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A tension leg cage system for offshore aquaculture in the Mediterranean

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SUMMARY – A number of submerged cage designs now exists, but few have been tested fully in Mediterranean offshore conditions. Of these, the REFA tension leg system, which relies on a flexible cage bag element retained from below by a tension mooring system, may offer particular advantages of simplicity, relative cost efficiency and good security in highly exposed conditions. This paper outlines the key design features and their comparative advantages, and describes the practical installation and testing of a tension leg system in a commercial marine fish culture operation in the Mediterranean.

Key words: Aquaculture, Mediterranean, offshore, cages, technology.

RESUME – *"Un système de cage "tension leg" pour l'aquaculture en mer ouverte en Méditerranée". Il existe un grand nombre de conceptions pour les cages immergées, mais peu ont été complètement testées en conditions offshore méditerranéennes. Parmi ces systèmes, le système REFA "tension leg", qui comporte un élément flexible de cage retenu au-dessous par un système d'ancrage sous tension, peut offrir des avantages particuliers, comprenant simplicité, efficacité par rapport au coût, et bonne sécurité en conditions très exposées. Cet article souligne les caractéristiques importantes de la conception, et leurs avantages comparatifs, et décrit l'installation pratique et le testage du système en conditions commerciales d'opération de mariculture en Méditerranée.*

Mots-clés : *Aquaculture, Méditerranée, offshore, cages, technologie.*

Introduction

The majority of cages in current use for marine aquaculture are of the surface-flotation type, with net bags suspended from a timber, plastic pipe, reinforced rubberized tube or steel framework. For highly exposed offshore conditions, only the latter two types, notably the Bridgestone and Dunlop systems, and the Farmocean cage have been used with any confidence. However, these systems have not been without problems, many of which have been related to the exposure of the upper surfaces to high energy environments, and to disjunctive motion effects between surface and subsurface elements. If the major part of the cage system can be held below the surface, many of these problems could be lessened or eliminated. Furthermore, if the cage net can be retained from below, rather than suspended from above, some of the constraints of the need for an upper framework could be removed.

A small number of submersible cage designs now exists, some of which have been practically tested in recent years, and may be suitable for use in Mediterranean conditions (see also Scott and Muir, this volume). These cages remain at the surface in normal conditions but can be submerged, hopefully before storm conditions reach the farm site. Some of these systems retain a rigid frame structure, while other rely on tensile structures.

Submersible cage systems

A limited range of submersible cage systems has now been developed to pilot and early commercial stage. These vary in both concept and structural features. In the open sea, wave motion is sequentially "filtered" with increasing depth. Thus the sea is practically calm at a depth corresponding to half the wavelength of the waves at the surface. While at the surface there may be 6-m high, 50-m long waves, at a depth of 20 m the wave motion will be limited to less than 0.5 m. By placing a

substantial part of the cage system in this lower zone, routinely or temporarily, its structural stresses are considerably reduced, risks are greatly lessened, and stocks are much less stressed.

The Ocean Spar is a cage developed in the US and utilized in areas with high seawater current velocities. Using four vertical spars securely moored to form "corner posts", with horizontal tension lines between the spars at upper and lower levels, a tensed 3-dimensional form is provided in which the cage bag can be set (Loverich and Goudey, 1996). The design of this cage ensures little reduction of cage volume with current, and can be submerged below the surface. A more recent design from the same company, the Sea-station, is shaped like a double cone, with a central spar, and is equipped with variable buoyancy chambers and dead weights so that it may be actively submerged in rough weather and brought back to the surface later for normal operation.

The Sadco-Shelf is a cage with rigid tubular steel supporting structure within which the net-cage is supported. The configuration is similar to the semi-submersible FarmOcean cage, with an "umbrella" shaped structure, but in most models is of a smaller size. Two units have been developed for bass and bream rearing in Italy. It too is equipped with variable buoyancy chambers and has to be submerged before waves approach 3 m at the surface.

A number of other submersible cages, have been designed and proposed to farmers, but have not yet been fully tested in practice.

The Tension-Leg Cage (TLC) is based on a completely different principle compared to conventional cage systems. It is a concept originally developed by MARINTEK/SINTEF in collaboration with REFA a/s (Fig. 1).

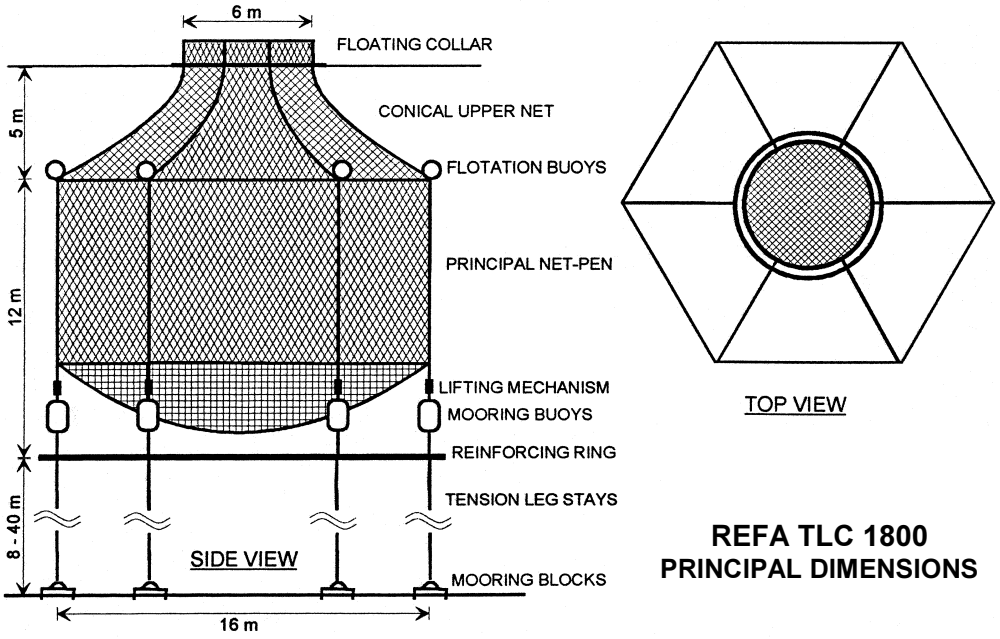

Fig. 1. The REFA TLC 1800 cage.

This "semi-submersible" cage is characterized by vertical mooring lines, a supporting frame below rather than above the net-pen, and a flexible floating collar of reduced size at the surface. The result is an improved hydrodynamic system, wherein the strain on mooring lines and flotation elements is drastically reduced. Rather than opposing the marine forces, the upper part of the TLC moves flexibly with the waves almost like the fronds of seaweed.

During storm periods with high surface current velocities, the cage is pushed sideways and downwards, submerging below the violent surface wave motion. This is achieved through natural forces, without any variable buoyancy systems, dead weights, nor interventions on behalf of the farmer. The REFA TLC consists of two modules:

(i) The MOORING MODULE, comprising the main section of the installation's buoyancy and the rigid section of the construction.

(ii) The CAGE-NET MODULE, comprising the net-pen, the flotation buoys and the surface floating collar.

The mooring module is permanently installed and consists of 6 tension legs placed in a circle. These are attached to mooring blocks on the sea floor, while the mooring buoys provide the tension in the lines. A reinforcing ring maintains a constant distance between the tension-legs.

The net-pen is divided into a lower cylindrical part (principal net-pen) and an upper conical part. These are joined with heavy-duty zippers, enabling quick removal of the upper part when bringing the net up to the surface for maintenance, fish handling or net change.

The floating collar is like a conventional plastic cage of reduced size, which provides access to the cage-net for routine inspection and maintenance. A dome-shaped structure is formed across the upper handrail circle, forming a frame over which a top net can be placed. The net-pen is fully antifouled, in order not to require changing during a typical rearing cycle. However, the upper, surface section can be more easily replaced and cleaned if required.

Performance of the REFA TLC

The supporting structure of the TLC is positioned at depth, while the components near the surface are small, flexible and loose, to absorb wave and current action. The strain on the net, the mooring lines and the flotation elements is minimal since the cage does not endeavour to oppose the marine forces but moves with the sea almost like seaweed.

In operation the flotation collar remains at the surface in normal sea conditions. As waves approach a height of 3 m the cage begins to submerge as wind generated currents "push" it sideways. Figure 2 shows the position of the top cage section in 4-meter waves, when it is completely submerged and removed from the influence of the most violent surface waves.

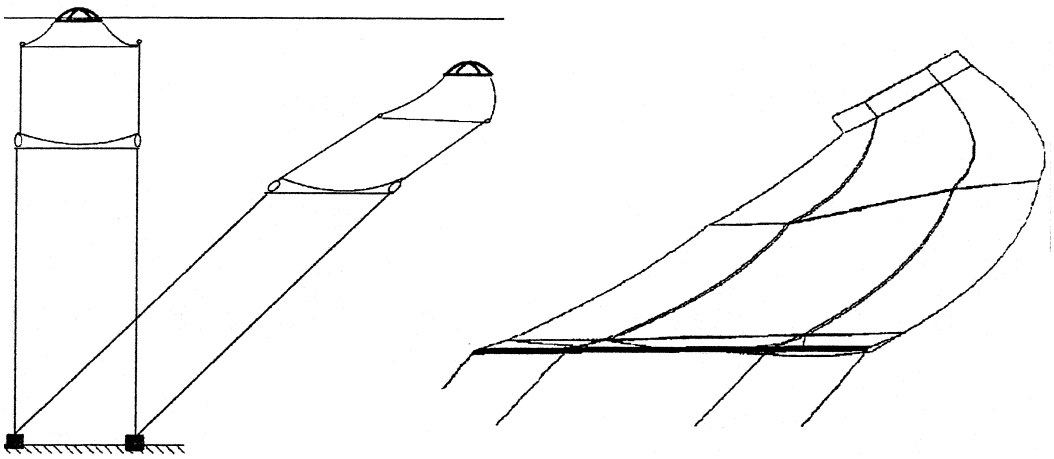

Fig. 2. Cage in submersed and deflected position.

The base of the net stays horizontal, and the whole cage remains very steady in the water column, without any violent motion. For the sake of explanation, Fig. 2 exaggerates the deflection during high exposure condition. The shape of the whole net-pen changes slightly as it absorbs some of the current forces, whilst retaining almost all its rearing volume. This is achieved through the action of sea motion rather than by variable buoyancy systems and interventions by the farmer. The TLC is not subject to the deformation and volume reduction of the net, which is a frequent cause of mortality and damage to fish cultured in surface cages.

Use of the REFA system in the Mediterranean

We have further modified the TLC to make it more suitable for bass and bream farming, and have installed a facility with 3 cages in the Eolian Archipelago off the coast of the Sicily in 1995, which has subsequently been doubled in capacity (Fig. 3) The installation process is described in Lisac (1996). The farm site is exposed to an open-sea fetch of almost 2000-km to the west, equivalent to that between Singapore and the Philippines.

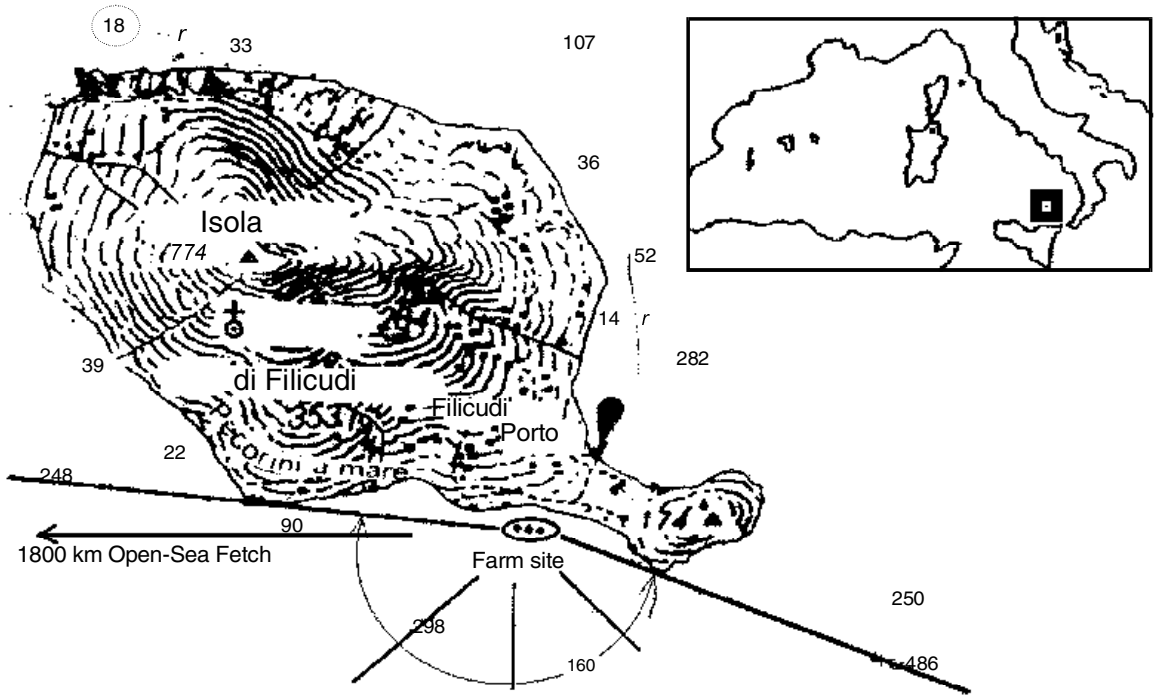

Fig. 3. TLC cage site in the Eolian Archipelago, Sicily.

The following modifications were introduced to render the cage more suitable for Mediterranean species such as bass and bream, including:

(i) Elimination of the dome structure above the float collar, resulting in less wind and wave impact on the cage, and increasing the flexibility of the top cage section.

(ii) The cage was dimensioned to a diameter of 16 m, with an effective rearing volume in the principal net-pen of 1800 cubic meters (plus an additional 500 m^3 in the top conical part).

(iii) The introduction of an internal "pregrowth net" of 600 m^3 within the cage for stocking small fry in the initial rearing stages. This net has a zipper opening in the bottom panel for conveniently transferring the fish into the main net-pen once they have reached 15-30 g.

The cage components occupied little space in transport and no specialized equipment nor heavy machinery was required for their assembly. The installation of the moorings was simple despite the highly irregular seafloor at this site (adjoining mooring blocks were displaced even 3 m in the vertical plane), and the lines are shorter than the water depth below the cage. The cages were supplied complete with float collar, antifouled net-pen, mooring lines, etc., providing ease of installation and low overall costs.

During the 1995/96 winter, storms with 8 metre waves hit the cage site on two occasions, with no harm to the facilities or to the reared fish.

Both present and long-term maintenance for the cage system has been found to be minimal. The components and links of the cages are few and well-tested; metal (galvanized steel) parts are limited

to the mooring module; there is no marine fouling on the net although adjacent mooring buoys are covered with long algae, barnacles and other organisms. The low level of stress forces acting on the components of the cage contributes to its longevity.

Conclusions

For farms operating in open waters the Tension Leg Cage, due to its seaworthiness, ease of operation and maintenance, combined with simple installation and limited investment requirements, appears to represent an attractive farming system for the culture of warm water marine fish species. Longer term assessments should confirm its ability to withstand demanding offshore conditions – experience to data has been positive, and has been combined with effective and secure husbandry, suggesting a potentially competitive level of overall performance.

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