio. As the formula indicates (Appendix A) the effective population size is affected most by the numbers of the least frequent sex. It is important to consider this in the breeding plan. In salmon, because a male can be used to fertilize the eggs of a large number of females, there is a temptation to do so. This temptation should be moderated by the necessity to maintain an effective population size which will assure that adequate genetic variation is maintained in the population. A minimum effective population (N_e) of 400 should be maintained. At this size the rate of inbreeding will be 0.125 percent per generation which should not have a significant effect on the long term fitness of the population.

In some cases, for example with chinook and steelhead, small population size may be unavoidable. In such cases a plan should be developed to offset the effects of small population size by infusion of genes from a source outside the hatchery population, such as the original donor source. Help in designing these breeding plans can be obtained from the Principal Geneticist, FRED Division, Alaska Department of Fish and Game.

While developing hatchery stocks from wild donor sources it is important that the genetic variability in the donor stock be protected. Cropping of the early or late run segments of a donor stock can change the timing of that run, which will reduce genetic variability of the population and may be detrimental to the stock's prospects for long term survival. To prevent such selection, sliding egg take scales for donor stock transplants should allocate no more than 90% of any segment of a run for broodstock.

RESEARCH

The necessity for much of this policy arises from our ignorance the genetics of wild salmon populations and the effects of ir domestication in hatcheries. The policy is based more on rapolation from other disciplines such as agriculture than om first-hand knowledge of our resource. As a result, the policy is a somewhat conservative interpretation of these data in order to assure the long-term viability of salmon populations. The Committee has identified several areas in which specific knowledge would clarify this policy and contribute to the effectiveness of salmon enhancement. The Committee encourages cooperative research efforts among the university, state, federal and private sectors directed toward the general areas listed below.

1. Development of performance profiles of hatchery stocks and potential for genetic improvement. Information about stocks kept in culture will be useful in several ways. If taken in a standard manner, the data will be useful in determining the extent of variability in the species and will aid in the choice of stock to be used for outplanting or transplanting. The information will also be helpful in maximizing the production of a particular facility.

2. Potential for genetic improvement of cultured stocks. A sequel to the cataloging of the variability within and among stocks will be to experimentally assess the potential for genetic improvement by selective breeding. To do this, it is necessary to determine the heritabilities for traits of interest, that is the part of the phenotypic variability present in a population which results from genetic (heritable) causes as opposed to environmental causes. Traits such as size of adults, age of return and various timing parameters are particularly interesting to industry.

Application of artificial selection is responsible for the enormous advances that have been made in agriculture; the potential also exists in aquaculture.

3. Assessment of the effect of introgression of genes from hatchery fish into wild populations. To examine this effect, one must first have an estimate of the rate of straying and the factors that influence straying. Such factors might include transplant distance, run strength, source of the hatchery stock and year-to-year environmental differences. By using a genetically marked stock, one can monitor the flow of "hatchery genes" into other populations. Because the effect of such introgression may develop over time, it is necessary that such an experiment be conducted over several generations. For this kind of study, it may be necessary to develop a means for marking fish cultured at production levels.

   The second part of this problem is to establish the impact of introgression. A range of potential interactions is possible ranging from introgression between two unrelated stocks to the [illegible]gression of fish subject to the selective pressures [illegible]ery back into the wild stock from which they were [illegible] Research to examine these effects could best be do[illegible]xperimental hatchery where hybrid stocks could be pro[illegible]ed and all releases marked. Port sampling and stream walking would be necessary to evaluate survival, straying and other phenotypic effects.

4. The effects of inbreeding and maintenance of inbred lines. Accompanying the artificial propagation of a species is the potential for inbreeding, loss of genetic variability and increased homozygosity. Information pertinent to the extent of inbreeding depression that results from various levels of inbreeding is necessary in determining adequate effective population sizes. This is especially important for species

for which a large effective population size is difficult to maintain. In addition, this information would permit a judgement on the efficacy of enhancing very small remnant populations. This work could be done both by performing crosses designed to accomplish some level of inbreeding, and by the maintenance of small randomly breeding populations. In both cases, it is important to keep careful controls.

APPENDIX A

Appendix A

The relationship of breeding structure, effective population size, and rate of inbreeding.

Breeding structure can profoundly affect effective breeding size (N_e) of a population. We can, at least in theory, determine the effective breeding size for many breeding structures and obtain the rate of inbreeding (ΔF) as

$$\Delta F = 1/2N_e$$

relating variation in breeding structure to loss of ariation.[1/]

The following demonstrates the consequence of some breeding structures to effective population size.

Number of males and females: Unequal numbers of males and females in the breeding population reduce effective population size. Sex ratio is related to effective population number (N_e) as

$$N_e = 4N_m N_f / (N_m + N_f)$$

where N_m and N_f refer to the total number of males and females respectively. The effective population size is strongly influenced by the number of the least frequent sex.

Unequal numbers in successive generations: If the numbers of breeding individuals is not constant in successive generations the mean effective number is the harmonic mean of the number in

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1/ See D.S. Falconer. 1981. Introduction to Quantitative Genetics. Longman Inc., New York.

each generation. Over generations the effective number is approximately,

$$1/N_e = 1/t(1/N_1 + 1/N_2 + 1/N_3 + \ldots\ldots 1/N_t).$$

The generation that has the smallest number will have the largest effect.

<u>Nonrandom distribution of offspring among families</u>: When there is large variation in family size the next generation is made up of the progeny of a smaller than expected number of parents. This can be related to loss of genetic variation through effective population number as

$$N_e = 4N/(V_k + 2)$$

where V_k refers to the variance in family size. When variation of family size V_k is equal to 2, then $N_e = N$. When the number of males and females are unequal, the variance of family size may be unequal in the two sexes and

$$N_e = 8N/(V_{km} + V_{kf} + 4)$$

where V_{km} and V_{kf} are the variance of family size for males and females respectively.

<u>Overlapping generations</u>: In species other than pink salmon generations are not discrete, they are overlapping. When generations overlap the effective population size is

$$N_e = 4N_cL/(V_{km} + 2)$$

where L is the generation time and N_c is the number of individuals born in a year, that is the cohort size. The cohort size N_c is related to the total number (N_t) by $N_c = N_t/E$ and E is the mean age at death. As before V_{km} is the variation of family size.

The effect of unequal sex ratio and unequal numbers in successive generations on population size can be easily estimated. On the other hand it will be difficult or perhaps impossible to estimate the variance of family size. Nevertheless, we should keep in mind the relationships of family size and overlapping generations. Overlapping generations will in general increase the effective population number in that individuals mating in different years contribute to greater diversity. Variance of family size can radically reduce effective population size. Procedures that contribute to variance of family size or separation of year classes should be avoided.

The best thing that's happened to the South since cotton?

A fish tale worth telling

Diners find the fish produced by Paul Battle's ponds more appealing on a plate

TIMOTHY A. MURPHY—USN&WR

PAUL DAVIS FOR USN&WR

■ "Farm-raised catfish is as mild and fresh tasting as any fish you could ever eat," it says on the box of Mrs. Paul's frozen catfish fillets. Catfish? Yep, but it takes three more puffed-up paragraphs to explain that this is not the ugly, whiskered 10-pound tough guy that dredges the bottom of the Mississippi River for sustenance. No sir. This, says Mrs. Paul's, is an "exquisite" fish.

It's going to take more than three paragraphs for the Richards Group, the new advertising agency for the catfish industry, to convince consumers of that. But last month, for the first time, the nation's catfish farmers anted up $1.5 million for the Dallas-based firm to try. And just in case anybody thought they didn't mean business, last week they brought in Golin Harris, the public-relations firm for companies such as McDonald's and Sara Lee.

"We're tired of this," says Bill Allen, head of the American Catfish Institute, the $200 million industry's marketing arm in Belzoni, Miss. "We are trying to differentiate our product from the scavenger fish that everybody thinks about."

Farm-raised catfish is, in fact, a different product. Grown in man-made spring-water ponds, the fish is fed a rich diet of grain and minerals. Enjoyed for years by Southerners, who eat it fried with cornmeal fritters called hush puppies, it has shown up lately on menus in trendy Manhattan restaurants responding to the regional-food craze. Last year, Church's, the nation's second-largest fried-chicken chain, bought $55 million worth of fillets to introduce at their outlets nationwide. But that is not enough. Says Allen: "We want it to be perceived as a classic, Dover-sole kind of fish."

Swimming upstream

Unfortunately, says Richards Group account executive Jeff Upshaw, "there is more than one misconception about catfish." Market research shows that in addition to its reputation as a mud grubber, catfish is believed by some consumers to be good only when fried, while others don't want to prepare it at home because they think it smells bad. Harder to combat is its image as what Upshaw calls a "strictly jeans-and-T-shirt product. People feel it's not chic to order it in an upscale restaurant."

This is a problem that catfish processors have already begun to fight at the food-service level. Delta Catfish Processors, Inc., of Indianola, Miss., the world's largest catfish processor, recently hired New Orleans chef John Folse as a consultant. His demonstrations of elegant recipes such as catfish mousse and pan-sautéed catfish with sauce meunier even are available on video.

In New York, chic delicatessens such as Balducci's and Zabar's carry a smoked version of the fish, and fried catfish is featured on menus from the Gulf Coast restaurant in Greenwich Village to Park Avenue's Ritz Cafe. Delta Catfish Processors' Delta Pride line now offers preseasoned frozen Catfish Classics to restaurants lacking adventurous chefs. Available in Cajun, butter-garlic and lemon-pepper flavors, they will soon be available in grocery stores.

All this is good news to the ailing farmers of the Mississippi Delta, where 85 percent of the world's catfish is produced. John Dillard, a catfish farmer and stockholder in Delta Catfish Processors, says that this year Mississippi farmers will produce 250 million pounds of catfish—30 million pounds more than last year—and farmers in Arkansas, Alabama and Louisiana will add to the pile. "If we end up with 20 million pounds we can't sell, we're in trouble. We've got to sell them because there's no loan on catfish, no government payments."

Like most catfish farmers, Dillard began growing catfish on unused farmland as a sideline to his main business of cotton, soybean and rice farming. But now, he says, "the catfish business is bigger than our farming operation in terms of dollars." Says Webb Franklin, Mississippi's second-district congressman: "Catfish farming is the only bright spot agriculturally I see in my district."

There even are rumblings of changing the generic name from farm-raised catfish to Mississippi-raised or Delta-raised, a possibility the Richards Group intends to explore. Why not? Idaho has its potatoes and Florida its oranges. Maybe it's time for Mississippi to claim catfish. ■

by Julia Reed

CRISP FRIED CATFISH

6 small farm-raised catfish fillets
1 teaspoon salt
1/4 teaspoon pepper
2 cups yellow cornmeal in a brown paper bag
1 quart cooking oil

Sprinkle catfish lightly with salt and pepper. When ready to fry, drop fish into the bag and shake to coat with cornmeal.

Use a deep pot or iron skillet filled half full with cooking oil. Heat until just smoking hot. Place each piece of fish into oil separately. Cook on high heat until fish floats to the top and reaches a golden brown. Drain well on paper towels. Serve hot. Makes 6 servings.

MEMORANDUM

State of Alaska
Department of Law

TO: Hon. Don Collinsworth
Commissioner
Dept. of Fish and Game

DATE: October 25, 1988

FILE NO.: 221-88-0958

TEL. NO.: 465-3600

SUBJECT: DeNardo v. State

FROM: Larri Irene Spengler
L15
Assistant Attorney General
Natural Resources Section
Department of Law

CONFIDENTIAL: ATTORNEY/CLIENT PRIVILEGE

In June of this year, the state was served with the complaint filed in superior court in Anchorage by Daniel DeNardo, representing himself, in which Mr. DeNardo requests the court to issue a judgment declaring that the legislature's extension of the moratorium on most finfish farming (ch. 145, SLA 1988) is unconstitutional, in violation of the interstate commerce clause, the privileges and immunities clause, and federal equal protection guarantees. DeNardo v. State, 3AN 88-6467 Civil. Mr. DeNardo also requests in the complaint an injunction precluding enforcement of the "acts of the legislature forbidding issuance of the necessary licenses for salmon farming."

As explained in the July 5, 1988, memorandum from Liza McCracken, Assistant Attorney General in the Anchorage Attorney General's Office, Mr. DeNardo is a fairly well-known pro se litigant, who has filed a number of actions against various state officials and challenged several statutory provisions. Before going on an extended leave, Liza filed a motion to dismiss the action based on lack of standing, which motion was denied by superior court Judge Rene J. Gonzalez, on October 7, 1988.

Subsequently, on October 11, 1988, Mr. DeNardo filed a motion for summary judgment, arguing mainly that the moratorium is a violation of the United States Constitution's commerce clause, as being protectionist in nature. I will be opposing that motion for summary judgment, and will in turn file a cross-motion for summary judgment on all three claims. I will keep you informed of any developments.

LIS:dlm
cc: Hon. Dick Eliason
P.O. Box 143
Sitka, AK 99835

Norman Cohen
Dave Benton
Brian Allee
Department of Fish & Game

Steve White
Juneau AGO

Liza McCracken
217 Hambletonian
Eugene, OR 97401

IN THE SUPERIOR COURT FOR THE STATE OF ALASKA

THIRD JUDICIAL DISTRICT AT ANCHORAGE

DANIEL DENARDO, Plaintiff, vs. STATE OF ALASKA, Defendant.	3AN 88-6467 Civil

SUBSTITUTION OF COUNSEL

PLEASE TAKE NOTICE that Larri Irene Spengler, Assistant Attorney General, Department of Law, P.O. Box K, State Capitol, Juneau, Alaska, 99811, phone: (907) 465-3600, hereby enters her substitution for Sarah Elizabeth McCracken as counsel of record in the above-captioned matter on behalf of defendant State of Alaska.

Copies of all notices, motions and pleadings should be sent to the address referenced.

DATED: October 26, 1988

GRACE BERG SCHAIBLE
ATTORNEY GENERAL

By: Larri Irene Spengler
Larri Irene Spengler
Assistant Attorney General

This is to certify that on this date a copy of the foregoing is being caused to be mailed to plaintiff at the following address:

P.O. Box 100682
Anchorage, AK 99510

Dorian L. Morris 10-26-88
Dorian L. Morris Date

ATTORNEY GENERAL, STATE OF ALASKA
STATE CAPITOL
P.O. BOX K, JUNEAU, ALASKA 99811
PHONE 465-3600

IN THE SUPERIOR COURT FOR THE STATE OF ALASKA

THIRD JUDICIAL DISTRICT AT ANCHORAGE

DANIEL DENARDO,)
Plaintiff,)
vs.)
STATE OF ALASKA,) 3AN 88-6467 Civil
Defendant.)

MOTION FOR SUMMARY JUDGMENT

The state requests that summary judgment be entered on its behalf in this case. This motion is supported by the accompanying memorandum, and by attachments 1 and 2 submitted with the state's July 13, 1988, motion to dismiss.

DATED: October 26, 1988

GRACE BERG SCHAIBLE
ATTORNEY GENERAL

By: Larri Irene Spengler
Larri Irene Spengler
Assistant Attorney General

This is to certify that on this date a copy of the foregoing is being caused to be mailed to plaintiff at the following address:

P.O. Box 100682
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Dorian L. Morris 10-26-88
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IN THE SUPERIOR COURT FOR THE STATE OF ALASKA

THIRD JUDICIAL DISTRICT AT ANCHORAGE

DANIEL DENARDO,	)	
Plaintiff,	)	
vs.	)	
STATE OF ALASKA,	)	3AN 88-6467 Civil
Defendant.	)	

MEMORANDUM IN OPPOSITION TO PLAINTIFF'S OCTOBER 11 MOTION FOR SUMMARY JUDGMENT & IN SUPPORT OF STATE'S MOTION FOR SUMMARY JUDGMENT

I. INTRODUCTION

This case involves a constitutional challenge to a legislatively mandated moratorium on issuance of permits or licenses for salmon farming. The complaint seeks a declaratory judgment which would invalidate a legislative moratorium on authorization of most commercial finfish farming until July 1, 1990. Chapter 70, SLA 1987, extended by sec. 21, ch. 145, SLA 1988.

The complaint alleges that the legislature's action violates three provisions of the United States Constitution: article I, section 8, clause 3 (interstate commerce); article IV, section 2 (privileges and immunities); and the Fourteenth Amendment (equal protection).

On October 11, 1988, plaintiff moved for summary judgment with respect to the interstate commerce and equal

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protection claims. The state herein opposes that motion, and supports its cross-motion for summary judgment on all three claims of the complaint. Summary judgment is appropriate under Alaska Civil Rule 56 if there is "no genuine issue as to any material fact and the moving party is entitled to judgment as a matter of law." As will be shown below, the relevant facts are undisputed, and the state is entitled to judgment on the interstate commerce, privileges and immunities, and equal protection claims.

II. BACKGROUND

The subject of fish farming has been of increasing public interest in Alaska in recent years as reflected by the legislature's actions in 1987 and 1988. Chapter 70, SLA 1987; ch. 145, SLA 1988. As noted in a column by Senator Dick Eliason, chief sponsor of the 1988 legislation which clarified the authorization for shellfish farms while continuing the moratorium on most finfish farms, "fishermen, environmental organizations, recreational and other user groups, as well as a great number of individual citizens" addressed the legislature during an extensive series of public hearings in coastal communities throughout the state. Attachment 1 to state's motion to dismiss. "To the question of whether Alaska should allow development of salmon farms to begin this year, the response has been a resounding 'no!'" Id.

Questions in recent years regarding whether commercial finfish farming was or could be authorized in Alaska led to

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several attorney general memoranda of advice. These concluded that: (1) finfish farming is not prohibited by the Alaska or United States Constitutions or by statute (other than the present moratorium); (2) the activity may only occur if allowed by regulations; and (3) finfish farming is not presently authorized by regulation of the Board of Fisheries, quite apart from the present legislative moratorium prohibiting such authorization. See 1985 Inf. Op. Att'y Gen. (Jan. 31; 663-84-0187); 1987 Inf. Op. Att'y Gen. (Mar. 10; 661-87-0360); 1987 Inf. Op. Att'y Gen. (July 8; 663-87-0454); 1988 Inf. Op. Att'y Gen. (June 24; 663-88-0500).

There are presently no commercial finfish farming operations in Alaska, nor have there been any in the past. Attachment 1 to state's motion to dismiss (Eliason column). However, even under the moratorium challenged in this case, the activity could be authorized by regulation in a privately owned fresh water body that has no outlet to state waters. Section 1(b), ch. 70, SLA 1987; see 1988 H. Jour. pp. 3716, 3733; 1988 S. Jour. p. 3614; see also 1988 Inf. Op. Att'y Gen. (June 7; 883-88-0143). Commercial shellfish farming has been authorized previously, and is now specifically governed by the provisions of the 1988 legislation, codified at AS 16.40.100 -- 16.40.199, and by 5 AAC 41.001 and 5 AAC 41.200 -- 5 AAC 41.400. See also 1988 Inf. Op. Att'y Gen. (June 7; 883-88-0143; 1988 Inf. Op. Att'y Gen. (June 24; 663-88-0500).

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Fish farming is defined in AS 16.05.940(14) as "the business of propagating, breeding, raising, or producing fish . . . in captivity for the purpose of marketing the fish . . . or their products." That provision also defines "captivity" as having the fish "under positive control, as in a pen, pond, or an area of land or water which is completely enclosed by a generally escape-proof barrier." Thus, fish farming is distinguished from the raising of fish in hatcheries, where fish are released into the wild to grow to maturity; private nonprofit salmon hatcheries have been authorized in Alaska since 1974 under AS 16.10.375 -- 16.10.480.

There are many public policy considerations involved in the issue of mariculture generally, and commercial salmon farming specifically. Concerns include the economic effect on existing commercial fisheries, the allocation of public resources, the economic effect on local communities, the health of fish and other species, and impact on availability of recreational areas. <u>See</u> attachment 1 to state's motion to dismiss (Eliason column). In addition, potential environmental impacts of salmon farming are clearly areas of concern, including "water circulation and suspended sedimentation," "organic sedimentation and impacts on benthic organisms," "fish and megafauna impacts," "water quality impacts," "increased phytoplankton growth," "introduction of non-native species," "use of antibiotics and hormones," "proliferation of human pathogens," "transmission of disease to wild fish," "genetic alteration," "use of toxic

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substances," "conflicts with marine birds and mammals," and "impacts from associated hatchery and processing operations." 45 Anadromous Law Fish Memo, "Anticipating the 'Blue Revolution': The Growth of the Salmon Farming Industry and its Public Policy Implications" (April 1988), pp. 6-11; attachment 2 to state's motion to dismiss.

Awareness of such important policy issues led the legislature to establish a finfish farming task force in the 1988 legislation which extended the finfish farming moratorium until 1990. Section 20, ch. 145, SLA 1988. The task force is to examine a number of questions, including whether "the farming of finfish can be conducted in a manner that protects the health of the state's fishery resources," what criteria should be used for "the siting of finfish farms to minimize the land use conflicts and protect the environment," and the "net economic costs and benefits of finfish farming in the state to state residents," including an examination of jobs created or lost, tax revenue, and cost of state regulation and monitoring. Id. In addition, the task force is to consider the "cost of providing adequate regulation of finfish farming to protect wild stocks, the environment, public health, and existing beneficial uses of the state's coastal water and land" and the "role of the private sector in providing pathelogical and other services." Id.

It is against this background of legislative concern that plaintiff's claims must be evaluated.

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III. ARGUMENT

A. The Moratorium Does Not Violate the Commerce Clause

Plaintiff argues that the challenged regulation violates article I, section 8, clause 3, of the United States Constitution, which provides:

> Congress shall have power . . . to regulate commerce within foreign nations, and among the several states, and with Indian tribes.

The test for the commerce clause analysis was discussed by the United States Supreme Court in Hughes v. Oklahoma, 441 U.S. 322, 336 (1979). The court said that under the commerce clause it must inquire

> (1) whether the challenged statute regulates evenhandedly with 'incidental' effects on interstate commerce, or discriminates against interstate commerce either on its face or in practical effect;
>
> (2) whether the statute serves a legitimate local purpose; and if so,
>
> (3) whether alternative means could promote this local purpose as well without discriminating against interstate commerce.

The moratorium challenged here applies evenhandedly to both Alaska residents and nonresidents, with only "incidental effects" on interstate commerce. Under the moratorium, nonstate residents are in the same position as all Alaska residents -- they may engage in commercial shellfish farms under the statutes and under the applicable regulations, they may request the Board of Fisheries to authorize finfish farming in any "privately

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owned fresh water body that has no outlet to state water," */ and they may not engage in other commercial finfish farming. In addition, nonstate residents and residents who are not interested in finfish farming may fall into any one of a number of categories -- outdoor recreationalists concerned with the continued availability of prime coastal sites for recreation, commercial fishermen concerned with competition on the economic front, environmentalists concerned with maintaining the quality of Alaska's marine environment and the health of Alaska's native stocks. It is clear that there is no discrimination against interstate commerce either on the face of the moratorium challenged here, or in its practical effect. Thus, the commerce clause analysis need not be pursued further.

To the extent, however, that it is relevant, the requirement of a legitimate local purpose has been clearly demonstrated in the list of genuine concerns about land use, environmental quality, and allocation of available resources, discussed above. The legitimate local purpose -- allowing time to study these important issues before embarking on a program authorizing finfish farming in Alaska -- could not be promoted by any alternative means, since allowing any finfish farming other than in private ponds not connected to state water could

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*/ Section 1(b), ch. 70, SLA 1987.

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begin to have the deleterious effects which are the concern of the legislature, and are the job of the task force to examine.

Aside from the conclusion that the commerce clause is not violated because the challenged moratorium regulates evenhandedly, it is clear that plaintiff has no standing to challenge the moratorium on this ground. According to section II, paragraph 1, of the complaint, plaintiff is "a citizen of Alaska," and thus even if the moratorium discriminated against interstate commerce (which it doe not), he would not be injured by that discrimination, and would have no standing to challenge it on that basis. Moore v. State, 553 P.2d 8 (Alaska 1976).

Therefore, the state's motion for summary judgment on the commerce clause issue should be granted.

B. The Moratorium Does Not Violate Privileges and Immunities Principles

Plaintiff argues in his complaint that the challenged regulation violates article IV, section 2, of the United States Constitution, which provides:

> The citizens of each state shall be entitled to all the privileges and immunities of the citizens of the several states.

In analyzing this issue, the court will have to apply the framework developed by the judicial system for the analysis of privileges and immunities claims. In Robison v. Francis, 713 P.2d 259, 263 (Alaska 1986), the Alaska Supreme Court noted that the clause does not protect nonstate residents against "all forms of discrimination." Its reach is limited to "fundamental

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rights" involving "basic and essential activities, interference with which would frustrate the purpose of the formation of the union." Id. quoting Baldwin v. Montana Fish and Game Commission, 436 U.S. 371, 387 (1978).

Even if a right is involved which triggers the privileges and immunities analysis, the clause "is not an absolute." Toomer v. Witsell, 334 U.S. 385, 396 (1948). While it does prohibit discrimination against residents of other states "where there is no substantial reason for the discrimination beyond the mere fact that they are citizens of other states," it does not preclude "disparity of treatment in the many situations where there are perfectly valid independent reasons for it." Id. The court explained that "the inquiry in each case must be concerned with whether such reasons do exist and whether the degree of discrimination bears a close relation to them." Id. The court cautioned that the

> inquiry must also, of course, be conducted with due regard for the principle that the states should have considerable leeway in analyzing local evils and in prescribing appropriate cures.

Id.

As discussed with respect to the commerce clause issues above, the challenged moratorium simply does not impact nonstate residents any differently than it impacts state residents, and thus the privileges and immunities test is not even triggered. Even if there were some impact on nonstate residents which was different from that on state residents, there are, as

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discussed above, a number of "perfectly valid independent reasons" for the moratorium, which gives the legislature a chance to study the important policy questions raised by finfish farming, including environmental and land use impacts.

Again, just as with respect to the commerce clause argument above, plaintiff lacks standing to bring this challenge. Plaintiff is an Alaska resident, and thus even if this moratorium had a disproportionate impact on nonstate residents (which it does not), he would have no standing to make this challenge. Moore v. State, 553 P.2d 8, 23 (Alaska 1976).

Thus, the state's motion for summary judgment on the privileges and immunities issue should be granted.

C. The Moratorium Does Not Violate Equal Protection Principles

Plaintiff argues in his complaint that the challenged moratorium violates the equal protection provisions of the Fourteenth Amendment of the United States Constitution, which provides that no state may

> deny to any person within its jurisdiction the equal protection of the laws.

The United States Supreme Court has applied dual standards to equal protection challenges. The state must prove a "compelling state interest" to justify classifications based on race, national origin, or alienage, and such classifications are subject to strict scrutiny. Commercial Fisheries Entry Commission v. Apokedak, 606 P.2d 1255, 1261 (Alaska 1980). A similar standard is applied when fundamental rights are at stake. Id.

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In cases not involving suspect classes or fundamental rights, the United States Supreme Court has generally applied a less restrictive rational basis test. Id. at 1262. Plaintiff here does not suggest that the alleged legislative moratorium on finfish farming involves a suspect classification, and "the availability of employment opportunity has not been considered a fundamental right so as to require application of the compelling state interest state." Id. The applicable test, therefore is "whether the classification is reasonable, possesses some rational connection to the measure's legitimate purpose and treats all within the class alike." Id.

The legislative moratorium on finfish farming, other than in privately owned ponds without an outlet to state waters, establishes no classifications in itself. In other words, it does not say that certain individuals may participate in finfish farming in state waters, and others may not. Thus, there is no classification inherent in the moratorium which the state need defend against an equal protection challenge.

It may be that plaintiff is arguing that individuals desiring to develop finfish farms are somehow similarly situated to individuals engaged in commercial salmon fishing in Alaska, or to individuals involved in operating private nonprofit salmon hatcheries. That is simply not the case.

As mentioned in section II above, finfish farming is an untested type of development in Alaska, which raises a number of environmental, land use, allocation, and economic concerns.

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In contrast, commercial fishing -- as well as sport fishing and subsistence fishing -- has been authorized and conducted in Alaskan waters since long before statehood. The impacts and risks of commercial fishing are relatively well-known, and it does not pose any danger to native stocks, other than through the possibility of overharvest, which is controlled by the state's conservation laws. Similarly, private nonprofit salmon hatcheries have been authorized since 1974, under strict statutory standards governing siting, salmon egg sources, inspections, release sites, reporting requirements, etc. AS 16.10.375 -- 16.10.470. In addition, hatcheries are subject to numerous and detailed regulations. 5 AAC 40.005 -- 5 AAC 40.990. Further, hatcheries dovetail well with existing economic dependence of coastal areas on commercial fishing, since the hatchery fish are available for harvest by commercial fishermen, as well as sport and subsistence fishermen, before they return from the open sea to the hatcheries.

In sum, there is a reasonable basis for the legislature to wish to proceed carefully in a new and complicated area of development, such as finfish farming, because of the many environmental, land use, allocation, an economic concerns. The moratorium operates evenhandedly on all, and does not allow certain classes of people to develop finfish farms and others not to. Commercial finfish fishermen and operators of nonprofit salmon hatcheries are situated very differently from individuals who might be interested in developing commercial finfish farms.

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Thus, the state's motion for summary judgment on the equal protection claim should be granted.

IV. CONCLUSION

For the above reasons, the state asks that plaintiff's October 11, 1988, motion for summary judgment be denied, and that the state's motion for summary judgment be granted.

DATED: October 26, 1988

GRACE BERG SCHAIBLE
ATTORNEY GENERAL

By: Larri Irene Spengler
Larri Irene Spengler
Assistant Attorney General

This is to certify that on this date a copy of the foregoing is being caused to be mailed to plaintiff at the following address:

P.O. Box 100682
Anchorage, AK 99510

Dorian L. Morris 10/26/88
Dorian L. Morris Date

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IN THE SUPERIOR COURT FOR THE STATE OF ALASKA

THIRD JUDICIAL DISTRICT AT ANCHORAGE

DANIEL DENARDO, Plaintiff, vs. STATE OF ALASKA, Defendant.	)	3AN 88-6467 Civil

ORDER

IT IS ORDERED that the state's motion for summary judgment in this case is granted.

DATED; ____________________

Rene J. Gonzalez
Superior Court Judge

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IN THE SUPERIOR COURT FOR THE STATE OF ALASKA

THIRD JUDICIAL DISTRICT AT ANCHORAGE

DANIEL DENARDO,)
Plaintiff,)
vs.)
STATE OF ALASKA,) 3AN 88-6467 Civil
Defendant.)

ORDER

IT IS ORDERED that plaintiff's October 11, 1988, motion for summary judgment is denied.

DATED; ____________________

Rene J. Gonzalez
Superior Court Judge

ATTORNEY GENERAL, STATE OF ALASKA
STATE CAPITOL
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MARICULTURE IN ALASKA

The unpolluted, productive waters of Alaska's many protected bays and fjords are considered ideal for many forms of mariculture. Alaska also has healthy populations of many species of shellfish, finfish and aquatic plants that could contribute broodstocks for sea farms.

Alaska's first experience with mariculture involved the experimental culture of oysters near Ketchikan in the early 1900s. There now are a handful of active oyster farms in Southeast and Prince William Sound.

Blue mussels also have been successfully cultured at Halibut Lagoon in Kachemak Bay. Juvenile mussels are collected from the wild and grown on longlines or from rafts.

The State of Alaska recently entered into an agreement with the Japanese Overseas Fishery Cooperation Foundation to test the feasibility of collecting and farming weathervane scallop on Kodiak Island, and the growing of giant kelp *(Macrocystis)* at Sitka. The scallop project involves several private "cooperators" who will conduct operations at various locations around the island.

The state also is cooperating in a National Marine Fisheries Service experimental project to examine the biological feasibility of farming salmon on Baranof Island in Southeast. Growth performance during the experiments suggests that six to nine pound (market range of most farmed salmon) chinook salmon can be produced in three seasons.

Interest in mariculture has been growing in Alaska over the past few years. When a diverse group of Alaskans examined issues related to mariculture for the state in early 1986 it supported immediate development of farming operations for shellfish and aquatic plants. Voicing concern about the potential socio-economic impacts upon Alaska's important fishing industry, the group suggested that market impacts of farmed salmon be more closely examined before allowing the pen-rearing of finfish.

POLICY ISSUES RELATED TO MARICULTURE DEVELOPMENT

Legal/Regulatory Status—The legal status of mariculture in Alaska is uncertain. While it is now possible to obtain a fish farming license, changes in state law or passage of new regulations would be necessary before individuals could engage in most mariculture activities. The only clear existing permitting process currently available is for the farming of oysters. However, it is possible to obtain permits to commercially harvest some juvenile native species and to grow them to a commercial size. State law prohibits state and private non-profit salmon hatcheries from selling surplus eggs to fish farmers.

Disease and Genetics—Some concern has been expressed that mariculture could result in the spread of disease to wild stocks. However, a 1986 study prepared for the University of Washington said there is no evidence to indicate this has ever occurred. "While fish held in culture are likely to show more frequent appearance of disease than wild fish," the study said, "disease does not appear to be transmitted to wild populations." Similarly, the study said, there is no evidence to support concerns that escapes of cultured organisms will lead to interbreeding with wild stocks and cause genetic problems.

The State of Alaska has taken a cautious approach on disease and genetic issues in development of Alaska's ocean ranching program, and this is likely to continue with mariculture. Sea farming activities will fall under the state's disease and genetic policies.

Environmental Effects—Mariculture operations appear to have a small effect on water quality beyond the immediate vicinity of the culturing facilities. Potential problems would be posed only in areas of extremely limited flushing action (tides or currents) or if culture density was very great.

Concerns also have been voiced about sedimentation under floating mariculture facilities. Shellfish culture generates relatively small amounts of solid waste, while salmon farming can produce fairly large quantities of unutilized feed and feces which settle to the bottom. This sedimentation can result in major changes to the ocean floor. However, the materials are deposited in the immediate vicinity of the culturing facility and the effects are localized.

Sedimentation and water quality issues can be addressed with the use of siting criteria to ensure proper flushing action. Mariculture operations will be monitored by state water quality enforcement programs and must comply with provisions of the federal Clean Water Act.

Use of Tidelands—Mariculture is one of many potential uses of Alaska's tidelands and adjacent uplands. A major factor in the tidelands permitting process in determining whether a site will be approved for sea farming is compatibility with existing uses. Siting of sea farms generally involves obtaining approval from at least the Departments of Natural Resources, Fish and Game and Environmental Conservation, Environmental Protection Agency and Army Corps of Engineers.

Leif Larson displays a shipment of oyster spat (an early life stage) at a farm near Wrangell.

Brood Stocks—The initial growth of a mariculture industry will be shaped by availability of marine organisms in early life stages. In most mature mariculture industries, sea farmers purchase marine organisms in early life stages from hatcheries producing fish or shellfish with genetic characteristics adapted to farming conditions. However, some species, such as scallops and mussels, may depend upon continual access to wild stocks.

Acquisition of brood stocks for salmon farming would require changes in existing law. Access to wild stocks which support other important commercial fisheries also may require statutory or regulatory changes.

Capital Investments—As a general rule, the farming of shellfish requires a smaller front-end investment than the pen-rearing of salmon or other finfish. Many shellfish operations can be family-sized businesses, while most salmon farms have 3-10 employees. The economy of scale of mariculture operations in Alaska is unknown at this time. Japanese shellfish farmers achieve economy of scale through the use of cooperatives for processing, transportation and marketing.

Paralytic Shellfish Poisoning—Paralytic shellfish poisoning (PSP) is a serious health concern in many wild and farmed shellfish. The state requires that many species of shellfish be certified before sale. Farmed shellfish must be pulled out of the water and quarantined while samples are flown to a laboratory in Palmer for analysis prior to sale.

Tidelands Leasing—The state's current tidelands permitting process allows shellfish farmers to obtain one-year use permits. Long-term leases also may be obtained, but the surveying and appraisal process required is expensive and time consuming. The one-year permits do not provide farmers with the assurance that they will obtain the site in subsequent years and may not be used as security for loans.

Economic Impacts on Commercial Fisheries—Many commercial fishermen and processors are concerned about the impact of salmon farming on the world market price for salmon. A 1986 study by the University of Alaska's Marine Advisory Program concluded that salmon farming worldwide "may immediately impact only a small portion of the Alaskan salmon industry." However, the study went on to say, the growth of salmon farming throughout the world suggests these trends should be watched closely.

The Alaska Department of Commerce and Economic Develoment is gathering comments on mariculture development from various coastal communities for consideration by the 1987 legislature. During these "town hall" meetings, the department will present information outlining potential effects in Alaska from a range of mariculture development scenarios. Included in the report to the legislature will be an analysis of the potential impacts on existing salmon markets from additional Alaska supplies (wild and farmed sources) of chinook and coho salmon.

WHAT IS MARICULTURE?

Mariculture is the farming for profit of shellfish, finfish and sea vegetables in the marine environment. The organisms to be cultured are produced in hatcheries or gathered from the wild. The growing takes place in net pens, from rafts, longlines, and on the ocean floor or intertidal area. In some cases sea water is pumped to shore-based enclosures. Some of the more common mariculture products are scallops, shrimp, salmon, mussels, nori and kelp.

This captive culture is distinct from Alaska's existing **ocean ranching** program which involves raising salmon to the juvenile stage for release to intermingle with wild stocks. Ocean ranching in Alaska is conducted on a private non-profit basis or by public agencies. The returning salmon must contribute to the common property fisheries (commercial, sport, subsistence and personal use).

A more encompassing term is **aquaculture** which includes mariculture, ocean ranching, and farming in fresh water with such species as catfish, shrimp, trout and crayfish.

GLOBAL MARICULTURE TRENDS

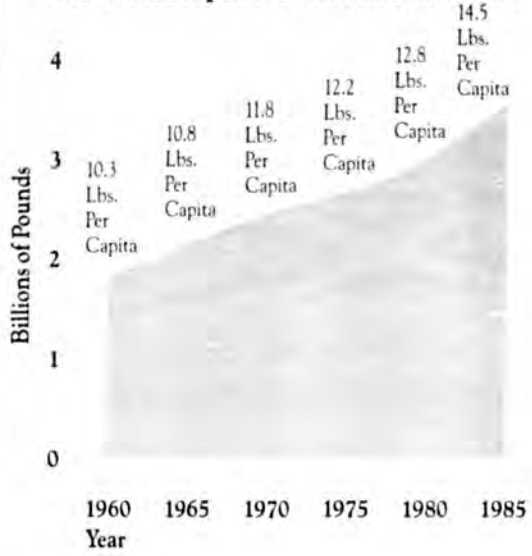
Although fish farming originated in China many centuries ago, relatively recent advances in controlling diseases, understanding nutritional requirements and breeding domesticated stock have led to an aquaculture explosion throughout the world.

Global aquaculture production of fish and shellfish was estimated at 22 billion pounds in 1983 and is expected to reach 48 billion pounds by the turn of the century. Aquaculture produced 12.2 percent of the world's total supply of edible fish and shellfish in 1983.

Meanwhile, production curves of commercial fisheries landings have flattened out. While aquaculture production is expected to rise by 5.5 percent annually over the next 25 years, the annual increase for wild fisheries is expected to be .3 percent.

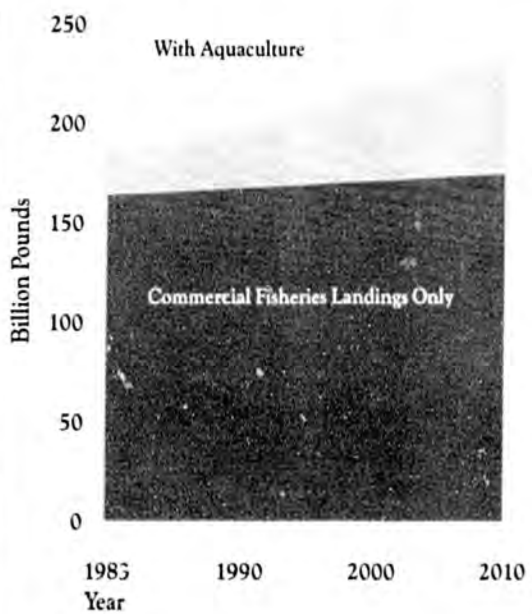
The increases in production of cultured fish and shellfish correspond with a steady growth in seafood consumption throughout the world. These trends are readily apparent in the United States where consumption of fish and shellfish climbed by 609 million pounds or 21.5 percent between 1982-1985.

U.S. Consumption of Fish and Shellfish



National Marine Fisheries Service

Actual and Projected Annual World Fish and Shellfish Production



International Aquaculture Foundation

HOW TO OBTAIN ADDITIONAL INFORMATION ON MARICULTURE

Department of Commerce and Economic Development
Bill Paulick
Office of Commercial Fisheries Development
Department of Commerce and Economic Development
P.O. Box D
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MARICULTURE IN ALASKA

A DISCUSSION OF THE ISSUES INVOLVED IN SEA FARMING DEVELOPMENT IN COASTAL ALASKA

Vol. 20(3)

WORLD AQUACULTURE

Tropical Fish

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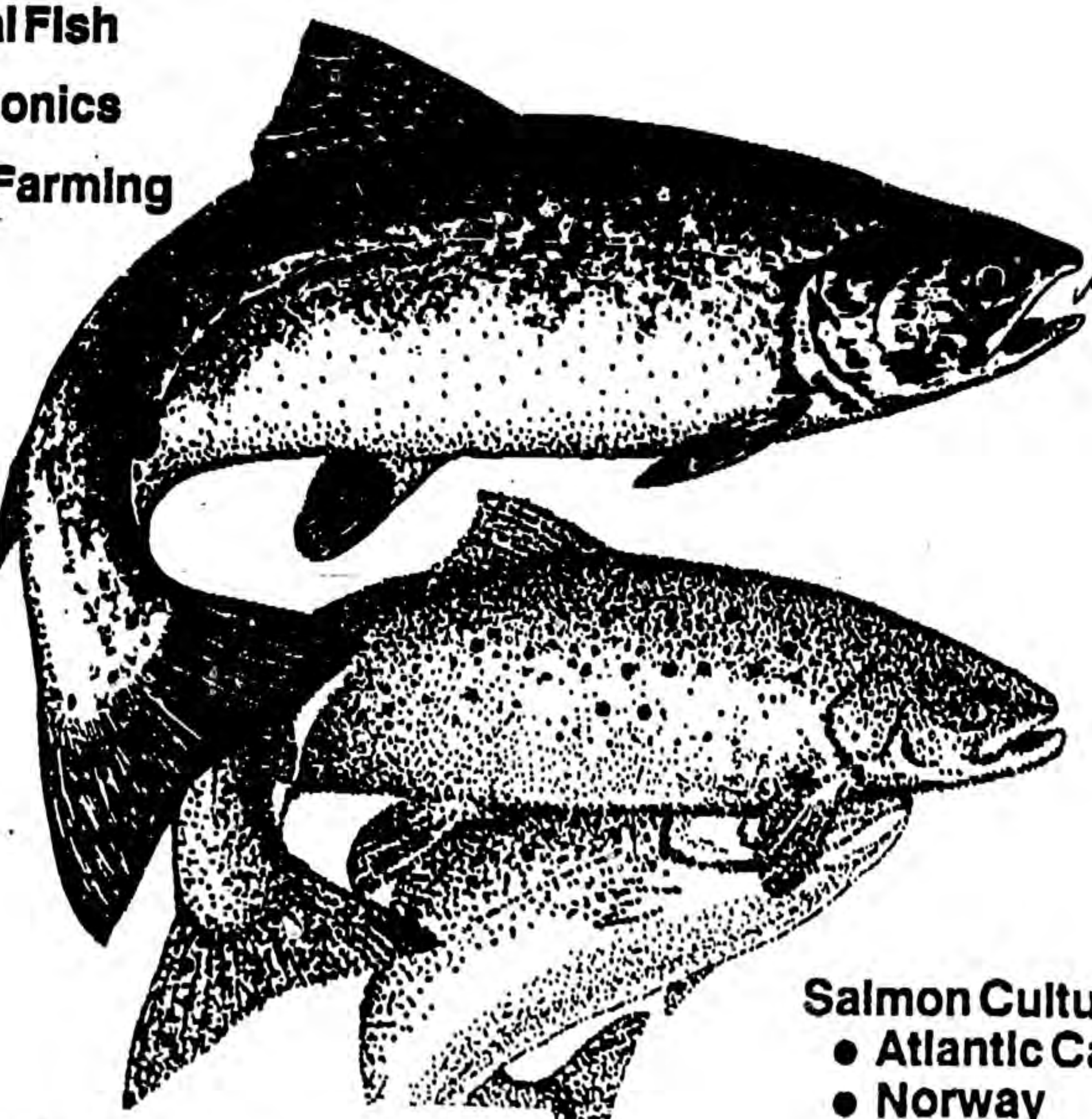

Salmon Culture:
- Atlantic Canada
- Norway

South Carolina Aquaculture

September, 1989

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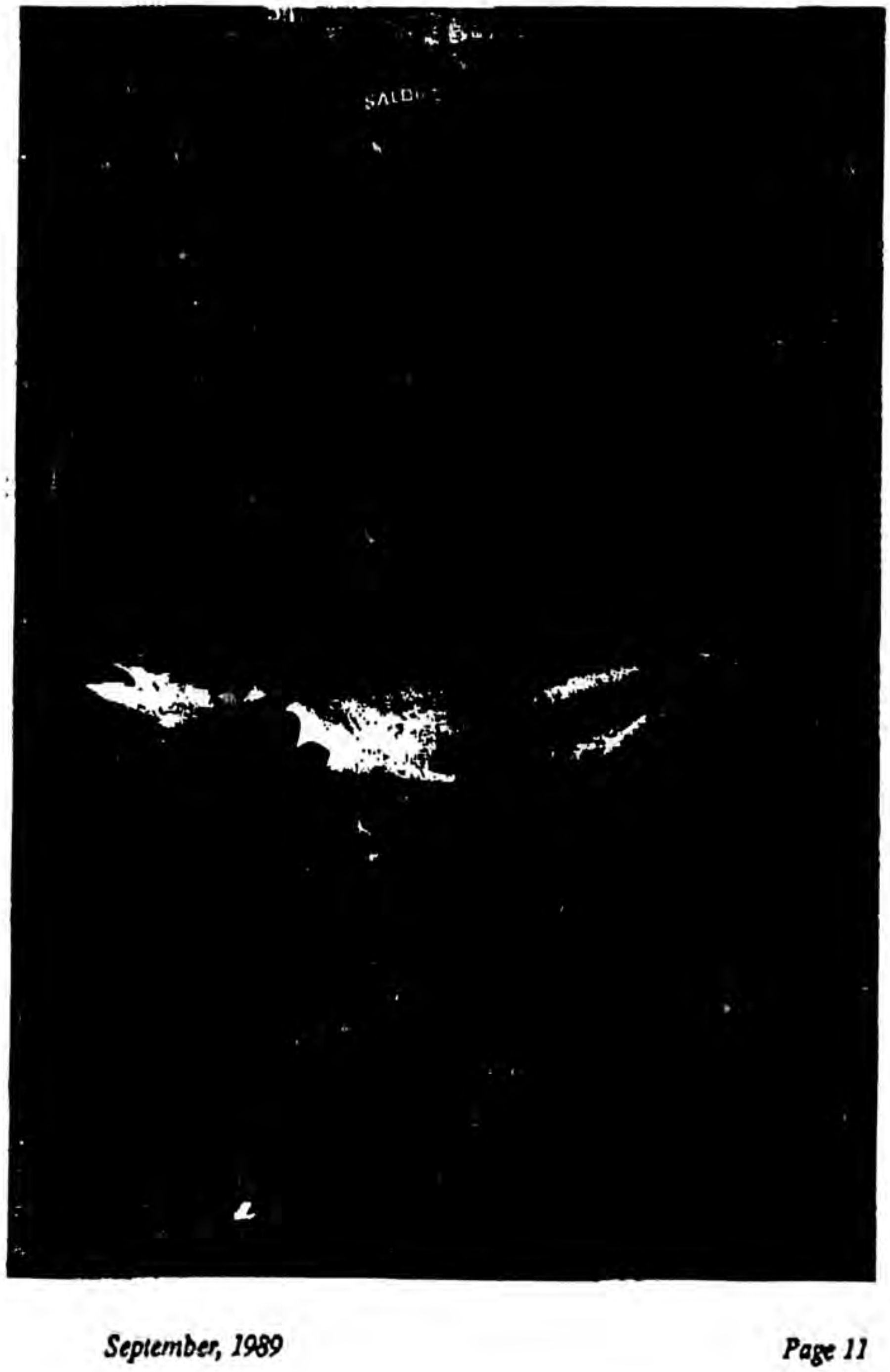
the economics of Salmon farming in the Bay of Fundy

Text by Dave Aiken

Photography by Bill McMullon

The Atlantic salmon has always been "The King of Salmon" in the Maritime provinces of Canada. From the prehistoric Algonkian Indian fishermen to the modern farmer growing salmon in sea cages in the Bay of Fundy, *Salmo salar* has been a potent economic force.



The upscale Canadian market for Atlantic salmon was once supplied by Maritime fishermen who netted the noble fish when they returned to their ancestral rivers to spawn. But the numbers of wild fish eventually declined to dangerous levels, and the federal government was forced to end the commercial harvest. That shut off domestic sources of *Salmo salar,* and for the first time in history Maritimers had to go offshore for their Atlantic salmon.

Then in 1978 Dr. Arnold Sutterlin, a research scientist with the Canadian Department of Fisheries and Oceans, convinced federal, provincial and private interests to test his theory that Atlantic salmon could be farmed in sea cages in the southern Bay of Fundy. Earlier attempts by others had been terminated by "superchill," literally the freezing to death of salmon that occurs when the temperature of seawater declines to minus 0.7°C.

But Sutterlin insisted this was not an insurmountable problem. He knew that temperatures in the open Bay of

Continues...

Fundy remained comfortably above the lethal level throughout the winter, and that lethal chilling probably occurred only in the shallow and protected coves and inlets around the perimeter of the Bay. Unfortunately, it was those coves and inlets that offered the protection required for salmon sea cages. The terrible winter gales and intimidating seas of the open Bay of Fundy would make short work of salmon cage designs available in those days, and therein lay the conundrum: in the open Bay where the salmon could survive, their cages could not. In protected coves where the cages could survive, the salmon could not.

Sutterlin and his colleagues focused on the Fundy Isles region in the southwestern Bay of Fundy. Here a string of islands form a broken barrier between the fearsome open water of the Bay of Fundy and the sheltered, shallower and significantly cooler water of Passamaquoddy Bay. Among the islands powerful tidal currents surged twice a day, driven by tides with • vertical range of more than eight meters. Here coves, inlets and channels offered protection from winter gales and destructive seas, protected sites where water temperatures were moderated by warmer water from the adjacent Bay of Fundy.

In one of these, on the outer coast of Deer Island, eastern Canada's first commercial sea cage salmon farm was established in 1978. With technical expertise and funding from the federal and provincial (New Brunswick) governments, and other contributions from a private company, 3,800 salmon smolt were stocked in a 12-meter octagonal cage similar to those used in Norway.

As the winter of 1978 deepened and seawater temperatures in many areas sank below the lethal level, the team watched their livestock not only survive but grow. The following autumn 6.3 metric tons of prime Atlantic salmon were harvested from the cages, establishing the validity of Sutterlin's theory and the viability of net pen salmon culture in the southern Bay of Fundy.

History

From that modest harvest in 1979 the industry has grown at an impressive rate, roughly doubling its harvest in each successive year. There are now 44 approved cage sites and roughly 40 active farms scattered throughout the Fundy Isles region of New Brunswick from Grand Manan northeastward past St. George and Beaver Harbour.

The development of the industry on the Atlantic coast contrasts sharply with the history of the "BC" industry on Canada's west coast. The Pacific industry has been heavy on promotion and a bit light on performance; the Atlantic industry, on the other hand, has developed quietly but steadily, building on performance rather than promotion. Where the Pacific industry leaned toward public companies and venture capital, the Atlantic industry developed through small partnerships and more conventional financing. Where the Pacific industry focused on coho and chinook salmon — both difficult species to cultivate — the east coast industry farmed the cooperative and dependable Atlantic salmon.

Sutterlin's group provided the inspiration and basic technology for Fundy salmon farms, but several other factors combined to make the industry what it is today. Take smolt, for example. To run a salmon farm you must have smolt, and to have smolt you must have broodstock; the well known chicken-and-egg situation. Fortunately the federal government had been producing smolt for years to enhance wild stocks, and they annually produced a small surplus that could be

The Deer Island Story

To start a new industry you must have good timing, the required resources, and dedicated people. This is a story about two such dedicated people.

To those of us who know and worked with them in the late 1970s, Arnold Sutterlin and Eugene Henderson were that rarest of species — dedicated government scientists with a vision. Aquaculture was not a household word in those days. In government research circles it was not even a popluar word, but to "Arnie" and "Gene" it mattered not. They were determined to prove that salmon could be overwintered in the Bay of Fundy and that a viable salmon culture industry could be established in the area. A site was carefully selected on the outer side of Deer

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Arnold Sutterlin (right) and Eugene Henderson, part of a team that in the late 1970s helped make Bay of Fundy salmon farming a reality, discuss old times at the second St. Andrews Atlantic Aquaculture Fair. Sutterlin was honored with the "Aquaculturist of the Year" award in recognition of his early contributions to the local salmon industry.

Deer Island Story

(from previous page)

Island, one of the Fundy Isles that rim the western side of the Bay of Fundy, the "Deer Island Project" was born, and the rest, as they say, is history. Their vision and hard work helped establish an industry that last year grossed about $40 million in direct sales and employed about 170 people.

Sutterlin and Henderson were the quintessential match of opposing personalities. Sutterlin was a free spirit whose creative mind could never fully accept the constraints of bureaucracy with its penchant for detailed reporting of minutiae and endless forms filed in triplicate. Henderson, in contrast, was a detail man, patient and meticulous. Sutterlin was the one who cut the swath but it was Henderson who gathered, bundled and stacked. Together they accomplished much more than the simple sum of their labors.

It also helped that both could endure long hours and hard physical work, a trait that was put to the test during the long summer days of 1978 when those first cages were being prepared for the crucial test — a winter on the fringe of the notorious Bay of Fundy.

As a government scientist Sutterlin was expected to focus on commercial species, but his naturally curious nature frequently diverted him to such esoterica as hagfish, sea cucumbers and tomcod, none of which appeared on any list of government research priorities. Chafing for the freedom to pursue his inclinations, he left the government in September of 1978, and was soon exploring the wonders of mussel farming, trout farming, lobster holding systems, and marine fish farming.

Sutterlin's departure from government research came just as his Deer Island project was heading into its first crucial winter, and it left the project without a chief scientist. Typically, Gene Henderson took control of everything from animal husbandry, food preparation and on-site data collection to searching for a source of funds to carry them through the following summer. Salvation finally came

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Harvesting Atlantic salmon from sea cages in the Bay of Fundy is cold, wet and hazardous. Late in the year winter gales sweep the cage sites and walkways become ice-coated from freezing spray.

used to start the industry. However, the fact that it was a *small* surplus prevented the industry from expanding prematurely; there simply weren't enough fish available in the early years to support a reckless expansion.

Site limitation was another factor. The threat of superchill and an early uncertainty about many otherwise suitable farm locations restrained development. So did the ultraconservative financial community, which wasn't eager to advance large sums of money on an unproven enterprise that, even if successful, would operate with a negative cash flow for two or three years.

Finally, there was the moratorium. Just as salmon fever was about to erupt among Bay of Fundy entrepreneurs, the Province of New Brunswick clapped a moratorium on new leases. That lasted for two long years during which world production of farmed salmon soared and market pressures finally came to bear. The moratorium was lifted early this year, but the signs of softening world prices were unmistakeable for astute observers.

Industry Profile

In 1987 there were 28 active farms in the Fundy Isles region with fish in 525 cages, 447 of which contained salmon for market. An additional 13 held broodstock salmon (11 additional cages contained rainbow trout and 54 were empty). From these 447 "production" cages roughly 341 thousand salmon were harvested, and their value was approximately US$12-14 million. The 1988 harvest was close to 3,600 mt, worth roughly US$32 million.

The industry in 1987 consisted of a high proportion of small operations. Only ten percent had more than 50 cages in the water (the largest had 70), and nearly half were operating with fewer than 8 cages, each containing an average of 2900 fish. A medium sized Fundy salmon farm in that year had 24 cages in the water and employed ten people, three of which worked part-time. A farm of this size could have annual sales of approximately one million US dollars, and required roughly US$480,000 in working capital.

Fundy salmon farming is now a maturing industry that has been in operation long enough to generate reliable numbers on capital and operating costs, equipment and employment requirements, and revenue expectations. It is also possible at this point to estimate the auxiliary benefits, the general economic well-being that surrounds a viable and growing industry. Information of this type is seldom available on a new industry, yet it is extremely valuable for individuals contemplating entry to the industry. It is also useful for the financial institutions that are asked to provide funds to the industry, [illegible] the lens of [illegible] [illegible] for [illegible] [illegible] back. [illegible] project, [illegible] and [illegible] made significant contributions, but it's safe to say that [illegible]'s insistence that it could be done and Henderson's determination that it would be done, the Fundy industry would have been delayed [illegible] years, if indeed it developed at all. For his contributions Gene Henderson was formally honored in [illegible] through a presentation at the Regional Fish Health Workshop in Halifax, Nova Scotia. This year Arnold Sutterlin's contributions were similarly recognized through the first "Aquaculturist of the Year" award presented at the Atlantic Aquaculture Fair, an annual event at St. Andrews, New Brunswick.

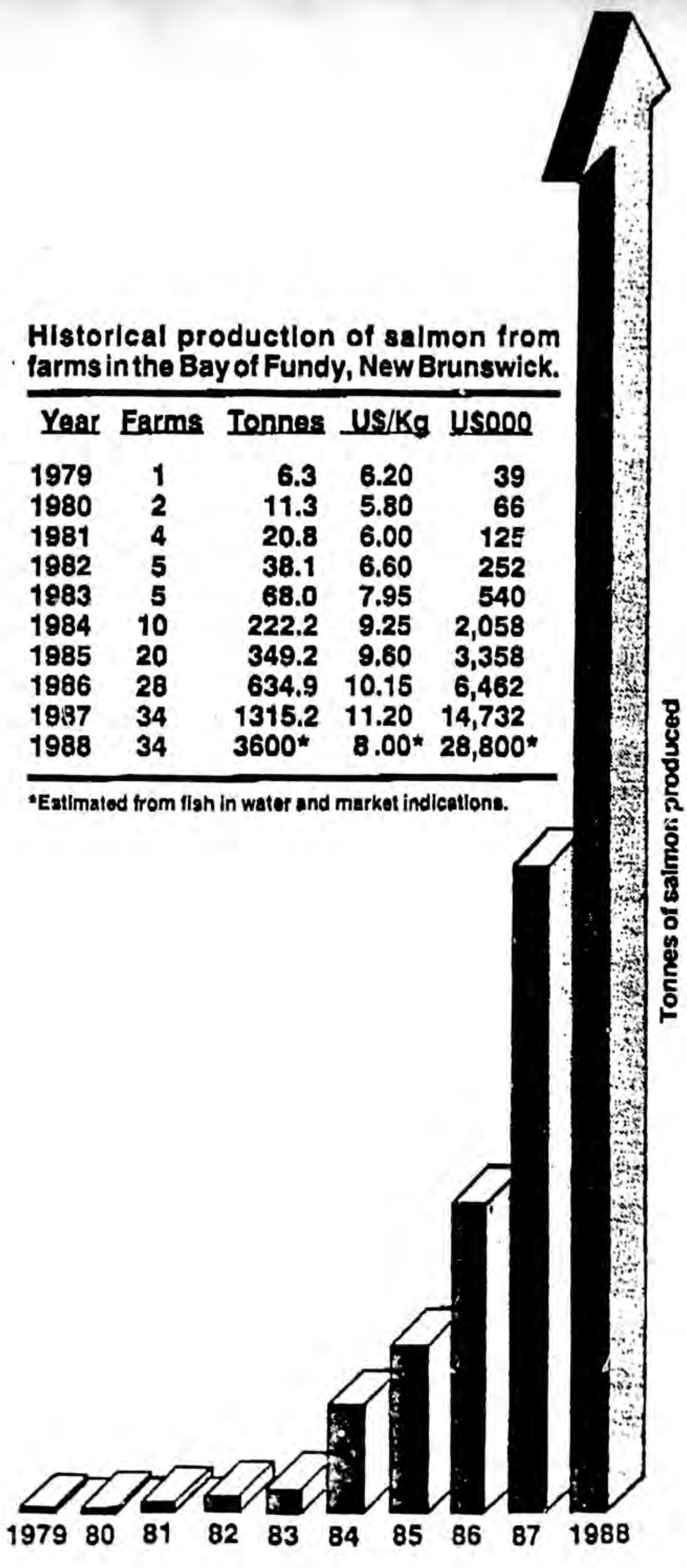
Gene Henderson retired last year from the government service to manage the industry's Salmonid Demonstration and Development Farm in New Brunswick, and has since been appointed General Manager of the New Brunswick Salmon Growers Association. He continues to be an avid supporter of the Fundy industry. Arnie Sutterlin eventually followed the Trans Canada Highway east to Newfoundland, where he coordinated a government study on the feasibility of salmon culture. At the moment he is the manager of the Bay D'Espoir Salmon Hatchery, which supplies smolt to the salmon farms in Newfoundland.

Typically, neither Sutterlin nor Henderson has profited financially from the industry that developed from their dedication and hard work, and neither seems the least disturbed by that fact. Apparently it is sufficient that the cages are there, the fish are growing, and that each autumn and winter tonnes of the finest salmon available in the world are harvested from the Fundy Isles region of the Bay of Fundy, a place that Sutterlin and Henderson helped put on the map. ●

Historical production of salmon from farms in the Bay of Fundy, New Brunswick.

Year	Farms	Tonnes	US/Kg	US$000
1979	1	6.3	6.20	39
1980	2	11.3	5.80	66
1981	4	20.8	6.00	125
1982	5	38.1	6.60	252
1983	5	68.0	7.95	540
1984	10	222.2	9.25	2,058
1985	20	349.2	9.60	3,358
1986	28	634.9	10.15	6,462
1987	34	1315.2	11.20	14,732
1988	34	3600*	8.00*	28,800*

*Estimated from fish in water and market indications.



Market crisis

As world production soars the market for salmon softens and prices plunge, bringing chaos to the British Columbia industry and the promise of big changes in the global picture.

The fact that it was inevitable in no way softened the impact of this summer's precipitous decline in world salmon prices.

Fingers seem to be pointing toward Norway as the cause of the price slide, but in fact Norway is only a part of the underlying problem — the incredible explosion in salmon production world-wide. Chile, Iceland, and the Faroe Islands have come on stream as significant producers, augmenting the major production increases that have occurred among most of the established producer countries. This year the world-wide supply of farmed salmon was expected to jump 60-80% over last year's already impressive output, while market growth was expected to slow to 40-50%.

At the forefront of the crisis was Norway. Last year Norwegian farms produced 89,000 mt. Spectacular as that was, they projected a major increase to 120,000 mt for this year. Spectacular as *that* was, it proved to be too low and had to be revised upward to 150,000 mt when a mild winter combined with increased survival produced a better than average crop. Shortly after that prices began to slide, squeezing profit margins and triggering a cascade of reactions that included early harvesting by cash-starved farmers, further price depression and finally intervention by financial institutions.

Norway's influence in the industry is not restricted to the production of salmon. Norwegian banks have been active in financing salmon enterprises outside of Norway, and the industry in British Columbia is indebted to Norwegian banks to the tune of an estimated C$70 million.

The price for chinook on the Seattle market tumbled from U$9.90 a kilo in April to only US$5.05 a kilo by the end of June, and B.C. salmon farming concerns — the majority of whom will bring their first major harvest to

Continued next page...

to entrepreneurs who might consider becoming involved on the support side, and to governments that are trying to keep the new developments in proper perspective.

Recognizing this, federal and New Brunswick provincial governments jointly commissioned a detailed economic study of the Fundy industry by Fiander-Good Associates. Their analysis, published in 1988, provided an excellent overview of the industry through 1987. The following economic profile draws heavily on their findings. All values are expressed in United States dollars, assuming the Canadian dollar to be worth US$ 0.80.

Economics

The new salmon farmer, stocking his cages with smolt for the first time, faces 18-20 months without income while the livestock grow to harvestable size. During this period the fish must be fed and maintained, so a significant amount of working capital will be required. To operate through the second year a line of credit approaching $600 thousand might be required.

The farmer starting with 8 cages of 2500 smolt each and expanding to 24 cages within three years can incur a loss of $254 thousand in the first year, but harvesting late in the second year combined with income tax adjustment from the first year should produce substantial earnings. By year-5 gross earnings should be stabilizing at nearly a million dollars a year with after-tax profits of roughly $250 thousand.

Profitability will continue at this level unless conditions change and if there is a change, profitability will be altered according to the relative sensitivity of different components of the culture system. For example, the economic viability of salmon farming is considered *highly sensitive* to changes in the selling price and mortality rate of fish, *moderately sensitive* to changes in feed costs, and *relatively insensitive* to changes in smolt costs.

- **Selling Price.** In 1987 the standard sale price was $10.55 per kilo. In 1988 market pressures forced this down to $8.80 per kilo, resulting in a 35% decline in annual net income. This degree of change indicates the system is relatively sensitive to changes in selling price.

  Under these conditions cash flow for a new farm becomes slightly negative in the second and third years of operation. If the selling price were to drift down to only $7.00 per kg, net income would be reduced by 70%, producing a strongly negative cash flow in years 2 and 3, and delaying payment of income tax to the fifth year. This situation would greatly increase the amount of financing needed to provide adequate working capital.
- **Mortality.** The current standard is 16% mortality from stocking to harvest. If this were to increase to 25%, net income would decline by 18%. However, reducing the mortality rate to 10% (a realistic expectation) would *increase* annual net income by 12%.
- **Feed Costs.** At the 1987 price of 72 cents per kg, fish feed consumed more than 30% of annual operating costs. However, if the feed price were to increase to 90 cents per kg (a 25% increase), net income would be depressed by 8%, suggesting the salmon culture system is moderately sensitive to changes in feed costs. Fortunately, the feed industry is highly competitive and prices have remained stable for the past three years.
- **Smolt Costs.** The annual purchase of 30,000 smolt (12 cages at 2,500 per cage) at the 1987 price of $2.40 per fish represented 15% of annual operating costs. In 1988 the price rose to $2.80, and in 1989 to $3.20. At $3.20 per fish, net income declines by only 5%. An increase to $4.00 (23% of operating costs) would produce only a 23% decline in net income, so salmon cage culture can be considered relatively insensitive to changes in smolt prices.

Capital Costs

The capital cost of establishing a 24-cage salmon farm in the Bay of Fundy in 1987 varied from $215 thousand to almost $600 thousand depending on the type and size of cage selected. Over a ten year period the total capital requirement, including replacement of equipment, could range from $400 thousand to almost a million dollars. These costs are made up of everything

Prices (previous page)

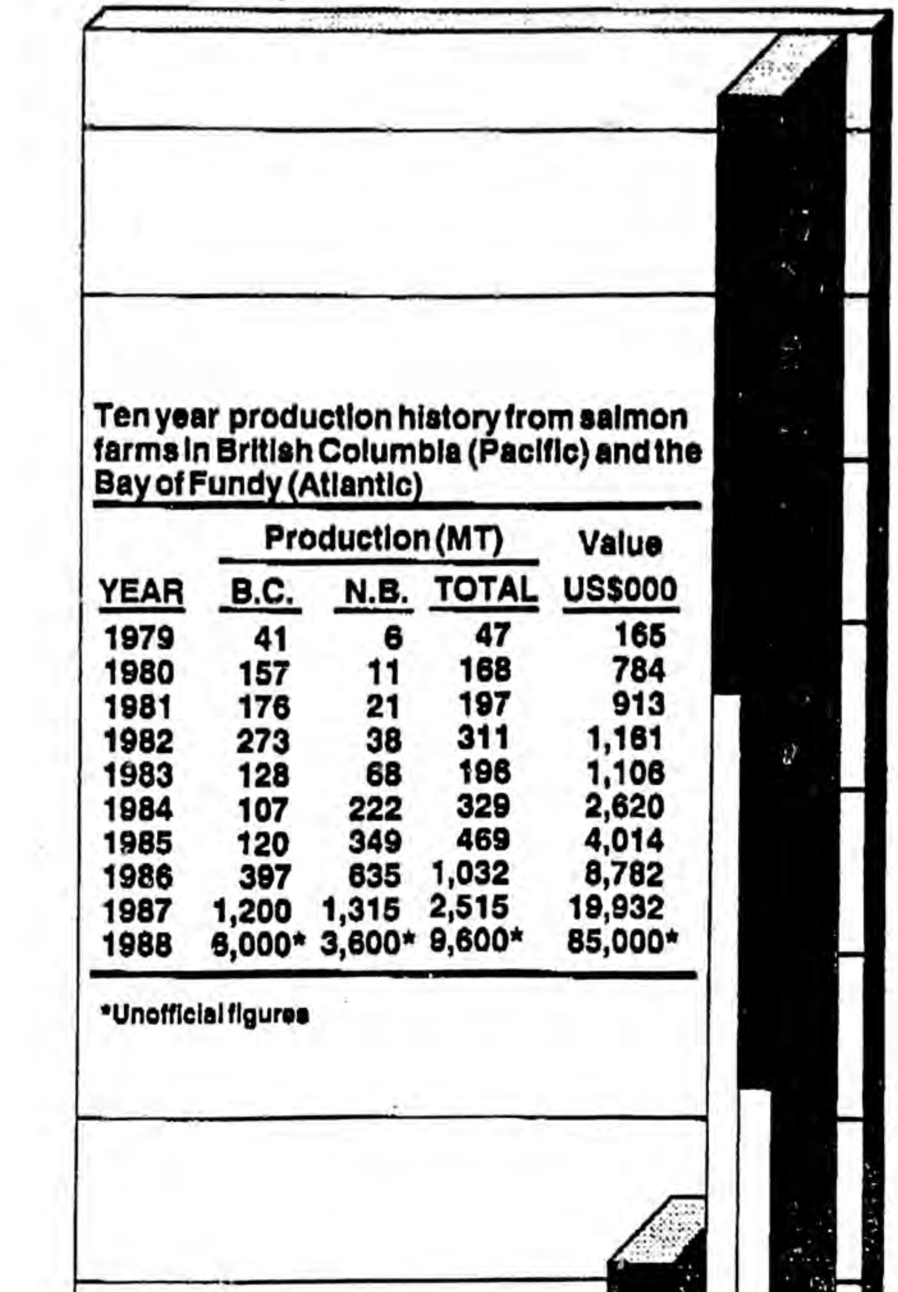
market this year — could see only darkness at the end of the tunnel. For those farms still struggling to recoup their heavy initial investment, the prognosis was not good.

Hardy Sea Farms Inc. was one of the first to go, with control being assumed by a subsidiary of Bergen Bank. Others would follow, and the net result will likely be a major restructuring of salmon companies in B.C. The general feeling is that a lot of assets will change hands as a result of the current squeeze, but there is not likely to be any significant reduction in total production capacity.

One positive thing that may come out of the current crisis is a revamping of the B.C. industry's marketing procedures, which to date have been less than satisfactory. European producers have developed sophisticated marketing and distribution systems to cope with the nuances of the export trade. Norway, for example, funnels fish from its 500 farmers through a single export agency, but B.C. farmers have been selling their product through a six-city United States distribution network that was geared to an annual 3-month wild fishery. This, in the opinion of some, is largely responsible for the magnitude of the current problem in B.C.

Meanwhile, the Norwegians are making some adjustments of their own that are contributing to the evolution of the global industry. Recognizing the difficulty of competing effectively on the North American market, the Norwegians have set their sights on Japan, the world's largest consumer of salmon. In addition, Norway will probably freeze a large part of this year's production, making it more attractive for the European market.

Whatever the outcome — and there are several major players still to be heard from — it is clear that the character of the global marketplace for salmon is undergoing major change, and the capture fishery will probably be affected as profoundly as the culture fishery. In short, the salmon industry has become a full fledged, highly competitive global industry, and those who hope to survive had better recognize that fact and adjust to it. ●



Ten year production history from salmon farms in British Columbia (Pacific) and the Bay of Fundy (Atlantic)

	Production (MT)			Value
YEAR	B.C.	N.B.	TOTAL	US$000
1979	41	6	47	165
1980	157	11	168	784
1981	176	21	197	913
1982	273	38	311	1,161
1983	128	68	196	1,106
1984	107	222	329	2,620
1985	120	349	469	4,014
1986	397	635	1,032	8,782
1987	1,200	1,315	2,515	19,932
1988	6,000*	3,600*	9,600*	85,000*

*Unofficial figures

from cages and predator nets to moorings, boats and buildings.

Simple wood-frame rectangular net pens can be constructed for as little as $3,200 but the life expectancy of these cages is only five years. The octagonal Malloch cage (designed by pioneer salmon farmer John Malloch), was an early favorite in the Fundy Isles region. A complete Malloch pen constructed of local spruce timber and equipped with a predator net could be floated for roughly $4,800.

Many of the farms are changing to larger and more expensive plastic or galvanized steel cages. A heavy duty galvanized cage almost 12 meters on a side has a volume of nearly 545 cubic meters and, at 8 mt of fish per cage, will hold livestock conservatively valued at $65,000. These cages will last at least 15 years but are correspondingly more expensive ($10-$15 thousand). Some farmers have switched to a 23-meter circular plastic cage and others have replaced their Mallochs with a 12 x 12 meter cage constructed of PVC. These will carry 20% more smolt than the Malloch but they also cost considerably more (over $7000).

Cages in the Fundy industry carry two types of net: a livestock net that has a mesh of 28-55 mm, and a heavy predator net with a mesh of 20 cm to keep seals and cormorants out of the cage. Nets can vary in price from $800 to $2400 depending on size, material and coating, and nets for the average sea cage cost $3,500 -$4,000 in 1987. Moorings to secure the cages and boats to service the facility add another $24-32 thousand.

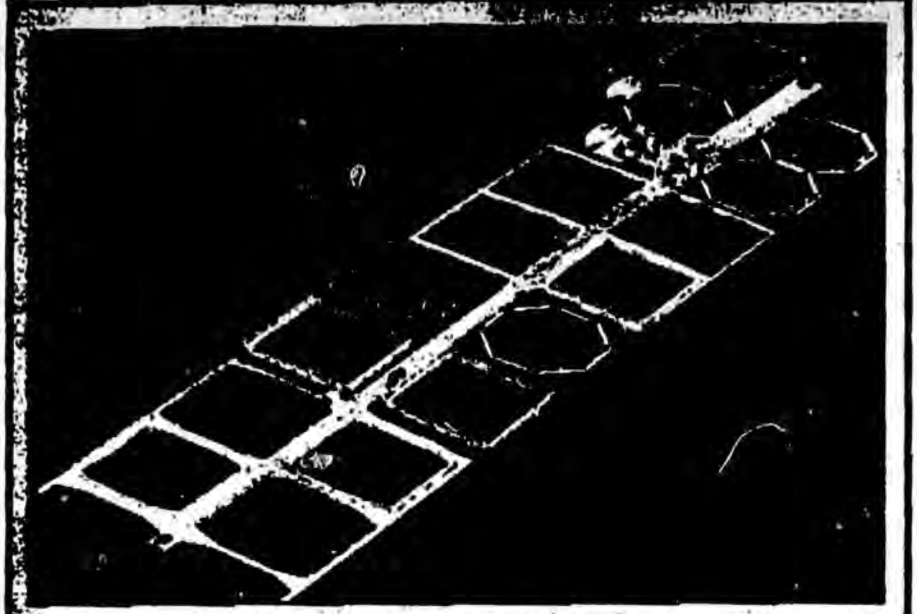
Operating Costs

Annual operating expense for smolt, feed, labor, insurance and other items on a 24-cage farm ran close to $475 thousand in 1987. Roughly 15% of the total was spent to purchase smolt ($70 to $75 thousand).

Food for the growing salmon is a major expense, upwards of $146,000 for a 24-cage farm in 1987, or 31% of total operating expense. In the Fundy industry 80% of the feed has been a moist formulation supplied by a local manufacturer, who delivered 6 days a week for 73-77 cents per kg. Feed conversion ratio over the 18-month growout period has been running at 1.5 to 2.0 kg of food supplied for each kg of fish produced (often called FCR and expressed as 2:1 or simply 2), which at 1987 prices represented an annual feed cost of $3.23 per fish.

The 24-cage Fundy farm requires a full-time manager, four to six full time employees and one to three part-time employees. Average wage for laborers in 1987 was $6.54 per hour, but ancillary costs increased the wage burden to an average of $7.38 per hour, or $15,360 per person-year. The full-time manager cost approximately $32 thousand per year, raising total employment to approximately $145 thousand, or 31% of total operating costs.

The Fundy Isles region in the vicinity of St. George, New Brunswick. Myriad small islands provide a barrier against the tumultuous winter seas of the open Bay of Fundy, while providing access to the more moderate water temperature from the Bay. Currents associated with tidal amplitudes of 8-9 meters surge past the cages four times each day, assuring abundant oxygen, pure water and Atlantic salmon of the highest quality.



Salmonid Demonstration Farm

Extension services and training facilities are extremely important in agriculture and aquaculture, especially when the technology is new or there are a lot of new entrants to the industry. Agriculture has developed an excellent extension capability in North America, but services have been much more limited in aquaculture.

The Fundy Isles salmon farming industry got a major jump on this problem with the establishment, in 1985-86, of a commercial scale experimental salmon farm in the heart of the Fundy Isles industry.

The farm was funded by the federal government, and its experimental program was developed annually with approval from a steering committee that consisted of representatives from industry and the federal and provincial governments. Early trials focused on diet formulation, broodstock development and on ways to improve the rate of growth. Data developed at the Farm served, in a way, as a standard against which all farms in the Fundy Isles region could measure their own achievements.

The Demonstration Farm also became an important element in the Salmon Genetics Research Program, a joint scientific program of the Atlantic Salmon Federation, through its research facilities near St. Andrews, and the local federal laboratory (the Biological Station). This program is involved in the development of four strains of Atlantic salmon, two for sea ranching and two for cage culture.

Unfortunately, federal funding expired this spring, and since then a lot of local effort has been expended just trying to secure a future for the Demonstration Farm. Ownership has been assumed by the New Brunswick Salmon Growers Association, but most of the equipment is still owned by the federal Department of Fisheries and Oceans. That Department and the NBSGA signed an agreement to keep the Farm operating (some 20,000 smolt are in the water) on a temporary basis, hopefully until some long term funding arrangement can be developed.

As part of the upheaval the Farm lost its existing water site and was forced to relocate to a new site almost a kilometer away from its land-based facilities. Gene Henderson, general manager of the Demonstration Farm, was recently appointed general manager of the New Brunswick Salmon Growers Association, and it will be his responsibility to deal with the many problems currently facing the facility.

The major concern behind all the maneuvering is the possibility that an important facility for technology transfer and training in the science and art of salmon farming will be lost to the Atlantic region. ●

Many farms in the Bay of Fundy carry some insurance against loss. Insurance of livestock without superchill coverage typically costs about 5% of the covered value and averages about $20 thousand. In addition there are costs for processing and marketing the product, typically about $58 thousand. Fuel costs will be roughly $13 thousand, and electricity can add another $6,500. Small things can add up to a surprising amount in such an operation. The ice used to quick-chill salmon at harvest costs only $1.60 per kg, but since 5 mt are required for each cage harvested, a 24-cage farm would spend more than $2 thousand on ice each year.

Revenues

Salmon farms derive revenues from two major sources: marketing of fish and sale of eggs. Each broodstock female can produce 275-365 eggs per kilo of fish weight, and the assumed industry average is 10,000 eggs per female. In 1987, green eggs were worth 6-7 cents each, which means each broodstock female was expected to produce $600-700 worth of eggs. The total broodstock inventory in 1987 probably produced 17 million eggs, worth more than a million dollars. In 1988 nearly 26 million eggs were anticipated, and these should have brought in nearly $1.7 million.

At harvest the average salmon weighs just over 3.6 kg but may range from just under 2 kg to well over 5 kg. Smaller salmon (less than 3.2 kg) often sell for less than the standard price, and those heavier than 5 kg often command a premium. For the average 24-cage farm at full production in 1987, harvesting 12 "standard" cages of fish per year, revenues should have approximated 970 thousand U.S. dollars, or more than $80 thousand per cage.

Spinoff

A major industry requires a variety of products and services, and these are usually supplied by individuals and small companies in the area. Sometimes the total economic benefit from this spinoff can equal the direct employment and operating revenues from the major industry. Fundy salmon farming has spun off three obvious satellites: smolt production

Walter Balasiuk and George Wolf of Jail Island Salmon Ltd. pack freshly harvested Atlantic salmon for shipment to market. The fish are dressed, washed and quick-chilled to 0°C, packed in styrofoam containers that contain about 27 kg, and loaded on refrigerated trucks for the 7 hour trip to Boston (or same-day air shipment to Canadian markets). Until 1987, 80% of the harvest stayed in Canada, but the majority of the harvest now goes to consumers in the United States.

(hatcheries), feed manufacturers and euipment manufacturers.

The industry was severely restrained in the early days by a shortage of smolt, but private industry rallied, and in 1987 over 900 thousand smolt were made available by eight private, one non-commercial and two federal hatcheries. Sea Farm Canada, with three hatcheries, was the largest supplier of smolt in an industry that employed more than 40 persons and paid more than $600 thousand in wages. In spite of the expanded capacity the industry has never had enough smolt to service the demand (the 1989 shortfall was 250-300,000 smolt). Within the industry there is concern that the loss of one of the three major suppliers could create havoc within the industry.

In the feed industry alone 40 person years of employment and over a half-million dollars in wages could be attributed to the salmon industry in 1987. Cage fabrication added another 4 person years and $50 thousand in wages, and miscellaneous related activities (moorings, packing boxes, flotation, marketing services) added another 70 person years and $390 thousand in wages. All told the ancillary industries employed 114 persons in 1987 and paid out $1.56 million in wages.

Future

Although some 40 sites are currently occupied in the Fundy Isles region, surveys indicate the entire Bay of Fundy offers no more than 60-70 sites that have the necessary protection from storms and access to safe winter water temperature. The Bay of Fundy salmon industry is therefore site-limited by current technology, but even 60-70 sites could theoretically produce 12,600 mt annually which, at current prices, should be worth more than US$ 100 million, a significant infusion of cash for an area that has been economically depressed.

Alternatives to the current site limitations are being examined. Land-based farms are one solution and open water cage systems are another, but both are costly alternatives. In the end the profit margin will determine the extent of innovation the industry can tolerate.

The 1989 harvest from the southern Bay of Fundy should approach 4100 mt but a major increase is expected in 1990 (2.2 million smolt stocked in 1989 should yield upwards of 7,500 mt in 1990). However, the value of the harvest in future years will depend on how the world market develops. There seems little question the industry is in for a period of instability and adjustment, out of which should emerge a different but stronger industry in which ownership is more consolidated, the profit margin is narrower, farming operations are more efficient and the market is more effectively exploited. •

Dave Aiken and P.W.G. (Bill) McMullon are with the Canadian Department of Fisheries and Oceans at St. Andrews, New Brunswick.

Bill McMullon has been photographing Canadian fisheries and aquaculture developments for years. His work appears frequently in this magazine.

Norway.

The Norwegian Fisheries Industry from Capture to Cultivation

by Bjarne Mark Eidem

Some years ago an old fisherman I know in Northern Norway went into aquaculture. In explaining his reasons for going into this new field he said, "We have harvested the sea for thousands of years; now the time has come to plant some seeds."

The fishing industry is really no further advanced than were the hunters and gatherers of a thousand years ago, moving from one area to the next, harvesting the natural crop where they found it, hunting animals in the forest.

We Norwegians are relative latecomers to the field of aquaculture. Two years ago I visited China and was very impressed with what I saw. The aquaculture tradition there is thousands of years old, whereas in Norway we more or less stumbled into this field during my children's lifetime.

But we have made important advances in aquaculture in the relatively short time we have been active. We have invested great sums of money, and we have reaped the profits of this investment. And yet, what we have seen so far is only the beginning.

I want to briefly describe the development of aquaculture in Norway, a modern industrial nation with long traditions in conventional capture fisheries, and then tell you about the difficulties we have encountered, how we have tried to solve our problems, and what we are thinking about doing in the future. I will also look briefly at market development and the prospects for farmed salmon, since this has become a major concern, as you will see.

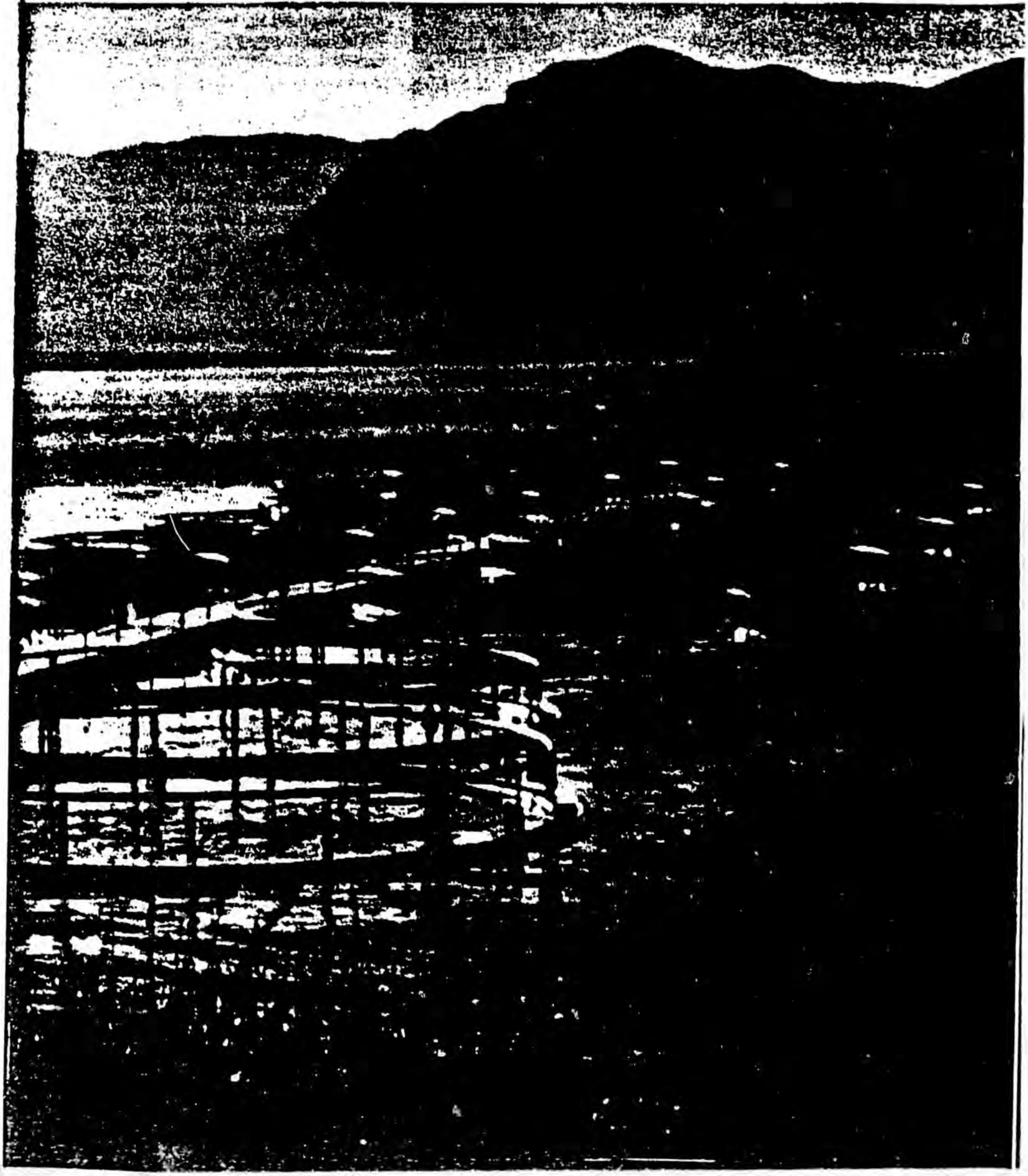
Aquaculture development

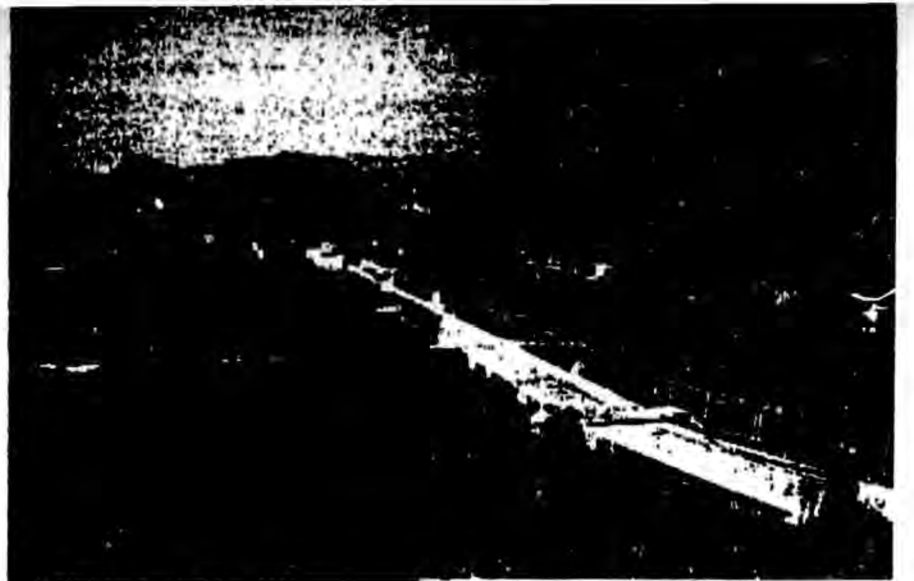
Not even the most optimistic Norwegian aquaculture pioneer envisioned the fantastic development that would occur in the industry. In the beginning they were viewed with skepticism, particularly by financial institutions.

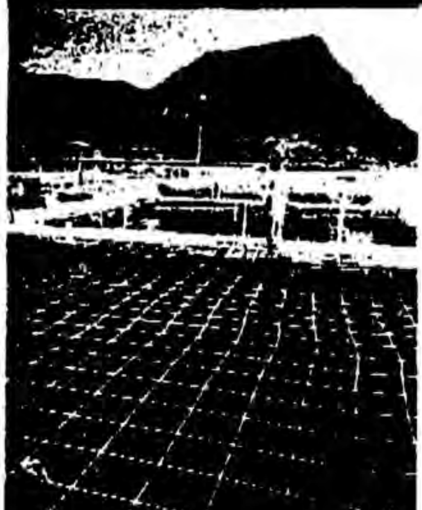
Incontrovertible signs of success did not appear until the 1980s. Production in 1979 was only about 4,000 metric tons; nine years later, in 1988, it was 18 times that, and the growth continues.

Salmon and trout farming is an important growth industry in Norway, and it has definite political objectives at the regional and national level (e.g. contributing to employment in rural and coastal areas). The export value of farmed salmon and trout in 1988 was more than 4.0 billion NOK, or about US$ 615 million. The industry employs about 5,000 people directly, and as many more in related sectors.

All photographs in this article courtesy of the Marketing Council for Norwegian Salmon







Today there are some 667 hatcheries—with a total capacity of about 217 million smolt per year—and 786 grow-out farms, with a total production volume of about 6 million cubic meters. It is a bit difficult to estimate the total production capacity, since this depends on the stocking density, but experts we have consulted suggest some 200,000 metric tons per year.

Advantages

Norwegian success in salmon farming has surprised some people because Norwegians do not have a long history as fish farmers. Some Norwegians along rivers have been releasing smolt for decades, but more for sport fishing than as an industrial enterprise.

The following competitive advantages have been identified as having helped Norway become the leading producer of farmed salmon in the world:

- A long coastline with fjords and islands that protect fishfarms from heavy weather;
- Good quality seawater at the optimum temperature for salmon, trout, halibut, wolffish and other coldwater species (the Gulf Stream ensures relatively warm and stable temperatures along the entire coast);
- Sufficient freshwater for production of Atlantic salmon smolt;
- Sufficient fish byproducts from the traditional fish industry to provide raw materials, for the fish feed industry (protein of marine origin is required for the production of a well balanced diet);
- Excellent infrastructure along the coast;
- Experience in research, production and trade in Atlantic salmon. Norwegian research has focussed on genetics, fish-feed, and diseases.

Legal framework

The Ministry of Fisheries exercises legal and administrative control over the fish farming industry, through its regional offices, which are under the jurisdiction of the Director of Fisheries.

A legal framework for the salmon farming industry was introduced in 1973 with the establishment of the first bill governing the production of aquaculture products. The system introduced with that bill was retained in the temporary act of 1981, and also in the new permanent Act Relating to the Breeding of Fish, Shellfish etc. which was passed in 1985, and which today regulates the industry.

The licensing system is the main instrument used by the authorities to maintain the fish farming industry as a profitable and viable regional industry. The system limits the maximum size of each farm, as well as the maximum number of permits given for fish farming. The number of permits has been strictly limited, but there has been considerable pressure to liberalize this (it should be noted that this limitation applies mostly to farms growing salmon and trout. For other species, a much more liberal attitude has been adopted).

In 1987, the Ministry of Fisheries issued a Parliamentary Report on Aquaculture, which provided the first broad overview of the policies. The main objectives for the industry are closely related to the major political objectives: employment, balanced regional settlement, agricultural, fisheries and industrial activities. We have learned three things from our experience with these regulations. Firstly, the rapid growth of the industry generated an overwhelming number of applications for permits, and our administrative apparatus was unable to handle them efficiently. This led to a serious delay in reviewing applications and necessitated new and more efficient ways of handling the applications.

Secondly, there were instances where different interests conflicted: economic, environmental, transportation, fishing, recreation, etc. This conflict is perhaps the most difficult to deal with, but it is also of great importance, as it involves a balanced development of different activities in our society.

Finally, we need more knowledge about this industry and about the consequences of a large scale operation. The need for more research in fields related to aquaculture is urgent. Industrial-scale aquaculture requires an advanced level of both technical and organizational knowledge, and we realize that more work is needed in this field.

Production

Norwegian salmon farming has grown along a rising curve that has been broken only once. This break (in 1987) was due to factors we can explain, and if we look at the growth of the industry in a longer perspective, that brief stagnation is insignificant. The forecasts published by the Fish Farmers' Association early this year are optimistic, but we see no reason to revise the projections at this point, especially concerning the next two years.

Our expectations for the Norwegian salmon farming industry up to 1995 are shown in the accompanying graph. The basis for this prediction is, of course, the number of smolt set out in the grow-out pens. In 1988 we saw a record number set out, over 70 million smolt, so that at the present time we have about 80 million fish in the sea cages. This crop will reach harvesting size in late 1989 and early 1990, and should bring 1989 production to about 120,000 metric tons, and 1990 production to about 160,000 metric tons. In addition, we expect to harvest about 5,000 mt of large trout.

Problems

In the past two years, certain events have occurred that indicate continuing unrestricted expansion of the salmon farming industry is unlikely.

Disease. Intensive cultivation always increases the likelihood of disease, and new diseases were both feared and expected. In 1985 the first major disease to hit the industry was "Hitra disease," otherwise known as "coldwater vibriosis," caused by the bacterium *Vibrio salmonicida*.

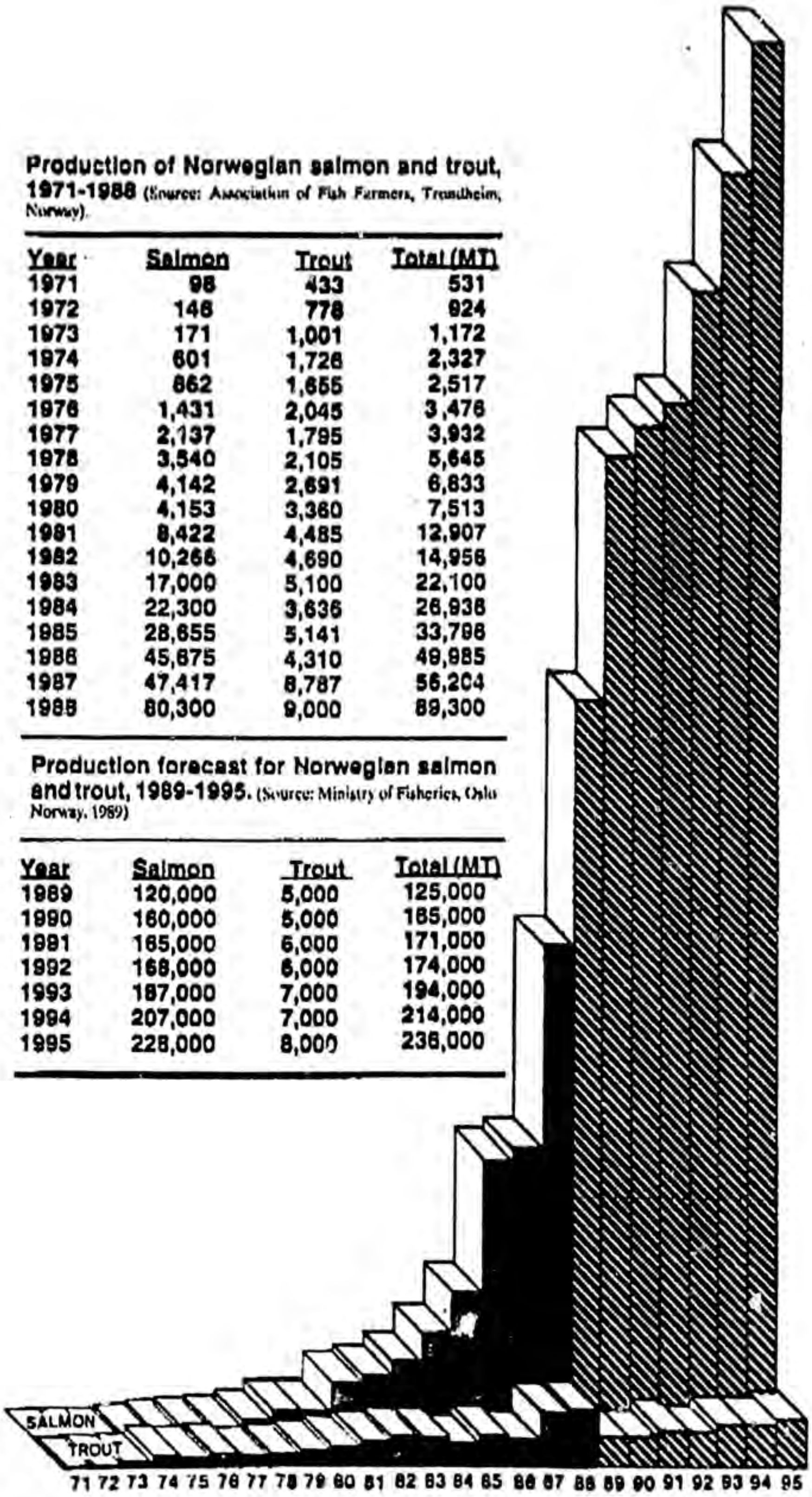
This disease forced some farmers to slaughter all their livestock just on suspicion of the disease. It also caused the premature marketing of perhaps 8,000-10,000 metric tons of relatively small salmon in 1986. This in turn reduced the 1987 production. Researchers have now developed a vaccine, and results so far are encouraging. In essence we feel that with proper farm management, Hitra disease can be controlled.

Production of Norwegian salmon and trout, 1971-1988 (Source: Association of Fish Farmers, Trondheim, Norway).

Year	Salmon	Trout	Total (MT)
1971	98	433	531
1972	146	778	924
1973	171	1,001	1,172
1974	601	1,726	2,327
1975	862	1,655	2,517
1976	1,431	2,045	3,476
1977	2,137	1,795	3,932
1978	3,540	2,105	5,645
1979	4,142	2,691	6,833
1980	4,153	3,360	7,513
1981	8,422	4,485	12,907
1982	10,266	4,690	14,956
1983	17,000	5,100	22,100
1984	22,300	3,636	26,936
1985	28,655	5,141	33,796
1986	45,675	4,310	49,985
1987	47,417	8,787	56,204
1988	80,300	9,000	89,300

Production forecast for Norwegian salmon and trout, 1989-1995. (Source: Ministry of Fisheries, Oslo Norway, 1989)

Year	Salmon	Trout	Total (MT)
1989	120,000	5,000	125,000
1990	160,000	5,000	165,000
1991	165,000	6,000	171,000
1992	168,000	6,000	174,000
1993	187,000	7,000	194,000
1994	207,000	7,000	214,000
1995	228,000	8,000	236,000

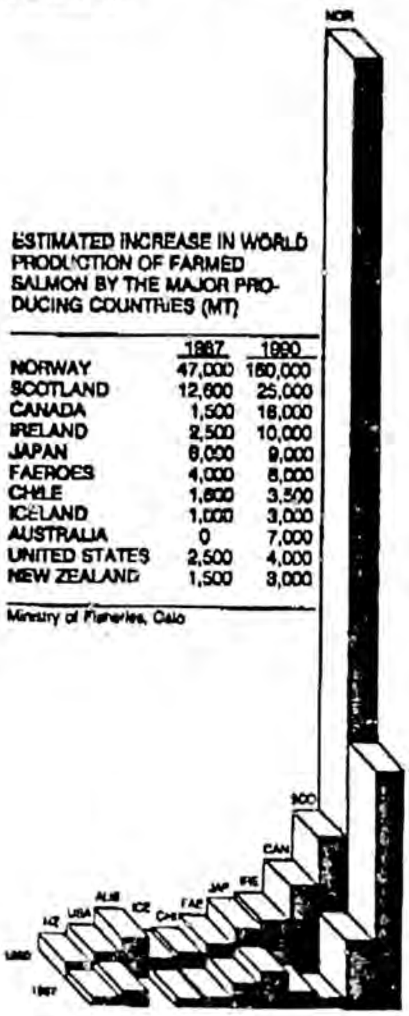


Continued on page 65

We have encountered other diseases as well. BKD, IPN, furunculosis and others. While they are all a serious threat to the industry, we believe that we are now able to manage the disease problem. In general, we have upgraded our awareness of disease, and we have upgraded the capability of the institutions that have been established to deal with disease.

Health control on fish farms is under the jurisdiction of the Veterinarian General. The main strategy is to prevent the spread of communicable diseases through close monitoring of farms and strict enforcement of rules, particularly in relation to hatcheries. In spite of this, various diseases have occurred.

When an outbreak is noted, the farmers are required to contact the veterinarian authorities for permission to administer antibiotics. No fish treated with antibiotics may be harvested until nine weeks after treatment has ceased. This is to ensure that no antibiotics are passed on to the consumer.



ESTIMATED INCREASE IN WORLD PRODUCTION OF FARMED SALMON BY THE MAJOR PRODUCING COUNTRIES (MT)

	1987	1990
NORWAY	47,000	160,000
SCOTLAND	12,600	25,000
CANADA	1,500	16,000
IRELAND	2,500	10,000
JAPAN	8,000	9,000
FAEROES	4,000	8,000
CHILE	1,600	3,500
ICELAND	1,000	3,000
AUSTRALIA	0	7,000
UNITED STATES	2,500	4,000
NEW ZEALAND	1,500	3,000

Ministry of Fisheries, Oslo

All our efforts so far have been directed at disease control, and only recently have we instituted programs for disease prevention. With the development of new vaccines, and with the incorporation of a disease prevention program we feel confident that disease problems will be controlled.

Environmental Problems. Last year, we experienced what many thought would be the ultimate catastrophe: a full fledged algal bloom in Skagerak and along our southern coast. But as soon as fish started dying, farmers started moving their pens away from the affected areas. Through a superb effort by the salmon farmers' organization and the authorities, almost all the farms were saved. Only some 500 metric tons of salmon were lost, or about 0.6% of our total 1988 production.

However, this incident served as a warning that we must pay much closer attention to the marine environment. Partly as a consequence, the authorities and the salmon farmers' organization have established a round-the-clock surveillance and warning system, which warns about algae, oil spills etc. and also about changes in temperature, weather, and other factors which are important to the salmon farmer. The system is based on a complex network of buoys, satellites, and earth stations which monitor our area.

I would like to point out that it is not enough to be informed about these disasters when they develop. We must also try to prevent the pollution of our marine environment as well as our air and our soil.

Competition. We now see massive investments in the salmon farming industry in countries such as Scotland, Ireland, Iceland, the Faeroes, Canada, USA, Chile, Australia, and New Zealand. Others are sure to follow. As a curious example, a joint venture is now being set up in East Asia between a Norwegian company and the Soviet Union, on Soviet soil.

Norway is concerned about this competition. In Chile, production costs per kg are reportedly about $0.50 below what they are in Norway, and transportation costs from Chile to the west coast of the United States are about equal to those from Norway to the U.S. East Coast. Canada is coming onstream now with high quality salmon, both Pacific and Atlantic, at production costs about the same as those in Norway, but with the U.S. market at its doorstep. So in the North American market, we see Norway being squeezed on both sides, to the south and to the North, and possibly losing market shares rapidly over the next two to five years. However, there is still room for considerable expansion in the North American market.

In Europe, Norway is still competitive with regard to quality and the costs of production and transporta-

The harvesting process combines hard physical labor *(below)* with mechanization *(facing page, top)* to move the fish rapidly from cage site to processing plant.

tion but we are facing serious challenges from within the Common Market. Producers in Scotland, Iceland, and the Faeroes are giving us a hard fight for the market, and I fear that our market shares will decline.

Market Saturation? In preparing this paper we searched in vain for authoritative figures on the future demand for farmed salmon. Perhaps most people in the industry feel that demand will be limited only by supply. We have attempted to estimate the market for farmed Atlantic salmon, and the figures are, I think, rather astounding. Still there are those who believe the market is even larger than we estimated *(see figure, overleaf)*.

But an enormous increase in market demand will not come about by itself. A considerable effort both in terms of promotion and product development will be needed.

It should be pointed out that product development within the salmon industry has been practically non-existent. The salmon farming industry has supplied just a few simple products: fresh whole salmon, frozen whole salmon, and smoked salmon. The industry has had no need to come up with a more varied assortment, but we believe this will be necessary in the future, particularly to utilize more profitably the lower quality fish.

The future

Norwegian salmon farming will face a number of challenges in the future.

While we in Norway are relatively optimistic about the market prospects, we also realize that the worldwide increase in production and resulting competition will force prices down. To meet this challenge, we must improve the economic performance of our industry, the quality of our product, and our product development. To hold our own, we are planning to double our research and development efforts. In fact the government contribution to research more than doubled between 1985 and 1989.

We expect that Norwegian salmon farming companies will enter into joint-venture operations in other countries. Indeed, some Norwegian companies have already started operations abroad. According to a survey taken at the beginning of 1987, Norwegian companies were involved in 72 foreign operations in 15 countries, and this number has increased since the survey was completed. Norwegian companies have been particularly active in Canada.

We also expect there will be developments in sea ranching, or as we call it, "culture-based fisheries." We know that the Japanese have been experimenting with salmon sea ranching for some time, and our good neighbors to the west, the Islanders, have also looked into it. Salmon sea ranching is still experimental, but we hope to

Great care is taken to ensure delivery of premium quality product, everything from the careful removal of small bones from a fillet *(left)* to the rapid processing and chilling of the harvested product before shipment. Salmon that meet the standards of superior quality are identified with a golden tag—the consumer's assurance of quality *(facing page, top)*.

move into the commercial phase very soon.

New species

Norwegian scientists have for some time been working on species other than salmon and trout. By the early 1990s, we expect that production will take off, and by 1995, farmed fish will become an important factor in our international high quality markets, particularly in the fresh fish markets.

Among the species we are working with at the moment are cod, halibut, turbot, wolffish, Arctic charr, oyster, mussels, and scallop. By the end of 1988, 420 permits had been granted for production of species other than salmon and trout. For many of these species, difficulties in fry production has been the major obstacle to success.

The most promising new species is cod. This is also the species with which we are closest to commercial operation. In 1987, we produced roughly a million cod fry, from which about 500 metric tons of cod were expected by late 1988. However, some problems developed, and the 1988 production was not that high. By the mid-1990s we expect that our farmed cod production will be 10,000 - 20,000 mt. In other words, cod is becoming a major factor in the development of Norwegian aquaculture.

For the other species, it is too early to estimate production figures, but we expect that Arctic charr and turbot will become commercially viable very soon.

In summary, the Norwegian salmon farming industry has undergone explosive development, particularly in the last six to seven years. In 1988, about one-third of the value of our fish exports came from aquaculture and the shift from capture to culture fisheries is therefore very much a reality in Norway.

However, the Norwegian aquaculture industry is facing increasingly difficult times because of the expanding competition. We expect that as more producers enter the market, prices will decline. In fact, we saw the first signs of this in 1988. As a result the focus of the industry will shift to the economics of production.

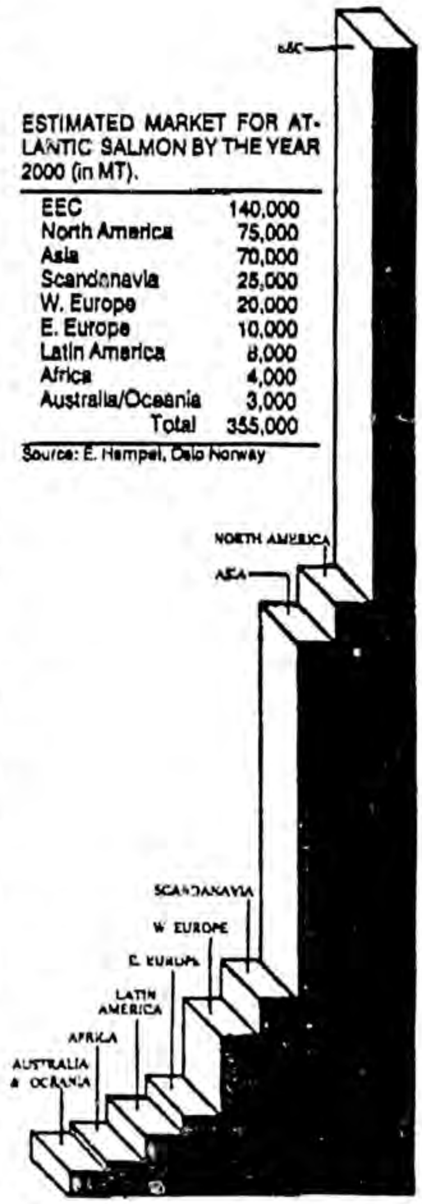
Health and environmental considerations will also play an increasingly important role in the industry's development. Soon we will have to have to be more concerned with margins that originate from efficiency of operation. When this happens, we expect the Norwegian industry to fall behind its competitors, because of the structure of our industry. We also expect that farming companies will want to establish operations in other countries to achieve the necessary economies of scale, proximity to market, and lower production costs.

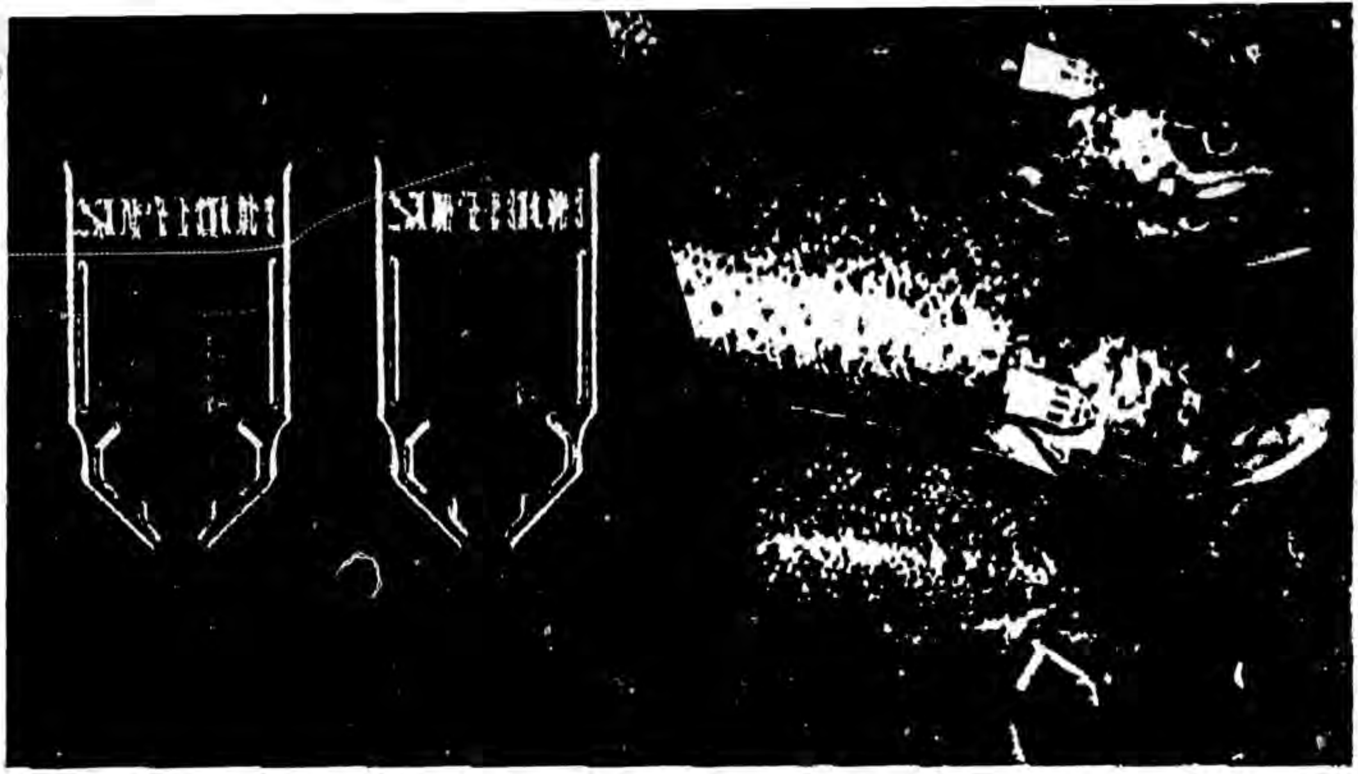
Problems such as disease and pollution have already affected the Norwegian industry, and may continue to do so. As the industry develops, and requires greater emphasis on good management, we will see problems of another nature emerge. So far, the economics of Norwegian salmon farming have been good, but we do

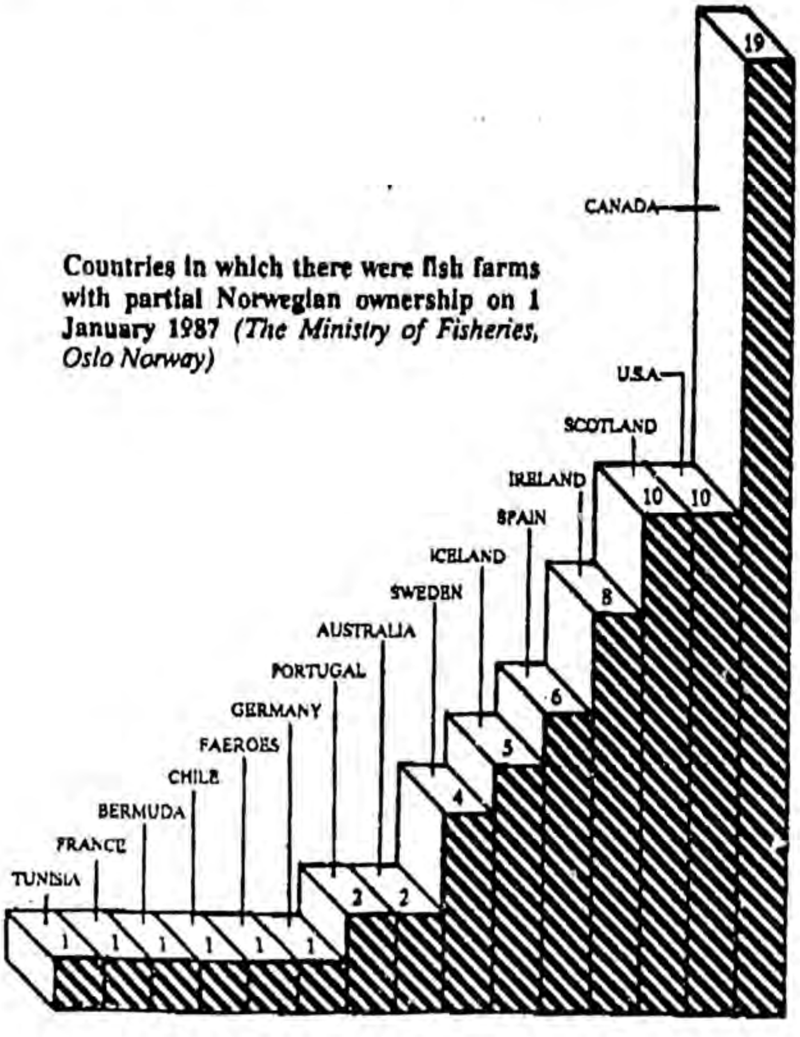
ESTIMATED MARKET FOR ATLANTIC SALMON BY THE YEAR 2000 (in MT).

EEC	140,000
North America	75,000
Asia	70,000
Scandanavia	25,000
W. Europe	20,000
E. Europe	10,000
Latin America	8,000
Africa	4,000
Australia/Oceania	3,000
Total	355,000

Source: E. Hempel, Oslo Norway







Countries in which there were fish farms with partial Norwegian ownership on 1 January 1987 *(The Ministry of Fisheries, Oslo Norway)*

expect that harder tim·s will force a restructuring of the industry, and the adoption of alternate methods of farming, such as land or sea-based closed systems. Norway has developed the technology for this on a large scale, and we expect to see the results of this soon.

Finally, we hope that Norway will continue to be among the leaders in the farming of such new species as cod, turbot, Arctic charr, halibut and lobster.

We have a deep belief in aquaculture as a future growth industry. I personally believe that it will, over the decades, become a substantial supplement to our traditional fishing industry as a source of animal protein. We see this as a natural development of the fisheries industry as we move from capture to cultivation. ●

Bjarne Mark Eidem is the Minister of Fisheries for Norway. This article is a distillation of his keynote address at the opening session of Aquaculture '89 in Los Angeles California, February 1989.

Health 5/89

Recycling the land to keep pace with our passion for seafood

FISH

by Donna Florio

Inhabitants of Atlantis would understand aquaculture. Farming the sea or redesigning cotton, tobacco and rice fields to grow fish is a concept people of that watery domain could easily embrace, but one that takes some rumination on the part of land-bound humans. After all, we are accustomed to growing vegetables—not fish—in the ground.

But take a moment for deliberation. Land animals—chickens, cows and pigs—are grown for their food value, fed and nurtured until they're the perfect size for slaughtering, or until the price is right. Fish and shellfish, on the other hand, are wild creatures, available for harvest only when the time, tides and whims of nature are right. But our ever-increasing taste for them is forcing processors to look for new seafood sources, and aquaculture appears to be a practical choice. So practical, in fact, that a small army of American aquafarmers has sprung up in the past two decades, producing everything from salmon to oysters to catfish, in an attempt to satisfy our hunger for heart-healthy seafood.

Aquaculture is the production of aquatic plants or animals—fish, shellfish and amphibians—in a controlled environment for all or part of their life cycles. For example, fish that are normally found in freshwater rivers and lakes, like striped bass, tilapia (a warm-water fish native to Africa) and catfish, are reared in man-made earthen ponds or even cement

Here: An aerial view of a catfish farm, once the site of rice and soybean fields, in Humphreys County, Mississippi. Each pond averages 17 acres. *Above right:* To harvest catfish, workers use huge, weighted [illegible]—called seines—to gather thou[illegible] fish into a corner of a pond. (Graded nets enable farmers [illegible] harvest fish by size.) A [illegible]-operated basket scoops up 800 fish [illegible] time from the seine and loads them onto a [illegible]ter-filled truck.

tanks (often called raceways) filled with clean well water. There they are fed, protected from disease and easily harvested. Although the term "aquaculture" is used to describe both freshwater and saltwater farming, the latter is sometimes called "mariculture"—aquaculture with a grain of salt, so to speak.

The practice of freshwater fish farming dates back 3,000 years to China, where carp were—and are—grown in ponds as a major protein source. The tradition is so strongly entrenched throughout Asia that Eastern countries contributed 84 percent of the world's aquacultural production in 1985.

There are other forms of aquaculture as well. Bivalve shellfish (clams and oysters) are grown under less controlled conditions than are freshwater fish. Tiny baby clams and oysters, known as larvae, are coaxed to "sit" or attach themselves to shells that are placed in appropriate intertidal zones to mature. The shellfish aren't fed special food; rather, they dine on algae—microscopic plants—found in the water. Saltwater fish like salmon are grown in small net pens that float in open bodies of salt water. Shrimp are grown in saltwater ponds.

A Fish Story

Unlike the rest of the world, the United States was slow to initiate fish farming. The seemingly limitless supply of natural resources, high start-up expenses for farms and the lack of proven technology tempered interest in the concept until the '60s.

Now there are aquafarms scattered throughout America. The bulk are catfish farms in the South, primarily Mississippi, but there are trout farms in Idaho as well as salmon and shellfish farms in Maine, Oregon and Washington—and business is booming. Aquaculture is the fastest-growing segment of the agriculture industry, averaging a 20 percent growth rate in the '80s. The U.S. Department of Agriculture (USDA) estimates that 700 million pounds—nearly $550 million worth—of cultured seafood were harvested stateside in 1987. Catfish, salmon and rainbow trout are far and away the market leaders, followed by hybrid striped bass, redfish, mussels, clams, oysters, crawfish, shrimp and even alligators.

"Some farmers weren't doing well with traditional crops and were looking for alternatives. They found aquaculture," explains Dave Harvey, a USDA economist specializing in aquaculture. While commercial wild-harvest fisheries have room for expansion, it's mostly in species Americans don't eat, like menhaden, which is used for pet food and fish meal. Fishing for the species people do eat is often restricted or banned due to overfishing or contamination by PCBs (polychlorinated biphenyls). Yet the National Fisheries Institute reports that seafood consumption is increasing: Americans ate 15.4 pounds of fish per person in 1987, up from 12.8 pounds in 1980, meaning that the seafood industry needs to produce an additional 640 million pounds of seafood annually.

In 1988 an estimated 10 percent of all seafood eaten in the United States was the product of aquaculture. And for some species, the percentage is far higher—all the rainbow trout, catfish and hybrid bass served in restaurants or sold in markets are farmed. A high percentage of the shrimp we eat is imported, much of it cultured in countries like China, Ecuador, Indonesia, Mexico and Taiwan. Although farmed fish and shellfish cost more to produce than wild fish—ponds, food, equipment and staff are expensive—these products often offer more consistent availability, quality and, some would argue, safety and taste.

How Farmed Fish Shape Up

PRODUCT	SPECIES	CALORIES	FAT	CHOLESTEROL	OMEGA-3
Catfish	*Channel*	128	6.9 g.	33 mg.	0.1 g.
Salmon	*Atlantic* *Coho*	129 150	5.6 g. 6.6 g. *(varies)*	35 mg. 39 mg.	1.4 g. 0.8 g.
Trout	*Rainbow*	131	5.8 g.	56 mg.	1.1 g.
Crawfish (Crayfish)	*Red Swamp; White River*	80	0.8 g.	90 mg.	Not available
Shrimp	*White*	90	8.0 g.	96 mg.	0.34 g.
Oysters	*Japanese*	90	2.2 g.	47 mg.	0.71 g.
Mussels	*Atlantic*	89	2.2 g.	28 mg.	0.43 g.

(All figures for 3½-ounce, uncooked portion)

A smorgasbord of aquaculture, *opposite page*. From top to bottom: *far left*, blue mussels, hard clams; *center*, channel catfish, rainbow trout, hybrid striped bass, tilapia, red tilapia; *right*, Pemaquid oysters, white shrimp, Blue Point oysters.

The Catfish Craze

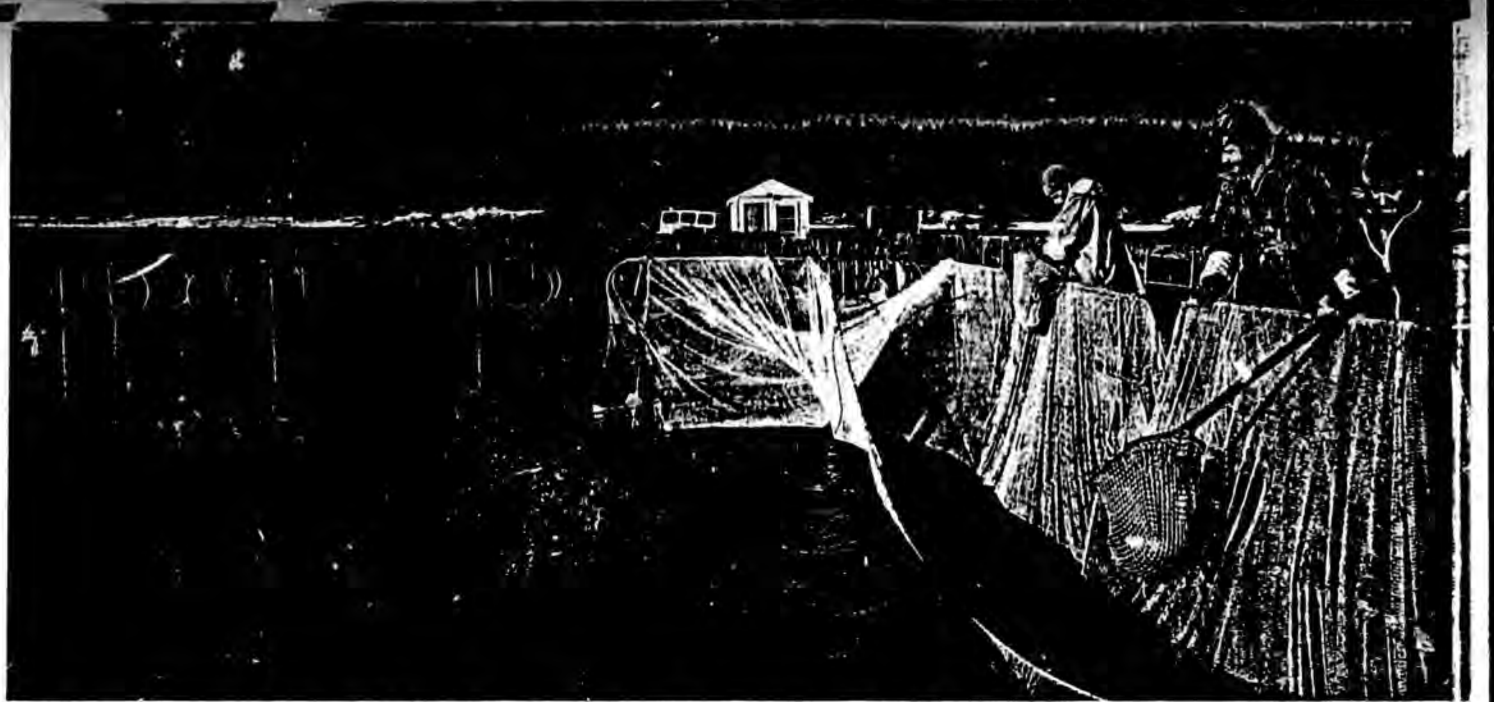
Among American-bred seafoods, catfish is the runaway success story. The species's mild white flesh, wide availability and reasonable price, along with aggressive marketing by major producers, have given status to a lowly "trash" fish, once eaten only by poor people in the rural South. Catfish is sold throughout the United States, in the Orient and in Western Europe, and is so popular that production jumped from under 10 million pounds to 280 million pounds in less than 10 years.

But the South is still home to the catfish; 80 percent of growers hail from Mississippi, with the remaining 20 percent scattered throughout Alabama, Louisiana, Texas and other states in the region. One up-and-coming farm, Carolina Classics Catfish, is in Ayden, North Carolina, a small town located between Greenville and Kinston.

On an icy day last winter, I drove there to see what all the excitement was about. I found a modest, modern processing plant, some former tobacco fields

spawned an aquaculture revolution

MICHAEL GEIGER. SEE PAGE 89 FOR FISH CREDITS



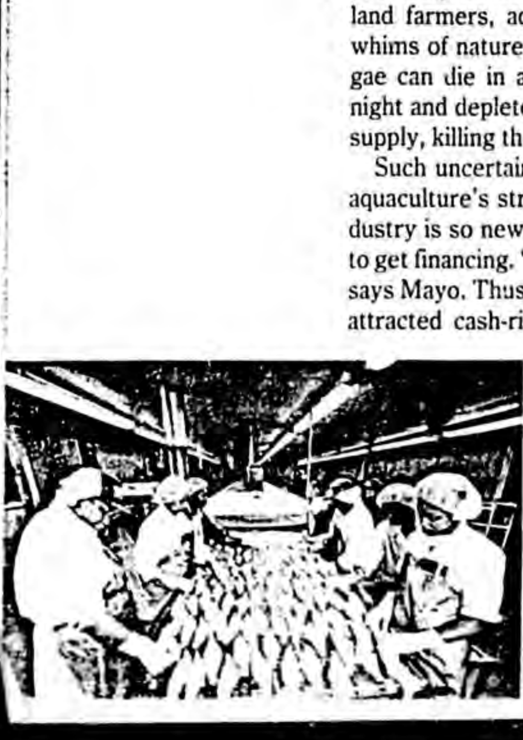
***Above:* Harvesting farmed Atlantic salmon at Ocean Products in Eastport, Maine. Gentle handling of fish during harvest minimizes the possibility of bruised meat. *Below:* Employees at a Mississippi processing plant load cleaned catfish onto a conveyor belt for passage through a quick-freezing machine, the final step in the market-preparation process. As an alternative to freezing, some companies ship fresh catfish packed in ice.**

converted to fish ponds and a young, savvy company president, Rob Mayo, who is an anomaly among area farmers. His farm, founded in 1986, is smack dab in the middle of Pitt County, "the largest flue-cured-tobacco–growing county in the free world."

From 20 acres of ponds, Carolina Catfish Classics has grown to several hundred acres and a full-scale processing plant. Although the former oil-industry engineer won't disclose current production figures, Mayo says the company's short-term goals are to harvest and process a thousand acres of ponds, or roughly one million pounds of fish. That, says Mike McCall, editor of *The Catfish Journal*, is large, even by Mississippi standards. "The average size of a Mississippi fish farm is 255 acres," he says.

To start a catfish farm, you need flat land in which to dig ponds; good, clay-based soil; and an abundant, clean supply of fresh water. Most of all, you need money. Start-up costs average $2,000 to $3,000 per acre for a 300-acre farm. It takes 16 to 18 months for a two-inch fingerling to grow to a foot-long, one-and-a-half-pound catfish ready for harvest. During that time, a grower not only has to pay interest on his capital investment, but he also needs a steady flow of operating cash for the first two years. And, as with land farmers, aquaculturists are vulnerable to the whims of nature. In warm weather, for instance, algae can die in a pond overnight and deplete the oxygen supply, killing the fish.

Such uncertainty is one of aquaculture's strongest drawbacks. Because the industry is so new, it's difficult for interested farmers to get financing. "The easiest part is selling the fish," says Mayo. Thus far, the industry's rapid growth has attracted cash-rich megacorporations; Hormel and ConAgra now have operations in Mississippi. But most farmers have more modest backers—if any.



Such matters mean little to a catfish. Those farms that don't have on-site hatcheries where fish eggs are fertilized and nurtured until ready for the pond purchase fish as fingerlings, two to eight inches long. Some farmers prefer smaller fish, which take longer to grow but cost less than larger fingerlings. Though expensive, bigger fish are stronger and reach full size more quickly. Mayo's ponds—roughly 12 acres each—are home to up to 70,000 fingerlings at a time.

As at other farms, the water in Mayo's ponds is monitored to be sure the fish receive sufficient oxygen and to control levels of ammonia or nitrates from their bodily wastes. To ensure a steady supply of oxygen, crews check the ponds regularly, often several times a night in hot weather. If the oxygen level dips, aerators are used to bubble more air into the water.

Twice a day in the summer, once daily in the winter, the fish are fed with the help of a tractor-pulled machine that blows food pellets across each pond's surface. The pellets are designed to float—both to keep the fish from dining on the pond's bottom and to allow observation of the fish. If appetites seem poor, a staff member checks the fish for disease and, if necessary, treats them. The fish are also routinely sampled for contaminants and fed vitamin C.

Those fish that survive the 18 months of tender loving care from egg to harvest size are scooped up in huge nets designed to let smaller fish escape and transported live to a processing facility. A few are sacrificed for a taster who microwaves and samples pieces of tail meat. If the fish taste "off"—flavor can be influenced by algae and the earth from which ponds are made—it's back to a clean, freshwater pond for a few days to improve flavor.

Once fish pass muster, they're unloaded into aerated concrete troughs. Eventually they're conveyed into the plant, electrically stunned, headed with a band saw, gutted, skinned, chilled and sized. Some are shipped as is—the term is "dressed." Others are processed into steaks, fillets, fingers or nuggets. Part of the harvest will be frozen for buyers; the rest will be boxed and shipped fresh. Total elapsed time from pond to shipping is less than 12 hours.

A lifetime of regularly eating seafood

KIP BRUNDAGE/OCEAN PRODUCTS

Down the Hatch

What catfish eat is as important as how much. Exact formulas vary, but they're similar to diets of other farmed fish. The basic pellet mixture consists of 50 percent to 55 percent soybean meal, 25 percent to 35 percent corn and 15 percent to 25 percent other nutrients, including a fair portion of fish meal, which is the "chief gustatory ingredient," according to Mayo.

The percentage of fish meal is actually quite small, although raising it may increase the amount of omega-3's (see "How Farmed Fish Shape Up," *page 73*) found in farmed fish, particularly salmon and trout, and produce a stronger "fishy" flavor, says Joyce Nettleton, author of *Seafood and Health* (Osprey Books, 1987) and director of a recent study of farmed catfish by The Catfish Institute.

While the daily diet of farmed catfish may not sound exciting, it is reasonably clean and extremely efficient. It takes 1.4 to 1.8 pounds of food to raise a fingerling to the one-and-a-half-pound market size, compared to eight pounds of feed for a pound of beef or three pounds for a pound of chicken. Chickens are also fed small, regular doses of antibiotics, to which bacteria can become resistant. And that can pose problems to both sick chickens and the humans who eat them. Though cultured fish develop parasitic, bacterial and viral diseases just like dogs, cats and

may prevent heart disease

humans, says John Plumb, professor of fisheries and aquaculture at Auburn University in Alabama, they're likely to be treated with antibiotics or other therapeutic substances only when ill.

In some instances, medication isn't the answer. At press time, the first North American outbreak of an untreatable fish virus—viral hemorrhagic septicemia (VHS)—inexplicably occurred in two wild salmon hatcheries in the Pacific Northwest. VHS is prevalent in wild and farmed European fish, especially salmon, and is spread through fish urine and feces, so cultured fish in ocean pens can contract it. While not harmful to salmon or humans, it is fatal to some species of sport fish, such as rainbow trout and steel-

A Mackerel a Day...

Medical studies around the world have presented evidence that a lifetime of eating fish and shellfish three or more times a week may lower the incidence of heart disease, help stave off some types of cancer and lessen the severity of inflammatory diseases like rheumatoid arthritis. "All these effects have been shown in experimental animals and sometimes in humans," says Dr. William E. Connor.

Omega-3's are very long-chained fatty acids found in small quantities in certain vegetable oils and in larger amounts in fish oils. Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are thought to be the two components that may trigger heart-protecting mechanisms. Since omega-3's are concentrated in fish oils, generally the fattier the fish, the bigger the dose you'll get.

Studies by Connor have shown that triglyceride levels dropped significantly when patients ate plenty of salmon and eliminated all other fat from their diets. Very low-density lipoproteins (VLDL, one of the "bad" cholesterols) also decreased. Levels of HDL (high-density lipoprotein, the "good" cholesterol) and LDL (low-density lipoprotein) remained about the same. According to Connor, a high-omega-3 diet increases cholesterol excretion from the body and sometimes decreases the production of LDL. Research also indicates that EPAs may reduce the ability of platelets to stick together in the blood, thus preventing heart-attack–causing clots.

Joyce Nettleton recommends that people obtain their omega-3's from fish rather than fish-oil capsules. "In addition to providing omega-3's, the fish will substitute for other food that may be worse for you, such as fatty steaks or cheese. That will do something for you that no capsule can." And she points out that capsules not only vary in the amount of EPA they contain, but also that they add more fat to the diet, an unsound nutritional practice.

"People should get their nutrition from food whenever possible," concurs Connor. Capsule use is acceptable in certain instances, he says—when a person is allergic to seafood, for example, or is ordered by a doctor to use capsules to help lower high blood triglyceride levels.

To get optimum results from your seafood, experts advise the following: ■ Eat a variety of fish, lean and fat. Of the farmed species, fattier fish like salmon, sardines and rainbow trout offer the most concentrated sources of omega-3's. Wild salmon, mackerel, herring, mullet and tuna also have high oil contents. But leaner fish such as cod also are excellent sources of omega-3's. ■ Replace other sources of animal protein with fish and shellfish like oysters, scallops and clams. But don't expect fish to be a panacea. Your general diet should be weighted in the direction of lower fat and cholesterol. ■ Don't sabotage your diet by frying fish or ladling on rich sauces. Instead, opt for baking, broiling, stir-frying or poaching, and use low-fat toppings.

head. Washington officials killed millions of fish eggs and young fish in an effort to halt the disease and were planning to examine marine life in rivers to determine how widespread the virus is.

How Pure?

Close attention to quality control has gained farmed fish a strong reputation in the marketplace. For example, processors routinely monitor waste for contaminants and boast that their products are far cleaner than many species of wild-harvest fish. Also, catfish, like trout, tilapia and hybrid bass, are usually grown in drinking water from regional aquifers or deep-water wells. This makes them less likely to encounter pollutants that may be found in the reservoirs, rivers and streams where their wild cousins live. In inspections of catfish as they arrived for processing, "we found no significant levels of the pesticides the Food and Drug Administration [FDA] regularly looks at, and PCBs were well below the allowable levels," says Dr. A.M. Guarino, chief of the Fishery Research Branch at the FDA's Dauphin Island, Alabama, facility. The Catfish Institute study, in fact, concluded that catfish "pose no measurable risk to human health" from PCBs, heavy metals or chlorinated hydrocarbon residues.

Logically, Guarino says, "We would have expected more indication of pesticides in catfish samples. Many of these fish farms are former cotton farms, so there should be lots of hard pesticides in the ground—that's the logic—but there aren't."

One theory holds that most of the pesticides have been washed down into the groundwater. Ponds are built above the water table, and the tightness of the soil apparently prevents any remaining chemicals from tainting the water. Tony Mazzaccaro, aquaculture specialist for the USDA, speculates that pesticides are probably not a problem for diners because they're so deadly to the fish. Still, fish farmers are asked not to build ponds over a "hot spot"—the area where the farm's pesticide tank was filled—because the soil can contain pesticide buildups.

The relative lack of contaminants in farmed fish is a selling point marketers are touting even more vigorously in the wake of concern about the condition of the oceans and pollution's toll on seafood. "We know where our fish's mouths have been and what they've eaten," says Mayo. "And they're raised in well water that is free of agricultural contaminants."

While this holds true for cultured products raised in fresh water, those fish that spend all or part of their lives in salt water, depending on the location of the pens, may be exposed to the same contaminants, diseases and parasites as their cousins who live in the wild. Salmon, however, are routinely vaccinated at the hatchery against prevalent bacterial diseases and, because their diets are controlled, rarely consume common parasites that can be transmitted to humans. But oysters, clams and mussels are partially raised in near-shore waters that may contain pollutants from municipal and industrial waste plants, as well as runoff from farms and city streets. Shrimp ponds are generally filled with water from such estuaries. However, aquaculturists try to choose unpolluted farm sites.

In spite of the potential problems of wild stock and saltwater-cultured seafoods, cases of illnesses related to them are low. From 1978 through 1984, the Centers for Disease Control received reports of only 5,080 such cases—a mere 5 percent of food-borne illnesses. Most of these resulted from people eating raw oysters and clams; the others, from fish contaminated with the naturally produced poisons, ciguatoxin and scombrotoxin.

"Generally, most fish in the marketplace—wild and farmed—are safe," says Nettleton, who has been at the forefront of research on the nutritional safety of seafood. "But some species of wild fish, particularly if they're older and larger, may concentrate pollutants." Bottom-feeders such as croaker and red drum generally dine on creatures that burrow in the mud, where heavy metals settle in polluted areas. "Worms, little snails and crustaceans pick up small amounts of contaminants from the sediment and the larger fish eat them," explains Nettleton. "During the digestive process, these can enter the fish."

But John B. Pearce, deputy director for research

(Continued on page 89)

The Salmone in Gradela borrows from traditional Italian cuisine. After basking in a lemon-and-olive-oil marinade, salmon fillets are dipped into a fennel-and-bread-crumb mixture, then gently sautéed. Chef Joyce Goldstein of Square One Restaurant in San Francisco serves her version with sautéed Swiss chard or spinach and sliced lemon. For this recipe and others, see *page 94*.

To some chefs, farmed fish are superior

(Continued from page 76)

and science of the National Oceanographic and Atmospheric Laboratory in Wood's Hole, Massachusetts, says there have been few, if any, documented cases of death in the United States or Europe due to ingesting toxic trace metals found in fish, because the amount of such metals is so minute. As part of a team of scientists working on the United Nations' second report on the world's oceans, he says that researchers today "don't see toxic trace metals as a major environmental problem." Such metals could affect the reproductive capabilities of fish, but that's another issue. "The real impact of all this is on the seafood itself, not on the people who eat it," he says. "There is concern about future increases and how that might affect marine life or seafood."

Outweighing the uncertain potential for illness are the health benefits of eating fish and shellfish. Dr. William E. Connor, director of endocrinology, metabolism and nutrition at Oregon Health Sciences University in Portland and coauthor of *The New American Diet* (Simon & Schuster, 1986), is a proponent of seafood in the diet. "Fish and even some shellfish have a low cholesterol and saturated fat index," he says. "They are good sources of calcium and protein. But the more positive benefit is the inclusion of omega-3's, as they may lessen the incidence of coronary heart disease when consumed over a lifetime."

So where does this leave the fish-loving consumer? Obviously, aquaculturists believe their products are superior. Aquatic Systems, Inc., of San Diego, produces hybrid striped bass in circular concrete tanks filled with artesian geothermal groundwater. Not only are those fish not exposed to as many potentially pathogenic viruses, bacteria or contaminants saltwater or wild species contend with, they have a much lower incidence of parasites. Trout farmers in Idaho and North Carolina also claim to use clean aquifer water. And some crawfish are pond-raised, giving them the same advantages as trout, catfish and bass.

But consider that in Tokyo, the Japanese pay up to 100 percent more for a high-quality wild fish than a cultured fish. According to Richard Lord, information officer for New York's Fulton Fish Market, the aesthetics of the fish—color, firmness and a good "figure"—are very important to these most sophisticated of all seafood consumers. To them, farmed fish are soft and lazy. In this country, too, soft texture and bland flavor have been the main targets of aquaculture critics.

As a seafood consumer, you are the final arbiter, and the best decision is an informed one. Go to the seafood market. Inspect the varieties of fish, ask which products are farmed or wild, and choose one whose appearance and price appeals to you. For the next few nights, return, and choose something different each time. Cultured fish—salmon, catfish, hybrid bass and trout—will surely be in the refrigerator case, along with shrimp (perhaps from Ecuador) and maybe crawfish, tilapia and carp. Before long, you'll understand the differences among the various wild and cultured species enough to make your selections confidently, and you'll be varying your choices enough to make mealtime interesting. The people of Atlantis would approve. [H]

DONNA FLORIO *is a seafood specialist and freelance writer living in Charleston, South Carolina.*

PROVIDERS OF FISH FOR PHOTO ON PAGE 72: CHANNEL CATFISH FROM CATFISH FARMERS OF AMERICA; RAINBOW TROUT FROM CLEAR SPRINGS TROUT COMPANY; OYSTERS AND BLUE MUSSELS FROM GREAT EASTERN MUSSEL FARMS, INC.; HYBRID STRIPED BASS AND HARD CLAMS FROM SOUTH CAROLINA MARINE RESOURCES DEPARTMENT; TILAPIA FROM AWBROOK MOUNTAIN AQUAFARMS.

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Alaska Magazine 6/89

From Ketchikan to Barrow.

Ralph Bache reels in a lantern net containing several hundred oysters destined for restaurants in Alaska and Washington. (John Church/Alaska Sea Grant College Program)

While Alaskans continue the debate over salmon *farming, other forms of aquaculture are flourishing in the state.*

Take Don Nicholson's oyster farm in Coffman Cove, on Prince of Wales Island in southeastern Alaska, for example.

Each year since 1985, Nicholson and partner Annie Caldwell have raised 100,000 plump, juicy oysters for up-scale restaurants in Anchorage and Washington. And although the fresh oysters are shipped via costly floatplane and commercial jetliner, Nicholson and Caldwell manage to stay competitive in the marketplace.

"Our prices are a little higher than those from the Lower 48," said Nicholson, co-owner of Canoe Lagoon Oyster Co., "but we have a high-quality product that's grown in pure Alaska waters, and we are able to maintain a consistent supply for our customers."

Entrepreneurs throughout Alaska are starting to successfully harvest mussels, clams, scallops, abalone and seaweed.

There are about 40 licensed aquaculture farms in the state, raising mostly oysters and mussels, according to Janet Burleson, resource manager with the Alaska Department of Natural Resources in Juneau. That number is up from only 10 three years ago.

"We believe the aquaculture potential in Alaska is enormous," said Roger Painter, executive director of the 200-member Alaska Mariculture Association. "It may take us a while to get there, but eventually aquaculture will be a major industry in Alaska."

One stumbling block for newcomers to the aquaculture industry is the numerous regulatory hurdles that Painter said are partly the blame of commercial fishing interests worried about competition.

"We have a billion-dollar fishing industry that has proven thus far to be more viable," said Eric King, spokesman for the Alaska Trollers Association.

Federal Express buys Tiger International

Four Flying Tigers cargo jets line up at Anchorage International Airport, while a Federal Express truck drives by. A merger of the two companies will boost Alaska's economy. (Walt Johnson)

Federal Express announced in Decem-*ber the $880 million purchase of Tiger International Inc., the parent company of Flying Tigers Line, one of the world's largest cargo airlines.*

As many as 400 new jobs may be added to Flying Tigers' Anchorage operation.

Industry observers say the buyout signals that Federal Express will accelerate plans to make Anchorage a hub for overseas deliveries, particularly to Japan.

"I would guess in the course of five years there might be well over a thousand jobs (in Anchorage)," Scott Hawkins told the *Anchorage Daily News*.

Hawkins is president of the Anchorage Economic Development Corp., a primarily public-funded agency that has a contract to build a $10 million Federal Express facility in Anchorage and to create 100 new jobs in 1990.

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Additives to the Environment of Net-Pen Reared Fish

Pacific Marine Fisheries Commission 42nd Annual Meeting
Seattle, Washington, Ocober 16-18, 1989

PHD Arthur H. Whiteley and Annamarie Johnstone

We have been asked to address our remarks to the matter of additives to the environment of net-pen reared fish. In this particular forum, we assume the emphasis should be on additives that may have an impact on humans when these fish come to market, rather than the impact on the plant and animal communities in the natural environment, though these are not wholly separable.

By its very nature, net-pen rearing of salmon requires the use of numerous chemicals, sometimes in large amounts, some used in the fresh water hatcheries to produce the fry and smolts, some used in the grow-out period in the marine pens, and others used during processing of the fish for the market. Partial lists are shown in Table 1, compiled from Austin and Austin, 1987, from a 1988 report for the Nature Conservancy Council by the University of Stirling, and from other sources.

The lists include chemicals used in salmon and in other forms of fish culture, both in this country and in foreign countries. Inasmuch as farmed fish are imported from some of these other countries, inclusion of these chemicals in the lists may be relevant to the matter of seafood surveillance in the United States marketplace.

Chemotherapeutics. The most relevant additives for present purposes are antibiotics and therapeutants used to control bacterial diseases. Because of stress, disease may cause losses of 30-40%, sometimes higher. Diseases in salmon farms include *Vibrio anguillarum* (vibriosis), *Aeromonas salmonicida* (furunculosis), *Aeromonas hydrophila* (hemorrhagic septicemia), *Yersenia ruckeri* (red mouth), *Vibrio salmonicida* (Hitra disease), *Renibacterium salmonarum* (bacterial kidney disease). To combat these diseases, medicated food containing antibiotics is supplied. In Washington, the FDA approved antibiotics and therapeutants are oxytetracycline (OTC), Romet 30 (sufadimethoxine and orthomeprim) and sulfamerazine. In addition, Tribrissen (sulfadiazine and trimethoprim) is used in Norway and Scotland, and in British Columbia erythromycin is used to control BKD. In Japanese fish culture a wide variety of antibiotics has been used, but has recently restricted the use of chemotherapeutics in cultured fish (Aoki, 1988, pers. comm).

In the US, Norway, BC and Scotland, doses of drugs are as indicated in Table 1B. It is anecdotal, however, that additional amounts of antibiotics are used by farmers, who may mix the drugs with feed and binders. Control of use of antibiotics in Norway and Scotland is regulated by veterinarians, and this is supposed to be the case in B.C. In the British Isles it is apparently easy to find legal loopholes to permit other antibiotics and doses to be used (Austin and Austin, 1987). In Washington fish farmers are supposed to notify the Department of Fisheries if they use antibiotics, but veterinarian supervision is not required. Generally approval exists for only therapeutic use of these drugs. Nonetheless they often are used prophylactically inasmuch as sick fish may not take the medicated food.

There appears to be no medical or public health supervision or regulation here, or in the other fish farming countries, on the use of antibiotics and chemotherapeutics other than the requirement of FDA approval of the three drugs and their dosages. There appears to be no monitoring by agencies of the use of these drugs or their persistence in marketed fish.

The amounts or drugs used are enormous. In Norway last year, 48 metric tons (105,000 lbs) of OTC alone were used - more than in animal husbandry and human health uses combined (Mehli, 1988, pers. comm. and press accounts). This figure has grown from 13,691 lbs in 1984 (Midtlying, 1985). The 1984 figure for Tribrissen, nitrofurazolidon and sulfamerazine is 30,204 lbs (Midtlying, 1985). Comparable figures for British Columbia and Washington are not at hand. Assuming the dosages cited earlier for the 13 Washington pens, calculation leads to a first approximation of about one ton of OTC, a figure similar to that given by a Washington fish pen operator (Dr. A. Bill, 1989, pers. comm.).

The relevant issue here is "Do these uses affect man?" Consumers clearly would be exposed to residual antibiotics in the fish meat. Because of the potential for these residues producing a serious problem in public health, Japan has recently restricted the use of chemotherapeutics and does not allow cultured fish to move to market if residual drugs can be detected in fish meat (Aoki, 1988, pers. comm.). The potential for adverse effects has been emphasized by Austin (1988, conference in Vancouver, B.C.; Austin and Austin, 1987). The current regulations for control of such residues are based on admittedly minimal research. The FDA requires a 21 day withdrawal period after the last medicated feeding of OTC and 42 days for Romet 30 before slaughtering for the market. In B.C. the withdrawal period is 42 days, and in Norway 61 days. Very few data exist for measurement of persistence of these drugs in fish flesh after feeding. McCracken et al (1976) measured the presence of trimethoprim in trout muscle 77 days after medication; Salte and Liestøl (1983) calculated that the withholding period for trout receiving OTC should be 100 days at winter temperatures, and for Romet 30 they recommended withdrawal periods of 60 days, above 10^{0}C. All authors emphasize that temperature is a seriously complicating factor - residues of Romet 30 persisted for several months in fish at colder temperatures, leading Salte and Liestøl to recommend using the component drugs only in summer. Clearly these limited data do not support the FDA regulation of 21 days. New, more refined measurements of drug residues in salmon coming to market clearly are needed - a recurrent theme of the Austins. Some of these measurements are being made now at the University of British Columbia by McErlane et al. (1989), and Grondel et al. (1987) have published a pharmacokinetic analysis of OTC distribution in carp. In the absence of more detailed studies, humans ingesting farmed salmon may be receiving subtherapeutic doses of antibiotics. One would like to see regulations established for testing the product, by agencies, as it comes to market to ensure the absence of detectable residues. Methods used should be such as those approved by the National Committee for Clinical Laboratory Standards used by the Clinical Laboratories, Laboratory Medicine, University Hospital, University of Washington.

The issue extends beyond the limits of the penned salmon. Much of the antibiotic fed escapes into the fluid environment and, notably, into the sediments that accumulate beneath the pens (Jacobsen and Berglind, 1988), where it may be exposed to native fish, shellfish, and other indigenous species, thus providing another avenue to humans who may catch and consume these forms.

The medical consequences of the mis-administration of antibiotics are numerous, and are well discussed in such modern treatises as Goodman and Gilman (1985) and Kucers and Bennett (1987). A number of them are antigenic and elicit immunological hypersensitivity responses; some have toxic effects in various tissues varying with the physiological and health state of the person; some particularly should be avoided during pregnancy; tetracyclines lead to discoloration of infants' teeth and may interfere with bone growth; some, notably the tetracyclines, may lead to the development of superinfections by resistant strains of bacteria; they may interfere with the normal immune repsonse; and the breakdown products of antibiotics, including OTC, can be toxic particularly in individuals with compromised livers. Basically, it is poor medical practice to ingest unneeded antibiotics or deteriorating antibiotics.

Another cluster of problems associated with use and misuse of antibiotics is the generation of strains of pathogenic bacteria that have resistance to the drugs. Such strains have now appeared in essentially all fish culture communities that have been adequately tested. Mostly the resistance factors are carried on R plasmids, which also usually are found to carry resistance determinants for 1 to 8 additional antibiotics, thus showing multiple drug resistance. In high proportions, these R plasmids are transferable to other bacteria, and thus drug-resistance may be disseminated to other ecosystems. Studies at the Centers for Disease Control have shown that outbreaks of salmonellosis could be traced to drug-resistant *Salmonella* derived through the foodchain back to land farms associated with agricultural antimicrobial use (Cohen and Tauxe, 1986). It is prudent to evaluate the possibility for a similar generation of R plasmids in fish farms and their dissemination to human populations in the marketplace. When drug-sensitive populations of pathogens are replaced by drug-resistant populations, then treatment of the affected fish becomes ineffective, and, if the R plasmids are in human pathogens, treatment of patients would be adversely affected. Particularly, it is a general principle that medically important antibiotics, including oxytetracycline, the sulfas and erythromycin, should be restricted in their nonmedical uses to minimize R plasmid selection and transmission.

When antimicrobials are used in fish farms near commercial or recreational shellfish beds, there is the further potential for drug-resistant organisms to be concentrated by the shellfish, through filtration, and thus enter human populations.

Food additives. The dry pellets, fed to the penned fish in the marine environment, contain fish meal, grains, fish oils and carbohydrates, supplemented by minerals and vitamins as indicated in Table 2. While these additives have no direct human import, it is reported that planktonic blooms of the ichthyotoxic dinoflagellate, *Gyrodinium aureolum*, were enhanced by the biotin in fish farm wastes (Turner et al., 1984). These blooms cause mortalities to cultured fish, and, unfortunately, to wild fish as well (Bullock et al., 1985).

Pigment is added to the feed to produce a colored flesh in farmed salmon, inasmuch as the color of wild salmon flesh is derived from natural food organisms. In Great Britain, the carotenoid canthaxanthin, an analog of astaxanthin common in natural food organisms, is used in the form of carophyll red. It is stated in a report from the University of Stirling that this use is banned in the US because of possible carcinogenic properties of canthaxanthin (NCC Report, 1988). To date a petition for its use has not been submitted to the FDA (FDA, Seattle Office, 1989). A petition is presently under consideration for use of astaxanthin as a colorant. A main local supplier adds canthaxanthin as a colorant. There clearly are gray areas here where research and regulation is sorely needed.

Many wild fish are rich in omega 3, polyunsaturated fatty acids. A higher ratio of omega 3/omega 6 fatty acids is believed favorable for maintaining low cholesterol levels in humans. Cultured fish and other sea foods, because of their artificial diets, may have low levels of omega 3 fatty acids, and thus unfavorable ratios of omega 3/omega 6 (Suzuki et al., 1986; Chanmugam et al., 1986). Consequently, individuals eating farmed salmon in the expectation of gaining this supplement will typically be erring, unless the farmer has specifically added it as a dietary supplement and indicated this in marketing. The dry pellets supplied locally generally do not have omega 3 acids added as a supplement (Moore-Clark Co., 1989, pers. comm.) because these are contained in the fish oils of the fish meal used.

Moist pellets, which are more commonly fed during the hatchery phases of salmon farming, are derived from fish meal that is pasteurized, combined with additives, and frozen. However, moist pellets used in some fish farms in Puget Sound contained *Salmonella spp.* (Draft PEIS, WDF, p. 116, 1989). Moist pellets used in British Columbia have been found to contain *Salmonella* (Kelly, 1988, pers. comm.; Babink, 1988, pers. comm.). In these cases it is unclear whether the pathogens had survived the pasteurization, or had appeared subsequently. These pathogens can persist for a period of time in marine waters, are harbored by fish in polluted waters, without harm to them (Buttiaux, 1963). Marine shellfish can concentrate *Salmonella* and transmit them to humans. There is, therefore, a potential for fish culture to join animal husbandry as a mode for affecting humans in the manner described by Cohen and Tauxe (1986).

Hormones. At this time, hormones are being used in B.C., experimentally and perhaps to an extent in actual culture, to control the sex, size and behavior of penned salmon, both *Oncorhyncus* spp. and *Salmo salar*. Gonadotropin, gonadotropin releasing factor and analogs, and antiestrogens have been used in adult females to modify spawning. Androgens and estrogens are used to cause feminization, and, in combination with other techniques, to produce triploid and tetraploid stocks for production of sterile salmon. A review is provided by Donaldson (1986).

In general, these treatments are used on egg-producing females or on eggs and sperm, and the likelihood of carry-over of hormones to adult, marketable fish is tiny. Anabolic steroids including methyl testosterone, thyroid hormones, somatotropins, certain pituitary hormones can be used to accelerate growth in juveniles and the timing of smoltification (Donaldson, 1986). If these hormones, or androgens and estrogens, were used for growth acceleration or other effects on near-harvest adults, then there would be cause for concern to human consumers.

Pesticides. A remarkable list of agents are or have been used in salmon culture. Examples are: formalin, malachite green, acriflavin, Nuvan, Neguvon, Chloramine T, MS222, copper sulfate, tributyltin, diquat, in addition to the chemotherapeutics. Some are used in Scotland and Norway which apparently are not used, or not permitted, in the U.S. and B.C. Lists are incorporated into Table 1 of this presentation.

Treatment of salmon lice (***Lepeophtherius salmonis***). These copepod ectoparasites pose a severe problem for adult penned fish in Scotland and Norway. In Europe, organophosphate pesticides (Nuvan^R (dichlorvos; Scotland) and Neguvon^R (trichlorfon which forms dichlorvos; Norway) are primarily used. Fish are treated by immersion in a concentration of 1 ppm for 1 hr, as needed. In 1984 39,600 lbs of Neguvon were used in Norway (Midtlyng, 1985). They are inhibitors of acetylcholinesterase activity in the cholinergic nervous system. These agents not only kill fish lice, but other crustacea in the environment as well, including commercially important species such as crabs, lobsters and mussels (Egidius and Moster, 1987), and they cause potentially serious problems to the treated fish (Davies and McKie, 1987; NCC Report, 1988). These agents are restricted by the EPA in the U.S. (Seattle EPA Office, 1989). In Washington, the carbamate Sevin^R (carbaryl) has been suggested for use for treatment of salmon lice, and it is used in oyster culture for controlling ghost shrimp. Sevin, also, is an inhibitor of acetylcholinesterase. Sevin has recently been restricted in parts of the United States, and its discharge is regulated by an NPDES permit. BRAVO (chlorothalonil), a fungicide has been suggested for and used recently on fishpen nets, a use banned by EPA because it is a class B carcinogen (EPA, Seattle, 1989).

Disinfectants and Antifoulants. Formalin and malachite green have been used for control of ectoparasites and fungi, usually in the fresh water phases of farming. Malachite green, a potential teratogen (NCC Report, 1988), is now banned. MS-222 is used under certain conditions for anaesthesia, but with a 21-day withdrawal period for clearance from tissues. Hatchery ponds are sterilized with chlorine.

To prevent fouling of nets by growth of algae and encrusting invertebrates, fish farmers have treated nets and pen structures with the antifouling agent, tributyltin (TBT). This substance, at exceedingly low concentrations, has a variety of adverse effects on marine invertebrates and perhaps on vertebrates (Bailey, D.S., 1987). When, in 1987, farmed salmon appeared in the Seattle markets carrying substantial amounts of TBT in their flesh, the state enacted a law prohibiting this use and partially eliminating it from use on boats. A similar law exists in the national statutes, in Great Britain and other parts of Europe. Despite this ban, a Canadian Governmental memorandum on August 11, 1988, titled "Private Salmon Hatcheries and Netpen Facilities, Some Serious Concerns" indicates that 25% of BC pens are still treated with unregistered boat hull paints, sometimes including TBT, which liberate large quantities of particulate paint into the water, sometimes onto oyster beds, thus creating potential hazards for two kinds of aquacultured products.

If antifoulant is used on nets now, usually it is copper-based. Copper and other heavy metals are highly toxic to many marine invertebrates. Standards for permissible amounts of copper in farmed fish flesh appear to be lacking.

Summary. There are a number of chemicals and additives used in net pen culture now that have the potential for adverse human impact. Often these are used at the discretion only of the user, and with little or no external monitoring. There appears to be little or no input into this regulation by public health agencies.

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Table 1

Chemicals Used in Net Pen Culture of Fish

(From Austin and Austin, 1986; The Nature Conservancy Report, Scotland, 1988; and other sources)

Chemotherapeutics

- Oxytetracycline
- Romet 30^{R} (sulfadimethoxine and orthomeprim)
- Sulfamerazine
- Tribrissen^{R} (trimethoprim
- Erythromycin
- Penicillin G
- Oxolinic acid
- Minocycline
- Clindamycin
- Kitasamycin
- Rifampicin
- Hyamine 3500
- Copper sulfate
- Streptomycin
- Sulfisoxazole
- Kanamycin
- Fumequine
- Chloramphenicol
- Chloramine T
- Acriflavin
- Acetic acid
- Formalin
- Malachite green
- Iodine
- Iodophor
- Benzalkonium
- Nitrofurantoin

Pesticides

- Dichlorvos (Nuvan^{R}, an organophosphate)
- Trichlorfon (Neguvon^{R}, an organophosphate)
- Carbaryl (Sevin, a carbamate; used in oyster culture
- Diquat

Antifoulants and Disinfectants

- Tributyl tin - now banned
- Copper paint
- Bitumen
- Chlorine
- Chlorothalonil

Anaesthetics

- MS-222 (tricaine methane-sulfonate)
- Benzocaine
- Carbon dioxide

Food additives

- Colorants-canthaxanthan
- Minerals
- Vitamins
- Omega 3 fatty acids

Table 1B

Doses of Antimicrobials Commonly Used in Salmon Net-pen Culture

Antimicrobial	Dose, mg/kg of fish/day	Days of Treatment
Oxytetracylcine	75	10
Romet 30	50	5
Sulfamerazine	220	14
Tribrissen	30	10
Erythromycin	10-25, or unspecified	4-21

These regimens are repeated 2 or 3 times a year

Table 2
Mineral and Vitamin Food Additives in Salmon Pellets

(Data from Nature Conservancy Council Report 1988, and Moore-Clark Analysis)

Minerals

- Calcium phosphate
- Magnesium sulfate
- Sodium Chloride
- Potassium chloride
- Iron sulfate
- Zinc sulfate
- Copper sulfate
- Manganese sulfate
- Cobalt sulfate
- Chromium chloride
- Ethylenediamine dihydroiodide
- Selenium

Vitamins

- Thiamine hydrochloride
- Riboflavin
- Calcium pantothenate
- Niacin
- Pyridoxine hydrochloride
- Biotin
- Folic acid
- Cyanocobalamin
- Inositol
- Ascorbic acid
- Choline chorlide
- Menadione
- alpha tocopherol acetate
- p-aminobenzoic acid
- Retinol acetate
- Vitamin A
- Vitamin B12
- Vitamn D3
- BHA-BHT, antoxidant