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OPPORTUNITIES AND PROBLEMS OF OFFSHORE FISH FARMING ALONG THE MEDITERRANEAN COAST OF ISRAEL

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ABSTRACT

Offshore fish farming is a rapidly growing field of activity in many parts of the world, among them the Mediterranean Sea. In Israel, offshore production has been going on at small scale in the Red Sea, while in the Mediterranean Sea it is making its very first steps. The environmental conditions along the Mediterranean coast of the country are more difficult than in many other regions of the same sea. Experience accumulated abroad and calculations show that only certain high-tech, expensive floating cages could suit the environment. Such a solution, an aluminium-alloy cage that can be submerged, was purchased from France and installed in the sea, at Mikhmoret. The cage is part of the equipment used in the aquaculture teaching program of the Mevooth-Yam Nautical School; it also will serve as a pilot plant for the R&D work carried on by the Technion in cooperation with Israel Oceanographic and Limnological Research. A second cage of the same type has been ordered and the development or acquisition of further experimental cages are under study.

INTRODUCTION

Thousands of years ago men switched from hunting to rearing domestic animals, and from collecting wild fruit to agriculture. As to sea food, humankind continued to rely on wild catch. There is evidence that fish growing in confined fresh water has been known for several hundred years, while fish rearing in sea water seems to have started in the Far East, by the beginning of this century. Later, offshore fish farming in floating cages became an important industry in Japan. Pioneering work began about three decades ago in Norway and Scotland, two countries that are today the largest West-European producers in the field. Sweden, Denmark, the Faeroe Islands and Ireland followed. In the Mediterranean Sea *mariculture* — that is sea aquaculture — expanded exponentially in the last decade.

The main reasons behind the accelerated growth of mariculture are:

- the increasing need for food, in general, and for proteins, in particular;
- a change in consumption habits based on medical evidence that sea fish are healthier than red meat;
- diminishing wild-catch resources in certain seas, for example in the Mediterranean Sea.

Year	Greece	EEC
1986	100	1800
1992	6500	11200
1993	9000	15000
1996	16000	31000

Table 1: Sea-bream and sea-bass production

Table 1 illustrates the development of offshore fish farming in the Mediterranean, in tons, according to Aqua Revue, September 1993. The data for 1993 and 1996 are projections. The production of Greece has been deducted from that of other countries belonging to the European Economic Community (EEC).

Onshore aquaculture has been successfully practiced in Israel for many years. Sea activity has been limited until now to the Red Sea where two small-scale farms exist at Eilat. Fish farming in the Mediterranean is in an incipient, research stage. The Israeli coast of this sea is nearly 200 kilometres long, about half of them are occupied by urban building. The conditions along this coast are more difficult than in many other parts of the Mediterranean:

- there are no bays, fjords or islands that could offer protection against the full force of the waves;
- the slope of the continental shelf is slow so that cages must be placed far from the shore in order to ensure sufficient depth under them;
- the wave regime is rougher than in other regions of the same sea.

Figure 1 illustrates the last point. The ***design wave*** to be taken into consideration for fish cages is the highest wave expected in the average in 20 years. The curves illustrate the predictions for the Israeli coast and for the coast of Monaco, the mooring location of the hatchery/nursery ship *Labrax*. The point annotated *Saint Raphäel* corresponds to the location of the Aquavar farm off the Santa Lucia port. The values are *significant wave heights*, $H_{1/3}$; *maximum wave heights* that can be at least 1.8 times higher.

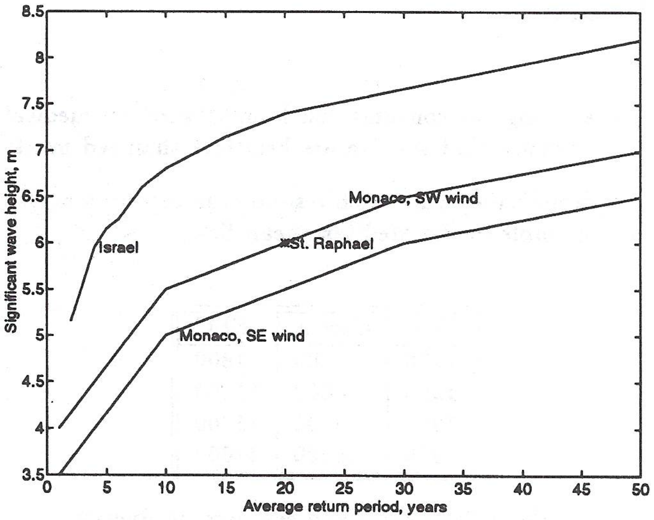

Figure 1: Design wave

The projections for the Israeli coast are not exaggerated. A significant wave height close to 7.60 metres in 29 meters depth was recorded in December 1991, 6.75 metres in the same depth were recorded in February 1992, and significant heights close to 6.75 and 7.03 in deep waters were measured in November and December 1992.

Conditions like those described for the Israeli coast present serious challenges to Naval Architects and other engineers.

OPEN-SEA CAGES

In Europe, offshore fish farming started in protected areas, such as the fjords of Norway, or the sounds and lochs of Scotland. Protected areas are also exploited in the Mediterranean, for instance between the many islands of Greece. Experience shows that fish grow faster and are healthier in open-sea locations where dissolved oxygen is more abundant and pollutants are quickly dispersed. The present trend is to place fish farms in more exposed sites. High-tech equipment has been developed for use at open-sea locations. These solutions, based on long experience in offshore engineering, include

- flexible cages that follow the sea-surface profile;
- semi-submerged cages that minimize the effect of waves;
- cages that can be submerged to avoid most wave motions.

The main components of flexible cages are tubular collars that keep the form of the nets in which fish are reared. Made of thick, large-diameter hoses, the collars are compliant structures that follow the changing shape of the water surface, thus avoiding large amplitude motions and loads. The weight of the nets is taken by small floats distributed along the cage perimeter.

In operating condition, the collars of semi-submerged cages are kept under the surface. The waterplane area of the surface-piercing structure is very small; therefore, the sensitivity of these cages to wave motion is greatly reduced. A large cage of this type resisted well in Cyprus in a severe storm that damaged cages of other types at the end of 1992.

Cages that can be submerged use the fact that the amplitude of orbital motion decays with depth. During storms such cages are pulled down, towards the bottom, and thus are protected against large-amplitude wave motion.

Newer solutions presently under test include sparbuoy cages that have no collar at all, and a tension-leg cage whose upper opening becomes immersed in strong surface currents.

THE PILOT FARM AT MIKHMORET

The research on the promotion of offshore fish farming along the Mediterranean coast of Israel is led by the Technion. The work is being done by the *Agricultural Power and Machinery Center*, in cooperation with *Israel Oceanographic and Limnological Research Ltd*, and is sponsored by the Office of the Chief Scientist of the Ministry of Agriculture. A pilot and educational farm is under establishment at *Mevooth Yam*, the School for Technicians and Marine Officers at Mikhmoret. With the massive help of the Ministry of Education, a land base has been founded there and a cage that can be submerged has been purchased. The land base includes tanks for breeding fingerlings, a sea-water circulating system, a laboratory and aquaria. The cage, designed and produced by the French company *Aquavar*, consists of a rigid structure of marine aluminium alloy, interchangeable synthetic-fibre nets, a depth-control system, and several anchoring and security-mooring concrete blocks. The site of the cage is situated one nautical mile from the shore, at a location where the local depth is 29 meters. The cage was moored in March 1994 and a second cage of the same type was ordered immediately after this. In cooperation with the Nautical School and other parties, the Technion, is studying the details of developing or purchasing further cages. Basing these cages on other principles will enlarge the scope of the research.

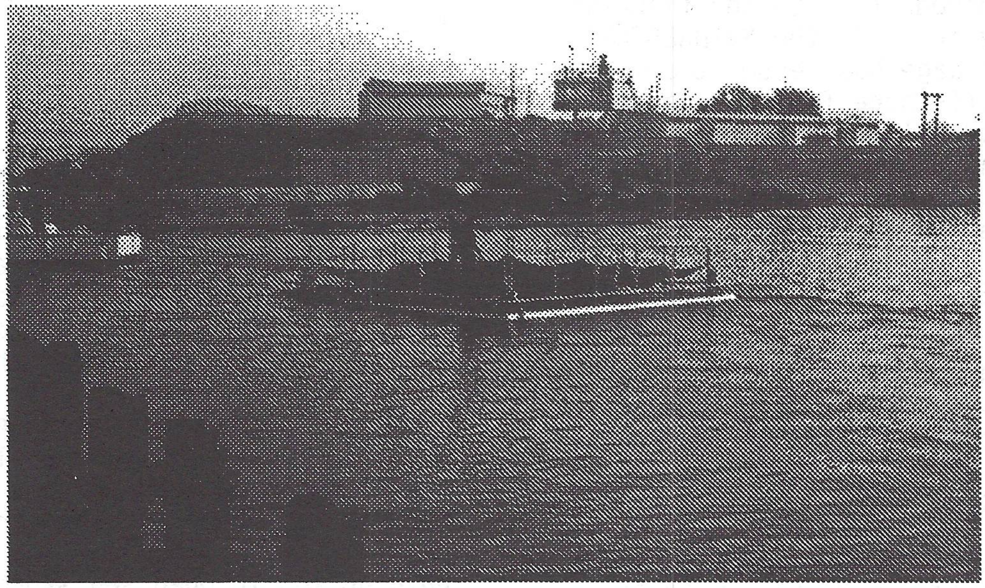

Figure 2: Towing the cage out of the Mikhmoret anchorage

THE TECHNOLOGY OF BRIDGESTONE FISH FARMING CAGES

J. Gunnarsson, Bridgestone Hi-Seas, Faroe Islands

ABSTRACT

To further expand the potential for commercial farming of fish into more exposed environmental conditions, BRIDGESTONE CORPORATION of Japan in the early eighties developed a so-called off-shore type fish cage. The cage-frame is built from flexible marine rubber hose strings which hold a floating net-pen for the farming of fish. The cage-frames, nets, and mooring systems are adapted to actual installation sites.

INTRODUCTION

Since its introduction to the fish farming industry in 1983, the BRIDGESTONE HI-SEAS fish cage has become the most successful off-shore fish cage system in the world, outselling all other systems combined many times over This paper will outline the history, design, philosophy, and marketing of the system.

ABOUT BRIDGESTONE

Bridgestone Corporation of Japan is best known as a manufacturer of tires. The company does, however, also produce a wide variety of other products, mostly from rubber, such as fenders for ports and harbours and rubber hose for the oil industry.

In 1979 some tuna-fishermen in Japan approached Bridgestone to ask if it would be possible to make an enclosure to keep and transport bluefin-tuna. The schools of tuna were migrating away from the coast and it was getting more difficult to bring the tuna fresh to the markets. The idea of the fishermen was to use a large holding pen to store and then transport the tuna from the fishing grounds and back to port. This then was what Bridgestone set out to do, and consequently the frame collar and nets were designed to withstand the enormous stress of offshore weather conditions as well as the strain of being towed behind a ship at up to 3 knot speed over long distances.

It was during the development period that Bridgestone realized that its invention could also be used as an alternative to the inshore fish cages then in use around the Japanese coast. The further development of the frame collar and the nets was therefore changed also to include this other intended use.

Japan is a world-leader in aquaculture, producing more than 1.2 million MT of farmed fish, shellfish, and seaweed every year, while at the same time having limited numbers of sheltered sites. Fishfarms in Japan are therefore often placed close together in confined areas, resulting in some cases in severe environmental damage and loss of fish.

DESIGN

Conventional fish cages then - as now - were almost all made from rigid materials such as plastic, wood, steel, aluminum, and variations thereof, and in order to make an open-sea cage for transport and farming, Bridgestone with its extensive experience in rubber technology for marine application, concluded that the use of specially designed rubber frames provided a viable solution. Research commenced to determine if the flexibility of rubber could be applied to a fish cage, so that the frame used had the necessary flexibility to withstand the forces of wave action in open sea storm condition, yet at the same time retain sufficient rigidity to maintain the general overall shape of the cage. Also the frame must have sufficient reserve buoyancy to support the structure.

TESTING

A whole series of tests was made and various constructions of flexible rubber hose were considered before scale models were made. These were then tank-tested and different types and sizes of nets were used and data gathered on drag, etc.

The results were analyzed an correlated to a prototype full-scale fish cage which was then field tested for a full 2 years before the Bridgestone Hi-Seas fish cage system was perfected and marketing and selling commenced.

Already during the field testing in Japan the prototype cage was hit by several typhoons and withstood the enormous forces.

The first Hi-Seas cage was supplied to a fishfarmer in Japan in 1983 and since then about 250 cages have been sold, and in some of the most exposed open seas sites in Japan, Ireland, New Zealand, Faroe Islands, Norway, Denmark, Australia, Hong Kong and elsewhere the cages have proven the original design idea. The cages are used for the farming of several species of salmon and seatrout, yellowtail, snappers, striped jack, seabream and seabass, tuna as well as other species.

DESIGN PHILOSOPHY

The fundamental design philosophy behind Bridgestone's cages is that the frame has but one function, and that is to keep the shape of the net. The structure is not intended to carry the net or to hold add-on service facilities, nor to act as a working platform. Bridgestone believes that a structure suitable for operation in a sometimes hostile environment is best made from flexible material which will ride the waves rather than break them.

SHAPES AND SIZES

Hi-Seas cages are square, hexagonal or octagonal in shape, and the standard side-lenght is either 16 or 20 metres, although other lenghts can be made to order. Each side consists of a rubber hose string and 2 steel corner joints.

The sides are bolted together using only 4 bolts per corner, and there are no hinges or moving parts. The whole of the wave action is absorbed in the flexible rubber hose sections. Steel stanchions support the jump-net and handrail, while cornerfloats give the joints the same buoyancy as the rubber hose sections. The fish- and predatornets are not hung on the frames or the stanchions but are suspended inside and outside the frame collar and float in their own right with the help of purse-sein floats. Where necessary a roofnet is used for bird deterrant.

There has been a clear tendency for the Hi-Seas cages to get bigger. In the beginning a few 10M hexagonal cages were built. Later the 16M hexagonal became the norm, and in the last 4-5 years the 16M octagonal cage has been our best-seller. A few 20M square cages are in use in Japan, and our biggest user in Europe, a fishfarmer in Ireland, has for two years now been using a 20M octagonal cage, which as far as I know is the biggest fish cage in the world. It is 160M in circumference and has a surface area of almost 2,000M^2. The nets have also been made bigger. In the beginning they were at most 10M deep, but now many are 15 or even 20M deep. We are presently talking with fishfarmers in Norway about 20M octtagonal cages with 30M deep nets. These would have a production volume of about 55,000M^3 and could hold about 1,000MT of salmon at a time.

Although the first Hi-Seas cages are more than 10 years old, there has been no need for major design changes. The basic system has proved to be superbly suited for its intended purpose and only minor changes have been made to the corner joints, the stanchions, and to the corner floats, mostly to accommodate requests from users for ease of operation.

MOORINGS

The cages are moored either individually or jointly by using mooring ropes from each corner, connected to anchors on the seabed. The anchors are concrete blocks or steel ships-anchors depending on the seabed conditions.

It is our firm belief that a successful fish cage system requires harmony between the 4 aspects of; frame collar, nets, moorings, and site location. Therefore, in each case before installation, site-data is gathered and sent to Japan where engineers from Bridgestone will calculate the forces which will apply before making recommendations for size and type of cage as well as for the nets and mooring system to be used. Detailed manuals are given to each user with specifications and drawings of all components, recommendations for nets and moorings, as well as instructions for installation and maintenance.

All components from sub-suppliers are thoroughly checked and in most cases Bridgestone or its representatives will supervise or perform the installation work.

After installation representatives from Bridgestone will visit the user to make sure that the cages are being properly used and maintained.

NET DESIGN

The nets used in Bridgestone cages are also unique in their design. The basic intent is to build a net which is able to withstand the same environmental forces as the cage and to protect the fish during such extreme conditions. Consequently the nets have been designed to absorb as much wave action as possible in the top sections. The net is therefore made with a floatline which has enough buoyancy to carry the weight of the net, even when fouled. Just below the floatline a lacing has been incorporated which allows for elasticity and flexibility. Below the lacing is a strong portion of trawlnet where the mesh are on the diamond so that the net can stretch vertically and horizontally. Only then, below the hanging net, is the standard square-mesh fish net. From that same point the jump-net extends on the slack up to the stanchions.

The effect of this design is, that when a wave rolls through a Bridgestone fish cage, the cage collar itself will ride the wave. The net inside the frame will benefit from the break-water effect of the collar, and in addition the floatline on the net will also ride the wave. The lacing and the diamond mesh below the floatline will stretch vertically in front of the wave and horizontally behind. The result is that the actual fish net, below the hanging net and further down the sides and into the bottom panel, will be much less affected by the wave motion on the surface than a conventional cage and net. The benefits to the fish are obvious. Such a net design and operating conditions of course mean different stress and wear on the nets. We have, therefore, from the beginning put much effort into monitoring and developing the nets. We have chosen to work with a few, but reputable, netmanufacturers and continously work with them and our many users to further develop and improve our nets.

HANDLING AND SERVICING

With so many cages in use in so many different applications, handling and servicing have now in most cases become routine. Normal day to day operations such as feeding, transport of fish, net changing, grading, disease treatment, harvesting, etc. are handled safely. We tell our users and potential future users that we do not necessarily have ready-made and fixed solutions or answers to all their questions about operating large cages. What we do have, more than anyone else, is the vast experience from 250 cages in use for more than 10 years.

FUTURE DEVELOPMENTS

We do not foresee drastic changes to our cages in the future, but we are constantly improving and perfecting the system with the help of our many users.

We expect most developments to be in the way fish farms are operated in exposed sites. Boats, feeding systems and especially monitoring systems for biomass control will become more effective and popular and hence viability of off-shore sites will improve further.

In Japan the government is supporting the development of off-shore service platforms for servicing of cages, and 3 of these are already in use.

In the fall of 1993 we supplied our first cages into the Mediterranean. A raft of four 15M square cages to Telia Aqua Marine in Cyprus. The cages are located on the eastcoast south of Ayanappa in an exposed site. In January and February this year two 16M hexagonal cages were installed off the soutwest cost of Sicily. The owner is Sicily Fish Farm and the cages are located in a very exposed site about 2 miles from the closest point of land and about 3 miles from Porto Palo which is the closest port. The cages in Cyprus are moored using concrete blocks while 500KG steel anchors were used in Sicily. We have a contract to supply 10 more cages into Sicily in July this year. They are for Acqua Azzurra SRL in Catania and will be located off the southeast point of the island and in a very exposed site. These cages are 16M square, one raft of 6 and one of 4 units.

We work with specialist people and companies in the business and can offer a wide range of expertise and products for the industry. We are for example this summer supplying a copletely integrated fish farm to a company in India. Juvenile fish will be supplied from Europe into a nursery station on the Andaman Islands in the Bay of Bengal for ongrowing. After 3-4 months they will be transferred into Bridgestone fish cages which will be serviced by a purpose-built boat before being harvested and sold. We see these developments as important steps in the further expansion of fish farming in offshore environments.

Early in 1992 we were given data on the environmental and hydrographic characteristics of the Mediterranean coast of Israel for evaluation. The data was processed in Japan by Bridgestone engineers who concluded that the expected exposure to Hi-Seas cages in this area would be well within the conditions our cages are used to. I am, therefore, confident in saying that also here off your coast there is great potential for commercial fish farming.

FOOTNOTE

The idea to use the cages for transport of tuna was dropped in Japan already before the cage was fully developed, but in 1991 the idea surfaced again, this time in Australia, and one 16M hexagonal cage was supplied to tuna-fishermen there. They towed some 3,500 tuna with an average weight of 20KG each behind a purse-seiner for about 100KM from the fishing grounds south of Port Lincoln to shore. The mortality was only a few percent.

So finally the cage is also being used as the designers originally planned.