What Can U.S. Open Ocean Aquaculture Learn From Salmon Farming?

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Farming Salmon: An Example of Aquaculture for the Mass Market

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I. INTRODUCTION

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Tables		
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Aquaculture products serve two broad market categories, namely, 'niche' markets and 'mass' markets. There are hundreds of different species produced in aquaculture, most of them niche-market species, that is, those produced in modest volumes and sold at relatively high prices to a limited number of people. Examples include various species of eels, flatfish, bass, grouper, snappers and bream. In general, at present costs of production, these species will not meet mass market value expectations and are not likely to be candidates for future, large-scale aquaculture expansion. In contrast, there are very few species that are produced on a scale large enough and at a cost low enough to be considered mass market items. Examples include some shellfish, carp, tilapia, catfish, and salmon.

The distinction between these two market segments is important because expectations for aquaculture are so high. National and international agencies, such as the US Department of Commerce and FAO, now realize that catches from the world's natural fisheries will not increase sufficiently to meet future seafood demand. They acknowledge that an increase in aquaculture production of many millions of tons is the only hope of bridging the gap (USDC 2000, FAO 2000). However, expansion on such a scale assumes an equivalent level of acceptance by consumers, and this means that the products must offered must meet the value expectations of a mass market.

The inclusion of farmed salmon as a mass market product will be questioned by some. Although global production now exceeds one million metric tons per year (Table 1), critics of the industry claim that it damages the marine environment, that it trespasses on public space in inshore waters, and its future growth is unsustainable. However, this is a narrow and shortsighted view of what salmon farmers have achieved. If aquaculture really is going to be able to bridge the projected gap between seafood supply and demand, it must be able to produce products that are both appealing and affordable to millions of consumers, that is, a mass market. This is exactly what the salmon farming industry has done. In so doing, it has shown that farming at sea in cages, or net pens, works on an industrial scale and that, in future, such an industry could meet both mass market expectations and the hopes of those institutions whose task it is to ensure

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TABLE 1
World Farmed Salmon Production-includes Atlantic, Coho, Chinook salmon and ocean-grown trout. (Sources: www.intrafish.com, www.fis.com)

Country	1999	2000
Norway	460,000	465,000
Chile	230,000	315,000 (E)
Scotland	115,000	125,000
Canada	67,000	72,000 (E)
Denmark	39,000	36,000
USA	23,000	24,000 (E)
Ireland	16,000	18,000 (E)
Others	18,000	18,000
TOTAL	968,000	1,073,000

that these are fulfilled. This article examines the reasons for the salmon farming industry's success and its significance for the future development of aquaculture in general.

II. WHY SALMON FARMING HAS SUCCEEDED

A. EASILY REPLICATED TECHNOLOGY

Salmon are farmed in cages or net pens (Figure 1). This is a particularly simple and low-cost way of managing large volumes of water for aquaculture. A cylindrical or box-shaped netting bag is suspended from floats in a sheltered body of water where currents, created by wind or tide, cause water to flow through the net meshes, thus maintaining good growing conditions for the fish. In this way thousands of cubic meters of water volume can be contained with rates of water exchange many times greater than is ever practical in fish farms on land. Cage designs vary widely and they can be made from several different materials, but they all adhere to the same, simple, basic principle. It is this simplicity that enabled salmon farmers from Norway to Chile to get started and to set up farms with only modest investment in fixed assets and without a prolonged period of construction. It is most unlikely that the industry could have developed as rapidly as it has if this were not the case.

FIGURE 1. Example of modern galvanized steel salmon cages. (Courtesy: Erlendur Johannesen, Marine Construction, Norway.)

B. ACCESS TO A HUGE RESOURCE

A critical requirement for successful fish farming in cages is that they must be sited in suitable bodies of water. These must provide protection from heavy seas, have at least 15 m of depth, have sufficient natural water flow to create adequate water exchange in the cages, and a temperature regime that is well suited to the fish species to be farmed. For salmon such conditions occur in several countries and some, such as Norway and Chile, have extensive, protected coastlines. More than anything else, this topographical advantage enabled them to develop large and successful salmon farming industries. Other countries with similar topography but less of it, such as Scotland, Canada, and Ireland, also developed salmon farming industries but on a lesser scale. Salmon farmers have been particularly favored in this respect. Access to such extensive, protected, coastal waters is not available to farmers of warmer water marine species.

C. ATLANTIC SALMON IS A GOOD FARM FISH

Atlantic salmon, and to a lesser extent other salmonids, have particularly favorable attributes for farming. They include:

- Hatchery rearing of juveniles is reasonably straightforward. Eggs from captive broodstock are obtained readily, they are easy to incubate and the young alevins, when they have absorbed their yolk sacs, will feed directly on dry feed.

- During the on-growing phase they adapt well to farm conditions. This includes acceptance of dry feeds and tolerance to moderate crowding and careful handling. They are also moderately resistant to disease and, in recent years, this resistance has been substantially enhanced by the use of vaccines.
- They grow quite quickly to a large size. There are fish species that grow more quickly, but by reaching a weight of up to 5 kg in 18 months from the time a 50- to 100-g salmon juvenile is put to sea, the growth performance of Atlantic salmon is more than adequate. A large size is helpful when it comes to processing the harvested fish. It is easier to process large fish than small fish and to make value-added products from them.
- The meat quality is good. The preference for different seafoods varies among individuals and cultures, but salmon meat has characteristics that are generally appealing to a wide cross section of consumers.
- The fillet yield is high, up to 60% edible meat. Many fish have much lower yields than this, for some as low as 30%. When fish are sold whole or 'head on, gutted' this makes little difference. However, for processing and the production of value-added products, yield is critical. Although good comparative data on many potential aquaculture candidates is not readily available, Atlantic salmon appears to be one of the highest yielding of all fish. This is a substantial advantage when it comes to meeting mass market expectations of value.

D. LOW COST OF PRODUCTION

Systematic improvements to farming methods for Atlantic salmon over 20 years have lead to a high degree of efficiency. The production cost on well-run salmon farms is now about $2/kg and in some cases even lower. The differences in rates of currency exchange and certain local costs cause some variability between different producing countries, but the cost breakdown in Table 2 is indicative of what the industry, in general, has been able to achieve.

Feed now makes up over half the total cost of production. In part this is because salmon feed is rich in high-quality protein and fat and, at about $0.90 to $1.00/kg, is expensive compared with many other animal feeds. In part, it is also because salmon farmers have become so efficient in all other respects that costs, other than for feed, are quite low (Table 2). For example, labor productivity on many farms is now often more than 200 metric tons per man-year, while management and overhead expenses have been minimized, as farming companies have become bigger and captured economies of scale, and, at production levels of between 15 to 20 kg per cubic meter of cage volume per year, fixed capital is used efficiently, so the cost contribution from depreciation is low. Although some other species of fish, such as Tilapia, can be farmed more cheaply than salmon, at $2/kg, when fillet yield is taken into account, salmon can still be priced competitively. In fact, salmon meat is now becoming increasingly competitive with many other mainstream meat products, and here too yield is a significant advantage (Forster, 1999).

TABLE 2
Indicative Costs for an Efficiently Run Atlantic Salmon Farm in 2000

Cost item	$ per kg produced	% of total cost
Juveniles	0.33	16.5
Feed	1.10	55.0
Labor	0.16	8.0
Other cost + overhead	0.29	14.5
Depreciation	0.12	6.0
TOTAL	2.00	100.0

E. CORPORATE OWNERSHIP

In many aquaculture industries governments and economic planners have encouraged individual farm ownership and small-scale 'mom and pop' operations. This is an attractive social model and was used in Norway in the early days of salmon farming there when licenses were only given to owner operators. However, it is a model that is inconsistent with the demands of the modern market place. Seafood buyers, be they for food service operations or large retail chains, are imposing increasing demands on the supply sector. These include traceability through the whole production and distribution cycle (the 'value chain'), year round availability, the ability to supply large volumes and an absolute assurance of quality, all of which must be provided at an internationally competitive price.

Individual owner operators find it difficult or impossible to meet these conditions. Moreover, as research identifies new ways to increase efficiency, there is a constant need to update equipment and to apply new technology. Individual owner operators find this difficult too due to lack of both technical and financial resources. Corporations find it easier because they are able to spread the costs of hiring the best technical talent across much greater production volume and have readier access to capital. In addition, corporations tend to be fiscally disciplined and have the financial resilience to be able to survive through commodity pricing cycles. Some even benefit from them by buying up weaker players who get into financial difficulty. Corporations also have the management resources to cope with the other demands of doing business in the modern world, such as credit control, dealings with government and public relations.

Accordingly, salmon farming has become an increasingly corporate business. The largest salmon farming company, Nutreco Inc. now owns farms that will produce 165,000 metric tons in 2001 and several other companies have capacity for between 50,000 to 100,000 metric tons per year (Korneliussen, 2001). Furthermore, the production of these companies is distributed between several different countries, thus spreading risk and facilitating development of global marketing programs. This is not the 'mom and pop' model to which many regional aquaculture programs aspire, but it is one of the most important reasons for the salmon farming industry's extraordinary success in the last 20 years. If aquaculture is going to be able to bridge the projected global seafood gap, it will have to meet the demands of the modern market place. Corporate ownership of aquaculture businesses is likely to be necessary for this to be accomplished.

F. MARKETING

Salmon farming was fortunate to develop at a time when several market factors moved in its favor. These included continuing discoveries of the health benefits of eating fish, especially oily fish like salmon, demand for fresh vs. frozen fish and general world trends in other seafood production. All of this occurred during a period of general economic prosperity, at least in the economically developed countries. Salmon farmers took advantage of these circumstances by responding aggressively to what the market was telling them. In particular, they focused on the ability to supply fresh fish year round, put strong emphasis on quality, and supported these efforts with a variety of corporate and generic marketing programs. In so doing, they have now made fresh Atlantic salmon a 'staple' on many supermarket shelves and restaurant menus.

Despite these circumstances and marketing efforts, however, the dramatic increase in farmed salmon production meant that salmon farmers were not able to maintain selling prices at the levels at which they started in the early 1980s. In real terms, the first sale ('cage side') price for whole, ungutted salmon has fallen by as much as 70% since that time. It is questionable how much further it would have fallen had the marketing effort not been made, but, clearly, the industry could not have developed as it has unless the cost of production had been able to keep pace. As stated earlier, the large-scale future expansion of aquaculture presupposes an equivalent level of acceptance of its products by consumers. Price is a key component of such acceptance and price competition from a bewildering variety other meat products will determine, to a large extent, what consumers will pay for aquaculture offerings. That salmon farmers have been able to compete is testament to what they have accomplished and instructive for farmers of other species that may seek to follow.

G. GOVERNMENT SUPPORT

Aquaculture industries that have been successful are in countries where the industry enjoys government support. Salmon farming is no exception and in Norway, Chile, and Scotland, the three leading producers, governments have been helpful. In fact, salmon farmers in Scotland and other EC (European Community) countries, such as Ireland, have received substantial EC rural development grants to help the industry get started. Governments can support aquaculture in several ways. These include:

- Creation of space in public waters for it to occur.
- Provision of a predictable and timely permitting or licensing process.
- Provision of security of tenure to the permittees and a transferable property right.
- Development of regulations that investors can trust and enforcement that is consistent.
- Encouragement of corporate investment in the industry.
- Standing firm in the face of scare mongering and exaggerated claims of environmental damage by industry opponents.
- Provision of funds for research and development.

Most governments do well when it comes to supporting aquaculture research and development but many struggle with the obstacles of creating space in public waters for it to occur and the regulatory process that goes with this. Yet a clear, supportive regulatory framework is critical if aquaculture is to meet the goals and aspirations that agencies such as FAO and the US Department of Commerce have indicated.

Throughout the world water, especially seawater, is a public resource. It has not been, or can it be settled, claimed, and divided in the same way as land has been divided through the ages, because it is constantly moving from place to place. Moreover, in part because of this, our oceans are now held in trust as public space for navigation, commercial fishing, and recreation. However, marine aquaculture must have private access and use of some of this space if it is to flourish, and large-scale development of aquaculture demands that such access be substantial. Inevitably, such a prospect is not viewed favorably by existing user groups, and in salmon farming this has led to conflict. Only governments can resolve such conflict and unless they are willing to do this and make space for aquaculture, often over vigorous objections, the industry cannot succeed. No amount of research and development will create an industry that needs an equal measure of political will to make it possible. This has been amply demonstrated by leading countries in aquaculture such as Norway and Chile, where salmon farmers have shown that, when their governments make it possible for them to farm, innovation and commercial success will follow.

H. CONSEQUENCES OF SUCCESS

As salmon farming has become more successful it has attracted a higher profile and with it detractors who find fault with the industry. It has been challenged on several issues, which relate not just to salmon production, but to the whole concept of using net pens to farm the millions of tons of seafood that aquaculture is now being urged to produce.

It is a fact that in every case in which challenges to salmon farming have been the subject of judicial proceedings, or a formal review process, the claims made against it have been shown to be exaggerated or unjustified. Examples include a Washington Sate Programmatic Environmental Impact Statement (Parametrix 1990), a review of Salmon Aquaculture in British Columbia by the BC Environmental Assessment Office (EAO 1997) and a hearing before the Pollution Control Hearing Board of Washington (PCHB 1998). It is also true, however, that critics of the industry dispute the conclusions from these reviews and continue to allege that salmon farming causes environmental problems. Moreover, in each of the documents cited, recommendations were made for improvements to industry practice and government oversight of it.

There is no human endeavor that cannot be improved in some way, so that it should be no surprise that salmon farming, a business that is only 30 years old, cannot be done still better. In fact, salmon farm performance has improved dramatically in 30 years and is vastly better now than it was only 10 years ago; improvement that has come about as a result of the industry's own efforts to get costs down and to be responsive to market forces, rather than coercion from regulators or environmentalist agitators. Nevertheless, given the importance of salmon farming as a model for future marine fish farming industries to follow, there is no room for complacency. The main issues are discussed below.

I. DISCHARGE OF FISH WASTES

Wastes discharged from salmon and other fish cages are almost completely biodegradable and hardly different from the wastes produced by wild fish. Allegations by industry critics to the contrary are often wildly exaggerated and seem designed to be deliberately misleading. When adequately diluted by marine currents, these wastes are assimilated as part of the marine nutrient cycle. This often results in increased productivity in the immediate vicinity of the cages and there are numerous anecdotal reports of increased populations of wild fish and invertebrates occurring underneath and around floating fish farms. Sadly, such enhancement is rarely documented in scientific research on the environmental effects of salmon farming, which has tended to focus on the supposed negative effects rather than those that may be more positive. It is an interesting irony that when wastes from terrestrial animals are applied to the land for assimilation by field crops it is considered to be environmentally friendly and termed 'organic' farming, whereas the application of similar wastes to seawater is perceived in the opposite way.

The key to fish wastes becoming useful nutrients is dilution, which occurs when they are dispersed by ocean currents. Dispersal facilitates the assimilation of the wastes by natural processes within the receiving waters, the capacity of a water body to accomplish such assimilation often being called the 'carrying capacity' or 'assimilative capacity'. For fish farmers, the challenge is to understand and define the carrying capacity and then to operate within it.

An aspect of this on which salmon farmers have been criticized most heavily is the organic enrichment of benthic sediments under salmon farms, which, unless cages are located in areas with especially strong currents, can occur and cause changes to the benthic community. It is well documented that when such enrichment occurs, it is always both localized and reversible (e.g., Ritz 1989, Anderson, 1992 and Mahnken, 1993). If farm production is stopped, or the farm is moved, the sediments will return to their previously unenriched state, often in only a few months. Moreover, the significance of these changes and their relative importance to the marine ecosystem, in general, is a matter of individual interpretation. Some people are intolerant of any change, a position that seems inconsistent with their tolerance of many things they accept on land, for example, paving of roads and parking lots. For others the economic benefits that flow from the establishment of a salmon farm far outweigh any possible negative consequences of the temporary organic, enrichment of a small area of seabed.

In the 30 years since the first salmon were produced in cages, salmon farmers have learned much about where and where not to locate farms in order to achieve good dispersion of wastes. They have also made great strides in reducing the amount of wastes produced by their fish. For example, food conversion rates now average 1.1:1 to 1.3:1 on most salmon farms vs. 1.7:1 to 2:1 some years ago. This has been achieved through improved feed digestibility and nutrient balance as well as better feeding practices, all of which have contributed to less waste per unit weight of salmon produced.

Nonetheless, critics of salmon farming champion so-called 'green' technology that would allow some of the solid wastes to be screened and collected before discharge. To do this requires either that farms be moved on land and water pumped ashore, or that impermeable 'bags', instead of net cages, are floated in the sea and through which water must then be pumped in order maintain healthy growing conditions. Both are more expensive to build and operate than cages and require the consumption of valuable energy to pump water, all so wastes that cause only minor perturbations to the marine environment can be collected. Whether this is a wise use of capital and energy seems to be a matter of individual values. Arguably, in this case, critics put insufficient value on the waste of energy or the desirability of an industry that produces a highly nutritious product and creates employment in economically vulnerable coastal communities. A less extreme position might recognize this and instead encourage the industry's own efforts to minimize problems by careful site selection and management.

J. ESCAPES

Some fish will always escape from fish cages, although the number of them can be greatly reduced by good management. Critics of salmon farming charge that these domesticated escapees threaten the genetic integrity of wild fish populations by possibly interbreeding with them. In situations where salmon are farmed that are nonendemic, such as Atlantic salmon on the Pacific Coast of N. America, critics also charge that escapees threaten native populations through possible colonization and competition. Neither charge is supported by any evidence that escapees have actually caused such harm (Alverson and Ruggerone, 1997). Instead, they seem to be based on an obsessive desire to find fault with the farmed salmon industry and an overzealous application of the 'Precautionary Principle' to hypothetical risks.

This does not mean, however, that fish farmers must not take all reasonable precautions to prevent escapes. Clearly, it is in their own interests to do so anyway. Where possible, nonreproductive stock should be used, and the development of techniques for the production of such stocks, such as triploidy, should be a priority for research. Continuous improvement is necessary in all businesses, but a zero escape standard for salmon farming is unrealistic and unnecessary.

K. DISEASE

The specter of disease, be it in animals or humans, is one of the easiest ways to alarm people, and misinformation about salmon disease has been used by critics of salmon farming for this purpose. Against salmon farming, critics have argued that there is an unacceptable risk of new diseases being introduced to regions where they did not exist before and that such diseases could then ravage wild fish populations. They have also argued that caged salmon if becoming diseased then become a reservoir of infection for wild fish. Both claims have been rejected by successive official inquiries into the salmon farming industry (e.g., EAO 1997 and PCHB 1998), a position with which most fish health experts appear to agree. However, disease is a complex and emotive subject, and it is very difficult to assure people that adequate rules and procedures are in place to protect wild stocks, especially following the recent problems in animal agriculture in Europe with BSE (Bovine Spongiform Encephalopathy) and Foot and Mouth Disease.

Against this background, salmon farmers can only respond by remaining constantly vigilant in their fish health management programs and by trusting the professionals who are trained to assess and manage the risks. In the last 10 years the overall fish health record of the industry has been good. In particular, there have been major advances in the development and application of vaccines against key salmonid diseases that have resulted in dramatic, industry-wide reduction in antibiotic use. This technology and experience is now being applied in other fish farming industries and even in hatcheries that produce juveniles for enhancement of wild fish stocks. There is never room for complacency in fish health matters, but neither should disease, or the specter of it, be used as a reason to curtail aquaculture development, or to subject it to overly burdensome regulations.

L. FISHMEAL AND OIL IN SALMON FEEDS

There are those who charge that salmon farming is ecologically wasteful because salmon feeds contain fishmeal and that the process of producing salmon therefore does not result in a net gain of fish protein for humanity. For example, a recent Environmental Defense Fund report (Goldburg and Triplett 1997) likened the farming of salmon to farming tigers, implying that they are obligate carnivores at the apex of the nutritional pyramid and intrinsically inefficient as farm animals. The same claim was repeated in a recent article published in Nature (Naylor *et al.* 2000).

There are several reasons why such a claim is not only unjustified but also misleading. First, fishmeal is produced because no one has yet found a cost-effective way to process the small, bony fish from which it is made into a form that is palatable to humans. Therefore, the implication that by using these fish for salmon feed salmon farmers are depriving needy people is false. Second, most of the fish from which fishmeal is made are forage fish, destined to be eaten by other fish anyway. Asgard *et al.* (1997) have shown that it is up to five times more efficient to catch them, convert them into fish meal, and feed them to captive salmon, than it is to leave them in the sea to be converted naturally into wild fish through the marine food chain. Therefore, in terms of net fish protein made available for people, there is actually a better return achieved by catching these fish and making them into fishmeal for use in salmon feed, than by leaving them in the sea. Third, it has now been shown that salmon will grow adequately on several protein sources other than fishmeal, including some of plant origin (Higgs *et al.* 1995 and Stickney *et al.* 1996). So the argument that salmon farming is ultimately unsustainable because there is not enough fishmeal in the world to sustain increased production is irrelevant. Although the use of alternatives to fishmeal in salmon feeds still needs to be perfected and applied throughout the industry, it seems probable that this will occur. Salmon will then be fed on diets based on the same raw materials as are presently fed to terrestrial livestock. Because farmed salmon competes in the market with these terrestrial products, it will ultimately be market demand that limits how much salmon is farmed, not the supply of raw materials to feed them.

As noted earlier, due to its high fillet yield, salmon is already competitive on a cost basis with some of the better cuts of meat and some lower yielding fish, even though such fish are cheaper to produce. A case can be made that salmon are, in fact, highly efficient farm animals (Asgard *et al.* 1997; Forster, 1999; and Forster and Hardy, 2001) and that resources invested in their production may yield a better return for humanity than the chickens, pigs, and cows on which we presently depend on for so much of our animal protein. Glib condemnations of the salmon farmers because they ‘feed fish with fish’ merely serve to betray failure by the accusers to look into this question deeply enough and hint at a regrettable bias.

M. SPACE IN COASTAL WATERS

Norway and Chile’s success in salmon farming is well known, and some of the reasons for it have been discussed above. In particular, the role of government in creating space for aquaculture in coastal waters was emphasized. For the governments of these countries, however, making decisions about the use of their coastal waters for salmon farming was quite easy. They have thousands of miles of relatively undeveloped coastline and tens of thousands of protected areas where farms can be located. Political pressure from competing users for this coastal resource was not intense.

This was not the case in other countries such as Scotland, Canada, or the USA, where attempts to site salmon farms in more crowded coastal waters have met with fierce resistance and with a battery of environmental allegations, some of which have been discussed above. In turn, this has led to government procrastination and, in some cases, unnecessarily burdensome regulation. Many other countries do not even have the option to develop an industry, because they have no sheltered coastal water at all. Yet, the governments of many of them say that they want to develop aquaculture and that there is a need for more seafood and for economic development in their coastal communities. A possible solution to this lack of space is to learn to farm fish 'offshore' in unsheltered water, out of the way of other inshore interests (Loverich and Forster, 2000).

The biggest challenge to doing this is to develop fish-containment systems that can function reliably in offshore conditions, where storms can produce large waves that will destroy conventional cages. This is not to say that farms have to be sited many miles out into open ocean. There is often plentiful space in open water near to shore, but in order to use it fish-containment structures must be able to withstand severe surface disturbances during bad weather. The potential for offshore farming is now recognized by the aquaculture industry worldwide, and there are many inventors working on containment designs. Concepts range from submersible, rigid framed structures to flexible, floating support collars that ride rather than resist the waves. Examples of two designs that appear to have special potential are shown in Figures 2 and 3.

Salmon farmers in several countries have been evaluating various offshore cage models for several years. Particular effort has been made in Ireland and New Brunswick, Canada, where the political will to expand the salmon farming industry is strong, but access to abundant, sheltered, coastal sites is limited. These efforts have shown that the idea is feasible and that salmon perform very well in open sea conditions, where water quality is often better and more stable than inshore. This success suggests that marine fish farming can now be developed in parts of the world where, due to insufficient sheltered water, this was not possible before. Because this includes many tropical and subtropical countries, the prospect of farming a number of warm water marine fish therefore is greatly enhanced. An

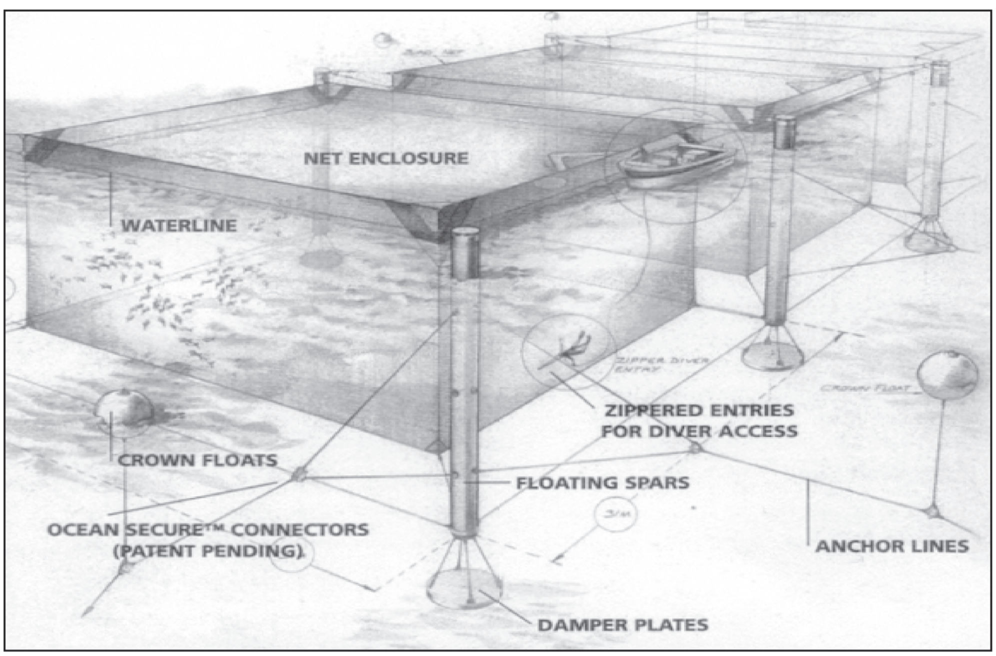

FIGURE 2. Example of a design of offshore cage known as Ocean Sparâ. Structural components at the surface have been minimized so the cage is 'transparent' to waves.

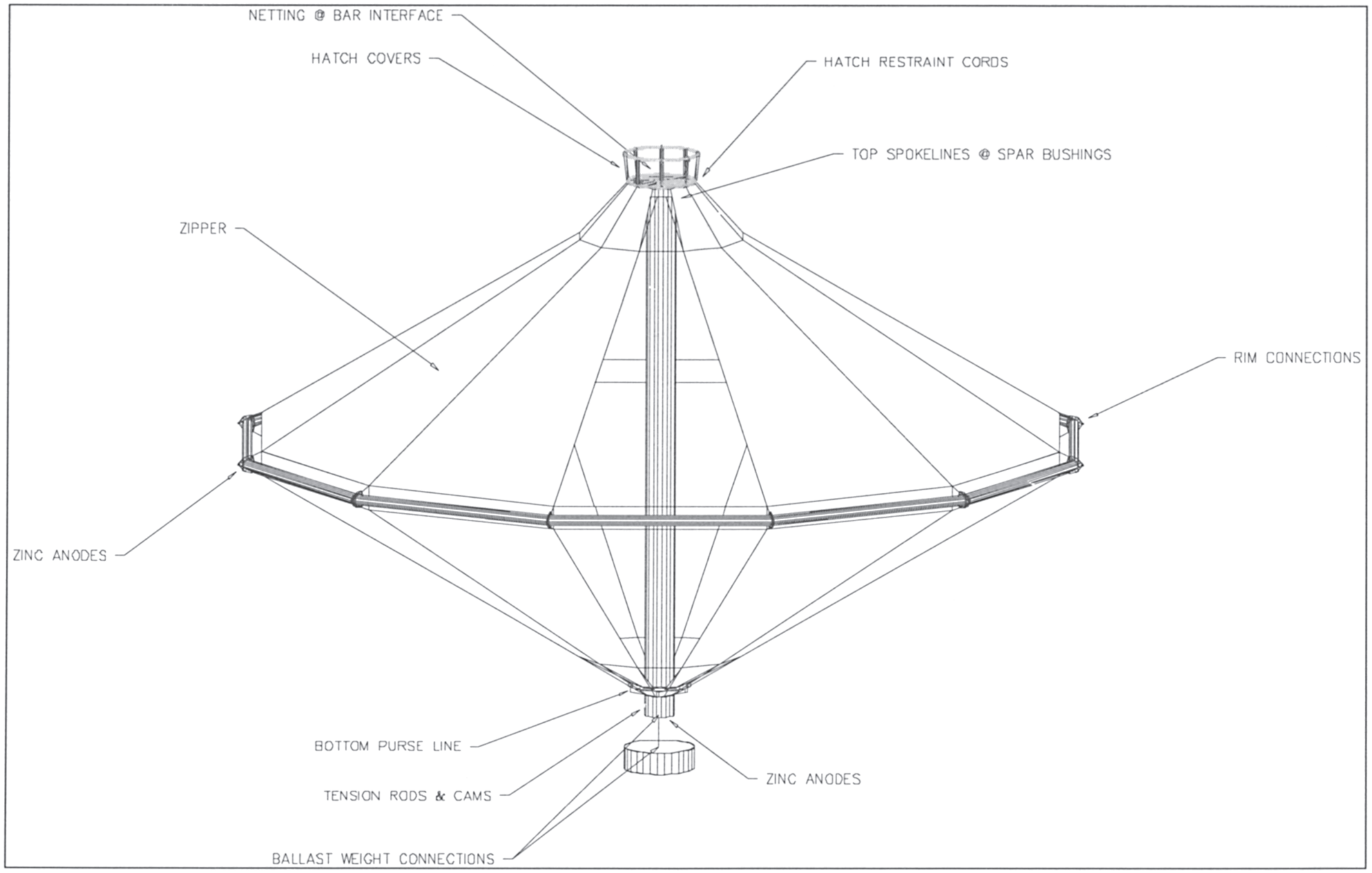

FIGURE 3. Example of an offshore cage design known as Sea Stationâ. This cage can be easily submerged by flooding the central float. Expelling the water with pressurized air refloats it.

example of this is the farming of the pacific threadfin *Polydactylus sexfilis* in Hawaii (Farewell and Ostrowski, 2001). At the same time, aquaculture expansion can now be contemplated in countries where farming already occurs, but where areas of available, sheltered water are limited. It would probably not be overstating the case to say that the advent of open sea cages has transformed the prospects for marine aquaculture worldwide.

III. CONCLUSION

In grappling with the challenge of reducing costs to make their product affordable and in bearing the brunt of some highly misleading environmentalist agitation, salmon farmers have pointed the way for new aquaculture industries to come. Farmed Atlantic salmon is now widely available and appreciated in N. America and Europe and increasingly in demand in Asia. Its 'mass-marketability' has been proven. It has met consumers' expectations of value and demonstrated that aquaculture really can bridge the forecast gap between seafood supply and demand.

Salmon farmers have made, and continue to make, major improvements in the way they operate their farms, as the continuing decline in the cost of production shows. Many of these improvements, such as the development of vaccines against key salmon diseases and the application of codes of best management practices, have also addressed the concerns of industry critics. Solutions are not perfect, or will they ever be, and some who criticize will never be convinced that this is a good industry. However, neither have critics made a case that the expansion of salmon farming, or farming of other species in cages, will lead to irreparable harm and that it should be halted. In fact, the evidence points to the contrary. Environmental degradation, when it has occurred, is never permanent and is usually susceptible to management changes. Moreover, positive effects, such as the potential for aquaculture to ease commercial fishing pressure on depleted wild stocks, or for cage structures to provide habitat for a wide variety of marine creatures have been documented inadequately. Consequently, they are rarely taken into account in evaluations of the industry. Yet, they should be because they are part of what the industry contributes in exchange for its use of a public resource.

By 2010, it is forecast that world farmed salmon production will increase to two million tons per year. Some of this will be grown offshore in open sea cages; some will be grown in sheltered waters along ever more remote coastlines using present day equipment, especially in Chile. At the same time the industry will continue to set new standards for efficiency and cost competitiveness. In so doing, it will also continue to point the way for the development of other large-scale, marine farming industries to follow, providing they too focus on the needs and demands of the mass market and seek to meet its expectations of value.

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