

## Open Sea Cage Culture: A New Frontier in Sustainable Seafood

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[doi.org/10.5281/FishWorld.19563394](https://doi.org/10.5281/FishWorld.19563394)

### Introduction

Open sea cage culture is a technique for raising fish in containers that are netted off on all sides and the bottom to keep the fish within while allowing for unrestricted water circulation and the removal of feed and metabolic waste. It ranges from the highly advanced industrial cages in rich countries to the old artisanal cages in developing countries. Cage culture, which has its roots in Southeast Asian countries, has developed into a major global cultural phenomenon. Originally developed in Japan in the 1950s, cage-based mariculture expanded mostly due to the salmon farming industry in northern Europe and North America during the preceding two decades. More than 90% of all seabass and sea bream produced in Mediterranean aquaculture come from cages, while about 60% of fish farmed along the coast are housed in cages. The main advantages of cages over conventional land-based systems are their low initial costs and simplicity of maintenance.

The commercial culture of yellow tail (*Seriola quinqueradiata*) was the result of fish farming research conducted at the Fisheries Laboratory of Kinki University in Japan in the 1950s, and by 1960, the practice had grown to be a large industry. Thailand has been developing cage culture methods for two significant marine finfish since 1970: grouper (*Epinephelus* spp.) and sea bream (*Pagrus major*).



In 1980, Malaysia pioneered large-scale grouper cage farming. Cage culture of black rockfish (*Sebastes schlegeli*) and olive flounder (*Paralichthys olivacens*) was established by the end of 1980 in Korea, and it evolved into a Salmonid culture that is now dominated by output from Norway, Scotland, and Chile. In 1964, the United States introduced fish cage culture.

### Current global status of sea cage farming

Over the past 20 years, the cage aquaculture industry has expanded extremely quickly, and it is currently changing quickly in response to challenges from globalization and the rising demand for aquatic products. From 62.7 million metric tons in 1997 to 98.6 million in 2020, the number of fish consumed in emerging nations would rise by 57%. In contrast, the number of fish consumed in wealthy

nations will only rise by roughly 4%, from 28.1 million metric tons in 1997 to 29.2 million in 2020. In developing nations, rapid urbanization, rising incomes, and population expansion are causing significant shifts in the supply and demand for animal protein, including fish and livestock. The industry's growing competition for resources, the need for economies of scale, and the desire for higher productivity per unit area all contributed to the shift in aquaculture toward the creation and application of intensive cage farming systems. The sector has accessed and expanded into new unexplored open water culture areas, including lakes, reservoirs, rivers, coastal brackish waters, and marine offshore seas, mostly due to the necessity for suitable sites.

### Cage farming in India

In May 2007, the first open sea cage was introduced in the Bay of Bengal off the coast of Visakhapatnam. With assistance from the Indian government's Ministry of Agriculture, the Central Marine Fisheries Research Institute (CMFRI) began open sea cage farming as a research and development project in 2006–07.

As first step an indigenous cage of 15m diameter was launched at Visakhapatnam with primitive mooring techniques seabass seed, then 6 m diameter cages were designed to cater to the needs of small farmers. The mooring and other aspects were also suitably modified. The volume of each cage is about 170 m<sup>3</sup> and production potential is about 3-5 t of fish. Nationwide demonstrations with different social engineering, environmental conditions and species of local importance were held to bring awareness and exposure to fishers, farmers, entrepreneurs, researchers, and government agencies. This has proved highly successful by seeing growing interest.



### Major cultured species

Commercial cage culture has been mainly restricted to the culture of higher value (in marketing terms) compound-feed-fed finfish species, including salmon (Atlantic salmon, coho salmon and Chinook salmon), most major marine and freshwater carnivorous fish species (including Japanese amberjack, red sea bream, yellow croaker, European seabass, gilthead sea bream, cobia, sea raised rainbow trout, Mandarin fish, snakehead) and an ever increasing proportion of omnivorous freshwater fish species (including Chinese carps, tilapia, *Colossoma* and catfish). However, cage culture systems. In terms of diversity, altogether an estimated 40 families of fish are cultured in cages, but only five families (Salmonidae, Sparidae, Carangidae, Pangasiidae and Cichlidae) make up 90 percent of the total production and one family (Salmonidae is responsible for 66 percent of the

total production. At the species level, there are around 80 species presently cultured in cages. Of those, one species (*Salmo salar*) accounts for about half (51 percent) of all cage culture production and another four species (*Oncorhynchus mykiss*, *Seriola quinqueradiata*, *Pangasius spp* and *Onchorhynchus kisutch*) account for about another one fourth (27 percent). Ninety percent of total production is from only eight species (in addition to the ones mentioned above: *Oreochromis niloticus*, *Sparus aurata*, *Pagrus auratus* and *Dicentrarchus labrax*) the remaining 10 percent are from the other 70+ species. Atlantic salmon is currently the most widely cage-reared fish species by volume and value; reported aquaculture production of this coldwater fish species increased over 4000-fold from only 294 tonnes in 1970 to 12 35 972 tonnes in 2005 (Valued at US\$4 767 000 million), with significant production of more than 10 000 tonnes currently being restricted to a handful of countries, including Norway, Chile, the United Kingdom, Canada, and the Faroe Islands.



**Pompano**



**Cobia**

**Cage culture operations**

**Stocking:** The carrying capacity of the cages and the feeding habits of the cultivated species determine the fish stocking density. The main and secondary productivity of the sites will also affect stocking for species that are low in the food chain. The ideal stocking density, which guarantees maximum yield and minimal illness prevalence, varies depending on the species and size of fish.

**Feeding:** The feeding of fish in cages is influenced by biological, climatic,



Feeding with commercial pelleted feed

environmental, and economic factors. Feeding time and intensity have an impact on growth rate.

The maximum amount of food that each species can consume, the frequency of feeding, digestibility, and conversion efficiency vary. These in turn have an impact on the overall production from the cage, fish size, survival rates, and net yield. Yellowtail, grouper, bream, snapper, and other carnivorous fish raised in marine cages primarily eat trash fish. In many nations where cage farming is practiced on a wide scale, the scarcity of waste fish is a serious issue.

**Cage management:** The goal of cage management is to maximize output while minimizing expenses. Effective management is mostly dependent on the farm's proficiency and productivity in terms of stocking, feeding, reducing illness and predator-related losses, keeping an eye on environmental factors, and preserving technical facility efficiency. In cage cultivation, maintenance tasks are also crucial.

**Floataction:** Field HDPE cages made of puff or foam are sufficiently buoyant to float in water. But the metal cage requires more buoyancy. The cage is floated using ten 200-litre fiber barrels that are filled with 30 pounds of air. When the cage is supported by inflated barrels, it creates a sturdy surface around which fishermen can stand and safely do tasks like replacing or removing nets.

**Harvesting & Marketing in Sea cage culture:** Harvesting, post-harvesting, and marketing strategies must be planned methodically based on price, environmental conditions, and market demands for cage culture to be effective. Sea cages are typically harvested in two stages: partially and completely. In order to make the crop economical, the stock was typically collected around the end of July, when trawls were prohibited along the west coast.

Harvesting is often finished in July, during the trawl prohibition period, as the culture



Floataction using HDPE Floats



begins in September (after the monsoon). Daily partial harvesting was carried out, and the fish were sold at the local market. Harvested fishes are usually graded and packed with ice in plastic boxes and sent to the market. As per market demand, fully grown fishes can be harvested first. More over live fish marketing is also possible. Fishes can be marketed to cater high end consumers to get better price. In cages partial harvesting is easier as compared to pond farming.

**Nets and netting materials for sea cage aquaculture:** Nets and the netting materials play an important role in sea cage aquaculture and farming practices. Nets are the most necessary components of cage farming since it delimits the fish stocking density. Fish stocking density depends on the net dimensions used for that particular cage.

**The selection criteria for nets for the cage aquaculture:**

Cost effective and durable, Strength to hold the large volume of fish, Low weight and convenient to use, Maintain designed shape, Resistant to abrasion and Low water absorption, Protection against predators, Resistant to fouling and ease of cleaning.



**Features of open sea cage nets:**

Shape and Design of the cage net:

Different shapes of cages viz. circular, square and rectangular are used for stocking the culture organisms. The cage nets are designed according to the shape of the cage frame. Four types of nets are used in open sea cage culture practices. They are 1. Outer net, 2. Inner net, 3. Bird net 4. Hapa net.

**Fig. Cage with three types of nets (outer, inner and bird net)**



**Cage maintenance:**

Since the cage is installed in open sea fouling will be a regular phenomenon. Cleaning of cage frame with knife and coir should be carried out on daily basis



**Fig. Different kinds of sea cage nets (a. Outer net b. Inner net c. Bird net d. Hapa net)**



**Fig. Maintenance of sea cage nets (A. Fouled net; B. Net exchange; C. Net transportation; D. Sun drying; E. Manual cleaning)**

### Types of cages

**Fixed-** these types of cages are supported by poles driven in to the bottom of the water body viz, river, lake. Fixed cages are inexpensive, simple to design, but they have limitations such as size, shape and restricted use.

**Floating-** these types of cages are designed with the buoyant collar supporting the net. These cages can be made in variety of designs like square, rectangular or circular to suit the purpose of the farmer and are widely used. Rigid materials such as GI pipes, bamboos and plastic pipes can be used as frames. The floating unit consists of a number of floats below the framework to provide sufficient floatation. The types of floats used vary from ordinary oil drums to used fibre glass barrels.

**Submersible-** The shape of these cages is maintained by the frame. This type's advantage is that the cage's location can be adjusted according on the weather.

**Submerged-** These cages are constructed from wooden boxes with spaces between the slots to allow water to flow, and they are fastened to the substratum's bottom with poles or stones.

### Advantages and disadvantages of cages compared to land-based structures:

Cage culture's benefits and drawbacks are evaluated by comparing it to other land-based culture systems in terms of the degree of technology needed for development, economic performance, resource utilization, social ramifications, simplicity of management, flexibility,

and the caliber of fish raised.

**Advantages:** Whether a cage is handmade or modern and complex, it is rather easy to construct.

In cages, it is simple to observe the animals, making routine maintenance and feeding simple.

Fish raised in cages have better quality in terms of look, condition factor, and flavor. Since cages utilize already-existing bodies of water, they can be provided to community members who do not own land (fishermen), whose income is impacted by the fishing industry for a variety of reasons. For these groups, it serves as an alternate source of income.

In cages, harvesting usually requires less labor. Fish are shielded from rivals and predators.

**Disadvantages:** Because they are unable to forage on their own, cage-grown fish have limited access to natural food, whereas pond fish can utilize naturally existing food. As a result, the farmer must feed cage-grown fish significantly more frequently.

Additionally, the food fed to cage-grown fish must be nutritionally complete, meaning it must include enough amounts of all essential vitamins and minerals.

The majority of farmers choose a high stocking density while raising fish in cages as opposed to ponds. Because stress weakens the immune system, a high stocking density puts the fish in a stressful environment. Thus, there is a greater chance of illness.

If the farmer doesn't give the fish the best possible water and a healthy food, the hazards will only get worse. The aquatic flora and fauna, the behaviour and distribution of local fauna, and the introduction or disruption of disease and parasite cycles can all be attributed to cage culture.

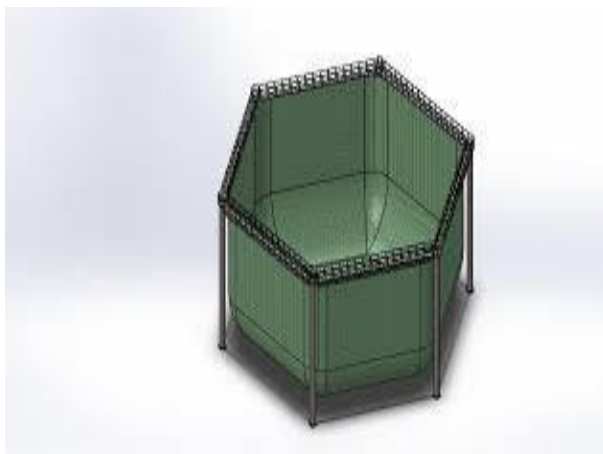
The location will become eutrophic due to the leakage of metabolic waste and uneaten feed from cages if there is inadequate water exchange.

### **Cage design**

One important element that pushes the boundaries of aquaculture system structural integrity and economic viability is cage design. The behavior of the cultivated species dictates the cage's design. Compared to square or rectangular cages, circular or hexagonal cages might be more appropriate.

Greater net space is needed for pelagic animals that swim close to the surface. These fishes typically swim in circles and congregate in shoals.

The form of the cages has no effect on the movement of demersal fishes, who are less active, territorial, and prefer to conceal with underwater structures.



**Hexagonal**

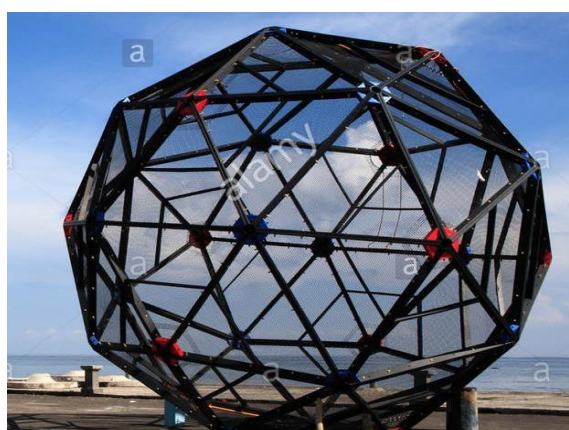


**Rectangular**

In these situations, rectangular or square cages have an benefit over a hexagonal or circular one in terms of simple cage assembly and maintenance.



**Circular**



**Polygonal**

### **India's advancement in open-sea cage culture technologies**

For fish production to be sustainable, a variety of aquaculture methods must be developed. Open sea cage farming is one of the technologies that can help the nation increase fish output alone in the marine sector from its current 32% to 60% contribution.

India would become the world's largest producer of fish if we added another 18% to 22% from the marine sector.

Various small and medium-sized open sea floating cages have been used in India up to this point. These cages require extra care during inclement weather and during hypoxia (the stage when the concentration of dissolved oxygen in the water is reduced), which causes fish to become

more stressed and eventually die because there is less dissolved oxygen in the seawater due to the growth of algae covering the cages.

At this point, India can massively adopt an open sea submerged cage system that will increase production and promote sustainable aquaculture in the near future.

Prior to choosing a location for cage culture, several factors need to be considered. The first focuses mostly on the physical-chemical factors that affect a species' ability to survive in a given environment, such as temperature, salinity, oxygen, currents, pollution, algae blooms, water exchange, etc.

Weather, shelter, depth, substrate, and other factors must be taken into account when choosing a site. Lastly, it is important to evaluate legal issues, accessibility, security, hatcheries or fishing harbors, as well as economic, social, and market factors. It is true that, within the constraints of the materials and construction techniques employed, costs per unit volume reduce as cage size increases. Very big cages, however, could restrict the possibilities for stocking, grading, and harvesting. Additionally, as cage sizes increase, maintenance tasks like replacing the net and treating diseases become more challenging.

### **Future Prospects**

The development potential of open sea cage culture is enormous. For instance, intermediate family-scale cage culture is quite successful in many Asian countries, and managing it rather than promoting it will be a major factor in its future growth and development. The existing reliance of certain cage culture systems in Asia on low-value/trash fish feed inputs, such as those for Pangasid catfish, and high-value species, including Mandarin fish, snakehead, crabs, and marine finfish, must be immediately reduced. Sea cage farming has not yet been commercialized in India, despite recent advancements in many Asia-Pacific nations, including China, Indonesia, Japan, the Philippines, Taiwan, Vietnam, and Korea.

The lack of sheltered locations that are perfect for sea cage farming is the main obstacle to cage farming's widespread adoption in India. We will be able to explore more exposed open sea regions thanks to the development of sophisticated mooring, anchor, and floating systems that can resist the effects of bad weather and currents. Therefore, it is believed that greater engineering and technology advancements in cage farming, along with the large-scale hatchery production of valuable and quickly developing finfish, can open the door for the sea cage farming sector to thrive in our nation in the near future.

Open sea cages, which are now the primary method of mariculture, can offer a huge aquaculture capacity and good economic benefits when placed close to the fish's natural ecological habitat. Current information technology is desperately needed to support

aquaculture in order to increase its level of intelligence and automation because of its position in open sea areas, complicated settings, high labor intensity, and high danger. In order to achieve the combination of fish behaviour and water quality monitoring, open sea cage monitoring will develop in the future in an all-encompassing, three-dimensional, and intelligent manner.

A multi-space unmanned water quality monitoring system can achieve the integration of water quality and sea, land, and air quality monitoring when combined with current online monitoring technologies, sensor technologies, buoy technologies, and emerging underwater robot and unmanned aerial vehicle technologies. The water quality monitoring system will serve as the foundation for behavior monitoring, which will combine fish biological models, machine vision, and sonar technology to create a dependable and multipurpose environment that will support data for accurate feeding and culture management.

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