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## Development of a Technological System of Floating Cages in the Sea for the Farming of Marine Fish Within the Coastline of ILO



**Abstract:** - The objective of the research work is to develop a technological system of floating cages in the sea for the culture of marine fish within the coast of Ilo. The research method is experimental, applied approach, the process is constituted by a marine cage system which includes the analysis of climatic conditions, oceanographic conditions, legislation, adequate environment and conditions suitable for the development of the project; to then design the prototype to operate the floating sea cage. The preliminary results through the study "Development of technical capacities for the cultivation of Corvina "Cilus gilberti" in the province of Ilo, Moquegua Region" through which the culture cages were installed approximately 1.2 km from the coast in front of the beach "Piedras Negras" north of Ilo in which juvenile corvina were planted. The design and construction of the marine cage for fish culture was appropriate because the materials used are in the optimal quality range, after submitting them in the simulations; you have fish in preliminary growth in the marine cages designed and built for fish culture; and finally, the maintenance of the cages was technically manageable, because it allows periodically its evaluation and maintenance.

**Keywords:** Culture; floating cage; marine fish, brackets; dead; HDPE tubes.

### I. Introduction

Asian countries were the source of 70% of global fisheries and aquaculture production in 2020, followed by countries in the Americas, Europe, Africa and Oceania. China remained the largest fish producer, followed by Indonesia, Peru, India, the Russian Federation, the United States of America and Viet Nam [11].

The yield of hydrobiological resources is approaching its maximum level estimated at 100 million tonnes per year; World fish production in 2018 is recorded at 179 million metric tons, by 2030 it will be 204 million metric tons [3]

Overfishing can be defined as "the reduction of stock abundance caused by fishing below the level that can produce maximum sustainable yield" [3]

The World Bank indicates that overfishing is compounded by challenges such as climate change and pollution of the seas, fishing catches reached their maximum capacity in 1996 at 130 million tons per year [1]

Unsustainable catch increased from 10% in 1974 to 33.1% in 2015. Global consumption of edible fish increased at an average annual rate of 3.1% between 1961 and 2017, a rate that is almost double the annual world population growth (1.6%) over the same period, and which is higher than that of all other foods containing animal proteins (meat, dairy products, milk, etc.), which increased by 2.1% per year. Per capita edible fish consumption increased from 9.0 kg (liveweight equivalent) in 1961 to 20.5 kg in 2018, by approximately 1.5% per year [3]

Cage aquaculture has grown rapidly over the past few decades and is currently undergoing major changes in response to the pressures of globalisation and an increase in global demand for aquatic products. [5]. The cage system is a set of different materials, provided with walls and bottom, with a limited volume of surrounding water, which makes it possible to keep the species captive, feeding them from their juvenile age to commercial size [6]

In particular, the need for these appropriate sites has led this activity to access and expand to new unexplored areas of open water cultivation, such as lakes, reserves, reservoirs, rivers and brackish and marine waters of the open sea. The enormous importance of cage aquaculture today and its key role for the future growth of the Peruvian aquaculture sector is recognized [11]

Currently the National Fund for Fisheries Development, is a public executing agency of the Ministry of Production, works on the development of new technological packages of marine fish of commercial importance, identifying among them the Corvina (Cilus gilberti), reporting that in the world, and by countries, Egypt is the main producer of croaker. In fact, in 2019 it was responsible for 47% of global production (96% aquaculture). Egypt is followed by the EU-27 (82% aquaculture), Angola (100% catch), Mauritania (100% catch) and Turkey (98% aquaculture), as can be seen Peru is also studying the feasibility of being present in this list of large producers. This species, given its high commercial value and demand in the national market, has allowed it to be positioned as a preference for national as well as

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international consumers, a situation that has generated a greater effort of its capture, causing a considerable decrease in the biomass available in the Peruvian sea of this important fishery resource [3]

The beginning of the experimental work with the croaker occurred from 2013, thanks to the work of adaptability to captivity conditions its total adaptation was achieved at the beginning of 2015. Then, the technical works for its reproduction in captivity began and in December 2016, the first reproduction of this species was achieved in the Morro Sama-Tacna Aquaculture Center, which will mark an initial starting point in the aquaculture of this species [11]

On the other hand, the Jorge Basadre Grohmann National University through the project: "Research and development of marine fish culture technologies of economic importance: Corvina (*Cilus gilberti*) and seabream (*Anisotremus scapularis*) in the Tacna region" to date has a stock of adult fish acclimatized and conditioned in captivity system that are maintained as breeders [16]

It is important to highlight that in 2014 two research projects of UNAM students called "Capture and adaptation to captivity of broodstock of *Cilus gilberti* croaker with three diets on the marine coast of Ilo" and "Effects of stocking density on the growth and survival in captivity system of juvenile corvina *Cilus gilberti* on the marine coast of Ilo" won funding from UNAM, approved with Resolution of C.O. No. 405 -2014-UNAM.

In Peru, specifically in the Province of Ilo, they have carried out important projects for the development of early stages of croaker cultivation, but technical and economic aspects of productive scaling that favor the introduction of these products to the market are unknown. That is why our main objective is to develop a technological system of floating cages in the sea, for the culture of marine fish within the coast of Ilo and take advantage of the appropriate conditions for the cultivation of commercial fish in different conditions, with high market value and high demand. Being one of the main objectives, to design the construction of the marine cage for fish culture and evaluate materials to be used, evaluate the growth of fish in marine cages designed and built for fish culture, evaluate the feasibility of maintenance and feasibility throughout the production process [15]

## II. Materials and Methods:

### 2.1 Marine Floating Cage Technology System

#### 2.1.1 Marine cage system

Aquaculture enclosures are a set of different materials, provided with walls and bottom, which limit a volume of surrounding water, where aquaculture species are kept captive, feeding them from their juvenile state until they reach commercial size [5]. In order to properly install this system of floating cages in open water, studies of the location area with modeling techniques and 3D printing must be carried out to test the proposed models of each project [2]. These floating cages generate greater efficiency in the control process and accelerate their growth cycle, reducing their mortality rate, selecting individuals, and preserving them from those of natural predators [12]. It is for this reason that the incorporation of controlled fish culture generates a greater production of the same, stocking in high densities with diets designed by life cycles, providing the physicochemical parameters necessary for an adequate and high healthiness development [14]. These floating cages are therefore the only viable procedure for farming in semi-protected sea areas, with the assurance that the fish that is farmed with so much effort will not escape our hands [6]

#### 2.2. Marine cage design

According to Alvarado [5] when designing an aquaculture structure, it is necessary to take into account the following requirements:

- a. That the installation has adequate conditions for the work to be carried out on the farm, such as production characteristics, maintenance, etc.
- b. That the whole of its floating structure, support and anchorage is calculated to absorb the forces exerted by the weight of the system and external actions.
- c. That the fish container enclosure has the appropriate size, shape and surface, according to the fish species and does not interfere with the marine currents that ultimately provide clean water with dissolved oxygen.
- d. That, meeting the above conditions, is economical and safe.

According to Alvarado [6], they indicate in their Manual of construction and management of floating cages for mariculture in the case of Ecuador, some recommendations chosen for their ease of handling and possibility of recovery of cultured species should be taken into account, they are the so-called floating cages, which are composed of the following elements:

- Sustaining structure
- Floating structure

- Fish container enclosure
- Anchoring system

### 2.3. Behaviour

The various physicochemical parameters of the water, which define its quality, must be within certain limits, precisely those in which the fish experience greater growth and do not adversely influence their health status. Wind is one of the variables of state of air movement. It is caused by temperature differences due to uneven warming of the various areas of the earth and the atmosphere. Currents and tides, differences in density between bodies of water or sea unevenness. The influence of the tide on ocean currents is not of great importance, because the variations in height are of little amplitude in this area, compared to the variations of sea level in coastal areas; The waves occur both in oceanic and coastal areas, and must be taken into account when it comes to the resistance of the materials and their useful life [11]

### 2.4. Water quality

Quality is one of the main aspects taken into account for technical feasibility, since the project depends directly on the quality of the surrounding water and the speed of water exchange between the cage and the surrounding water accordingly, at least the following parameters: Water transparency, Dissolved oxygen, Ammonia, Bathymetry and types of funds [13]

## III. Methodology

The research is experimental, applied approach, descriptive design, longitudinal; the objective is to develop a technological system of floating cages in the sea for the culture of marine fish within the coast of Ilo.

### 3.1. Selection of the place, choose appropriate sites for aquaculture.

Before placing the floating cage, the following criteria to be evaluated were considered, such as:

- Area naturally protected from strong currents.
- Physicochemical parameters suitable for the normal development of croaker growth.
- Primary production within the normal range, to avoid sudden changes in the oxygenation of the area.
- Obtain a concession permit for aquaculture use.

After verifying the necessary parameters, it was concluded to locate the floating cage, in front of the Piedras Negras beach, north of the city of ILO.

This beach is located north of the Province of Ilo, taking as reference the Southern Copper Corporation Smelter which is located approximately 2 kilometers south of the beach. This beach covers approximately 860 meters of coastline, where you could find rocks of different dimensions, the ground is smaller stones and its wave tide is medium to high; the beach does not have rescue personnel or watchtowers. The climate is variable depending on the time of year; however, water temperatures are partially cold throughout the year. The culture cages are located approximately 1.5 km offshore (-17.471018, -71.376109), [11]

### 3.2. Detailed description of the facilities

They are cages made of high density polyethylene (HDPE) tube of various dimensions, according to the needs. The frames and anchorages made of the following elements: dead, anchors, anchoring chains, anchorage stakes, network of buoys and stakes.[7]

**Table 1**  
*Specifications.*

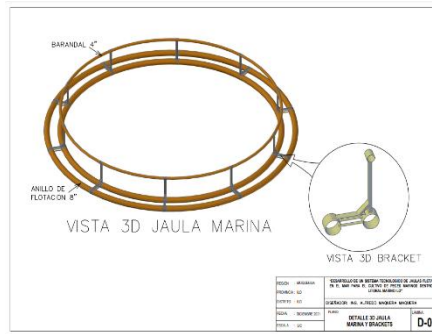
<b>PART</b>	<b>DESCRIPTION</b>
Inner diameter	8 m
Flotation system	Composed of two (2) HDPE pipe rings of 200 mm diameter, PN 8 or higher, tube separation and tube 30 cm.
Braces	10 Brackets stainless steel 304 and / or 316 (1/8" thick in case of stainless steel) with handrail height of 0.8 m, covered with antifouling paint.
Railing	110mm diameter HDPE pipe ring, PN 10
Buoy	Includes, 200 L buoy, with stainless steel basket 1/4" thick by 3/4" wide.
Anchor chain	Naval steel chain 1/2" x 50 meters long, coated with antifouling paint.

*Note.* Merma, Mendez, Gonzales & Felix, (2022).

### 3.3. Cage construction

The assembly of the floating cage was carried out on land in front of the location point.[7]

**Figure 1:** 3D detail of the floating cage.



**Note.** Merma, Mendez, Gonzales & Felix, (2022).

### 3.4. Handling

Following FAO procedures [3], the cages are installed in the concession "Association of artisanal fishermen not embarked and protectors of the marine environment of the port of Ilo", since September 2021, in the area called Escoria Miraflores. Marine fish culture was carried out in the prototype cages of the UNAM, for this the cages have been previously implemented with fish tank bag and anti-wolf fence, the fish are owned by the Association, which have been carrying out the cultivation of croaker in floating cages since 2020. To date it has been shown that there was no intrusion of sea lions in the cages in culture.

### 3.5. Maintenance

This activity consists of:

- The change of wolf and fish nets when damaged.
- Cleaning of floating HDPE tubes,
- Cleaning of biofouling matter from the ropes and anchor chains.

The maintenance and procedures are guided by the procedures proposed by Lopez et al[6], it is periodic and scheduled every month or 15 days, if necessary, the main problem is the adhesion of biological material (biofouling), as it is a great variety of organisms which adhere to substrates present in the aquatic environment.

## IV. Results

### 4.1. Mathematical model from strength of materials

The static analysis has been carried out; the drag force calculated on the module of the raft-cage for each speed of the marine current. Using fluid mechanics formulas, the drag force of the average marine current throughout the year can be calculated, using twice the atmosphere simulating a depth of 10 m, and the average marine density in the Peruvian sea [7].

**Table 2**  
*Force in Newton (N) according to the speed of sea currents in Ilo.*

Stream Meters per second (m/s)	Fluid density Seawater (kg/m <sup>3</sup> )	Atmospheres Millimeters of mercury (mmHg)	Trawling Newton (N)
0.20			25.67
0.30	1027.00	1520	57.76
0.40			102.70

Data recorded by the tide table were used, with the same fluid mechanics formulas at an atmosphere of 1 because it is at sea level and average density of the fluctuating air along the coasts of Ilo. [7]

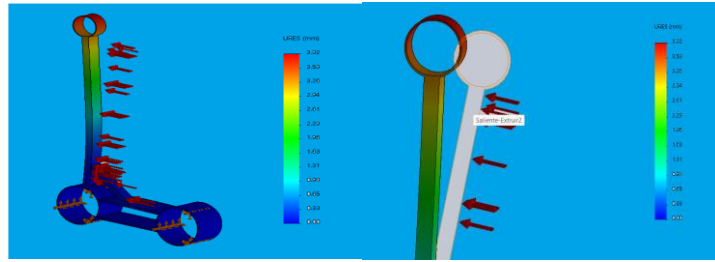
**Table 3**  
*Force in Newton (N) according to the speed of the wind at sea level in Ilo.*

Wind speed Meters per second (m/s)	Density of Air at sea level (kg/m <sup>3</sup> )	Atmospheres Millimeters of mercury (mmHg)	Trawling Newton (N)
1			1.25
5	1,225	760	31.25
10			125.00

**Note.** Merma, Mendez, Gonzales & Felix, (2022).

Using Table 3, the most affected red areas and resistance to external forces are described without reaching the resistance limit, within the expected parameters.[7]

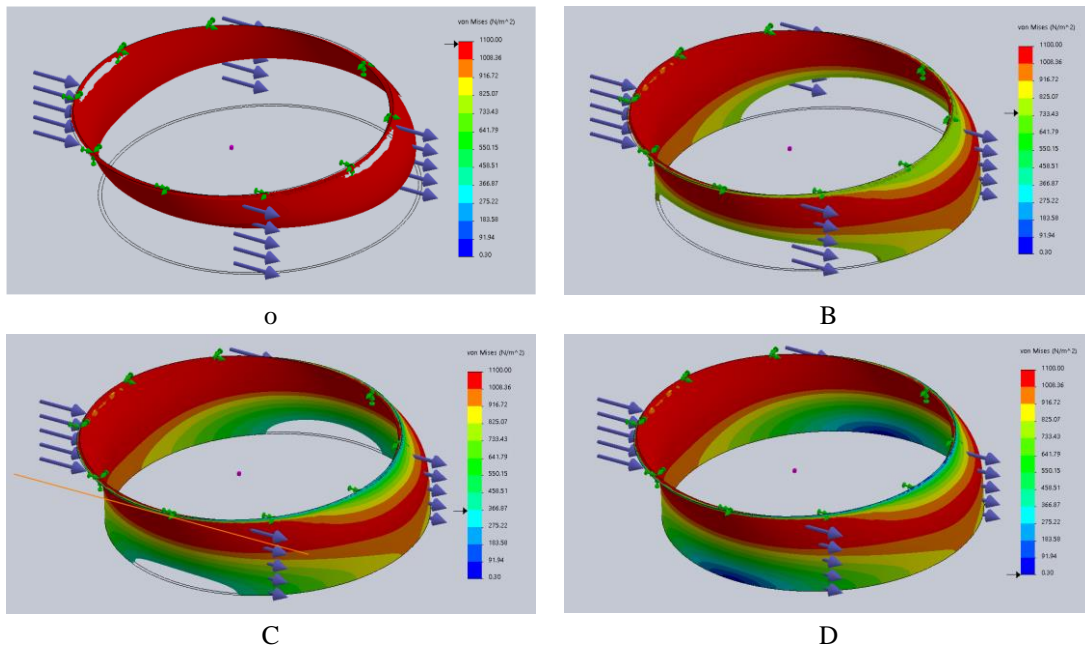
**Figure 2:**  
*Displacement of the brackets against extreme wind forces.*



**Note.** Merma, Mendez, Gonzales & Felix, (2022).

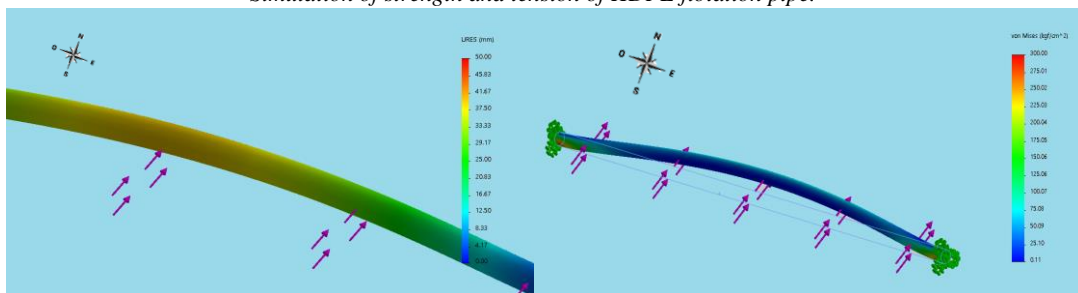
In image A it shows the greatest resistance tension that is located closest to the rigid part of the cage structure; in image B you can see how the tension force decreases as it moves away from the rigid part of the floating culture structure; image C and D are more mobile parts that have little resistance stress, Being flexible against the fluid of sea currents.[7]

**Figure 3:**  
*Key points in greater voltage resistance in the cage against sea currents; at different degrees of magnitude.*



The green arrows simulating the attachment of the shape and the purple arrows the direction of the sea current are observed; the clearest deformation is the center of the distance without fastening, but which does not influence its material resistance, since the critical point of maximum load for the resistance is very far from the normal conditions of the coastal sea off Ilo using data from Table 2 and 3. [7]

**Figure 4:**  
*Simulation of strength and tension of HDPE flotation pipe.*



**Note.** Merma, Mendez, Gonzales & Felix, (2022).

It is also important to mention that, in table 15, the considerations of atmospheric pressure at different depths, considered for the dead according to bathymetry data. [7]

**Table 4**  
*Atmospheric pressure at different depths.*

Depth (m)	Atmospheres	Pressure N/m <sup>2</sup>
20	3	303975
30	4	405300
40	5	506625
50	6	607950

*Note.* Merma, Mendez, Gonzales & Felix, (2022).

To determine the feasibility of the dead, it is necessary to know the resistance of reinforced concrete, being by Regulation of Construction of materials, it must have a resistance between 400 kg / cm <sup>2</sup> and 700 kg / cm <sup>2</sup>. That is why the wide difference in resistance it has against sea pressure is detailed in the following table. [7]

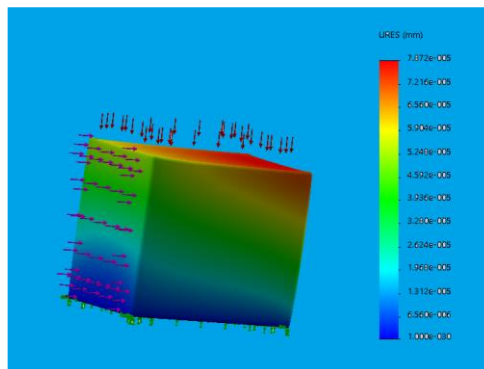
**Table 5**  
*Strength of reinforced concrete.*

Kg/cm <sup>2</sup>	PSI	N/m <sup>2</sup>
10	142.23	980641
20	284.47	1961352
30	426.70	2941994
40	568.93	3922635
50	711.76	4907414

*Note.* Merma, Mendez, Gonzales & Felix, (2022).

Taking into account the depth where the dead were located (30 m) and the material used for the construction of the dead, it can be concluded that it will have an acceptable resistance for the execution of the project. Own.[7]

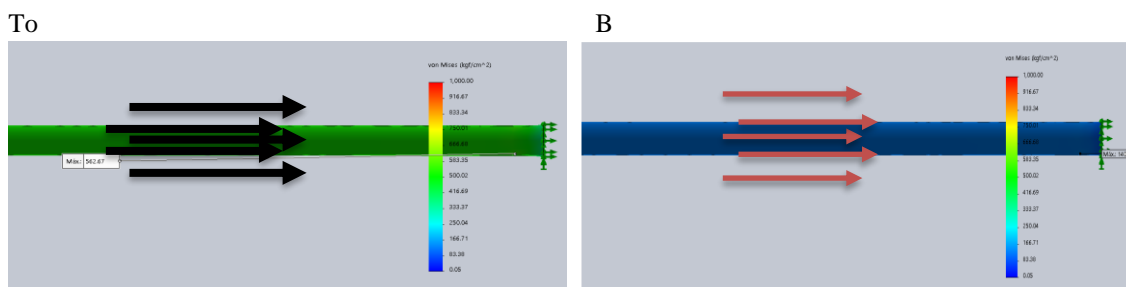
**Figure 5:**  
*Resistance of the dead and their displacement.*



*Note.* Merma, Mendez, Gonzales & Felix, (2022).

The resistance of the rope shows that it does not suffer any problem in its fastening function, having a useful life of several years, without the influence of any foreign agent (sea lions, boats or biofouling). Image A shows the maximum resistance ranging from 500 kgf/cm<sup>2</sup> and image B shows a resistance of 80 kgf/cm<sup>2</sup>; all indifferent to the material and its resistance Own.[7]

**Figure 6:**  
*Tension resistance on the ropes.*

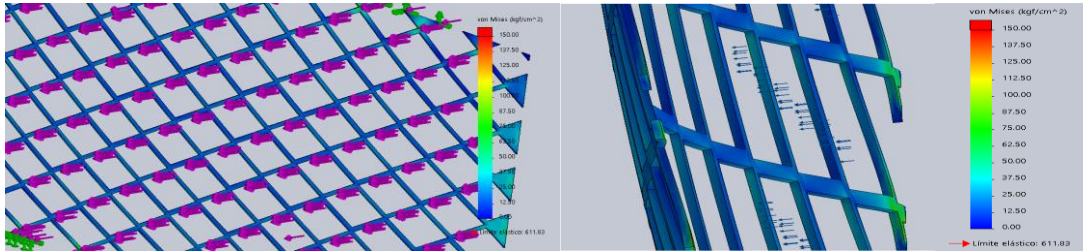


*Note.* Merma, Mendez, Gonzales & Felix, (2022).



The resistance of fishing nets is minimal; The displacement by influence of the sea, which is between 20 cm by 1 m ^ 2; showing the elastic limit of 611.83 kgf / cm ^ 2 if it reaches that limit point of elasticity. Own.[7]

**Figure 7:**  
Voltage resistance and displacement of the networks used.

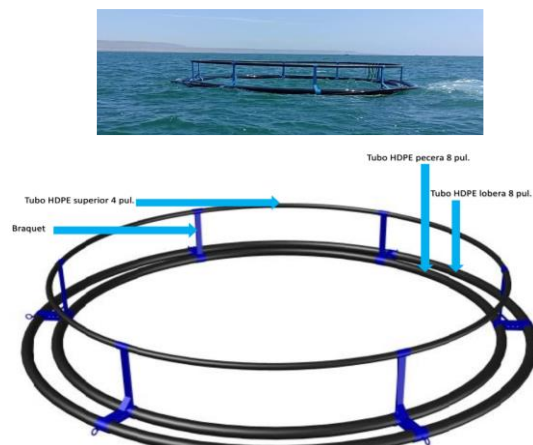


*Note.* Merma, Mendez, Gonzales & Felix, (2022).

A technological system of floating cages at sea was developed for the culture of marine fish within the coast of Ilo; taking into account the mathematical models of resistance of materials and the need for which it will be used.[7]

The project aims to have an adequate space and area, conducting an oceanographic evaluation, and then technically locating it in the area of the beach "Piedras Negras" north of Ilo. The installed cages are approximately 1.2 km from the coast, which were designed and built of flexible resistant materials described in table 01, for which they planted juvenile corvina still in operation at the research level.[7]

**Figure 8:**  
Floating cage installed in the sea and its descriptive plane.



*Note.* Merma, Mendez, Gonzales & Felix, (2022).

**V. Discussion**

The present research has used a Mathematical Model from the resistance of the materials, through which static analysis has been performed, drag force calculated on the module of the raft cage for each marine current, however according to the investigations of Costa Sanches and the Construction Manual applied techniques which their results are interpreted below for this discussion:

According to Costa Sánchez, A. (2022) carried out the "Feasibility study of the offshore construction of an aquaculture facility through additive manufacturing", his conclusion was positive in the aspect of building the entire aquaculture system by 3D printing, but the weakness or breaking point are the materials used for the elaboration of an entire 3D system, since the aquaculture system described in the present work carried out by the National University of Moquegua, indicates that it is essential to have movable, flexible and rigid parts throughout the construction and not only to be of a single material; that is why it is important to have carried out 3D simulations of the resistance of the materials used in construction.

According to the "Manual of construction and management of floating cages for mariculture in Ecuador" written by Julio López Alvarado and Walter Ruiz (2018); You show us the basic techniques for the elaboration of floating cages by hand, of a high density polycarbonate material; unlike the project carried out by the UNAM where the construction

technique was improved, especially in the implementation of stainless steel braquets that gave more stability and resistance to the physical-chemical inclemencies existing in the sea.

## VI. Conclusions

- The design and construction of the marine cage for fish culture was appropriate because the materials used are in the optimal quality range, favoring the final development of the species.
- There are good results in the production of the fish tested in the marine cage designed and built by the National University of Moquegua.
- The maintenance of the cages was technically manageable because it allows their periodic evaluation and maintenance.
- The feeding is constant and its easy acceptance and change of diet of the fish for a formulated food was proven.
- Taking the favourable results of the floating cage project, larger-scale replication should be taken into consideration for better results and acquisition of basic knowledge for the incorporation of a new technology in the fisheries market.

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