Netting specifications and maintenance of cages for finfish culture

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A cage is a space enclosed with some type of mesh forming a container for aquatic animals to grow. It is typically box-shaped or tube like structure with a rope system which supports the netting material, gives shape and allows for tying to the raft unit. In box type cages, the cage is constructed of four panels at the sides and one bottom panel. Anti-predator nets are deployed around the cage to prevent entrance of predators such as sharks and sea lions into the cages. An additional net would be provided on top of the cage to prevent bird predation.

Types of net cages

The cages usually are of two types: fixed and floating. The floating cages are interlocking cages suspended in a bamboo/wooden/ polyethylene frame. The cage is floated by either bamboo raft or styrofoam floats, and is held in place by heavy anchors.

The dimensions and mesh sizes of the cages are dependent on the species cultured and size. The mesh sizes of the cages depend upon the type of cage. In Japan, circular and square/ rectangular floating cages are used, whereas in Norway floating cages are not only circular, square/rectangular, but may also be hexagonally shaped. Cages that are either cylindrical or spherical are used in West Germany. In Singapore, the farmers use the more conventional square (cuboidal) cages. The square type usually measure 2×2, 3×3 or 5×5 m, with a depth of 2-3 m while rectangular types are 6×3 m, with a depth of 3 m. In Korea, the floating cage system consists of the cage and a frame to support the nets. In India, rectangular cages of 10mx5mx2.5m are used for the culture of Indian major carps.

Basically there are 3 types of cages:

Hapa cage is for stocking of the fish during the early nursery phase (Fingerlings to a Total Length of about 10 cm). This is made of very fine-meshed nylon net. It is used for rearing fry to fingerlings. Fry measuring 1–6 cm are initially stocked in this cage.

Nursery cage is used during the later nursery phase. Usually PE net is used for the net bag. This cage is stocked with 10 cm fingerlings till they reach a size range of 15–20 cm.

Grow-out cage is used for the grow-cut phase where the cultured fish reach marketable size of 30 cm and beyond. The netting used is usually PE net.

Broodstock require cages of mesh sizes larger than 50 mm.

The rope which is used for the main and hanging lines of the hapa and nursery cages is PP/PE rope (6 mm diameter), while for the grow-out cages, PP/PE rope of 10 mm diameter is used.

The frame which is used to hold the interlocked cages together in place also serves as a catwalk and working platform. A frame made of bamboo is preferred over a wooden one mainly due to economic reasons. Besides, the bamboo frame also acts as a floatation device.

As net bags are subject to damage by floating debris, large carnivorous animals and other agents, often a second larger mesh net is used outside the net to provide mechanical protection for the confinement net. The two nets must be placed in such a way that they do not rub each other, or one or both nets will be damaged by abrasion. E.g: the outer netting can be of HDPE braided twine of 3 mm diameter and mesh size 80 mm. There can be an upper selvedge of netting made of HDPE of 4 mm diameter braided twine of the same mesh size and 80 mm mesh size. This selvedge portion should be of 0.5 meter stretched length or equal to the length of the brackets/rings above the upper ring structure whichever is larger. Inner netting can be of HDPE twisted twine of 1.25 mm diameter and of mesh size 25 mm. An upper selvedge of netting made of HDPE twine of 2 mm diameter and with 25 mm meshsize. This selvedge portion should be of 0.5 meter stretched length or equal to the length of the brackets/rings above the upper ring structure whichever is larger.

Design Considerations

Designing of net structures require several forces to be considered; the main being static and dynamic loads. Static loads include the weight of the structure (net, support, and other structural parts), and added loads due to maintenance and operations. Dynamic loads include forces generated by wind above the water surface, waves at the air-water interface, and currents (particularly tidal currents) in the water. Additional dynamic loads may be encountered due to collection of floating debris, collision with water craft or large predators or other similar conditions. Effects of corrosion and fouling add to it. Wave forces on a net impoundment structure are based on the highest wave expected to occur in the design life of the structure. As fouling or surface debris drastically affect the coefficient of drag, this factor must be considered. Fouled nets create twice the resistance to tidal current as the same net when clean (Milne, 1970). The nets must be designed to withstand the sum of the forces, assuming that all the forces are at some moment acting in the same direction. If two nets are used, loads on the supporting structures will be the sum of the loads imposed by each net.

The aquacultural net enclosures should have good tidal flushing. Water flowing through the net will impose loads on the net and supporting or mooring structure. Kawakami (1964) developed the following Equation 12.9 to describe the load imposed on net structures due to flow at right angles to the net. The force on 2.50 cm mesh nylon net by a 1 m/s current is 0.42 N/mesh in the unfouled condition and 5.1 N/mesh after one month of immersion in sea water.

Nets enclosing fish are subject to damage by floating debris, large carnivorous animals and other agents. A relatively small hole in the enclosure net can result in loss of nearly all the fish. Hence, it is often wise to use a second larger mesh net outside the confinement net to provide mechanical protection for the confinement net. The two nets must be placed in such a way that they do not rub each other, or one or both nets will be damaged by abrasion. As all nets require periodic maintenance for cleaning or repair before design it must be decided whether the panels will be pulled out of the water for this work or divers will be used. If the panels must be removed from the water, some means to prevent fish escape will be necessary. The panels must also be small enough to be manipulated by the handling technique chosen. Panel weight will be actual panel weight plus weight of fouling. The following factors are generally considered in the design and operation of culture cages:

- It is advisable to put floating cages underwater to avoid wind action and also to reduce algal growth
- Use cage materials available within the locality to reduce the costs
- Before setting out the antifouling impregnated nets they should be dried so that the antifouling stays on the net.
- Consider the cost and durability of the materials
- Net size: It is better to design the size of net cage to suit the breadth of the netting rather than on a preselected size.
- Size of species: Net mesh should be smaller than the fish size to avoid escape of the fish through the meshes.
- Nets should have sufficient strength to withstand different forces encountered
- Net bag should have suffiecient looseness. To get a uniform spreading and flexibility to the bag 20-30% of excess net is to be used than the actual cage size
- Aeration can enhance water quality, reduce stress, improve feed conversion efficiency and increase growth and production rates. Aeration can improve cage production by 20 percent or more.
- Leave at least 10 feet between cages and keep cages away from weed beds. Weed beds and overhanging trees can reduce wind circulation and potentially cause problems.

Netting materials for cage construction

Netting yarn is a textile product suitable for the manufacture of netting and can be knitted into netting by machine or by hand without having to undergo further process. Yarn is made into a netting by twisting or braiding. Monofilaments are used directly for making into netting without further process, hence it follows that monofilament yarn is a netting yarn also. The Twisted netting yarns (netting twines) are made by a series of processes.

- Fibres twisted together to form a single yarn.
- A number of single yarns are twisted together to form a strand or ply.
- Three strands or ply are twisted together to form a netting twine.

Synthetic materials are predominantly used for construction of net cages. Synthetic fibres are produced entirely by chemical process or synthesis from simple basic substances such as phenol, benzene, acetylene *etc.* As compared with vegetable fibres, they have better uniformity, continuity, higher breaking strength and are more resistant to biodegradation. Depending on the type of polymer, synthetics are classified into different groups and are known by different names in different countries. Altogether 7 groups are developed; polyamide (PA), polyethylene (PE), polypropylene (PP), polyester (PES), polyvinyl chloride (PVC), polyvinylidene chloride (PVD) and polyvinyl alcohol (PVAA).

The synthetic netting yarns used in Indian fisheries sector are polyamide, polyethylene and polypropylene. PA and PE are the most commonly used fibres for netting while PP and PE are used for ropes. The material strength of net panels when exposed to sunlight (UV), wind, rain, acid rain, *etc.* get reduced. This process is called weathering. Even though all fibres, irrespective of natural or synthetic are prone to degradation on exposure to weathering, the problem is severe with synthetic fibres. The main factor responsible for weathering is the sunlight, *i.e.* the ultra violet part of the sun's radiation. Polyvinyl chloride (PVC) is the material that is most resistant to weathering, followed by PE and PA; PP has the shortest lifetime. The lifetime can be increased by adding a coloured (black) antioxidant, so that development of weathering is reduced. The resistance of netting materials to abrasion, *i.e.*, abrasion with hard substances such as frames, sea bottom and net haulers, or abrasion between yarns/twines is important in determining the life of a net.

Another material recently introduced is Ultra high molecular weight polyethylene (UHMWPE) available as Dyneema. It is very advantageous as aquaculture nets due to the low diameter, favorable weight/strength ratio, low elongation and nil shrinkage in water which helps the mesh size to remain stable during normal use of the netting. The resistance of Dyneema nets to UV light and abrasion is high, guaranteeing that nets last longer.

Selection of netting material

The following factors are to be considered for selection of suitable net material for the construction of cages: Synthetic fibres are preferred over artificial or natural fibres because of their durability and strength.

- Cages made of synthetic fibres are convenient to use as they can be easily folded and are light to handle. They are also easy to install and to remove. It is not surprising that many floating farms use such materials rather than rigid metal cages for rearing the fish

- The netting yarn should maintain its shape, *e.g.* monofilament netting, suitable for gill-netting, is not suitable as cage material as it tangles and folds up easily

- The material should be durable, resistant to abrasion and has high breaking strength

- The material should not be so heavy as to make handling difficult *e.g.* thicker netting material even though durable and resistant to crab bites/abrasion would be heavy at cleaning time especially when it is fouled.

- With the exception of the hapa net, cages are usually constructed of polyethylene (PE) material. Polyethylene is preferred for its high breaking strength, durability, high resistance to abrasion and cheaper cost when compared with other available materials like polyamide, polyester, polypropylene *etc.*

- Polymide (PA) and polyethylene (PE) netting are readily available locally. Knotless polyamide netting of 210Dx2x2 is popular for making cages that are to be used for stocking young fish fingerlings and prawns as the material has a smooth surface and there is minimal abrasion on the fish when the cage is lifted up during net change. PA is expensive and costs about Rs. 350-470/kg. However, it has a very high breaking strength and abrasion resistance. Its fibre deteriorates if subjected to prolonged direct sunlight and hence it is classified as having medium durability. The material being soft, can also be cut through by crabs and fish with strong dentition and the cultured fish can escape through gaps made in the cage

- Polythylene netting is generally preferred by cage operators because it is cheaper and protects better against damage caused by crabs and fish, although large-sized crabs can still bite through the material. It is the cheapest of the synthetic netting materials available, priced at around Rs. 200-275/kg, *viz.* around half the price of PA netting

- PE netting is available in various specifications of Denier and ply and also in knotless and knotted forms. The type that is selected would depend on the species and size of fish stocked. PE has also high breaking strength and abrasion resistance. However, like PA, it is to be stored away from direct sunlight, viz. in the shade. When used at the farm, the portion of the cage above water lasts for 3 years, whereas the rest of the cage which is submerged in the water lasts for 5 or more years. PE netting is usually for making cages for nursery and grow-out fish while for hapa, PA is preferred

Table below lists the synthetic fibres that are suitable for use as fish cages.

Table 1 Comparison of important characteristics of synthetic fibres

Properties	PA	PE	PP	PVC	PES	PVD	PVA
Specific gravity	1.14	0.96	0.91	1.35-1.38	1.38	1.70	1.30
Melting point °C	240-250	125-140	160-175	180-190	250-266	170-175	220-230
Durability	Medium	Medium	Poor	Very high	High	High	High
Breaking strength	Very high	High	Very high	Low	High	Low	Medium
Extensibility (wet)	High	Medium	Low	High	Low	High	High
Resistance against weathering	Medium	Medium	Low	Very high	High	High	High
Abrasion resistance	Very high	High	Medium	High	High	High	High
Cost	Very high	Low	High	High	Very high	High	High

polyamide (PA) is the most commonly used material for the fabrication of net bags, as the material is strong and not too stiff to work with. PE is also used to some extent because it is more resistant to fouling as the surface is smoother: however, it is stiffer to work with. Polyester (PES) has also been tried. Nylon used for nets is made as a multifilament twine consisting of several thin threads spun together to make a thicker one. The advantage with multifilament is that the thread is easy to bend, easy to work with, tolerates more loads and is more resistant to wear/rubbing. In contrast, monofilament is a single thread as used in a fishing line. It can be made of PE; it is stiffer and more vulnerable to chafing than a multifilament. Nets are either knotted or knotless.

Mesh size

Mesh size can be described in many ways. Bar length is the distance between two knots while mesh size is the distance between the knots on a stretched mesh (Fig. 1). In a hexagonal mesh, the mesh size is given as the distance between the two longest parallel bars. Mesh size may, however also refer to bar length, which makes this expression rather confusing.

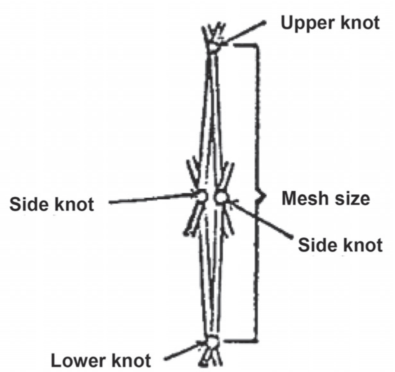

Fig. 1. Mesh size

Another factor which decides how the net panel is standing in water is how the net is stretched in the length and depth wise directions. This is called the hanging ratio of the net (E) which is the ratio between the length of the stretched net panel (Lm) and the length of the rope/line where the net is fixed (top line) (L):

$$E = L / Lm$$

Normally E for net bags for fish farming is in the range 0.6 – 0.9, while for a fishing net, E is between 0.4 and 0.6, meaning that netting of cages have meshes that are more stretched out (Fig. 2).

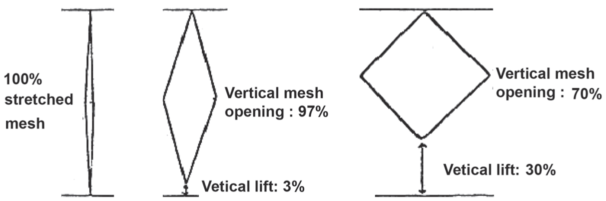

Fig. 2. Hanging ratio and corresponding vertical mesh opening

Solidity is used to describe the 'tightness' of a net. This is the ratio between the total area that the net covers, compared to the area covered with threads including knots. This relation is important when the resistance against water flow through the net is to be calculated.

Fouling on the net will increase the solidity, because the covered area is increased.

Mesh-size selection is dependent on the species and size to be stocked. The seabass, having a more pointed snout would require a cage of smaller mesh-size than would a grouper of the same size. The relationship between cage mesh size and a few fish species are summarized in Table 2 and recommended material amd mesh size for different cage types are given in Table 3.

Factors to be considered for mesh size selection

- Mesh size should not be less than 10 mm to assure good water circulation through the cage while holding relatively small fingerlings (10 to 12.5 cm) at the start of the production cycle.
- The meshes of the cage should remain open completely in water to form a diamond-shaped hole so as to allow good water exchange with minimum use of netting material
- Meshes should not be large enough to gill the fish stocked
- Mesh size should be roughly equal to about 25% of the body length of the fish

Construction of cages

Hapa cages

The dimensions of the hapa cage can range from 2×2×2 m to 3×3×3 m to 5×5×2-3 m depending on the scale of stocking. Mesh size can range from 8 mm to 9.5 mm

Table 2 Relationship between cage mesh size and fish species

Type of cage and netting material	Mesh-size (cm)	Grouper, TL (cm) (*Epinephelus tauvina*)						Seabass, TL (cm) (*Lates calcarifer*)				Snapper TL (cm) (*Lutjanus johni*)			
		5–10	10–15	15–40	40–50	50–75	75 and > Broodstock	7.5–10	10–25	25–30	>30 Broodstock	5–10	10–15	15–20	50 and > Broodstock
Hapa (PA 4 ply)	8	+						+				+			
Nursery (PE 15 ply)	13		+						+				+		
	25			+						+				+	
Production (PE 24 ply)	25			+							+			+	
	50				+									+	+
	75					+									
	100						+								

(Source: FAO, 1988)

Table 3 Recommended material and mesh size specifications for different cage types

Cage	Recommended material specifications	Mesh Size (mm)	Fish size recommended(TL, cm) Grouper	Seabass
Hapa	Polyamide (nylon) 210D/2x21200 meshes deep.	9	5–10	10 and <
Nursery	Polyethylene, 380D/2x3300 meshes deep.	9.5	10–15	10–15
	Polyethylene, 380D/3x3 or 5x3300 meshes deep.	12.7	10–15	10–15
	Polyethylene, 380D/5x3 or 6x3300 meshes deep.	19.1	15–30	15–20
	Polyethylene, 380D/6x3 or 7x3300 meshes deep.	25.4	15–40	20–30
Grow-out	Polyethylene, 380D/7x3 or 8x3300 meshes deep.	25.4	15 – 40	>30
	Polyethylene, 380D/9x3300 meshes deep.	38.1	15–40	>30
	Polyethylene, 380D/10x3 or 11x3300 meshes deep.	5.8	40–50	-

depending on the initial size of fry/fingerling stocked. The hapa cage is usually constructed of knotless material, *e.g.*, PA, so as to avoid any abrasion to the fish fingerlings during hauling of the cage. Knotted netting should be avoided as far as possible as the abrasions caused to the fingerlings could result in disease, especially bacterial infection. Besides, small-mesh knotted netting materials are also heavy and easily fouled as fouling organisms tend to be congregated to the knots. Main rope is made from PP/PE of 5–6 mm diameter. Bolch line is usually made of PP/PE of 2 – 3 mm diameter. PA netting twine of 210D/9x3 is used for hitching the bolch line to the main rope, and 210D/6x3 is used for joining the netting material/panels/sections to the bolch line.

Nursery cage

Like the hapa, the nursery cage can be of 2×2×2 m, or 3×3×3 m, or 5×5× 2-3 m, depending on the scale of stocking. The netting material used is usually of the knotted type. Polythylene (PE) is usually selected. Mesh size can range from 9.5 mm (3/8") to 25.4 mm (1") depending on size and type of fish stocked. Main rope is PP/PE of 8 mm diameter while bolch line is also PP/PE of 2mm diameter. PE twine of 380D/4x3 is used for joining the netting panels and 380D/6x3 or 7x3 is used for joining the bolch line to the main rope.

Grow-out cage

Cage dimensions of grow-out cages are similar to hapa and nursery cages. Like the nursery cage, grow-out cages are also constructed of knotted netting, usually of PE material. Mesh sizes start from 25.4 mm (1") and mesh size to be selected depends on the size of fish stocked. Larger sized fish of 30 cm could be stocked in cages of mesh size 50.8 mm. The main rope is PE of diameter 10 mm. Bolch line, as for nursery cages, is of PP/PE of 3 mm diameter.

Factors to be considered for cage construction

- The net panels should be cut such that there is minimum wastage of netting material
- The dimensions of the cage should be slightly smaller than the floating frame on which it is suspended so that the cage fits well within the frame.
- Cutting: Synthetic nets are to be cut by calculating the meshes required that would give the desired vertical mesh opening or hanging. Stretching the material to the actual cage dimension will result in uneven measurements and irregular fit.
- Vertical mesh opening or hang-in of the netting must be pre-determined. The vertical mesh opening or hang-in of the netting is defined as the mesh size of the netting at free hanging and is expressed as a percentage.
- A vertical mesh opening or hanging of about 70 % is recommended for cages as the mesh then approaches that of a square as seen in Fig. 2.

The side net panels are joined to the bottom panel by sewing with twine. Sewing is done by passing the twine along the outer edges of the two panels in a 1 mesh side to 1 mesh bottom ratio. For every 5 stitches, an overhand knot is made. A bolch line is to allow the attachment of the main rope to the netting material. It is passed along the 4 bottom seams of the cage between the side panels and bottom panel (basal bolch) and along the top square of the side panels (top bolch). Threading is done through each mesh, if necessary. The bolch line is a thin rope whose diameter varies according to the netting material used.

The main rope is used for giving the cage its shape and for suspending the cages. It is sewn on to the bolch line. It is of a larger diameter than the bolch line and its size, like the bolch line, varies according to the netting material used for the construction of the cage

Maintenance of the cage

The normal lifetime of a net bag will vary with the site conditions.. As a general rule, if the breaking strength of the net bag below the surface falls below 65% of the initial strength it is considered as unserviceable. With proper care, cleaning and repair, the economic life of polyethylene nets ranged from two to five years. The small mesh size net of less than 2.4 cm foul more rapidly and has to be cleaned more frequently. In temperate regions, the life time of a net bag is usually 5 years.

Biofouling

Biofouling is a major problem in cage culture during summer months especially at marine sites. Biofouling occurs as a result of the settlement and growth of sedentary and semi-sedentary organisms like barnacles, tunicates, tube worms, mussels, bryozoans and algae on artificial structures placed in water. It mostly composed of organisms with organic or mineral material trapped in between. Floating cage culture using nets is particularly vulnerable during the hot season. Although biofouling of artificial substrates has been well studied, biofouling pertaining to the aquaculture environment and biofouling on cages in tropical marine waters is less studied. The frequent cleaning of nets is not only costly and labour intensive but often gives rise to loss of stocked fish due to net changes and damage. Uncleaned nets on the other hand can cause severe physical stress on the cage nettings during strong current flow when they could tear. Fouling significantly impedes the water flow and therefore the supply of dissolved oxygen to the caged fish. Fouled netting also increases structural fatigue on cages and the fouling communities may harbour disease-causing microorganisms. Hydrodynamic forces on a fouled net can be 12.5 times that of a clean net. Concurrently, the weight of cages can increase sever-fold, causing further structural stress as well as a reduction in cage buoyancy and increased net deformation. Retarded water flow and inorganic and organic enrichment through fish feeds and faecal matter enhance the macrofouling assemblage on fish netting. The structure, colonization dynamics and depth distribution of the macrofouling assemblage are affected by salinity, water depth and substrate area and immersion period.

Multifilament netting material is particularly vulnerable to fouling, as it is non-toxic, contains many crevices that can entrap and protect settling organisms, and has a high surface-area to volume ratio. The materials used for making the nets (metal, synthetic materials) and their form (galvanized panels or nets) also affect fouling levels. Galvanized panels developed much less fouling than the synthetic fibre netting panels. Since fouling encrusts small mesh nets more rapidly, the fish farmer should use the largest mesh size permitted by the size of the fish. Netting colour significantly affected the growth and composition of algal fouling, but had no effect on invertebrate fouling.

Fouling Control

The prevention of fouling on mariculture structures is complicated by the choice of net material and the dangers of toxins to cultured species. Antifouling practices include predominantly the use of copper-based antifouling coatings. There have been incidents where antifouling has adversely affected fish: in the 1980s, trials with tributyl-tin on cages caused significant effects to farmed salmon. The antifouling solutions presently available are not ideal, and it is widely accepted that there is an urgent need for research into anti-fouling technologies. Such alternatives include the adoption of “foul-release” technologies and “biological control” through the use of polyculture systems. However, none of these have, as yet, been proven satisfactory. In view of current legislative trends and the possible future “phasing out” of available antifouling materials, there is a need to find alternative strategies. The use of most commercially available, antifouling chemicals or coatings on cage nettings is largely restricted due to concern of environmental toxicity. For these reasons, the natural control of biofouling or environment-friendly methods is to be used. Such methods require a better understanding of the fouling community of cage netting, particularly how it interacts with the physical environment and aquaculture itself. It has been recently demonstrated that silicone coatings provide an effective non-toxic solution to reduce fouling on sea-cages and to increase the ease of fouling removal.

Fouling organisms of the cage can be controlled biologically to some extent by using grazer fish species within the culture fish. Grazing by wild fish and other predators could also contribute to the slower colonization rates outside the cages. The introduction of predatory fishes or sea stars could provide some amount of control on the growth of fouling organisms. *Cyprinus carpio* consume algae on nets and in the cage. Thus polyculture, when it is possible, may be a solution to limit fouling development in some sites.

Abrasion

Abrasion of the netting with fishes, with the rafts and frames as well as between inner and outer net in cases where double netting is provided are problems encountered. It is a common practice to have double netting. The outer one serving as a predator net, to protect the inner net with the fish stock.

In cases where the netting has a chance of rubbing with the frames or brackets, provision of a selvedge netting of same mesh size but of thicker twine would avoid the breakage of netting along the point of abrasion

Maintenance procedure

Maintenance of cages involves net changing, cleaning and mending.

Cage changing: The frequency of change depends on the mesh size of the cage and the season for fouling organisms which cause the cage to clog. As cage changing is time consuming and laborious, a mechanised net hauler may be considered for lifting out heavily fouled cages.

Cage cleaning: The nets should be cleaned regularly to prevent excessive fouling that may result in net breakage and heavy losses of fish. The smaller the mesh size, the heavier the rate of fouling. Nets of mesh size less than 2.5cm should be cleaned within 1 or 2 weeks of use whereas the larger size nets need to be cleaned in 30 to 90 days. Fouling organisms are removed by a high pressure water jet.

Cage drying: The cleaned net is checked for holes and repaired before it is used again. It can also be hung-up to dry and mend in position.

Cage mending: Net panels may get damaged or ropes may become weakened from frequent use. Panel and roped replacement or partial replacement with rejoining may be required, in such cases.

Due consideration need to be given for the design, construction and maintenance of the cage for the success of cage culture. Selection of suitable netting material, fixing of optimum mesh size and periodic maintenance of the net bag are the most important parameters to be taken into account. Focused research is needed on selection of netting materials, optimization of cage design and construction for different species and culture sites and on fouling control measures.

References

Aqua Farm News, Vol X No.3 (May-June 1992), Bureau of Fisheries and Aquaculture Resources (BFAR) Regional Office.

Beveridge, M.C.M. 1987. Cage Aquaculture. Fishing News Books Ltd. Farnham. Surrey. UK. 352 pp.

FAO 1988. Training manual on marine finfish cage culture in Singapore, FAO, Rome

FAO.1988. Seminar report on the status of marine finfish cage culture in China, DPRK (Democratic People's Republic of Korea), Indonesia, ROK (Republic of Korea), Malaysia, Philippines, Singapore and Thailand

Kawakami, T. 1964. The theory of designing and testing fishing nets in model. In: Modern Fishing Gear of the World (H. Kristjonsson, D.), Fishing News (Books) Ltd., London.

Klust, G. 1973. Netting materials for fishing gear. FAO Fishing Manuals, Fishing News (Books) Ltd, London, England, 173 p.

Lekang, O. Aquaculture Engineering, Blackwell Publishing Ltd., UK. 340p.

Milne, P.H. 1970. Fish farming: a guide to the design and construction of et enclosures. Mar. Res. Bull. No. 1. Department of Agriculture and Fisheries for Scotland. Edinburgh

Nash, C.E. 1988. A global overview of aquaculture production. J. World Aquacult. Sot., 19(2), 51-58