Economics of
Open Ocean Aquaculture
Economics of Longline Technology in Offshore and Drift-Ice Environments: How to Make or Lose Money?

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Abstract

The expansion of marine aquaculture appears to be heading offshore, into the open ocean environment! Offshore longline culture operations are confronted with longer fetch, stronger winds, choppier seas and, additionally in some latitudes, to winter drift-ice conditions, which thus limit the number of available work days. For many northern temperate bivalves, two to five year production cycles are not uncommon. Submerged longline technologies are thus preferred for these environmental conditions. However, how do the advantages of unlimited space compare to smaller operations confined to protected nearshore embayments? The daily operations at offshore sites require extra travel time for human and material ressources, for maintenance and harvesting. Ultimately, it is the type of ship and its working capacity that become the factors that limit production or affect its cost. Although we expect higher production levels to bring in more revenues, once the volume of production exceeds a certain level, there is no more economy of scale, and profitability levels off. We examine the economics of duplication at different scales of production, and suggest alternative technologies that can be applied in order to reach new levels of economies of scale.
Introduction

No one should get involved in shellfish production if they don't plan on making a profit. How many would not scoff at such an obvious statement! Yet, it is amazing how many operations don’t really sit down to analyse how they will control the outflow of money once they’re in production mode.

Just consider the high capital expenditure and start-up costs as the volume of production is increased. Before any substantial inflow of revenue, there is a need for sufficient working capital for the first three to five years of operation. Then, as more product is marketed, the necessary revenues are created from the mariculture production to stay afloat. Some ongoing operations may even be making a profit! Since the market decides on price structure, the likely choice for greater profit creation is to expand.

There are two ways to make a profit. The obvious one is to increase the volume output to increase revenues. This can be achieved by duplicating the scale of production several-fold through an increase in the number of boats, manpower and longlines at sea. The other more challenging way to make a profit, without too much additional investment, is to reduce operating expenses and decrease the cost per pound. This requires a clear understanding of the limiting factors governing the calendar of operations, such as the working capacity of the boats and equipment in use, the potential yield per longline, the number of available days to accomplish each production activity and the flow of manpower per activity. A slight improvement in any of these areas may produce substantial benefits, especially as the scale of production increases.

The best strategy, however, is to combine both methods to attain economies of scale. This occurs when the efficiency of a unit increases, as for example, in the case of a longline producing 3,000 lbs of mussels instead of 2,200 lbs, simply by increasing the vertical length of socks from 3 to 4 m; or by increasing the working capacity of a boat by mechanizing an operation or reducing the handling time between longlines.
Whatever the mariculture production, economies of scale can be achieved through comprehensive analyses of the operation.

Objectives

In this study, we examine the economics of duplication at different scales of production. Specifically, we look at economies of scale when using submerged longline techniques for mussel culture in offshore environments.

We also examine which factors most influence the cost of production, in order to determine whether the expanded mussel production will make or lose money!

Description of mussel production parameters and activities

The location of the study area is in Baie des Chaleurs, just on latitude 48 West and longitude 65 North, along the Quebec coast of the Gaspé Peninsula in 25 m of water. The peculiarity of this temperate region is that it is inaccessible between December and April due to drift-ice conditions and frozen harbours. During the rest of the year, gale force winds are not uncommon, so the producer must work within a 31-week calendar year to produce and market the mussels.

The province of Quebec produces mussels along three latitudinal clines, so that the production cycle increases with latitude, from two years in the Magdalen Islands to four years on the Lower North Shore. All lagoons and enclosed bays are subject to 1-2 meters of winter ice and are accessible by truck or snowmobile during winter harvest.

This mussel producer is looking at a conservative yet realistic three year production cycle between the time the collectors are installed and the last mussels are harvested off the socks, at about 50-55 mm in length. There are no offshore winter operations, no visits on site, and all surface buoys and markers must be removed, and the lines must be submerged to at least 10 meters depth to avoid being tangled in winter drift ice. The longlines remain unavailable for at least 20 weeks of the year.
The selection of single backbone submerged longlines is based on the type of boats available in most coastal fishing harbours. The lines are 150 meters long between the anchors, and 133 vertical mussel socks may be attached on each longline. Since the longlines are submerged 10 m below surface year-round to avoid second-set of spat and winter drift-ice, there is an unusable segment of about 12 meters, after the corner buoy, at each extremity of the longline where no mussel socks may be attached (see Bonardelli 1996).

The boats may be made of wood, but fiberglass is preferred because of the ease of cleaning, its handling among the longlines and its greater resistance to ice during the first freezing in the harbours. The length of the boats are 10-12 m, and the deck space is at least 3 by 5 meters, sufficient to support a one-ton crane and five to six large tote boxes. One side of the boat is geared with a hydraulic hauler near the cabin and a star-wheel near the stern (Figure 1).

![Figure 1.](image)

**Production volume 1997-2004**

The projected production is to gradually attain a commercial volume of 1.25 million lbs of cultured blue
mussels. This requires some 55,000 mussel socks to be installed annually from the fourth year on (Figure 2). Since this is a wise company, it realizes that it must increase production levels in parallel with the acquisition of a trained labour force and of the appropriate types of boats and longlines. Thus, the number of socks to install will increase gradually from 10,000 to 18,000 to 37,000 socks in the first three years of its start-up phase.

![Graph showing harvest volume and socks made over years](image)

*Figure 2.*

This strategy allows for management to also adapt to the initial shock of harvesting commercial mussels while volumes are still relatively small and make a move on the outside market. The latter not necessarily so evident in a competitive industry. Thus, by the second and third year of operation, harvest volumes will increase respectively from 60,000 to 250,000, to reach about 0.9 to 1.2 million lbs in the fifth and sixth year. By the seventh year, the company reaches a stable production level.

This theoretical development plan is the starting point for establishing the technical, biological and financial parameters of the operation.

**Production parameters (true & tried)**

The scale of production, the production cycle and the environmental conditions at the proposed culture site, will
directly influence the type of equipment required and the complexity of each production activity. Site-specific conditions will determine the time frame that can be allotted within each activity.

In this study, the submerged longline can support 133 socks (3 m long) on 120 m single backbone. The distance between the anchors of the dynamic longline in 25 m water depth is about 150 m, such that each series consists of 10 longlines attached end to end for a total distance of 900 m. Thus, one series requires a string of eleven 2 Tm cement blocks.

The production cycle (sale of commercial size mussels from beginning to end of a cycle) is completed in three years, and it takes seven years to attain a stable production volume of 1.25 M. lbs. Because of winter ice, only 31 weeks are available to market the mussels. The maximum weekly volume is stabilized at 42,000 lbs.

The net market yield for a 3 m (10 ft) sock is 22.5 lb (10 kg)/sock. The price paid for this net product is established after the mussels have undergone several treatments by the wholesale processor. Specifically, the mussels are declumped and graded, then debyssed at the plant and bagged, which includes about 5% loss of mass for byssus and breakage that is removed at the inspection conveyor. The mass is further reduced anywhere from 5-12% for water loss during packaging and shipment to the buyer. This percentage fluctuates in relation to the reproductive condition of the mussels.

The additional percentage loss may seem elevated, but herein lies the onus on the producer to manage the density and
growth of mussels on the socks to minimize the amount of wastage that the processor must handle. Generally, the wharf price paid to the producer is determined from the net paid market yield.

**Production activities and annual timetable**

The model of the economic analysis calculates the manpower required on the basis of the amount of time it takes to complete each of the production activities. Managerial experience establishes the daily working capacity for each production activity. As the volume of production increases, the number of work-days required per activity is recalculated within the allotted time frame (Table 1). The same method is used to determine the number of days that a boat or piece of machinery will operate based on their daily production capacity. This is important so as to know when another crew or another work boat must be added to accomplish the task as volume increases.

**Table 1: Sequence of production activities of a mussel culture operation within an annual timetable of 31 weeks of operation on land and sea.**

<table>
<thead>
<tr>
<th>May</th>
<th>June</th>
<th>July-September</th>
<th>October</th>
<th>November</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floatation of</td>
<td>Spat collection</td>
<td>Assembly of new lines</td>
<td>Spat harvest</td>
<td>Sinking of longlines for</td>
</tr>
<tr>
<td>submerged</td>
<td></td>
<td>and upkeep of stock</td>
<td>and socking</td>
<td>winter</td>
</tr>
<tr>
<td>longlines</td>
<td></td>
<td></td>
<td></td>
<td>25 d (5 wk)</td>
</tr>
<tr>
<td>25 d (5 wk)</td>
<td></td>
<td>10 d (2 wk)</td>
<td>70 d (12 wk+2 wk off)</td>
<td>25 d (5 wk)</td>
</tr>
<tr>
<td>Identify and</td>
<td>Install collectors</td>
<td>Upkeep of production</td>
<td>Declump and</td>
<td>Remove all surface buoys</td>
</tr>
<tr>
<td>float lines</td>
<td>collectors</td>
<td>in progress and spat</td>
<td>grade spat</td>
<td></td>
</tr>
<tr>
<td>Add buoys to</td>
<td>Minimize</td>
<td>Assemble, prepare and</td>
<td>Install mussel</td>
<td>Move buoys to backbone</td>
</tr>
<tr>
<td>backbone</td>
<td>flotation</td>
<td>install new longlines</td>
<td>socks at sea</td>
<td></td>
</tr>
<tr>
<td>Add surface</td>
<td>Maintain records</td>
<td>Maintain close watch</td>
<td>Add correct</td>
<td>Monitor sock densities to</td>
</tr>
<tr>
<td>buoys to</td>
<td>of mussel</td>
<td>on spat collector lines</td>
<td>floatation for</td>
<td>upkeep stock assessment</td>
</tr>
<tr>
<td>longlines for</td>
<td>growth</td>
<td>and remove surface</td>
<td>longline tension</td>
<td></td>
</tr>
<tr>
<td>identification</td>
<td></td>
<td>debris hazards</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

These activities are based on a 5 day work week.

For a number of reasons other than drift-ice conditions in eastern Canada, a company may have to limit the time allotted to accomplish its production due to biological (fouling, spat transfer), environmental (temperature stress, storms or
hurricanes) or technical (equipment delays) reasons. A successful operation should have the necessary planning tools to determine where, when and how it is to proceed.

**Assumptions of Economic Analysis**

We compared a small-scale commercial mussel operation that produces 450,000 lbs annually, to a production level three times the size, that will produce 1.25 million lbs. The expansion of the mussel farm looks interesting for the increase in volume of sales, but will it make money!

The small operation which amounts to harvesting a little over 14,500 lbs per week, will annually install over 19,000 socks suspended onto 143 longlines, using two boats full time. The large operation plans to harvest over 42,000 lbs per week by suspending over 55,000 socks on 417 longlines, which will require eight boats working at peak capacity in some periods of the year.

**Objectives of the economic analysis**

We want to show if a mussel production using the single backbone submerged longline method is even more economical at greater production levels. Firstly, we analyse the production level for the projected 1.25 M. lbs operation, specifically:

- the type of investments & costs
- the working capital required
- the salaries & administrative costs

Once the analysis is completed for the 1.25 million lbs operation, we compare the cost / lb between the two production levels.

**Cost of submerged longlines for 1.25 million lbs**

After a period of seven years, some 1,400 lines are installed at a cost of $600 cdn each. The longlines, from anchor to anchor are made of 18 mm (3/4 inch) polyrope, include the installation of 2 mT cement blocks for anchors and are buoyed at each corner with 110 lbs floatation. Until a stable production
level is reached, there is a progressive addition up to 72,000 plastic 30 cm compensation buoys (65/backbone at commercial harvest size). The total investment cost is $1.2 million.

**Investments for boats**

The fiberglass hull boats may range from 10 to 13 m and and operate with a three-person crew, women not excluded. The work boat must handle itself in open ocean conditions and travel at least 9 knots, be equipped with a crane and hydraulic hauler and starwheels for manipulation on the longlines. The individual cost is $100,000 ea.

The daily working capacity of boats depends on the type of operation and season. Production activities include floating lines, installing mussel collectors and socks, adjusting line tension and routine inspections. They may also be fitted to harvest mussels and sink lines before winter. The rate of purchase in the number of required boats depends on the selected level of annual production (Table 2). Until a boat's working capacity is surpassed, and in situations where a boat is only needed for two weeks, renting during peak periods should not be excluded! The total cost for eight boats after seven years is $800,000.

<table>
<thead>
<tr>
<th>Year</th>
<th>1997</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase</td>
<td>2</td>
<td>-</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cumulative</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

**Table 2: Increase in number of boats purchased over a seven-year period.**

**Working capital requirements**

Based on a three-year production cycle and the gradual increase in sales revenue, the investment needed to support the start-up costs of mussel culture for the first five years, as the volume of production is built up, amounts to $350,000.
Table 3: Working capital requirements for the first five years of production.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Working capital</td>
<td>80 K</td>
<td>90 K</td>
<td>30 K</td>
<td>50 K</td>
<td>100 K</td>
<td>0</td>
</tr>
</tbody>
</table>

In the sixth year of production, sufficient revenue becomes available to support operating expenses.

Production activities and salaries

The daily capacity of a unit of workers within a production activity determines the total time it will take (cost) to complete an operation. Thus, we estimated the salary requirements until a stable level of production is reached in 2004, and compare this to the level for 1998 (Table 4). The total annual salaries reach $200,000 by 2003.

Table 4: Comparison of manpower requirements for the schedule of various production activities between 1998, when no harvesting occurs, and 2004, when production levels are stable and harvesting is continual.

<table>
<thead>
<tr>
<th>Production activity</th>
<th>May Floating of submerged longlines</th>
<th>June Spat collection</th>
<th>July-September Assembly of new lines &amp; upkeep</th>
<th>October Spat harvest &amp; socking</th>
<th>November Sinking of longlines for winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schedule</td>
<td>25 d (5 wk)</td>
<td>10 d (2 wk)</td>
<td>70 d (14 wk)</td>
<td>25 d (5 wk)</td>
<td>25 d (5 wk)</td>
</tr>
<tr>
<td>1998</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>2003</td>
<td>15</td>
<td>6</td>
<td>3</td>
<td>21</td>
<td>15</td>
</tr>
<tr>
<td>Harvest</td>
<td>6</td>
<td>6</td>
<td>3</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>21</td>
<td>12</td>
<td>9</td>
<td>27</td>
<td>21</td>
</tr>
</tbody>
</table>
Fixed annual expenses (before tax)

The administrative costs, including the maintenance (boats, longlines, lease fees) and other costs are $175,000

Salaries $200,000
Total fixed expenses $375,000

Summary of costs after 7 yrs

Longlines & buoys 1,200,000
Boats 800,000
$2 million

Working capital to support start-up costs $350,000

Economic Outlook for 1.25 M lbs

In terms of the cost of production invested and the volume produced after seven years, whence there are no new investments, annual revenues of $700,000 (wharf price of $0.55/lb based on net volume) and an annual operating cost of $375,000; the resulting operating cost is $0.30/lb.

However, at a wharf price of $0.55/lb, there is only $0.25/lb left over to cover all the investments!

Do we make or lose money?

If an investor is expecting a 14% minimum return on his original investment of $2.35 million, this project expansion is clearly not profitable. The following reasons support the investors decision:

After waiting for a period of seven years to reach a stable production level of 1.25 million lbs, he must sell the company at $3.3 million (14% Internal Rate of Return), which is highly unlikely, or

Not sell, and wait 10 more years to realise a return on investment of 10% (instead of 14%)! Even then, this scenario assumes no re-investment.
Comparison with a 450,000 lb production (1/3 scale)

In terms of the cost of production invested to reach a stable volume, after a period of seven years only two boats are required at full capacity. Despite a relatively small annual revenue of $150,000, there is no difference in the operating costs of $0.30/lb.

Thus, although there are greater revenues in the proposed expansion, there is no economic advantage to increasing the volume of production.

Can we attain economies of scale?

This study demonstrates that there is no economy of scale between a 450,000 lbs production level using two boats, and a larger operation producing three times the volume (1.25 million lbs), which requires four times more boats (8). The discrepancy in number of boats is related to increased activity during peak periods, because of the fixed calendar of activities within 31 weeks. Rentals (1-2) could replace purchases during these periods.

Thus, if the same techniques are used to expand production from 450,000 to 1.25 million lbs, there is no advantage in duplicating the levels of production.

Are there alternative strategies?

Four critical factors affect the production costs:

1. Boat production capacity (the number of lines floated or units of socks attached per day)
2. Longline technology and its production capacity (the type and length of longline determines the number of socks that can be attached, which can affect the yield or volume produced
3. Labour (manpower performance on boats and on land for each production activity may affect costs, but efficiency is also gained as more days are spent doing the same task)
4. Production cycle (the turn-over rate of the longlines is critical and related to both the growth rate of the mussels and the period available to harvest lines). If there is no possible way to change the duration of the production cycle, through better management and husbandry, then it is the production capacity of each activity that must increase. Either, it will be a short lived experience for the producer, or he considers alternative technologies to become more efficient.

A look at alternative strategies for offshore production systems!

There is little doubt that a long production cycle, combined with a shortened work season in northern climates makes for difficult operating conditions, but there are alternative strategies that can be explored. The objective is to increase production capacity and reduce operating costs. This can be achieved in several ways:

More socking units per longline

By increasing the length of the longline, more socks or droppers can be attached. The effect will be to reduce the overall number of longlines and the number of times a boat must switch lines in a day.

By adapting the double longline system, the yield per longline system can be tripled, but this requires greater capacity, more efficient (and more expensive $) workboats. This scale-up is only efficient beyond a certain production level, when the number of lines becomes too complex to manage.

Efficient offshore harvesting vessels

By investing in faster more efficient boats, travel time and labour costs may be greatly reduced, allotting more time to conduct actual production activities. This is critical for distant offshore sites.
By adapting integrated mechanised boats to reduce the number of manpower per boat and increase efficiency at sea, economies of scale can be achieved

**....or much lower wage rates!!**

- There is no price for qualified mariculture technicians and responsible captains that look after the expensive boats and longlines, that take care of the employees’ safety and that have the dedication and know-how to manage the production. The producer must balance the wage-rate game with his projected goals for solid growth in the company.

**Post script...**

We applied the same assumptions as in this study to sites with shorter production cycles (2 yrs). The project is profitable!

Just imagine the results of this model with a two year cycle, if the production capacity is also increased through more efficient longline technologies and greater vessel capacity!

**Discussion**

The producer must properly evaluate the cost structure of his present operation. If he or she has the right tools to conduct some sensitivity analyses of the proposed modifications, be they technical or financial, then the decision-making process will be based on a solid framework, instead of trial and error judgment.

Serious consideration must be made to determine a comfortable level of expansion that meets the production capacity of his equipment and labour force. There comes a level of production where the sole proprietorship mariculture model falls apart — there just are not enough days in the week to accomplish the operations without trustworthy, reliable partners.
Practical Experiences in Off-Shore Cage Rearing, the Good, the Bad and the Ugly

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The off-shore cage installations I refer to are the large flexible Dunlop and Bridgestone rubber cages that are in use in Ireland on a number of sites. At the last count there were circa 30 in operation, up to five miles out to sea. These are operating in wave action of up to 15 metres in height, and currents of 3-4 knots.

Open ocean aquaculture, is the rearing of fish in open hostile environmental conditions, in deep waters, with little to no protection from wind or wave action. These sites may exist only a few metres from the shoreline or conversely be many miles out to sea. Depending upon where the site is located, specialised equipment must be deployed with the confidence of not only allowing fish to grow, but also survive the conditions it will have to endure.

Locating an offshore site involves much research, integrating scientific, technological, biological, socio-economics and legislative issues, some of which are easy to find, and some which will cost money to find. The decision to build an offshore installation requires not only finance but also a dedicated team, the right equipment and the correct biological parameters that dictate all profits .... growth and performance of the stock.

The first commercial Salmon farm in Ireland was installed in a protected inshore site on the west coast in 1979. It was constructed of square wooden cages, held buoyant in the water with large blocks of polystyrene nailed, strapped or glued to the wooden beams. It became apparent quite soon that not only would the fish grow and earn money, but the choice of location would be of paramount importance as the structure and design of the proposed cages. From this initial trial period, in a space
of three years at least 10 salmonid farms established themselves in these inner bays and an industry was born. In conjunction with this new development was the designing of new cages and associated ancillary equipment, which all portrayed the industry in a good light, and created employment and spin-off industries. The fish farmers and feed companies were all getting a better biological handle on all aspects of the life-cycle of the Salmon, and production methodology was getting better all the time.

However, as more inshore sites were used up, and the farms getting bigger, there were inevitable problems, first with diseases and then over-crowding of each bay. This occurred circa 1985-1986, and it was felt by both the relevant governmental bodies and the salmon growers themselves that it was time to examine the options. From this the concept of growing salmon in offshore installations was born.

Currently the closest offshore site is located at the foot of a cliff half a mile from the shore, and the farthest is five miles out to sea.

In order for us to develop these type of farms we had to examine a number of parameters, each in it’s own way as important as the other. Due to the rapid developments in technology and cage design, especially the flexible cage, there was a way to construct a site, enable it to withstand the atrocious weather conditions it will have to endure and yet still be workable, accessible, and enable fish to perform.

Fish farming was now a big business, producing a quality product, but margins were getting tight. We had to look at bigger and better cages, and a way to develop them. Consequently we decided to go farther from the shore, into completely exposed areas and try to grow the fish. As we did this many types of cage designs were looked at and experimented with, from steel to plastic and of course the flexible rubber cage of varying designs. All these cages had to perform in strong currents, high waves (10-15 metres), prevailing winds and still allow a platform to grow fish and work on. This was or is no easy task, as these cages are in
extreme locations subject to the full rigours of the environment at all times with little respite.

Accordingly, to establish one of these farms, it costs a large amount of money in capital equipment and running costs. The site costs a lot to buy, maintain and service, with the ancillary equipment being specialised and expensive. The actual running costs of a farm offshore are daunting as compared to that of a successful inshore site, and one must always bear in mind the fluctuating price of fish in domestic and international markets, as this will also have a effect on costs and profit margins.

Whilst the costs are of major consideration, so too is the cage type to be deployed and the numbers of fish it can sustain. Will the numbers of fish realise profits, and does it take into account for higher than previously experienced mortalities?

Therefore setting up an offshore site is advantageous, as it:

1) Ensures better growing conditions, with deeper waters, strong currents and a vast water exchange, thus allowing for much improved biological growing conditions.
2) It’s much more environmentally conscious, as being distant from the shore means out of sight, out of mind. Pollution issues are much more diluted in every way, and the marine fauna and flora are not impeded or adversely impacted in any detrimental manner.
3) Once assembled and moored correctly, the maintenance of these cages and the moorings are relatively cheap, and little needs to be done to keep them this way.
4) More space=more fish=bigger profit potential.

These type of offshore cage systems are now in use quite successfully in Ireland, and although inshore sites are proven, in the last 3-5 years the bigger sites have more than proved themselves and farms are generating good profits.

So just what is required in setting up a farm like this?

Whilst licensing and lack of adequate inshore sites swayed us to go further out to grow our fish, but also, to
examine deeper more extreme potential sites around the coast. In addition to this we had to look at the straight practicabilities of local and experienced staff, an adequate infrastructure, and the help available in grant aid from relevant governmental agencies. Certain governmental agencies do provide financial aid in the form of grants to aquaculture industries setting up in peripheral areas, but as it would have it, many of the offshore sites had to be funded by themselves, as the huge initial start up costs may not qualify for grant aid! This is really just an indication of the huge financial resources one must be able to secure in order to start.

Accordingly, starting a site will entail some serious decisions. These include: physical location, navigational and fishermen's rights

- Prevailing winds and tidal conditions
- Water depth and quality
- Bottom type for moorings
- Wave action-strength and direction
- Accessibility by land (piers) and sea
- Availability of roads, infrastructure, ice-plants, etc
- Staff qualifications and availability/experience
- Disease status — any wild stocks/runs or rivers
- Site potential for further development
- P.R. issues/environmental issues
- Health and safety regulations and procedures
- Grant-aid and tax incentives and do bear in mind that whilst we cannot control the weather, we can prevent or limit its effects on the stock and equipment. The price of the fish however may not be in our hands, so each farm will have to factor this into its stock numbers, and allow a buffer zone for production.

Having looked at the practical/physical aspects of start up, let's examine everybody's favorite ... Financial considerations.

The cage design having been decided ... the cost of them.

- The costs of nets, ropes, chains, moorings, etc.
• The ancillary equipment ... boats, trucks, harvesting/grading gear
• Staff
• Feeds
• Medication/vaccines
• Maintenance/repairs
• Licenses/P.R. and legal costs
• Smolt costs (if not supplied in-house)
• Net-washing and repair facilities
• Insurance fees

Thus it’s of paramount importance to regulate all monies, and control spending on a week by week basis ... the reason for this is that if things will go wrong, they will! And it’s costly when you’re operating at this level.

**Performance of Off-Shore Cages**

The main feature must be its ability to survive the conditions its deployed in, and allow for the fish to grow. This may seem an obvious statement, but if it isn’t achieved, not only will profits be down, but one is only throwing money away!

No matter what system one chooses, it must be durable, flexible, sturdy, non-corroding, hardy and workable/assessable to work on. The most important feature of the cages will be how they are moored. Care and consideration should be taken when mooring your cages, as the weather takes no prisoners, and I have been in the unfortunate position of seeing cages break free, and travel their own way, with valuable stock! We would regularly work on these cages in storm force 6-7. Whilst the cage manufacturers may have their own preferred systems for moorings, this will be dictated by a number of features:

• Sediment type
• Previous mooring experience
• Average weather conditions
• Actual Type of moorings to be used/cost
• The equipment available to set the moorings
• The depth of water
Again I must reiterate ... the moorings and how they are set will dictate whether or not your cages and ultimately, your stock, survive to fruition. It’s worth spending decent money on them, and you’ll get a good nights sleep knowing your cages are still there in the morning! This may seem a glib comment, but our experiences have left us this way, and it happens on a regular basis throughout the European industry.

Whilst there are a number of different types of anchoring types, such as blocks of specified weights, metal anchors, drill type anchors, helix anchors and tension anchors, they all have to fulfill the same role, and that’s to keep the tension and stability/structure of the cages in all weather conditions. If they can’t or don’t do it, it’s a disaster waiting to happen, and it will!

There are a number of features I would like to comment on with regards to the actual running of these cages. I am referring to the type of cage we in Ireland helped to pioneer for salmon farming. These are flexible rubber Dunlop and Bridgestone cages with four sides, with 15 m sides, six sided or hexagons with 16 m sides and the biggest form, the eight sided or octagon cage with sides of 16.5 m or a circumference of 132 m, with nets ranging in depth from 15-25 m, or circa 13,500 m in capacity. This is probably the most common type we use, and run at a stocking density of 15-20 kg/m, which enable us to harvest circa 250-300 tonnes per octagonal. They are moored in depths of 3,040 metres, with a combination of one tonne blocks and one tonne anchors at 16 per cage with 32 mm braided rope and 2.5 inch studded chain. The stanchions range in height from 1 m to 4 m on the surface tubes, and these hold the net and bird net in place taking the strain at all times.

We stock them with 150,000 40-60 gram smolts in March/April, delivering them by helicopter. Some farms then either move the cage to a inner bay in October, or thin out the cage, down to 80-90,000 fish for on-growing, from September onwards.

Disease/Treatments

Due to the enormous working surface area of these cages, monitoring of the stock must be of paramount importance, and
a good observant biologist must be alert at all times. Daily vigilance of swimming and feeding behaviour will alert a good manager to a pending problem in the stock, which will have to be acted upon due to the large numbers involved.

Aside from disease diagnostic skills and identification, the actual physical aspect of treating these cages is enormous. Any viruses or bacterium can only be treated orally, incorporating the medicines in the feed. This of course poses it's own problems.

- Are all the fish getting the food/medication mix
- Is the dominance factor preventing even feeding
- Are the stock actually feeding in the first phase
- Is the antibiotic compatible with the feed
- The costs incurred in mixing and purchasing the medicines
- The wastage, and any detrimental effects on the substrata

These are only some of the considerations involved in disease/treatment area, but the key is to be vigilant at all times, and the golden rule is what appears on the surface, multiply it by three, and that's what happening in the depths of the cage.

The second method of treatment is by enclosure or bath method. This is near impossible in the large cages and is dependent on calm weather conditions. However we do use this method in the square cages for lice treatments, but with current legislation in progress, we are now experimenting with oral treatments, which are making things much easier, and we are having good success.

Bath treatments are not as successful due to:

- It produces high levels of stress in the stock
- Water volumetric calculations factors may be and are hard to get exact
- It is expensive and labour intensive
- The treatment may be ineffective
- Its hard to monitor the results
• 02 levels drop quickly and expensive oxygenation systems need to be used

Accordingly, the best method of treatment is prevention, and this can be achieved only by strict on-site vigilance, by all staff, at all times.

**Feeding**

It requires specific equipment to feed these large cages, due to the surface area and numbers of fish involved per cage. It also requires specialized boats to carry out this task. The most common method is by air/water cannon mounted on platforms in the boats. These machines are relatively cheap and easy to operate. Constant care and vigilance are required when feeding so as not to waste any food due to the prices, and not overfeed or more importantly underfeed the cage, as this achieves nothing either, and in fact the fish will damage themselves in the ensuing melee to get feed.

One must be careful and observe the fish in there feeding behaviour, as this will be the first indication of any problem in the stock. The amount of feed used should also be carefully monitored, as any wastage will be literally money thrown away, and we have achieved FCRs of 1:1.1 on some of these offshore sites. We have been able to monitor this using biomass scanners and end of harvest results.

**Diving**

Due to the nature of these locations and the need to know what’s happening with the stock at all times, the requirement for divers has increased dramatically. This is due to the need for mooring work and mort removal as well as general cage and stock maintenance. The need for trained in-house divers is vital and safety regulations have changed in order to take this into account on all fish farming installations. Having a diver on site at all times is necessary from net changes through to mooring work.
Harvesting

Harvesting, while a most integral part of the operation, is expensive and labour intensive. Again, specialized equipment is required and this isn’t cheap.

Large rafts, vacuum pumps and cranes are required either attached to boats or on separate rafts. Most harvests are bled and the bloodwater is treated at sea, so as the transmission of disease is kept to a minimum. The average harvest would be about 20-30 tonnes per day and this is iced on site, and bought directly to the packing plant, and accordingly onto the European market within 24 hours.

Ancillary Equipment

As the sites are in exposed areas or rough areas, the need for strong reliable and economic equipment is centre to the operation. At sea there should be working boats (half-decker type or plastic type), a boat with towing/crane and deck space facilities, sturdy rafts capable of large tonnage and possibly a barge for food storage.

At the land base, net washing and repair facilities, bin storage and ensiler space will be required. Offices, etc. may also be located here. These all take up space and the relative infrastructure will need to be there for them.

Legislation

This is a distinct parameter different in each country, and is often linked to the environmental aspect of current laws. Whilst it is in the fish farms best interest to have the cleanest and purest waters possible, it may be hard to access them or get a license to operate in these areas.

The problem we were facing in Ireland was an over population of inshore sites and not enough money to go offshore. As we developed these sites we were granted alternative fallowing sites, so as to break the up the longevity of production and any detrimental effects it may have on the bottom fauna and flora. So we now have a situation where
some farms put there smolts into the offshore sites in March/ April and bring them back into the inshore sites in October, for controlled growth. This has resulted in many legal difficulties and delays due to the fact that the laws hadn’t changed so as to keep up with the fast pace of development. At this particular moment, a new aquaculture bill is going through government, as many of the related laws went back to 1959 acts. This may not seem to be applicable to some of you, but if you are to develop, it’s good that the legislation is prepared to adapt as is required as well. We have experienced delays in getting licenses, and if you are waiting for grant aid, it certainly can stifle you.

Accordingly, many new insertions incorporated into these acts will be referring to specific environmental aspects, such as proximity to the shore, pollution issues and the aesthetic aspect of site location. We have also had to tighten up on net quality, so as to prevent escapees, due to storm damage, which have caused great consternation and debate with angling bodies.

Conclusion

Salmon farming is a profitable business, carried out in a number of countries. There has been tremendous strides forward in all areas of biological and technological related areas, from better faster growing smolts to sturdy equipment able to work in the most adverse weather conditions. We are now able to venture farther out to sea, with the better, more advanced gear available, and the enhanced knowledge of new species, thereby allowing a diverse spread of different species to be grown. We (the industry), have proved that offshore cage farming is feasible, profitable and sustainable. There is new equipment being tried, developed and tested all the time, thus providing a range of options to any prospective buyers/setup situations.

Finally, to explain my chosen title,

The good – Well, that’s easy. Its employment a challenge every day and a new industry worth developing.
The bad – This is the downside, working in atrocious weather, the risk financially of locating and operating in this environment, and the sheer logistics of it all.

The ugly – Having to try on a consistent basis to beat all the odds on a day-by-day basis.

However, it can and is successful, but be under no illusions, offshore cage farming is costly in the initial phases and it has to be done properly and economically, and there are experienced people out there to avail of.

The potential is as yet untapped though, and with a world attitude swinging towards the healthy perception of fish in diets, there is plenty of opportunity.