Longline Shellfish Culture in Exposed and Drift-ice Environments

John C. Boon-Lei, Ph.D.  
Marine Aquaculture Research Unit  
McGill University  
Montreal, Quebec, Canada

Abstract

The development of successful culture techniques at subpolar latitudes is critical to the expansion of the marine aquaculture industry. In the northern hemisphere, longline operations are frequently carried out in exposed and drift-ice environments. The research described here was conducted in the eastern Gulf of St. Lawrence, Quebec. A commercial longline operation was used in the cultivation of scallops. The following aspects of the longline operation were optimized for the specific conditions of this environment:  
1. The design of the longline rig was adapted to the ice conditions encountered in the study area.  
2. A new technique for the selection of suitable sites was developed that takes into account the ice and environmental conditions.  
3. The culturing seed stock was designed to withstand the adverse environmental conditions.  
4. The culture techniques were modified to accommodate the unique features of the environment.  
5. The marketing strategy for the product was developed to meet the needs of the market.  

The results of this research indicate that longline shellfish culture is feasible in exposed and drift-ice environments. The longline rig and culture techniques developed are suitable for the cultivation of scallops in such environments.  

References

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Biological and behavioral studies in relation to the environment

A measure of biological success in shellfish culture is when a producer can consistently maximize growth and survival, and minimize the risks due to mortality, loss of equipment, and increased material costs. Growth and survival are measurable parameters that may even be predicted with certainty after several years, not only through an understanding of the biological requirements of a species, but by good husbandry and knowledge of how the behavioral characteristics of an animal may be put to benefit over another. Thus, a suitable grow-out site for one species may not be suitable for that of another species. For example, two sites may have similar environmental characteristics, such as currents, temperature, and food regimes, but one may be more exposed to strong wave activity during storms. The differences are best observed when comparing mussel to scallop.

Mussel are well adapted to withstand wave action. They attach to the rock substrate with strong byssal threads and generally live in deeper water than in deep water. They are able to withstand periods of extreme heat in low tide in summer and continue to freezing temperatures in winter. The consequence for mussels that are grouped with sand particles will be a much thicker shell than those that were suspended at depth in a calm sea. During storms, feeding will be interrupted, but the animals undergo little stress. The spat collected near surface in the first 10 meters (30 ft) will grow well, attached firmly to the substrate. Under most conditions, mussels can be successfully cultured in a wide variety of locations.

Giant scallops, on the other hand, are adapted to live in protected zones and in deep water. They are predatory benthic animals, and can cause significant predation...
ters by clamping their valves and diverting the flow of expelled water. They live in temperatures up to 16°C, one wide-ranging change of 10°C within a day (Bushnell et al. 1999), and achieve to 21°C water at the depths of the Magdalen Islands. However, feeding may be interrupted when upwelled by wave-induced movement. Thus, nets may be suspended at least five meters (15 ft) below the surface to expose environments. Detritus in grow-out nets should be controlled according to visual size or mortality will occur due to a toxicity for gills and feeding of shells between individuals (Hendy 1997, Chou et al. 1999). The best settlement occurs on collectors suspended near bottom, and spat tend to remain attached by byssal threads up to 1.5-3.5 mm (1 inch) in collectors, but 80 mm wild animals can also be found attached to rocks and other shells. Shells may be successfully cultured when suspended at specific stocking densities and depths, however, under exposed conditions, submerged bag techniques are required to minimize stress.

Shellfish Aquaculture Development

Throughout most of the world's maritime regions, aquaculture development has occurred where sheltered harbors, river estuaries, semi-enclosed bays, and coastal zones are protected from rip, wind, and wave activity. To name but a few, some of the most suitable sites are in near-shore estuaries such as the sheltered bays of the Canadian Maritimes, Ireland, Chile, and Japan, the estuaries of France where there is no culture, or in Indonesia and China where lines are suspended from stakes driven in the sediment in shallow water. The use of sheltered and submerged bag techniques has been established in Japan for decades and is applied in Australia and New Zealand, Chile, and many coastal areas, but in all cases the varied technology was not readily adaptable without careful consideration of the local environmental conditions.

Expansion of the Industry and User Conflicts

As the aquaculture industry expands, there is a reduction in the number of sites with the most favorable environmental conditions for either fish culture or grow-out. This results in greater distances to harbor facilities, increased access to bays with particular micro-habitats, and in fewer sheltered sites. In turn, the potential for expansion is further curtailed by socio-economic factors, such as pressure from tourism, recreation, the extraction of the recreational and conservation sector, and the seasonal tours with summer cottages who want to maintain the pristine view and avoid looking at aquaculture bays. The threat of pollution increasingly conflicts with income from the capacity of local sewage treatment plants to keep up with the demand.

Site Selection In Chaleur Bay, Quebec

There are relatively few socio-economic constraints to the installation of near-shore mariculture facilities in the province of Quebec, compared to other coastal communities. The steep cliffs along the rugged coastline are a deterrenting factor for aquaculture and are less conducive to the construction of beach access. The environmental constraints, imposed by the local weather and water depths that limit aquaculture development in Quebec, are also those that limit cottage dwelling along the coast. While there is little negative pressure from inshore fishing communities, each sector of the industry needs to protect its local surf for species-specific sites and lobbying is restricted to a short season between May and October.

A clear understanding enforces good neighbour relationships, thus site selection and aquaculture techniques should accommodate the local fishermen. Mussel and scallop culture sites along the north shore of Chaleur Bay are located between 20 to 35 meters (60 to 115 ft) depth and over a kilometer from shore to avoid inshore lobster fishing. Mussel culture occurs up to 15 meters (50 ft) depth from May to July and offshore.
berring and mackerel fishing, beyond 75 meters depth from August to October. Further, the snags located along the north coast of the bay are ideal because the bottom structure is appropriate for scallop fishing for enforcement by bottom seining.

Environmental constraints imposed at the site must be carefully considered. The site orientation is important in (1) ensure that lines are oriented parallel to the shoreline and along the current, which facilitates operation and the transport of eggs; and (2) minimize the potential effects of drifting sand due to wind.

The technical challenge to open sea aquaculture in the northeastern Gulf of St. Lawrence cannot be underestimated. Deadlines in winter are present from December to April, and long lines must be 10 meters depth. In summer, there is a 5-10 day period of the strong winds, causing continuous swell due to the fetch from SE winds that travel westward from as far as Newfoundland into Chaleur Bay.

**What Grow-Out Method to Select?**

A measure of financial success in shellfish culture is profit. A producer can attain this by minimizing the risks due to mortality, loss of equipment, and increased material costs inherent to the operation. The success of production depends on the species cultured, the type of culture (e.g., short, mid, or long line), and the size of the facility. The profitability of the operation can be enhanced by minimizing the risk of mortality, loss of equipment, and increased material costs inherent to the operation.

**Three Methods for Grow-Out**

There are different alternatives for growing shellfish, depending on the region and local environmental characteristics. Cultured mollusks or shellfish may be seeded and grown on the bottom for bottom culture, suspended from floating rafts for raft culture, or suspended from a mainline that is supported by leads for longline culture.

1. **Bottom culture** was out of the question in Chaleur Bay due to the rapidly varying and bed nearshore, and poor sediment characteristics offshore. Furthermore, the only adequate bottom was for the exclusive use of the traditional scallop fisherman.

2. **Raft culture** was very risky due to the exposure of the rafts to the strong winds. It would be difficult to avoid the effects of extreme environmental conditions on oysters, such as exposure to wind and waves in autumn and winter drift-flows.

3. **Longline culture** could be used for mussel culture during summer, but to reduce the risk of loss due to storms and ocean currents, the longlines should be submerged below a depth of 35 ft. Submerged longlines are more stable, and their orientation is not affected by the wind and waves between May and December, and drifting pack ice between December and April. The lines would be safe if the water is 35 ft from the surface all year round.

Lastly, to accommodate the traditional lobster and herring fishers, the longlines had to be installed in a narrow zone between 60 and 120 ft water depth, up to a kilometer from shore and 200 miles by boat to the nearest wharf. With a longline submerged at 35 ft, fewer surface lines are required, and damage by passing watercraft is eliminated.

**Description of a Submerged Longline**

The geometry of a longline depends on the depth of water, the size of the boat, and the ability of the boat to withstand the longline. Longlines should be about 300 m in length to maintain a functional working tension over a longer period of time. A long mainline (>150 m) will tend to break due to the
loss in tension and the variations in current and distance. The tendency to buckle will also occur with a submerged longline that has too little tension. In corrective, a short line is not economical nor practical.

Structural characteristics of longines

The surface longline is a static structure, because the tension is maintained by the buoyancy of the surface buoys and does not respond to particular geometry, as long as the anchors are held up against the current and the boat is attached to it (Fig. 1).

- Static longline (surface structure)

The submerged longline, in comparison, is a dynamic geometric structure (Fig. 1). It must be brought up to the surface from a mid-water position, so that the boat can propel itself along its length without deviating from the anchors, where the mainline is released, it should remain at its original position and depth. The tension of the longline is critical in maintaining both its working efficiency from the surface and its underwater stability, without compromising its flexibility.

The structural tension of the submerged longline and the longline's capacity to maintain its dynamic geometry depends on a weight and varying elements at the extremities: a positive buoyancy provided by large submerged center buoys, and the angle of the anchor line, which is established from the relationship between the length of the anchor line and the submerged water depth (Fig. 2). These parameters will affect the length of the unused segment of the mainline, that segment between the center buoy and the extremity of the workable segment of the mainline.

Rope. The selection of the appropriate rope strength depends on a combination of potential stresses, those imposed by the trial or maximum load of the equipment of the submerged longline and by the wind forces acting upon the boat that is to be unfurled to the mainline. Standard fishing boats are designed to move forward. When they are stationary, they tend to act as a sail and drag the boat against or away from the longline, thus creating excessive tension on the mainline and anchor lines. Furthermore, one must account for rope stretch (up to 10 percent when loaded). For these reasons, it is advisable to re-adjust the line tension to optimize the working capacity from the boat. A slack line that is easier with animals is more difficult to manage.

Anchors. The use of either spoon, wheeled, or fixed anchors should be avoided for submerged longlines in exposed environments. Tension is quickly lost following storms or within minutes of working on the line. The anchors...
Submerged Longline Geometry

Structural tension vs. distance from end of leader

A

- Anchor line
- Leader line
- Submerged line
- Surface line
- Pulling force
- Structural tension

B

- Anchor
- Leader line
- Submerged line
- Surface line
- Pulling force
- Structural tension

C

- Anchor
- Leader line
- Submerged line
- Surface line
- Pulling force
- Structural tension

Preparation of the longline

The assembly of the longline is one of the most important steps in managing an aquaculture operation. The longline is prepared by marking the mainline with loops of six-strand braided wire every 75 cm or meter, depending on the grow-out site requirements (Fig. 3). The loops are used to keep the mainline from slipping off the surface while resting on the bottom. They are also used to secure the buoys and weights to be added to the mainline and thus avoid the possibility of losing them.

Building concrete blocks

- Concrete block: 6" x 12" x 18" = 1 cubic yard = 4000 lb. (Fig. 3).
- Transport to the site with equipment and three workers.
- Assemble 24 plywood molds and place a plastic sheet on gravel base to form molds.
- Pour one cu. of cement mix, mold, and complete eight anchors in one hour (one truckload).
Assembly of mainline and anchor blocks

Mainline preparation
- Cut mainline (3/4" static rope) to length
- Make a loop in line of rope
- Secure loop to deck or barge
- Run line through sheave and deck pulley
- Tape sheave to prevent rope from slipping

Current anchor
- Place anchor block
- Secure anchor to scaffold
- Run anchor line through sheave
- Anchor line to deck
- Block anchor
- Cure anchor

Fig. 3 Diagram of procedure and materials required for installation of submerged longlines at sea.

- Secure the two 1.5" poly rope rings into the cement to act as loops to tie the longlines
- Unload the next morning and assemble modules to remove 5 more blocks (8 hours later)

Loading longline on boat
- Have a loader on deck to move cement anchor rings to deck hole (6 blocks)
- Load 10 blocks on boat when the boat is docked (depends on tide and type)
- Depending on the size of boat, approach next series of blocks in the same direction

Preparation of longline on boat while preceding to site
- Spool out the longlines and attach each to the blocks
- Adjust the longline so it reaches the anchor for the depth of the site (maxiumum angle)
- Attach the anchor lines to mainline and a line at center of stanching
- Attach marker buoy with line running to the first anchor to mark start position at sea

Installation of longline on site (Avoid windy conditions or strong tidal currents)
- Define the position and drop first anchor with marker buoy
- Make sure block falls flat
- Run down anchor and parallel to shore as necessary (water is shallow)
- Tie buoy at center of mainline with one-half-drawn rope to mark depth to be submerged (25 ft)
- Release anchor once center buoy sinks to water
- Spool out longline slowly and position buoy carefully prior to releasing next block
- Finish first series of six lines (10 blocks) and start again (as seen on video display)
- If you cannot finish a series, let the anchor line float at the surface for recovery next trip
- Return to harbor, reload 10 blocks and return to site (1.5 hour round trip)
- May use smaller boat to pass anchor line when ready to continue down current (trip #2)
- Install, up to 500 cement blocks/day in calm weather - complete job in three days

Flexibility of submerged longlines

An efficient aquaculture operation spends a minimum time maintaining its longlines and gets on with producing shellfish. This suggests rapid access to sites, quick recovery of the longlines, and efficient movement along the mainline to add buoy or harvest produce. This is achieved by a geometric design that incorporates flexibility and structural tension (Fig. 4).

A new technique for Chaleur Bay - the submerged longline

In the fall of 1989, 50 longlines were installed within four days. They were placed between 60 to 140 ft deep water in parallel series of five lines attached to six cement blocks, each weighing 540 lbs (230 kg).
Fig. 6. Placement of the winch on the ship, showing the positioning of the longline. The longline is lowered to the bottom from the surface.

We first experimented with the technique by fitting a nine-foot stern block to our vessel. The use of deep blocks not only allowed the block to leave the harbour and head out to sea, but it also prevented the ship from being damaged when the blocks were lowered to the bottom. Once the block was positioned on the seabed, the longline was lowered into the water and the longline stopped out parallel to the shore. The position of the longline was then adjusted until the longline was parallel to the shore. As the second block is lowered, the position is maintained, as long as the wind or tide is not too strong.

A more efficient longline installation method was subsequently developed by fitting a steel ballasted 875-tonne boat with a stern block and winch so that the bitts of the bow blocks could be displaced on the deck. The blocks were then transported each trip to the site. An industrial quick-release mechanism allowed the blocks to be dropped into the water from the side of the boat. This reduced the time spent on the deck.

A total of 20 blocks were loaded per day for a total of three days of work. The longlines were positioned in parallel series separated by about 30 ft and consisted of six longlines sharing seven blocks (Fig. 5). The only disadvantage was the use of a quick-release mechanism that did not allow for the retrieval of the block if it fell to one side. Ideally, a more rigid vessel would be used, because this model only had the weight of 0.2 m/s, which is too high for manipulating anchors at depths of 60 m, even in choppy seas.

Advantage of submerged lineages

The cost of preparation and installation of seven-ton blocks was a greater initial investment, but surprisingly less expensive per bitts than the construction of conventional vessels (Table 3). The cost of longline blocks is less expensive for a longer period if it is used. The advantage of submerged lineages is the stability of the boat and the efficiency of the longline. The work efficiency is a function of the boat type, but the longline is not affected. The surface area of the lineages is reduced for winter, and there is less equipment on the surface, which reduces the maintenance of the longline.
Managing long-lines in exposed and drift-free environments

Rake situations are serious if the potential risks is not evaluated ahead of time. With regard to long-line management, several parameters are noteworthy. A producer should monitor longlines for potential changes in tension during the season, which may be caused by lost or damaged hooks, dislodged anchors, severed lines, or loss of production, either from damage, or from run-away equipment. When winter conditions are an annual event on a site, the producer should ensure that the longline will not be excessively trans- ported or will not float near the surface during winter if shellfish are lost. This may result in the longline sliding in the passing ice and becoming lost.

Harvesting in strong winds and freezing conditions is a risky situation, mostly for safety reasons. In strong winds, since the boat is tethered to the longline, it will bounce and lose the line, causing potential damage to the line and shellfish. When harvesting in strong winds or waves, the use of cranes and winches to haul shellfish on deck may also be a safety hazard. These situations should be avoided and the number of lost days should be tracked, especially in northern regions, before selecting a permanent site. In late fall and early winter, when wind and snow conditions are most prevalent, the deck of the boat and the equipment may become very slippery. At the least, it becomes difficult to handle heavy and equipment manually, causing stress among crew members, and damaging nets.

The selection of an appropriate ship and its carrying capacity per trip are important elements to consider. The daily operations at offshore sites require travel times and movement of human and material resources, both for maintenance and harvesting. Thus, the type of ship (deck) and its working area become factors that may limit productivity or affect its cost.

- Verification of position & depth

The organization of an aquaculture site is another important step in the proper management of an operation. Lines should be parallel to shore in most cases, where currents and winds are moderate to weak, and the distance between long-line series should equal to the depth of the water (Fig. 5). This ensures that the entire line is being worked on or set on the downwind side of the neighboring longline, as the boat is tossed downward.

The method used to determine the position of the installed longlines is simple. The use of Loran C, Geostationary Positioning System (GPS), or other satellite-positioning systems are basic tools for locating longlines at sea. This may be unnecessary at a nearshore site with good bearings, however, once the longline is set, it will require accurate positioning methods.

To recover submerged longlines after a winter season, the most practical management tool is without doubt the use of a depth sounder to measure the depth and general quality of the longlines from the boat, thus avoiding the costly use of diving. Doing is rarely done...
Organization of an aquaculture site

Fig. 5. The orientation of hoppers is varied to suit the hydrodynamics of the area. Hopper shape and size are designed to suit the particular species to be cultured. Hoppers are separated by channels to reduce the risk of damage by passing vessels and to facilitate harvesting operations. The channels are designed to facilitate the removal of excess fish and to minimize the risk of damage to the fish. Hoppers are sized to facilitate easy access to the fish and to minimize the risk of damage to the fish.
Dunlop "Tempest" Fish Cages

Dave Britain
Product Manager
Dunlop Oil & Marine Limited
Grimsby, England

Historically, marine aquaculture was carried out in small bays and estuaries that were reasonably sheltered from winds and waves. The nature of these early farming sites, being shallow, dictated that rigid cages of wood or steel construction, which were relatively cheap to manufacture, would be suitable.

However, being in sheltered surroundings with little or no current, the result was that the seabed beneath the cages and surrounding waters became heavily polluted by excreta, waste fish food and fouling. This caused material loss in gas formation and pollution of surrounding water and sediments.

Hence the move to offshore and exposed farming, where there is a greater water exchange, little or no pollution, and virtually disease-free sites. These conditions allow the fish to grow healthier at a faster rate and reduce the use of chemical treatments.

In the first quarter of 1988, as part of a diversification programme, Dunlop Oil & Marine identified aquaculture as a growth industry. At that time, with something like 35 years of experience in the offshore oil industry, it was immediately recognised that we had the technology to hand to enter this new industry.
Figure 1 shows a super tanker discharging crude oil through Dunlop hoses at a single point mooring buoy. Terminals such as this are located around the world and handle ships in all weathers. During its 35 plus years in the industry Dunlop has continually been the major supplier of hose to the oil industry and the name is synonymous with quality.

A flexible rubber hose is basically a pressure vessel with steel fittings chemically and mechanically bonded at each end. Figure 2 is a cross section of a hose and its fittings. The main components include:

- Lining - to contain the product
- Skirt - rubber compound that gives a smooth transition from the steel fitting to the hose body
- Main reinforcement - multiple plies of high strength carbon totally encapsulated in high adhesion rubber compound (in fact, very similar to the construction of a car tire)
- Binding wire - high tensile copper coated wire to provide a mechanical lock for the steel fittings
- Shoulder plies - high tensile cord plies to provide reducing stiffness between the rigid steel nipple and flexible hose body
- Felted wire or filter block - to provide crush resistance
- Holding or hoop plies - provides strength between rubber filler
- Cover - rubber compound that is highly resistant to abrasion, UV, ozone, and seawater attack

All hose types and designs are subjected to fatigue testing in the unique Dunlop test rig. Figure 3 shows the Hempel D single hose prototype system undergong tensile, torsional and compression testing in the rig. The result is an accelerated fatigue test.

Fig. 3

Following the fatigue test, a hose will be pressure tested to destruction and the results compared with those of a hose of the same construction that had not been subjected to the fatigue test.

Fig. 4
As well as fatigue testing on full-size boxes, each type is designed using the latest finite element techniques (Figure 4). This allows our engineers the luxury of designing boxes with stresses minimised in all areas.

The prototype Tempest 1 cage was installed in Loch Lomond, off the west coast of Scotland in December 1988 (Figure 5).

This cage, incorporating two concentric rings of flexible rubber hoses, coped superbly with a very harsh winter with winds of storm velocity on many occasions. As the concept was new, it was necessary to use this as a proof-of-concept cage only and to determine its feasibility before approaching the market in earnest.

Figure 6 shows the same cage in Loch Lomond shortly after installation. An arm worker (at the left) is manually feeding the fish. The Loch Lomond cage is seen again in Figure 7 with a feed-squeeze hose in one of the inclusion units.

![Figure 7](image)

Automatic feeding systems were later fitted onto the Loch Lomond cage (Figure 8).

Following this one year of trials, Dunkeld then entered the industry with a commercial 3-metre Tempest 1 cage.

In April 1992 an additional 29-metre Tempest 1 cage was installed off Oban, again on the west coast of Scotland. Here an automatic slow-feeder system was
is particularly troubled by birds—hence the net to deter predators.

This site is very exposed. The excellent water exchange meant that the use of chemical treatment is almost non-existent. This allows the farmer the opportunity of marketing his salmon as "green." The cage is shown with supply vessels in attendance (Figure 11-12).

The method of securing the buoy and spar for supporting the bird net at the Clare Island cage is shown in Figure 13.

Figure 14 shows the walkways, floats and moorings on the Clare Island cage. A two-metre swell going through the same cage. It is interesting to note that at the cage opening, there are no gaps between the cage and the troughs of the wave. Other more rigid cages do not conform to experts in this manner and consequently suffer failures.
In February 1990 at the Lambhavik site in the Faroe Islands, we supplied two 6- to 12-inch diameter box post F cages (Figure 16). The site is open to the predominant south-westerly winds and in the winter it is quite horrendous.

I visited the site in August 1990, two and a half years after installation, and was informed that virtually no maintenance had been carried out on the cages since installation.

The feeding system for the cages is somewhat unique. All the fish food is stored in three silos on the top of the intercables and delivered to the cages by gravity (Figure 17). The 6-inch plastic pipe that provides the coming
down the mountain-side enters the water and splits into two 4-inch pipes to service the cages (Figure 18).

Next we see the bull bars (Figure 19). The bull bars are the jumpropet support structures and give an added safety area for personnel to lean against when working on the cages.

The next cage is at Tempea. We supplied to Advik Sandvik in Norway in January 1993. This shows the area where two boxes in the system are connected, along with floats and a mooring eye. Most cages are slightly different by today's thinking. The top rope is replaced by chains to allow the cages more freedom of movement (Figure 20).
can see the bell safety here. (Figure 21).

Some six months after the installation of the unique design Tempest 2 cage in Scotland, we commenced working the Tempest 2 square cages on the west coast of Ireland.

Tempest 2 cages utilize only single-lone sides, something we were very experienced in, so negating the necessity to prove the product with field trials.

This cage is of modular design, which enables the farmer to add additional cages of three sides to a raft system as and when required.

Tempest 2 cages incorporate flexible rubber hoses that are pre-pressurized with air to provide the correct degree of bending stiffness to the cage structure and to make them compatible with the waves.

Rigid steel walkways are fitted to each corner of each cage, along with Teflone seats, to promote the safety of personnel when working on the cage.

Figure 22 shows a raft of six 15m² Tempest 2 cages, at Letter Hy, on the west coast of Ireland. This is an exposed site, open to the Atlantic ocean with a fetch of some 3000 miles. Another view of the same raft of cages shows how the raft moorings are released, allowing the system to "snorkel" in the swell following a storm. (Figure 23).

At the Invercail.

Feeding is usually carried out from a small boat. This is one of the earlier raft systems and it is possible to see a new design of walkway on one of the "Teflone sections. All Tempest 2 cages were now fitted with this type of walkway as standard (Figure 24).

Next you can see personnel from the farm inspecting the ropes and birds nets for damage following a spell of bad weather (Figure 25).

Still respecting the nets, it is reasonably easy to walk along the boxes in a swell (Figure 26).

On the next page we see six 15m² Tempest 2 cages that are installed in Conamara Channel off the island of Muck in the Muck temperamentite. This is a fine example of the moorings on the surface in a related site.
The first winter following installation, ten-metric waves, of a short period, were observed going through the cages (Figure 27).

Again at Malta, the centre cages of this uit system are utilising "split net" for nursery sardine. Espargelos are put in these nursery cages, which are protected somewhat from the wave and current, before being transferred to the outer cages (Figure 28).

Success with this type of cage naturally led to the introduction of the hexagonal Tempest 3 and the octagonal Tempest 4 cage types.

These are obviously larger cages and are designed for the more experienced farmers within the salmon industry where utilitlve service vessels are in use.

And in Figure 29 we have Tempest 4 Octagonal cage, with 16 more sides giving a surface area of 1235 ft² (6608 ft² larger than a baseball diamond), at Donegal Bay on the west coast of Ireland. With 15-metre deep nets this type of cage has a capacity of 300 tonnes will be in the region of 300 tonnes.

Summary

To date, in just over seven years within the industry, we have supplied cages to Scotland, Ireland, Shetland Islands, Faroe Islands, and Norway for salmon farming. Also to Malta, Morocco (in the south of France), Cyprus and Sicily for farmed-bass and barram in the Mediterranean area.

There are many advantages in using the Dalplp Tempest cage systems, as they are:

- Capable of surviving 365 days a year, even in the most demanding locations
- Quieter than rigid cages, ensuring less stress to the fish
- Virtually maintenance-free, therefore allowing the farmer to spend time on other important tasks around the site
- All exposed metalwork is Hot Dipped Galvanised to BS 779 and the construction of the steel tubes is schedule 30 oil field quality piping
- Moorings studies are carried out using the latest software technology developed for the North Sea oil fields, and guidelines in B.S. 3609, which cover the anchoring of marine structures (Figure 20).

Dalplp Aquaculture is an operating unit within Dalplp Oil & Marine and fully conforms to BS EN 15000 Qualify System, Part 1, which covers specifications for design, development, production, installation and servicing and finally

- All our cages are covered by a one-year consequential loss guarantee and we believe that we are the only company worldwide to offer such a guarantee.