# CAGE CULTURE SYSTEMS AND MANAGEMENT

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## Introduction

India is endowed with vast marine fisheries resources such as an 8,118 km long coastline, 193,834 km$^2$ of territorial Sea (12 nautical miles/ 22.2 km from the shoreline), about 4.0 million marine fishers living in 3432 marine fishing villages in 66 coastal districts of 9.0 maritime states and 2.0 Union Territories, besides 2.0 Island Territories of Andaman & Nicobar and Lakshadweep. Infrastructure available includes 6 Major Fishing Harbours, 40 Minor Fishing Harbours and 1537 Marine Fish Landing Centres. The relatively shallow inshore water along the vast coastline of mainland and island territories offers scope for Sea Cage Farming. However, sheltered areas such as bays, lagoons, and semi exposed and exposed coasts having less wave action are preferable. The existing marine infrastructure and marine fisher population would be serving as complementary resources. Cage culture, a successful method for cultivating marine finfish, has been practised for many years. Since the 1950s, Australia, Norway, Chile, and various Asian countries have effectively employed cage culture. The rising demand for the cultivation of numerous marine finfish, driven by their significant consumption value, has consequently fuelled a global increase in demand for marine aquaculture. Sea cage farming in India was initiated by CMFRI with support from the Ministry of Agriculture & Farmers Welfare and the National Fisheries Development Board (NFDB). Sea cage farming is gaining momentum as a commercial seafood production system in the country. Several R&D programmes in cage culture, demonstrations and participatory mode of cage farming have led to the emergence of an economically viable farming method which resulted in the popularization of the technology.

## Site selection

Effective cage culture relies on careful site selection, where the chosen location is designed and operated to ensure optimal water quality and minimize stress conditions. Before finalizing a site for cage culture, it is crucial to consider not only the water and sediment quality but also gather relevant biological and natural distribution information for the targeted species. Various factors involved in site selection are as follows

## Physical factors

Physical criteria constitute vital considerations in cage culture systems, encompassing key parameters such as current movements, turbidity, and water temperature. Turbidity, exacerbated by heavy monsoons and freshwater runoff, renders water unsuitable for cage culture during such conditions. Optimal water temperature is contingent on the cultivable species in cage culture. For most tropical species, a range of 27–31°C is preferred, while temperate species thrive in temperatures of 20–28°C. Across the Asian region, annual temperature variations span from 20–35°C in tropical countries to 2–29°C in temperate countries. Selecting an appropriate site for cage culture involves a meticulous evaluation of these physical factors to ensure the success and well-being of the cultivated species.

**Chemical factors**

The assessment of water quality in cage systems heavily relies on the chemical parameters of marine waters in cage culture. Salinity, Dissolved Oxygen, pH, Ammonia, Nitrates, and Nitrites stand out as the key chemical factors in this context. Different species of fish exhibit varying oxygen consumption rates; for instance, pelagic fish like snapper and seabass require more oxygen than demersal species like grouper. Tropical species generally thrive in optimal salinity, which is comparable to normal strength seawater; they show intolerance to low salinities, such as 10–15 ppt. Therefore, a suitable cage culture site should maintain salinities between 15–30 ppt to allow flexibility in changing cultured species based on market demands. The preferable pH range for most marine species is from 7.0 to 8.5. The level of ammonia-nitrogen in the water should be maintained below 0.5 ppm, and it is recommended to measure ammonia levels during neap tide when the water current is slow. Nitrite levels in a suitable cage culture area should not exceed 4 mg/litre, while nitrate levels should remain below 200 mg/litre. Although toxic blooms from a few tropical marine species of Cyanobacteria (e.g., Lyngba and Oscillatoria, Moore, 1982) are uncommon, various marine algae groups, including diatoms, Cyanobacteria, prymnesiophytes, and dinoflagellates, may form blooms.

**Topographical factors**

Topographical criteria play a crucial role in the successful establishment of cage culture. For stationary cages, it is essential to choose a site where wind velocity remains below 5 knots while floating cages require wind speeds not exceeding 10 knots. Wave heights should be limited to 0.5 m for stationary cages and 1.0 m for floating ones. Strategic placement away from navigation routes is advised to minimize the impact of vessel-induced waves. Ensuring ample depth beneath the cage is vital to facilitate optimal water exchange, prevent oxygen depletion, and mitigate the accumulation of debris and noxious gases resulting from waste decomposition. Ideal bottom conditions involve a firm substrate, combining fine gravel, sand, and clay, to enhance productivity in cage culture. Additional criteria for site selection should consider accessibility to the cages and the ability to relocate them in response to potential threats such as algal blooms or low dissolved oxygen events. Fouling tends to occur more rapidly in areas with low current velocities, high temperatures, high turbidity (enriched water), and high salinity. Therefore, an ideal culture site should be located near the shore, preferably with a jetty for boat connection to farms, and in proximity to a good road for land transportation.

**Cage fabrication**

The Central Marine Fisheries Research Institute (CMFRI) has played a pioneering role in introducing open sea cage culture in Indian waters. The institute is actively working to promote this innovative method at selected locations across all maritime states, fostering collaboration with the fishing community. The refinement of cage design and mooring technology is an ongoing process, driven by the dedicated and committed efforts of CMFRI scientists. Through their persistent work, CMFRI aims to enhance the effectiveness and sustainability of open sea cage culture, contributing to the advancement of marine fisheries in the region.

**Design**

The low-cost cage developed by CMFRI features construction using high-quality 1.5" GI pipe (B class). The cage, with a diameter of 6 m and a height of 120 cm from base to railings, is designed for durability and strength. To ensure extra strength, all joints are double-welded. After fabrication, the structure undergoes a protective treatment, receiving a single coat of epoxy primer and a double coat of epoxy grey paint to prevent rusting. The meticulous attention to detail in both design and finishing results in a sturdy cage with a total weight of approximately 700-800 kg.

**Floatation**

A puff or foam-filled High-Density Polyethylene (HDPE) cage is inherently buoyant, allowing it to float on the water surface. In contrast, a metal cage requires additional flotation. In this case, 10 plastic barrels with a capacity of 200 litres each, filled with air, are employed to provide the necessary buoyancy for the metal cage. The use of inflated barrels not only ensures the floatation of the cage but also creates a stable platform around it. This stable platform serves as a secure area where fishermen can stand and safely perform various tasks such as net clearing and replacement. The combination of buoyancy and stability enhances the functionality and safety of the cage system during operational activities in the water.

**Advantage of the low-cost cage**

The design differences between HDPE cages and low-cost cages significantly impact their functionality and cost-effectiveness. The HDPE cage floats on the water surface, allowing the outer net to be at water level, creating a potential entry point for predatory fishes between the outer and inner net. In contrast, the low-cost cage has its outer net positioned 60 cm above the water level, preventing predatory fishes from entering the middle space. Moreover, the structural differences are notable. The HDPE cage may sink if more than three persons climb on the side frame, while the low-cost cage can safely support the weight of as many as 10-15 persons on its platform. The cost distinction is also substantial. The HDPE cage, including netting and mooring, costs more than Rs. 6,00,000, requiring multiple crops (4 to 5) to recover the input cost. On the other hand, the low-cost cage, with all components included, costs only Rs. 1,50,000, allowing for a quicker recovery of investment, potentially in a single crop. Despite these differences, both cages have a similar performance area-wise, with a diameter and net depth of 6 meters each. The advantages of the low-cost cage lie in its affordability, buoyancy, and potential for faster cost recovery.

**Disadvantages**

In contrast to HDPE cages, metal cages experience greater wind action since they are buoyant on barrels. Therefore, without robust mooring, floating in open sea conditions during the monsoon can be challenging. Apart from this, the performance of metal cages surpasses that of HDPE cages. Designed with flotation properties, the sea cage frame comprises two collar rings and a middle ring functioning as a catwalk in between them (Fig. 1). When using HDPE, the pipe ends are fused through a plastic fusion welding process. The two flotation collar rings can be filled with either polyurethane foam (PUF) or thermocouple. Various support pipes, brackets, and T-joints secure the two collar rings, the middle catwalk ring, and the handrail ring in their positions. The handrail pipe, devoid of PUF, incorporates galvanized steel brackets for corrosion

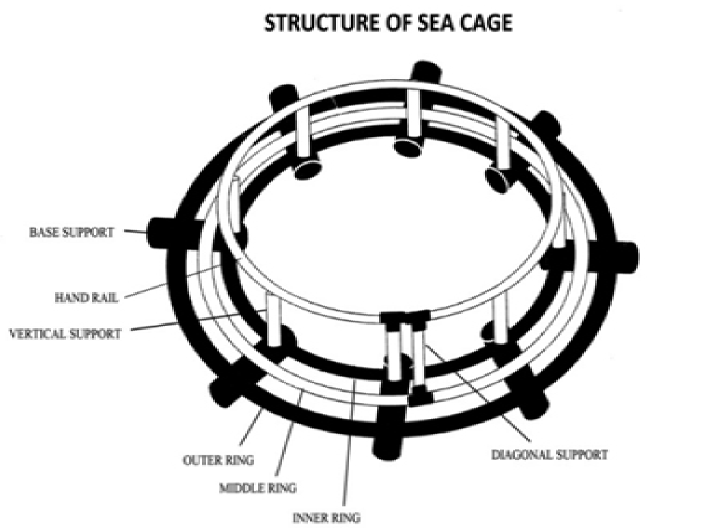
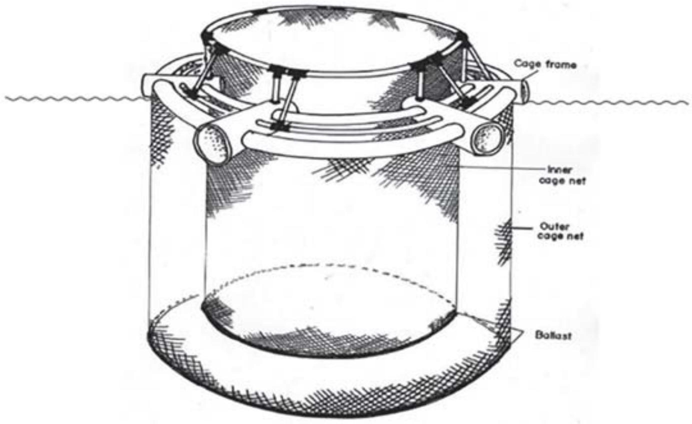


Fig. 1. Plan View of HDPE Sea Cage Frame - Collar Rings and Handrail

resistance, aligning with the pipe diameter. The handrail's maximum height should be around 100 cm, shorter than the shortest person. Essential for operational and maintenance activities such as feeding, cleaning, monitoring, and grading, the service systems (catwalk, handrail, etc.) are integral components. The catwalk's minimum width is approximately 60 cm. Brackets/base supports, along with vertical and diagonal supports, not only connect the collar rings, catwalk ring, and handrail but also enhance the overall stability and sturdiness of the frame structure.

To maintain the shape and structure of the net bags (Fig. 2), the ballast pipe serves as another necessary support system. Typically, a 1.5-inch (38 mm) diameter HDPE ballast pipe, featuring holes at regular intervals for water flow, is utilized. Metal lines are inserted inside the pipe to increase weight, ensuring that the ballast remains submerged in water.



Layout of HDPE Sea Cage - Frame and Net Cages (inner & outer)

**Mooring system**

The mooring system/assembly holds the cage in the desired position and at the desired depth using mooring lines, chains and anchors. Individual cages can be moored using a single-point mooring system (Fig 3). Single-point Mooring System components required for 10 cages:

(a) Anchors (embedment type) / Gabion Boxes – 100 kg each, 10 nos.

(b) D-Shackles – for 12.5 tonne SWL (Safe Working Load), 3 x 10 = 30 nos.

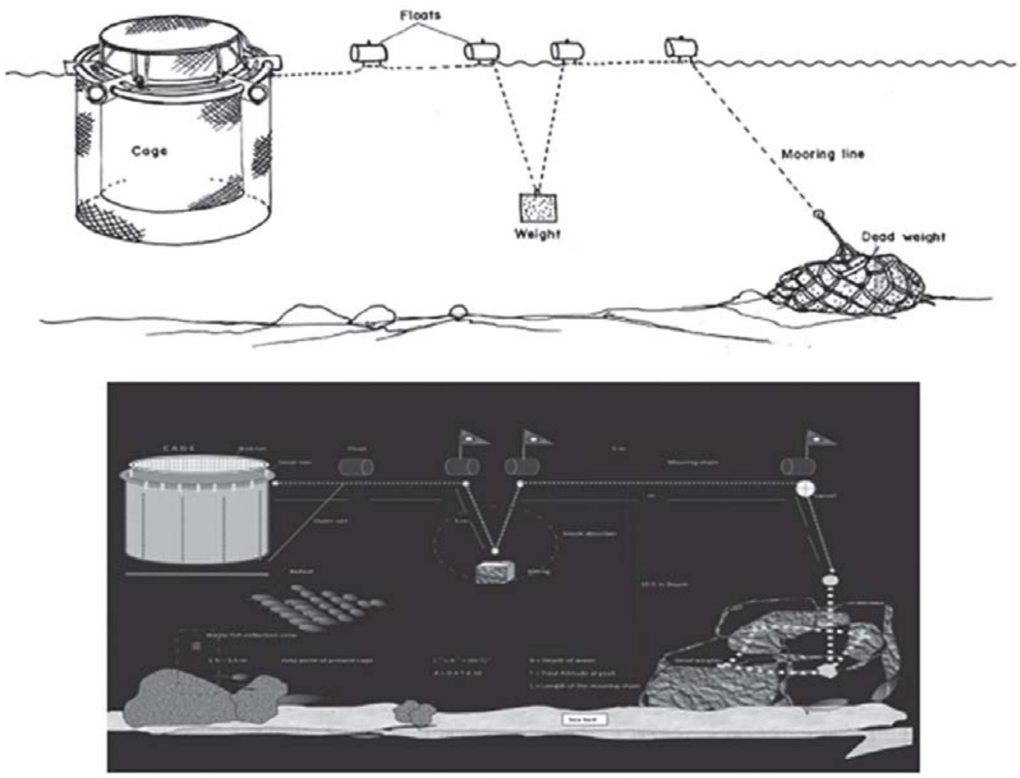


Fig. 3. Singel-point mooring system for Sea Cage : Schematic diagramme (above) and Artist's view (below)

(c) Mooring Chains – 38-42 mm thick, length four times the depth at site, 10 nos.
(d) Buoys – 200 litre buoyancy, 4 x 10 = 40 nos.
(e) Anchor Marker Line – poly-steel rope of 36 mm diameter and 37 m length.
(f) Mooring Rope – poly-steel rope of 48 mm diameter, 3-4 strands, and 100 m length. Also splicing, steel thimble and oval ring of 22 mm at one end, 10 nos.

**Netting materials**

Nylon (PA) and Polyethylene stand out as the most important and extensively utilized synthetic fibres, particularly in the fabrication of fishing gear. Mesh size for the net cages must be selected according to the species of fish farmed and also to ensure good water exchange. Proper water flow enhances water quality, reduces stress, improves feed conversion and allows holding more fishes.Net cages should be as per the dimensions of the cage frame and depth of water at the site. They must be securely fastened to the cage frame. For sea cage farming, 3 types of nets are essential as follows.

(i) Outer predator net

Given the turbulent nature of the sea and the presence of carnivorous animals, it is crucial to have an appropriate outer net cage to prevent predators from entering the sea cage culture. Typically, for optimum strength, durability, and cost-effectiveness, a braided UV-treated HDPE netting with a thickness of 3 mm and a mesh size of 80 mm is considered highly effective and recommended. The recommended dimensions for the predator net cage are a diameter of 7 m and a depth of 5 m, with the entire structure submerged.

(ii) Inner fish rearing net

To construct the inner net cage for fish rearing/grow-out, the choice of twisted HDPE netting falls within the thickness range of 0.75-1.5 mm, with a mesh size varying from 16 to 40 mm, contingent on the size of the cultivable species. The specified dimensions for the fish-rearing net cage are a 6 m diameter and 5 m depth, with 4.0 m submerged and the remaining 1.0 m extending up to the handrail, resulting in a total volume of 113 cubic meters.

(iii) Bird net

Overlaying a protective bird net on the cage frame is essential to prevent predatory birds from preying on fish. An ideal material for the bird net is HDPE twisted and UV-treated twine with a thickness of 1.25 mm and a mesh size ranging from 60 to 80 mm. High-Density Polyethylene knotted netting is the preferred choice for constructing net cages, and the mesh size is determined by the size of the individual farmed fish. Three sets of net cages, each with different mesh sizes (18 mm, 25 mm, and 40 mm), are required for the farming operation. To preserve the cylindrical shape of the net cages, it is necessary to use ballasts of appropriate weight. Concrete blocks, tied at suitable intervals, can be utilized for this purpose. Alternatively, an HDPE pipe with a diameter of 1.5 inches (38 mm), inserted with an MS chain or a wire rope of 10 mm thickness, can be employed.

**Nets suitable for open sea cage culture**

The selection of fishnet mesh size for cage fabrication is crucial, considering the species, water exchange requirements, and predator prevention. Aeration plays a vital role in enhancing water quality, reducing stress, improving feed conversion, and accommodating a higher fish population in cages, especially in open sea conditions. For predator prevention in open sea cage culture, a suitable net is essential. Braided UV-treated HDPE with a thickness of 3mm and a mesh size of 80 mm is recommended due to its strength, durability, and cost-effectiveness. This netting is effective in turbulent sea conditions and protects cannibalistic animals. The diameter of the cage can be adjusted based on specific requirements, ranging from 6m to 8m, with a depth of 5-7m for ease of handling. Mounting the cages to floating circular frames using ropes and rings ensures stability in the water. The inner cage, which directly contains the cultivable species, can be fabricated using twisted HDPE with a thickness ranging from 0.75mm to 1.5mm, depending on the size of the species. The mesh size for the inner cage typically varies from 16mm to 28mm. Recommendations for sea bass include a mesh size of 1.25mm/26mm to 1.5mm/30mm. Periodic cleaning of the inner cage is essential for maintaining durability. To prevent predator birds, protective nets made of HDPE twisted and UV-treated material with a thickness of 1.25mm and a mesh size ranging from 60mm to 80mm are recommended. These nets help safeguard the fish population from aerial predators and contribute to the overall success of open sea cage culture.

**Selection of fish species**

Cobia (*Rachycentron canadum*), Silver Pompano (*Trachinotus blochii*), Seabass (Lates calcarifer), Snappers (*Lutjanus* sp.), Groupers (*Epinephelus* sp.) and Spiny Lobster (*Panulirus* sp.) are highly suitable for sea cage farming. For the selection of a suitable species for cultivation in cages, a few key points should be taken into consideration.

1. To counterbalance the relatively high production costs associated with net cage farming, it is advisable to prioritize the cultivation of species with high market value.
2. It is essential to choose species that demonstrate hardiness and tolerance to confined, crowded conditions, as well as resilience during the handling involved in net cage changes.
3. Stocking density in net cages significantly surpasses that of pond culture, with, for instance, 5 fish per square meter compared to 40 fish per square meter for marine carnivore fish culture in ponds and net cages, respectively.
4. The greater physical contact and stress experienced by fish in net cages during feeding result from the frequent competition for food among the majority of the population in the cage. Fishes like groupers and seabass thrive in such crowded conditions.
5. Within the confines of the net cage, where small fish are the primary food source, it is crucial for selected species, especially carnivorous ones, to be adaptable to external food sources.

Dry feed, while commonly used, tends to result in greater feed loss. A practical approach involves suspending feeding trays in the net cage to catch falling pellets, a technique employed in shrimp net cage culture. Spiny lobsters and Rabbitfish (*Siganus canaliculatus*) showcase the ability to graze on algae growing on the net cage sides, deriving a portion of their food from this source. Additionally, these species serve as effective bio-fouling controls within net cages.

The procurement of seed, typically fry or fingerling, can be from either wild-caught or hatchery-bred sources. Wild-caught seed supply tends to be seasonal and unpredictable; however, these specimens are often more robust and hardy due to natural pre-selection. Conversely, hatchery-bred seeds offer a more predictable supply, and depending on whether the parent stocks were wild-caught or farm-raised, can be produced on schedule in a batch-operation sequence.

While various species are cultured worldwide, including *Latescalcarifer*, *Epinephelus* spp, *Trachinotus* sp., *Rachycentron* sp., *Lutjanus* spp., and *Acanthopagrus* spp., have proven to be particularly suitable for cage farming in India. These species are currently being successfully cultured in various coastal states.

The success of the grow-out culture in cages heavily depends on the quality of fish seed. To prevent escape, it is essential to stock uniform-sized seeds that are suitable for the mesh size of the fish net cage. This practice not only aids in selecting the appropriate feed size for the fish but also minimizes feed wastage and reduces cannibalism. The seeds chosen must be healthy, and devoid of diseases and deformities.

In India, the primary obstacle hindering the expansion of sea cage farming is the scarcity of fish seeds. Currently, a limited number of hatcheries in the country produce seeds for Cobia, Pompano, Seabass, and Groupers. Besides these species, seeds of wild-caught fishes like Mullets, Snappers, Milkfish, etc., can also be employed for cage farming. Addressing the escalating demand from farmers requires an immediate focus on generating a sufficient quantity of seeds, either through commercial hatchery production or importation, until self-sufficiency in seed production is achieved.

Culture details of some cultivable species done by CMFRI

| Species | Stocking Size (Length/ Weight) | Stocking Density (Nos./ m 3) | Production per Cage (kg) |
|---|---|---|---|
| Cobia | 15 cm/ 35 g | 8-10 | 2400 kg/ 7 months |
| Pompano | 10 cm/ 35 g 3 | 0-40 | 1800 kg/ 8 months |
| Seabass | 10 cm/ 30 g | 30-40 | 2000 kg/ 8 months |
| Grouper | 15 cm/ 40 g | 15-20 | 2000 kg/ 7 months |

**Fish nutrition**

The fundamental constituents found in any material used for feeding encompass the following five principles: (i) Protein, (ii) Carbohydrate, (iii) Fat, (iv) Minerals, and (v) Vitamins. Proteins play a vital role in the animal's growth, and a deficiency can result in growth retardation. For optimal growth, marine fishes necessitate a higher protein content (35-40%) in their feed. It is crucial to adjust the size of the feed pellet based on the fish's growth. The standard feeding rate for juvenile fishes is 10% of their body weight, which can be gradually reduced to 3% as farming progresses. It is advisable to use a feed with a Feed Conversion Ratio (FCR) of 1:2. To prevent wastage and environmental pollution, fish should only be given the recommended ration, as overfeeding can be detrimental. Carnivorous fish naturally prey on live organisms, and in aquaculture, there is a common practice of feeding cultured fish with low-value trash fish. However, this approach is not only economically inefficient but also environmentally unsustainable. Feeding fish with trash fish contributes to pollution. Under standard farming conditions, the Feed Conversion Ratios (TFCR) for marine carnivorous fish typically range from 2:1 to 4:1.

**Feeding**

Fish growth is closely tied to feeding rates and frequencies. Small larval fish and fry require frequent feeding with a high-protein diet, often in surplus. As fish grow larger, it becomes necessary to reduce feeding rates and frequencies. Feeding fish is a labour-intensive task, and the feeding schedule must be economically viable. Typically, growth and feed conversion improve with higher feeding frequencies. The timing of fish feeding is also influenced by various factors such as the time of day, season, water temperature, dissolved oxygen levels, and other water quality variables. It is essential to consider these factors when developing a feeding regimen to optimize the health and growth of the fish while maintaining economic efficiency. Feeds undergo deteriorative changes during storage, diminishing not only their nutritive value but also impacting their palatability and appearance. It is crucial to store feeds in dry, ventilated warehouses, shielded from direct sunlight, and maintained at a relatively constant temperature. To ensure optimal quality, all feeds should be utilized within the specified time frame, preferably within two months of manufacture, with regular inspections.

Extended storage durations may lead to issues such as fungal growth, degradation of vitamin potency, and fat rancidity. Care should be taken to minimize unnecessary handling, as it can damage feed bags and reduce pellets to a powdery form that is typically avoided by fish, resulting in wastage. Rigorous control measures are necessary to manage pests like rats and cockroaches in storage areas, preventing contamination. While proper feed storage is a straightforward process, maintaining high quality is paramount.

**Cage management**

Optimizing production at minimum cost is integral to Sea Cage management. The competence and efficiency of the farm operator play a crucial role in ensuring efficient management, encompassing aspects such as feeding rate, stocking density, minimizing loss due to diseases and predators, monitoring environmental parameters, and maintaining efficiency in all technical aspects. Routine inspections, including the cage frame and mooring, are essential, and any necessary maintenance and repairs should be promptly carried out. Bio-fouling, which clogs the mesh of net cages, reduces the rate of water exchange, causing stress due to low oxygen and accumulated wastes, ultimately leading to fish mortality. Hence, regular brushing of the net cage mesh is imperative.

**Harvesting**

To ensure maximum returns, harvesting can align with market demand. Practising partial harvesting, where larger fish are harvested first, helps prevent a market glut and the subsequent decline in sale prices. Site-specific records of harvest must be meticulously maintained. Undertaking large-scale sea cage farming requires a well-defined postharvest and marketing strategy. Production centres should be equipped with essential facilities, including proper craft and gear for fish harvesting, facilities for icing, holding, and storage of fish, live-fish transport options, and connections to post-harvest processing centres and market chains.

**Carrying capacity**

During the site selection process for fish farming, a critical factor to consider is the carrying capacity of the site, indicating the maximum production level the site can sustain. In intensive cage fish farming, the generation of waste can influence water body characteristics, affecting both abiotic and biotic factors. Conversely, less intensive methods may lead to excessive algae growth, diminishing overall productivity. This can significantly impact the profitability and viability of the venture. Therefore, a precise evaluation of the sustainable production levels at a specific site is crucial before initiating fish culture. Carrying capacity is determined by the loading (weight of fish per unit of water flow) and density (weight of fish per area of water body) of the fish in the system. Understanding and accounting for these factors are essential for those involved in cage fish farming to ensure responsible and sustainable practices.

**Environmental impact**

The release of waste into the aquatic environment in the form of uneaten feed, faeces, and other debris is a negative aspect of the cage culture system. Accumulation of these materials beneath the cages can lead to a reduction in dissolved oxygen, with a higher tendency for a large quantity of waste to settle on the sea bed in sheltered inshore sites. It is advisable to avoid continuous farming for several years at the same site in sheltered areas; a change of site after several crops is recommended. Alternatively, semi-exposed/ exposed sites with good tidal flushing are chosen to prevent waste accumulation at the cage bottom. Implementing adequate spacing between cages and farms is crucial for disease control. The indiscriminate use of antibiotics and their release into the aquatic environment may lead to the development of antibiotic-resistant bacteria. Cage culture has the potential to introduce diseases, transmit parasites, and induce changes in aquatic flora and fauna. Therefore, the carrying capacity of the environment, based on the nature of the site, must be prioritized when undertaking sea cage farming.