Water Quality Requirements for Selected Mariculture Systems

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Introduction

Presently, cage culture and other farming practices are gaining popularity along the coastal areas since it utilizes the existing water bodies with little inputs required for farming fishes. Commercially viable, environmentally and economically sustainable farming practices are possible with only proper site selection. So selection of the site is the most important factors that determine the success and failures of the cage culture system. Controlling water quality parameters in open water cage culture systems is impractical; therefore, the culture of any species must be established in sites having adequate water quality and frequent exchange. Before establishing a cage culture site, it is foremost important to conduct a field survey to gain prior knowledge on the environmental/ hydro-biological parameters of the site selected.

Criteria for selecting a site for cage culture

The selection of a site for cage culture should be based on the topographical criteria (wind, depth and bottom), environmental criteria (physical, chemical, and pollution), biological criteria (fouling and algal bloom) and social criteria (accessibility, security and legal)

Topographical criteria

Cages used in culture activities are susceptible to damage by the strong winds. So, the selected site should have less velocity of wind. Usually, the optimum wind velocity for a stationary cage should be < 5 knots and for floating cage < 10 knots. Site bottom with a mixture of fine gravel, sand and clay is the ideal site for cage culture. Bottom water exchange is more important to prevent accumulation of waste and oxygen deficiency. Therefore, the place with flat bottom and adjacent slope may bring in more water exchange and prevent waste accumulation thus forms a suitable area for cage culture. Generally a depth of 8-10 m during lowest low tide is an ideal condition. A bottom clearance of 3-4 meter is necessary to allow sufficient water exchange. But for a shallow water stationary cage with fixed pole mooring a minimum of at least 1-2 metre clearance from the bottom is necessary. For a stationary cage the maximum depth should not exceed 8 m since it is difficult to find sufficiently strong supporting posts longer than 8 m for mooring.

Environmental Criteria

Favourable tides and current brings fresh oxygenated water and remove waste from the cage. Strong currents will generate excessive strain on the fishes as well as on the cage structure, so a weak but continuous current is most suitable for cage culture operation to bring in the necessary oxygen and to remove accumulated wastes. The ideal current velocity for cage culture operation is 0.5 to 1.0 m/sec. Preferred tidal amplitude of around 1 m is found suitable for marine cage culture. Turbid water leads to the deposition of unwanted wastes and increases organic loads in cage culture site. The turbidity in the water may be due to colloidal clay particles, dissolved organic matter and abundance of plankton. The optimum transparency required for cage culture site should be < 5 m (secchi disc reading). Suspended solids in a suitable site for net cage culture should not exceed 10 mg/L. Fishes cannot control its body temperature with changes in the environment. Any fluctuations beyond its optimum temperature will affect the general well-being of the fish, The optimum water temperature needed for most tropical species is 27–31°C. Estuarine areas where seawater is mixed by freshwater influx are prone for huge variations in pH.The optimum range of pH for most marine species is from 7.0 to 8.5, any fluctuations will also affect the fish directly or indirectly.

Dissolved oxygen requirements vary with species, its size and other environmental factors like temperature and salinity. In general, dissolved oxygen should preferably be around 5 ppm or more. Demersal species require less oxygen (>3 ppm) when compared to pelagic species (>4 ppm). Inland saline waters may have salinity fluctuations due to tidal influences. Thus, the site selected for cage culture should have salinity range between 15–30 ppt for altering the species cultured according to market demands. The optimum salinity for better growth of different fish species are given in Table 1. Normally in the coastal areas, sewage discharge and industrial pollution are the main sources of higher level of ammonia in seawater. Apart from this decomposition of uneaten food and debris at the bottom can affect the fish. The level of ammonia-nitrogen in the water should be less than 0.1 mg/L. The excessive amount of nitrite in water leads to the oxidation of iron in fish haemoglobin, which causes hypoxia in fish. Nitrate serves as fertilizer for phytoplankton, so the increase in its level leads to phytoplankton bloom. Nitrate (NO_3-N) and nitrite (NO_2-N) also contribute to the level of inorganic nitrogen in seawater. The total inorganic nitrogen for marine fish culture is < 0.1 mg/L. Total inorganic phosphorous plays an important role in growth of algae and other aquatic plants and it should always be < 0.015 mg/L.

Table. 1: Optimum salinity requirement for different fish species

Species	Salinity (ppt)	
	Range	Optimum
Seabass (*Lates calcarifer*)	0–33	15
Pompano (*Trachinotus* sp)	5-35	15
Grouper (*Epinephelus* sp.)	10–33	20
Cobia (*Rachycentron* sp)	15-35	25
Rabbit fish (*Siganus* sp.)	15–33	25
Snapper (*Lutjanus* sp.)	15–33	25

Table. 2: Acceptable limits of heavy metals in seawater

Heavy metals	Acceptable limits (ppm)
Manganese (Mn)	< 1.0
Iron (Fe)	< 1.0
Chromium (Cr)	< 1.0
Tin (Sn)	< 1.0
Lead (Pb)	< 0.1
Nickel (Ni)	< 0.1
Zinc (Zn)	< 0.1
Aluminium (Al)	< 0.1
Copper (Cu)	< 0.01
Cadmium (Cd)	< 0.03
Mercury (Hg)	< 0.004

Dead phytoplankton, sewage discharge, industrial effluents, uneaten food and fish waste in the cage, becomes the source for organic load in water. The organic load in water can be measured by Chemical Oxygen Demand (COD) which should be less than 1 ppm for a suitable site. Industrial effluents and other anthropogenic activities are the main source for most heavy metals that are found in seawater. So the site selected should be free and away from industrial activities and sewage discharge sites. Heavy metals of importance to human and cage culture and their acceptable / safe limits are given in Table 2. Domestic sewage contains pollutants, detergents, toxic substances including several organic matters that affect cage fish farming. Selecting a site for cage culture away from such contaminations may avoid during the culture period. The acceptable level of Biological Oxygen Demand (BOD) should not exceed 5 mg/l at 5 days period.

Biological criteria

Open water cage culture is prone for fouling. Frequent cleaning and washing is required in areas of high fouling growth, to facilitate water exchange and to reduce the additional weight on cage frame. This makes net changing troublesome, tedious and time-consuming. To optimize the running cost, cages should be located in places unfavourable for the growth of fouling organisms. Algal blooms create problems to fish, directly by clogging its gills and indirectly by depleting dissolved oxygen at night. A site which is prone for sudden bloom may be avoid while selecting for cage farming.

Social criteria

The cage culture site should have access to both water-based and land-based mode of transportation. But at the same time the selected site should be away from navigational routes, since waves may be created from the wake of passing vessels. A floating raft with cabin for labourers close to the cages would increase their productivity. Since cage culture units are located in natural water bodies, security is a big concern while selecting a suitable site for cage culture. One should be cautious to prevent poaching and wise to select a site away from villages and common users to prevent such future problems. Government has the full rights over the land below the low tide level. Even though there is no leasing policy presently available for open water cage culture, the farmers should take prior permission or license before starting the venture with restrictions over area, species, size and type of culture practised. To avoid future conflicts with end users, prior identification of suitable sites for cage culture may be carried by the licensing authority. Cage culture operations should strictly follow the norms required by the government to avoid future problems and to sustain cage aquaculture as a profitable venture.

Pond culture system

In a pond culture system water quality is very much necessary for achieving higher production. Of the various water quality parameters, few are highly important and play a decisive role, they are temperature, pH, salinity, dissolved oxygen, ammonia, nitrite, CO_2, hardness and total alkalinity. Each parameter is important, but it is the aggregate and interrelationship of all these parameters that influence the health and growth rate of the fish. In the view of above a set of protocols has to be followed for maintaining good water quality for sustainable fish culture.

Site selection

- Topography and climatic conditions – an area having average natural elevation with loam based soil condition having clay content not more than 70%. The site having moderate rainfall and short dry season is most suited for fish farming activity.
- Water supply / source – Many problems associated with chemical and environmental issues will have its source or point of origin from water. Therefore, it is necessary to select adequate good quality water source with optimum water quality parameters is a prime need for fish production facility.
- Availability of relatively cheap and reliable electricity, labour, seed, equipment, commercial feed and other supplies ensure smooth operations and successful crop.
- Areas free from poaching and security risks is favourable.
- The farm area should have good accessibility by road, water and other communication systems.

Pond preparation and fertilization

The cleaning of a pond or removal of the wastes accumulated in the pond bottom, could be accomplished by drying, liming (dry method or wet method) and ploughing according to the possibility of the pond to be dried. The lime requirement of a pond depends on the soil pH. Agricultural lime ($CaCO_3$) or dolomite [$CaMg(CO_3)_2$] is recommended for liming of pond. For eradication of predators and competitors, 1 or 2 days after water filling application of tea seed powder at the rate of 20-30 ppm or calcium hypochlorite at the rate of 10 ppm is advised. The pond must be fertilized with either organic or inorganic fertilizer to stimulate the plankton bloom. Cow dung is the most common organic fertilizer used. Inorganic Fertilization is done with Urea and Ammonium Phosphate at (16:20) 20-30 kg/ha. Aeration can be done using paddle wheel aerator or long arm paddle wheel aerator. Maintenance of algal bloom is very much necessary in aquaculture. Regular application of cow dung juice, molasses mix and dolomite is necessary. Over bloom due to high plankton density can be controlled by application of algaecides BKC (Benzalkonium chloride) 0.1 – 1.0 ppm.

Table. 3:Lime application rate

Soil pH	Agri Lime Kg/ha
5.0	3000
5.0 - 6.0	2000
6.0 - 7.0	1000

Water parameters

The water obtained for fish culture may be filtered and treated but while culture is practiced, due to metabolic activities, accumulation of waste may pollute the water. The management of its quality is a complex process involving multiple water parameters. Out of them, few are very much essential and will have direct influence on the well-being of the fish cultured and inturn slighter variation from its optimum will affect the growth of fishes. Therefore, water quality management in fish culture systems assumes greater significance.

1. Temperature

Fishes are generally characterized as warm water species (25-30 °C), cool water species (15-25 °C). Although majority of the fishes tolerate water temperatures between 21 °C and 30°C, 24 °C to 28°C, have been found to be optimum and most suitable for the tropical fishes. A sudden change of 1°C even within the temperature tolerance range of that fish results in a serious stress to fish. Therefore, fish should be gradually acclimatized whenever shifted from one tank to another.

2. pH

Fish have an average blood pH of 7.4; hence a pH range of 6.5 to 8.5 is more optimum and conducive to fish life. The pH of water usable for fish farming may vary from acidic to alkaline depending upon its source, chemical and biological factors. The optimal pH for the growth of the majority of thefishes should be neutral or slightly alkaline i.e. 7-8.pH of pond / tank water can be corrected by following simple methods

1. Low pH (<7.0) can be corrected by application of limestone-calcium carbonate (CaCO3) @ 30-50 mg/L.
2. High pH (>9.5) is corrected by repeated application of Alum - aluminium sulphate [$Al_2(SO_4)_3$] @ 5-10 mg/L. However, alum should not be used in waters with total alkalinity of less than 20 mg/L as $CaCO_3$ because even a small amount will drastically lower the pH to a dangerous level.

3. Dissolved Oxygen

Fish must be cultured at optimum levels of dissolved oxygen (DO) to achieve high survival and good growth. It should remain well above 5 mg/L. A value of less than 5 mg/L can result in undue stress to the fish resulting in mortality below 2 mg/L. Fishes under culture would be under stress and prone for disease if optimal oxygen levels are not maintained. Factors influencing solubility and depletion of oxygen in water are

1. Higher water temperature
2. Accumulation of excessive organic mater
3. Formation of phytoplankton/algal blooms

Oxygen is dissolved in water by direct diffusion at the air-water interface. In emergencies oxygen level of ponds can be enhanced by constant aeration, circulation of water, sprinkling of water, surface agitation, etc.

4.Carbon dioxide

Fishes try to avoid free carbon dioxide. Free carbon dioxide at a concentration of more than 15 ppm is detrimental to fishes. Fishes can tolerate high level carbon dioxide provided dissolved oxygen content of the water is sufficiently high. But the presence of high free CO_2 may hinder solubility of oxygen. Generally CO_2 content in water may increase during night and decrease during day time. High level of free CO_2 can be removed by application of following for every 1 ppm of free CO_2: add 0.84 mg/L of $Ca(OH)_2$ oradd 0.64 mg/L of CaO

5.Water Hardness

The total hardness of the water is due to the sulphite and chlorides of soluble calcium and magnesium salts present in the water expressed as its calcium carbonate equivalent. The total hardness is mainly used to classify waters into 'hard water' or 'soft water'. Water with a total hardness of 0-75 mg/L is considered soft, 75-150 mg/L as moderately hard, 150-300 mg/L as hard and above 300 mg/L as very hard. Water with hardness of 50-200 ppm have been found to be optimal for the normal growth for majority of fish. Water with less than 12 ppm requires liming for higher production of fish. Hard water is also known to influence feed intake and growth of fishes.

The total hardness can be improved by the application of agriculture lime ($CaCO_3$) as per requirement. In case, total alkalinity is in the desirable range, total harness alone can be enhanced to optimum levels by using gypsum ($CaSO_4$) without affecting the alkalinity. Proper management of hardness and alkalinity will usually eliminate the need to worry about pH. Water hardness can be reduced by following methods such as apply EDTA at 1 kg/acre, softening of water by application of 'Zeolite' (Sodium alumina silicate) and addition of sodium carbonate

6.Total Alkalinity

Alkalinity is the capacity of water to neutralize acids without an increase in pH. This parameter is a measure of the bases i.e. bicarbonates & carbonates (CO_3^{2-} and HCO_3^-) and in rare instances, hydroxide (OH^-). Total alkalinity is the sum of the carbonate and bicarbonate alkalinities. Some waters may contain only bicarbonate alkalinity and no carbonate alkalinity. Fish grow within a narrow range of pH values and either of the above extremes will be lethal to fish. A culture system is considered well buffered when pH varies between 7.5 - 8.5 and total alkalinity ranges from 80-150 mg/L. The total alkalinity of water can be increased by the addition of lime in the daytime, which should be done in phases by monitoring the value of pH. Sodium bicarbonate at 20 kg/ha will improve alkalinity. A pH value of above 8.5 is not desirable for most of the species. There is no practical method to reduce total alkalinity of ponds. However, it can be reduced significantly by regular replenishing of water and suspending feeding and manuring for some time.

8. Total ammonia

Ammonia content of the water is due to the release of metabolic wastes and decomposition of organic matter including feed remains and feacal matter. Ammonia occurs in aquaculture systems in two forms i.e. ionized and un- ionized. The un-ionized form of ammonia (NH_3) is extremely toxic while the ionized form (NH_4^+) is not. Both forms are grouped together as total ammonia. The unionized or free ammonia is safe below 0.02 mg/L and toxic above 0.02mg/L in freshwater and 0.01mg/L in seawater. Above this level, free ammonia causes the fish to stress and at higher levels it may cause damage to gills and many internal organs, eventually resulting in fish deaths. As the temperature and pH of the culture system increases the level of free ammonia increases and of ammonium ions decreases. Hence, the balance between free ammonia and ammonium ions is determined by the pH and temperature of the water. The toxic level of ammonia can be best reduced in a culture system by immediate water exchange, control feeding rate and increase beneficial bacteria and carbon source.

↗ High temperature	↗ High free ammonia (NH3)
↗ High pH	↘ (low ammonium) (NH_4+)
Dangerous to fish	

↘ Low temperature	↘ Low free ammonia (NH3)
↘ Low pH	↗ (high ammonium) (NH_4+)
Relatively safe for fish	

9.Nitrite and Nitrate

The nitrites are produced in culture waters by bacteria (including *Nitrosomonas* spp.) through nitrification process when ammonia is broken down. At any situation, nitrite should not exceed 0.125mg/L in seawater. The toxicity of nitrite increases by decreasing pH. Nitrite poisons fish by binding the hemoglobin in the blood preventing it from carrying oxygen, in effect suffocating the fish. The gills of fish dying as a result of nitrite poisoning is a characteristic brown colour.

The nitrates are produced in culture waters by bacteria (including *Nitrobacter* spp.) through nitrification process when nitrite is broken down. Nitrate is generally of low toxicity though some species, especially marines, are sensitive to its presence. Nitrate levels in marine systems do not exceed 100mg/L. The high levels of nitrite and nitrate can be best reduced by immediate water exchange, controlling feeding rate, and increasing beneficial bacteria and carbon source.

Suggested Readings

Edward, L. L., Laxmilatha, P., Sreeramulu, K., Ranjith, L. and Megarajan, S., 2020. Influence of certain environmental parameters on mass production of rotifers: A review. Journal of the Marine Biological Association of India, 62(1), pp.49-53.

Franklin, D.A. and Edward, L.L. 2019. Ammonia toxicity and adaptive response in marine fishes - A review. Indian J. Geo-Marine Sci., 48(03), pp. 273-279.