# Fish health management in cage aquaculture

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## Introduction

Finfish is the primary source of animal protein for humans in many parts of the world and per capita consumption of fish has been increasing from an average of 9.9 kg in the 1960s to 19.2 kg in 2012 (FAO, 2014). Growing global population, dwindling natural fish stocks, and the increasing demand are the major drivers for increasing fish production. Aquaculture remains the only option to meet these demands and globally, the share of aquaculture is projected to rise to 62% of the total fish production by 2030. However, considering the limitations of the traditional aquaculture systems due to environmental issues, carrying capacities etc., it has been recognized that cage culture, especially mariculture has many advantages. Over the years, cage culture has become one of the economically viable methods of large-scale production of high-value food fishes. Many stakeholders consider open sea activities such as cage and pen culture as the aquaculture system of the millennium. High-value carnivorous fish species such as groupers, barramundi, snappers and pompano are increasingly being raised in small cages in inshore environments. Further, there is a move towards offshore mariculture using larger and stronger cages in China (FAO, 2014). Production figures show that about 60% of coastal fish culture is contributed by cage farming and cage culture contributes more than 90% of all seabass and seabream production (Syda Rao, 2012). Although history of cage culture dates back to 1800s in Southeast Asia it was in 1950s that commercial level marine cage farming started in the region.

## Cage culture - the Indian scenario

The first initiative on low volume brackishwater cage culture of seabass, funded by New Zealand Agency for International Aid (NZAID) was implemented through the fisherfolk Self Help Groups at Kodungallore in 2005-07 (Vijayan *et al*, 2007). Though the first open sea cage was launched in Bay of Bengal off Visakhapatnam coast in 2007 as a part of research and development (Syda Rao, 2012), reports are available on marine cage farming of fishes such as *Sillago sihama, E. hexagonatus* and *E. tauvina* way back in 1980s and 90s. In India, marine cage farming has become a prominent activity since 2008 and the Asian seabass *Lates calcarifer* has been the pioneer species for culture. Standardized hatchery technology, availability of hatchery-produced seed, good market demand and fast growth enabled appreciable adoption of cage farming by farmers. Another potential species is cobia *Rachycentron canadum.* According to Syda Rao (2012), among crustaceans, open cage farming of lobsters are proved to be economically remunerative.

**Disease problems in cage culture**

Although, cage farming has many economic advantages, like any other animal production system, diseases are one of the major limiting factors to the successful production. Increasing intensification and lack of adequate health management measures result in frequent occurrence of diseases. Since the basic cage culture practices are similar in all the regions, disease problems encountered will largely depend on the species being cultured, environmental conditions and management practices (Seng and Colorni, 2002). As in other aquaculture systems, environmental factors such temperature, salinity, dissolved oxygen, suspended particulate matters etc. are critical and any adverse changes in these parameters would make the fish susceptible to diseases. Similarly, crowding and handling stress and feed management also play a crucial role. Unlike closed systems, the risk of pathogen incursion through cohabiting animals and pathogen-contaminated water is more in open cage farms. However, like any other farming system, health management practices involving early detection of infection and prophylactic and therapeutic treatment are of paramount importance. Many of the biosecurity measures which are employed in land-based aquaculture systems will not have much relevance to cage farming, as the system is highly dynamic. However, a thorough understanding of pathogens, disease process, diagnosis, epidemiology and control measures are essential for better health management of farmed fishes in cages. As cage farming is in a nascent stage in India, the lessons learned in dealing with disease problems and their management in land-based aquaculture systems will be of immense use in cage farming in future. In this background, this article discusses various aspects of important pathogens/diseases of farmed marine and brackishwater fishes, especially those which are recorded from Asia-pacific region along with the challenges in managing these diseases in open cage system.

**Viral diseases**

Among the diseases with infectious aetiologies, viral diseases are the most consequential in aquaculture systems, and as new species of fishes are cultured, incidences of known and new diseases can emerge. Two major group of viruses, iridovirus (DNA virus) and nodavirus (RNA virus) have been reported from fishes reared in marine cage farms from different parts of the world.

**Viral nervous necrosis (VNN)**

**Disease and hosts:** Viral encephalopathy and retinopathy (VER) or viral nervous necrosis (VNN), is a serious disease infecting several species of marine fish. The disease is characterized by vacuolating lesions of the central nervous system and retina leading to significant losses, mostly in larval and juvenile stages. Although the disease primarily affects early stages, serious mortalities have also been reported in market-size and adult fish, such as Asian and European seabass, Atlantic halibutand seven-band grouper. Considerable variations have been noticed in the pattern of mortality. Further, morality is reported to be age-dependent where higher mortality occurs in larval stages,while in juveniles and older fishes it is low. In India the virus has been identified as a serious pathogen of hatchery-reared seabass, *Lates calacrifer* (Azad *et al*., 2005). Subsequently, many reports have been published on the virus from Indian fishes (Parameswaran *et al*., 2008; Binesh and Jithendran, 2013; Banarjee *et al*., 2014; John *et al*., 2014). The disease has been reported in more than 50 species, mainly marine fishes.

**Pathogen:** The causative agent was first isolated from striped jack, *Pseudocaranx dentex*, and the name striped jack nervous necrosis virus (SJNNV) was adopted and identified as a new member of the family Nodaviridae. The virus has subsequently been isolated from other fishes as well. Currently, the virus is placed under the genus *Betanodavirus* within the family *Nodaviridae*. These viruses are small (25-30 nm), non-enveloped and spherical. The viral genome consists of two segments of positive-sense single-stranded RNA (ssRNA). A 3.1 Kb RNA1 codes for replicase and 1.4 kb RNA2 codes for coat protein. Phylogenetically, four major genotypes have been identified based on a variable region of RNA2: designated: SJNNV-type, tiger puffer nervous necrosis virus (TPNNV)-type, barfin flounder nervous necrosis virus (BFNNV)-type, and red-spotted grouper nervous necrosis virus (RGNNV)-type.

**Epizootiology and how it is significant to disease outbreaks?:** VER infection is primarily transmitted horizontally especially via contaminated water. However, vertical transmission from broodstock to offspring has also been reported. Hence it is essential to screen the broodstock and ensure pathogen-free status before spawning because the success of farming depend on production and supply of VNN-free larvae and juveniles. Presence of wild reservoirs and use of infected wild caught seeds play a major role in disease dissemination. Betanodavirus can survive in sea water at lower temperaturesand even in frozen fish posing a potential risk. Further, surviving fishes can harbour the virus for prolonged periods and become lifelong carriers, transmitting the disease.In open water cages, transmission can occur easily through water current, boats and other appliances which will be used for transportation of men and material across cages. Further cohabiting wild fishes and the fish-eating birds can act as vectors.Water temperature plays a critical role in influencing the onset of clinical signs. This is especially true with VER outbreaks in farm-reared seabass and the infection is often known as ‘summer disease’. Control and prevention of the virus is a challenging proposition, especially in open cages, as avoidance of exposure to the pathogen is difficult. However, rearing of juveniles originated from pathogen-free broodstock can minimize the risk of disease to a large extent. Health monitoring of fry should be carried out before stocking in the cages. Though chemotherapy is not available, effective vaccination strategy showed promising results in groupers.

**Lymphocystis**

**Disease and hosts:** Lymphocystis disease (LCD) is an iridoviral disease first reported in European flounder and later in many other fishes and is characterised by nodular skin lesions. The infected fish show cream-coloured nodular lesions on skin and fins and internally over the mesenteries and peritoneum. Although highly contagious, the disease follows a chronic pattern with limited mortality. Juveniles fishes is more susceptible. Infected fishes generally recover within a few weeks after the onset of disease outbreak and the lesions and scar tissue almost disappear. However, the virus has not been reported from India.

**Pathogen:** Lymphocystis disease virus (LCDV) is the causative agent of lymphocystis disease. LCDV is a member of the family *Iridoviridae.* Iridoviruses are large viruses with icosahedral symmetry having a diameter of 120–350 nm. The virus possesses an envelope derived from host plasma membrane. The genome consists of a single linear molecule of double-stranded DNA. The genome is 102,653 bp in length.

**Epizootiology and control measures:** The virus has wide host and geographical range infecting farmed fishes as well as ornamental fishesin Asia-pacific. It is transmitted horizontally through direct contact andstress factors can favour the disease. As there is no effective therapy available, the best possible option to prevent the disease spread.

**Red seabream iridoviral disease**

**Disease and hosts :** Red sea bream iridoviral disease (RSIVD) is a serious disease (OIE-listed) of cultured red seabream reported first from Japan and more than 30 species of marine fishes. However, it has been reported that the disease is caused not only by RSIV but also by infectious spleen and kidney necrosis virus (ISKNV). Affected fish show lethargy, severe anaemia, petechiae of the gills and splenomegaly. Histologically, it is characterised by the presence of enlarged cells in spleen, heart, kidney, intestine and gill of infected fish.

**Pathogen:** The causative agent, red seabream iridovirus (RSIV), is a DNA virus of icosahedral symmetry with a diameter of 200–240 nm. The disease is also caused by infectious spleen and kidney necrosis virus (ISKNV).

**Epizootiology and control measures:** The disease transmission is horizontal via water and vertical transmission and vectors of the disease have not been reported so far. Mortality depends on fish species, size and age of fish, water temperature and other culture conditions. Since therapy is not available, preventive measures are recommended. Effective formalin-killed commercial vaccine for RSIVD is also available currently.

**Bacterial diseases**

It has been suggested that successful aquaculture relies on better insight into the complex interactions between the cultured organisms and the bacterial communities present in the rearing systems. The microflora of the aquatic ecosystem comprises diverse taxonomic groups and the major groups of bacteria belong to *Vibrio* spp., and *Pseudomonas* spp., followed by *Alteromonas, Acinetobacter, Alcaligens, Photobacterium, Thiobacillus, Achromobacter, Flavobacterium, Aeromonas, Bacillus, Micrococcus,* etc. Although majority of the bacteria in the coastal marine water bodies are harmless, some strains belonging to genera of *Vibrio, Pseudomonas, Aeromonas, etc.,* are opportunistic pathogens to aquatic animals (Table 1). Among the bacteria that cause fish diseases, *Renibacterium salmoninarum*, the etiological agent of bacterial kidney disease, and *Mycobacterium* spp. can be classified as obligate pathogens since these are rarely found in the absence of a host. The environmental changes due to rains, temperature, discharges into water bodies and many unknown biotic and abiotic factors can all contribute to changes in the microbial communities. In addition to these, vast number of inputs such as feed, probiotics, immunostimulants, growth promoters etc., that go into the aquaculture systems can also bring about changes and shifts in microbial communities. Understanding the population structure and shifts in microbial communities can help in tracking the causes of outbreaks in aquaculture systems.

***Vibriosis:*** Although a number of bacteria are reported to be associated with diseases in fish, only a few are responsible for large-scale mortalities. Bacteria such as *Vibrio anguillarum, V. alginolyticus, V. vulnificus, V. damsela, V. harveyi*, *Cytophaga-Flexibacter* group, *Aeromonas hydrophila, Pseudomonas fluorescens, Flavobacterium* and *streptococcus* have been implicated with major bacterial diseases in seabass.

Within the family vibrionaceae, the species which cause most serious diseases in finfish are *Listonella (Vibrio) anguillarum.* Vibriosis is the most significant disease of cultured and wild marine fish. The disease was first described in eels and is known to affect a wide range of marine teleosts. Vibriosis usually affects fish in salt or brackish water, especially in shallow waters during late summer when temperatures are high, *V. anguillarum,* the etiological agent of classical vibriosis causes typical haemorrhagic septicaemia. Fish show generalized signs of septicaemia with haemorrhages at the base of fins, exophthalmia and corneal opacity. So far, 23 serotypes of *V. anguillarum* have been reported to be associated with disease of which serogroup 2 is the most common strain causing epizootics world wide. Vaccines and chemotherapy are available for prevention and control of vibriosis due to *V. anguillarum*.

***Streptococcosis***

Streptococcosis has been associated with acute to chronic mortalities in several estuarine fishes. Infected fish display a disoriented whirling motion at the water surface and exhibit hemorrhages on operculum, around the mouth, at the base of fins and around anus. Abdomen is often distended with sanguineous fluid and exophthalmia is observed. The liver is pale and the spleen is deep red. The bacteria cause damage to the central nervous system, characterized by suppurative exophthalmia and meningoen cephalitis. Streptococcosis in fish is considered as potential zoonotic agent of human disease.

Presumptive diagnosis of streptococcosis is based on clinical signs, including the observation of Gram-positive cocci in the internal organs. Definitive diagnosis requires the determination of culture and biochemical characteristics of the isolate and serology. The bacteria can be identified by classical microbiological techniques while molecular techniques help in accurate and rapid identification.

***Photobacteriosis***

The disease is also called as pasteurellosis or pseudotubercosis is caused by *Photobacterium damsellae* sub sp. *Piscicida* (formerly *Pasteurella piscicida).* It has been reported in seabass, striped bass and sole in the Mediterranean countries and USA. However, there is no report of this disease in the Asian seabass. The disease is characterized by the presence of white nodules in the internal viscera, particularly in the spleen and kidney. Usually, heavy mortalities due to this disease occur during high temperatures and older fish are generally more resistant. The pathogen can be identified by classical microbiological techniques. Enzyme linked immunosorbent assay and polymerase chain reaction based techniques are also available. Vaccination protocols also have been developed.

***Flexibacteriosis***

It is also called as 'gliding bacterial disease', 'eroded mouth syndrome' or 'black patch necrosis'. The disease is caused by *Tenacibacterium maritimum (Cytophaga marina, Flexibacter marinus and F. maritimus)* and is reported from most parts of the world in a number of fish including sea bass. Environmental stress, particularly high temperatures aggravate the disease and its severity. Affected fish larvae have eroded and haemorrhagic mouth, ulcerous lesions on the skin, frayed fins and tail rot. Occasionally, the infection can lead to systemic disease. Clinical signs along with revelation of long rods in the wet mount or Gram stained preparations of gills or lesions by microscopy are used for presumptive diagnosis of the disease. Further confirmation is by isolation of the pathogen using classical microbiological techniques and identification.

PCR protocol for 16S rRNA gene target is useful in accurate detection of *T. Maritimum* in confirming the diagnosis as well as for epidemiological studies of marine flexibacteriosis. Vaccines have also been developed for the prevention of flexibacteriosis.

### *Mycobacteriosis*

It is a sub-acute, chronic disease reported to affect more than 200 fish species worldwide. *Mycobacterium marinum*is the primary causative agent of fish mycobacteriosis and causes tubercle granulomas in cultured and wild populations of fish. A number of other *Mycobacterium* spp. are known to cause similar disease. Signs and symptoms of mycobacteriosis vary according to species of fish. Internally, the disease is characterized by white nodules (granulomas) in spleen, kidney and liver. External manifestations include loss of scales,

**Table 1.** Bacterial diseases reported from farmed marine fishes (taken from Seng and Colorni, 2002)

| Disease | Causative agent | Host species affected (Marine/brackishwater) | |
|---|---|---|---|
| | | **Common name** | **Latin name** |
| **Gram-negative** | | | |
| Vibrionaceae *Listonellaanguillarum* | Vibriosis | Yellowtail<br>Amberjack<br>Horse mackerel<br>Red seabream | *Seriola quinqueradiata*<br>*Seriola dumerili*<br>*Trachurus japonicus*<br>*Pagrus major* |
| *Vibrio alginolyticus* | Vibriosis | Greasy grouper<br>European seabass<br>Seabream | *Epinephelus coioides*<br>*Dicentrarchus labrax*<br>*Sparus aurata* |
| *Vibrio parahaemolyticus* | Vibriosis | Golden snapper<br>Seabream | *Lutjanus johni*<br>*S. aurata* |
| *Photobacterium damsela* | Pasteurellosis | Yellowtail<br>Amberjack<br>European seabass<br>Seabream<br>Red drum | *S. quinqueradiata*<br>*S. dumerili*<br>*D. labrax*<br>*S. aurata*<br>*Sciaenopsocellatus* |
| Enterobacteriaceae *Edwardsiellatarda* | Edwardsiellosis | Japanese flounder | *Paralichthysolivaceus* |
| Cytophagaceae *Flexibactermaritimus* | Saltwatermyxobacteriosis | Red seabream<br>Greasy grouper<br>Asian seabass<br>Mangrove snapper<br>Japanese flounder | *P. major*<br>*E. coioides*<br>*Latescalcarifer*<br>*Lutjanus argentimaculatus*<br>*P. olivaceus* |
| **Gram-positive** | | | |
| *Streptococcus spp.* | Streptococcosis | Greasy grouper<br>Yellowtail<br>Amberjack<br>European seabass<br>Red drum<br>Tilapia<br>(adapted to seawater) | *E. coioides*<br>*S. quinqueradiata*<br>*S. dumerili*<br>*D. labrax*<br>*S. ocellatus*<br>*O. mossambicus* |
| **Acid-fast pathogens** | | | |
| Nocardiaceae *Nocardiaseriolae* | Nocardiosis | Yellowtail<br>Amberjack | *S. quinqueradiata*<br>*S. dumerili* |
| Mycobacteriaceae<br>*Mycobacterium marinum* | Mycobacteriosis | Seabream<br>European seabass | *S. aurat*<br>*D. labrax* |

accompanied by haemorrhagic lesions, extending to musculature in advanced cases.

Diagnosis is based on the signs and symptoms and identification of the pathogen. Smears of affected organs stained with Ziehl Neilsen's stain reveal characteristic acid fast mycobacteria. Precise diagnosis can be made by isolation and identification of the bacteria using selective culture media and phenotypic characterization including analysis of cell wall fatty acids and mycolic acids. Further, the etiology may be confirmed by 16S rDNA sequencing. The disease is asymptomatic for long time, stunts fish growth and it is impossible to treat affected fish by chemotherapy.

**Parasitic diseases**

Mortality associated with pathogens in wild fishes is seldom, as the balance between host and pathogen is rarely broken, except in situations where sudden fluctuations in environmental conditions occur. Wild fishes generally harbour many parasites but the intensity of infection most often remains very low in that it will not be consequential to the fish health. However, in confined conditions such as cages where the stocking density is very high and the resultant stress might act as a conducive factor for pathogens to cause diseases. High stocking densities coupled with fluctuations in environmental conditionsand/or stress can favour parasite proliferation leading to significant mortalities in net-cage-reared marine fishes.In aquaculture, there is an overall reduction in diversity of parasites and the general trend shows adecrease in infection with parasites having complicated/indirect life cycles.

Parasitic infections seriously impair aquaculture and the impact of parasites on marine finfish culture has been well documented (Table. 2). Except some protozoans, most of the economically important parasites infecting farmed fishes are ectoparasitic in nature, of which copepods such as *Lepeophtheirus* and *Caligus* are considered serious parasites causing mortalities. Ectoparasites feed on mucous, tissues, and blood/body fluids and the damage caused by their attachment and feeding activities may pave way for secondary infections. Major pathology associated with sea lice and other ectoparasitic infestation includes damage to the epithelial layer (skin & gills) resulting in haemorrhagic lesions on the skin and osmoregulatory dysfunction. They are also reported to act as vectors of some of the pathogenic viruses and bacteria besides making the fishes susceptible to secondary infection. Economic losses can be quantified in terms of direct mortalities, secondary infections, poor/reduced growth and expenses for treatment. Open cage farms facilitate easy transmission of parasites such as sea lice from wild to farmed fish and vice versa thereby causing unforeseen consequences in sympatric wild fishes. It has been reported that sea cages can becomes an unintended pathogen factory and can result in decline in wild fishes due to the spread of the parasites from the cage-farmed fishes. Among the other crustaceans, mortality associated with cymathoid isopod has also been reported in cage cultured fishes.

However, there is very little information available on diseases, especially of parasitic etiology from Indian sub-continent. The first record of serious mortalities in cage cultured fishes in India is that of a large-scale mortality in *Lates calcarifer* due to the crustacean isopod, *Cirolana fluviatilis* (Sanil *et al.*, 2009). Mortalities appeared one month after stocking and fish were found dead in cages with their flesh eaten away,leaving the remnants of skeleton. *C. fuviatilis* a voracious, carrion-feeding isopod widely reported from coastal waters was responsible for these mortalities. Though these isopods are bottom dwellers, in this case they have colonized the fouled net surrounding the cage and attacked the stressed

**Table 2.** Details of parasitic infections recorded from mariculture system in Asia-Pacific region (taken from Seng et al., 2006)

| Parasite | Site of infection | Clinical signs |
|---|---|---|
| **Ciliates** | | |
| *Cryptocaryon irritans* | Gills & body | Whitish spots on body surface, darkened body, lethargy, exophthalmia, increased mucus production, rub body surface against net. |
| *Trichodina* spp | Gills & body | Lethargy, non-feeding, pale gills with increased mucus production, rub body surface against net, hyperplasia andnecrosis of epidermis |
| *Brooklynella* spp | Gills & body | Lethargy, non-feeding, rub body surface against net, surface subcutaneous haemorrhage. |
| *Henneguya* spp. | Gills & body surface | Pale gills and hyperplasia. |
| **Dinoflagellate** | | |
| *Amyloodinium ocellatum* | Gills & body | Fish gather at water surface or aeration outlet, rapid gillsurface operculum movement, pale gills, darkened body, increased mucus production in gills. |
| **Myxosporean** | | |
| *Sphaerospora epinepheli* | Kidney, liver, spleen, & intestine | Loss of equilibrium, floating upside down, swollen abdomen & haemorrhages on mouth and body surface. |
| **Microsporidian** | | |
| *Glugea* spp. | Internal organs | Swollen abdomen, black nodules on internal organs |
| *Pleistophora* spp. | Internal organs | Swollen abdomen, black nodules on internal organs |
| **Capsalid Monogenean (skin flukes)** | | |
| *Benedenia* spp.<br>*Neobenedenia* spp. | Gills & body surface | Darkened body, erratic swimming behaviour, rub againstnet, pale gills, lethargy and loss of appetite, opaque eyes, patches of "dryness" on scales or loss of scales at forehead(above the eyes), haemorrhage & necrosis on body surface. |
| **Diplectanidmongenean (gill flukes)** | | |
| *Pseudorhabdosynochus* spp.<br>*Diplectenum* spp. | Gills | Darkened body, rub against net, pale gills, lethargy, loss of appetite, excess mucus production. |
| **Dactylogyrid monogenean (gill flukes)** | | |
| *Haliotrema* spp.<br>*Dactylogyrus* spp. | Gills | Rub against net, devoid of scales at forehead (above eyes), pale gills, lethargy, loss of appetite, excess mucus production. |
| **Microcotylid monogenean (gill flukes)** | | |
| *Heterobothrium* spp.<br>*Heteraxine heterocerca*<br>*Microcotyle spp. Bivagina sp.*<br>*Choricotyle sp.* | Gills | Show no clinical signs except lethargy, loss of appetite,pale gills and anaemia. |
| **Sanguinicoliddigeneans (blood flukes)** | | |
| *Cruoricola lates*<br>*Pearsonellum corventum*<br>*Cardicola sp. Paradeontacylix spp.* | Circulatory system | No obvious signs, affected fish gasp for air at the water surface, gill lamellae fusion & hyperplasia. |
| **Crustaceans (Sea lice, isopods)** | | |
| *Lepeophtheirus* spp. *Caligus* spp.<br>*Ergasilus* spp. | Skin & gills | Extensive hemorrhaging and skin erosion, lesions, Hyperplasia, congestion & erosion of gills |

fish causing heavy mortalities. This is an example where parasites/pests that have not been previously considered pathogenic can cause serious mortalities under certain circumstances.

Infections with the dinoflagellate *Amyloodinium ocellatum* is considered one of most important diseases affecting cultured marine and brackishwater fish. Outbreaks by *A. ocellatum* have been reported in *Trachinotus blochii* and *L. calcarifer* from India. It causes 'velvet disease' in marine fish especially when kept under captive conditions/hatcheries and in cages. The parasites infect the skin/gills leading to mortalities.Wide temperature and salinity tolerances and high transmission potential make them more dangerous. The monogenean *Diplectanum latesi* has been known to cause mortalities in finfish. Heavy infection with *D. latesi* has been reported in the broodstock of *L. Calcarifer* (Rajendran *et al.*, 2000), but mortality associated with this parasite in cage-farmed seabass has not been recorded.

Although efficient chemotherapeutic measures are available against sea lice, most of the organo pesticides and avermectin derivatives effective against sea lice are highly detrimental to cohabiting crustacean fauna. Therefore, practical difficulties in the application of chemicals in open cages and their environmental consequences discourage their use. However, biological control of sea lice through cleaner wrasse (Family: Labridae) has effectively being used in salmon farming.

**Lacunae/challenges in health management of marine fish culture**

Control and prevention of infectious disease in aquaculture is a function of management. Incidence and severity of infectious diseases are very often dependent on the quality of aquatic environment in which the fishes live and the quality of feed they consume. While there is scope to manage some of the environmental parameters in land-based aquaculture, in mariculture or cage culture set up, this may not be possible. The environmental quality is almost similar to the sea in the mariculture or cage culture set up as long as there is no anthropogenic pollution. For most of the cage-farmed marine fish, trash fish are being widely used as feed and trash fishes are a potential source of pathogen transmission and this need to be monitored. When live feed is used, it should be ensured that they are free from pathogens and development of efficient pathogen-free feed is a requirement for the biosecure production of farmed fish.

One of the important sources of disease transmission to cage cultured animals from extraneous sources will be through transmission of pathogens through water and unfortunately this mode of disease transmission would be almost impossible to prevent. As more and more species diversification happens in aquaculture, characterisation of new pathogens, development of new diagnostic tools and understanding the basic epizootiology and host-pathogen interaction, especially the basic immune system of cultured species remain to be elucidated. However, as the number of cultivated species increases, the resources available for developing a comprehensive health management plan for these species will become scarce. Further, implementing effective health management strategies become difficult in most of the farming system, as majority of the farms are operated by small-scale farmers,who do not have adequate resources to implement these measures. Effective quarantine and biosecurity measures need to be implemented at the hatchery level to ensure that the fry/larvae of fish are pathogen-free before being introduced into the net-cages. Practice of using wild-caught fry for stocking should be avoided.

Developing highly sensitive diagnostic tools which can be used in a non-lethal way (without sacrificing the valuable broodstock) and also development of cost-effective farm-level diagnostics are essential to improve and sustaining cage fish farming.

Although cage-farming in India is presently relying only on native species, translocation of stocks across different geographical region needs to be done with proper care. Before introducing any new species for culture in the open cages, even the native species, a thorough profile of its potential pathogens and the possible management measures need to be identified. Culture of diverse species of fishes concentrated in an area will be a serious biosecurity issue, as this would enhance the chances of disease transmission. Maintaining proper hygiene, disinfection and biosecurity is quite challenging in open cage systems because of obvious reasons. However, proper cage maintenance by removing excess feed and suspended particulate matter, cleaning of fouling agents from the cages and frequent monitoring of the farmed animals and removal of dead or moribund animals from the cages play a crucial role in better health management.

Chemotherapy is effective in controlling many parasites and some of the bacterial pathogens. However, any attempt to apply chemicals or antibiotics in water should be strictly avoided. As in other aquaculture system, problems of drug residue, drug resistance, consumer safety, environmental safety will be great concerns. Further, as mentioned elsewhere, application of chemicals in open cages will have serious environmental consequences apart from non-target species safety. Development of vaccination will have great prospects in cage aquaculture, as unlike other intensive aquaculture systems, vaccination of individual animals is more practical and effective.

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