Bulletin No. 20

DISEASES OF MUD CRABS IN INDIA

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PREFACE

Among the cultivable shellfishes, mud crabs (*Scylla* spp.) is considered as one of the important seafood items for aquaculture in Southeast Asian countries due to their larger size, delicacy and greater demand. This bulletin, **"Diseases of mud crabs in India"** is based on the observations from the research & development and on-farm outreach activities of the institute for the last five years besides published literature on mud crab diseases in India. Diseases of mud crabs (*Scylla* spp.) may be caused by living pathogens like viruses, bacteria, fungi, parasites and epicommensals. In mud crabs, diseases occur in combination of pathogens and are often complicated by nutritional, environmental and management deficiencies. There is a need to understand disease and the factors that contribute its development and outbreak. Further, the magnitude of existing diseases and emergence of new diseases will continue with intensification of crab culture. This bulletin aims to provide information on diseases observed among wild caught and cultured mud crabs in our country. Some of the diseases have been illustrated for pond-side diagnosis for field technicians and is first of its kind on mud crabs. It is believed that this bulletin will be useful to producers, hatchery operators, specialists and farm technicians on specific aspects of mud crab diseases and the preventive measures to be followed to ensure the nutritional quality and food safety issues.

07 September 2009

A.G.Ponniah
Director

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DISEASES OF MUD CRABS IN INDIA

1. INTRODUCTION

Mud crab is a large portunid crab, found in greater abundance in all estuaries, coastal lagoons and near shore waters of India. The mud crabs belonging to the genus *Scylla* are larger in size with high commercial value in terms of export and domestic markets by virtue of their delicacy and medicinal value. Although four species of *Scylla* have been identified, namely, *Scylla serrata*, *S. tranquebarica, S. olivacea* and *S. paramamosain,* only two major species of crabs *Scylla tranquebarica* (larger species) and *S. seratta* (smaller species) occur in Indian waters and have high potentials for aquaculture (Fig. 1 & 2).

Fig. 1. *Scylla serrata*

Fig. 2. *Scylla tranquebarica*

In India, mud crab farming mainly depends on fattening of “water crabs”, and after attaining sufficient marketable characteristics, they are harvested and sold at high price. The Central Institute of Brackishwater Aquaculture (CIBA) has carried out detailed studies on broodstock development and larval rearing of the two mud crab species. The technologies for captive broodstock development, induced breeding and hatchery seed production of these crabs have been standardised in India. At present, crab fattening is practiced in shallow backwaters of many coastal states like Goa, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Orissa and West Bengal. Recently, mud crab fattening has become an alternative livelihood option as an allied trade with lucrative employment opportunities for many women self-help groups in coastal regions.

Although hatchery production of the megalopae is feasible, the initial source of spawners and broodstock is mostly dependant on the wild stock. The mud crabs of different sizes are sourced mainly from the shallow coastal waters, estuaries, intertidal swamps and mangrove areas for farming also. Nursery production of juvenile mud crabs as a source for farming up to marketable size will open the door for the sustainable development of crab aquaculture in the country. Health management practices during the seed production are also important criteria to look upon. The basic understanding on the mass mortality of mud crab larvae and the biosecurity aspects during the four week hatchery cycle from zoea -1 to first crab instar stage is limited. It is clear that bacteria are strongly implicated in larval mortality as shown by bacterial load in rearing water. In general, various workers agree that routine application of antibiotics in mud crab larval rearing system is not desirable. The rich experience gained on shrimp diseases and the relationship between the hosts, pathogens and the environment that results in the form of disease outbreaks may be useful in studying diseases of mud crabs. CIBA has standardized captive broodstock development, maturation and larval rearing of mud crabs and developed technology for fattening and grow-out culture. However, little is known on disease problems in the larval, nursery or grow-out phase of Indian mud crabs. Hatchery seed production has only been started recently. It is only during larval culture that susceptibility to various infectious agents has been reported. The disease problems affecting captive broodstock and the larval stages and identifying measures for their prevention and control have received very little attention in India.

In order to make crab culture a sustainable enterprise, it is important to understand their diseases, host-pathogen interactions, prevention and control of diseases. The present compilation is an overview of the potential infections / diseases encountered in mud crabs, *S. tranquebarica* and *S. serrata* based on the observations from the research and development activities of CIBA and on-farm outreach activities since 2003.

2. DISEASE DIAGNOSIS IN MUD CRAB CULTURE

Diseases may be infectious, *i.e.,* caused by living viral, fungal, bacterial or parasitic organisms, or non-infectious, *i.e.,* caused by non-living factors such as nutritional deficiencies, behavioural problems and hostile environment or toxins. General principles of aquatic animal disease diagnosis may be applied in crab culture also. A broad outline of general principles of diagnostics in aquatic animals for both farm and laboratory level diagnosis has been given in the Asia Diagnostic Guide to Aquatic Animal Diseases (FAO). This is built on a frame work of three levels of diagnostics and activities, contributing valuable data and information at each level for optimum diagnosis.

Levels of disease diagnostics:

Level I	Diagnostic activity includes farm/production site observations, history and health management. A presumptive diagnosis based on clinical signs, necropsy, gross lesions, etc. may be achieved at this stage. This forms the baseline for other diagnostic levels (II & III).
Level II	Diagnostic activity includes parasitology, bacteriology, mycology and histopathology which require moderate capital and training and hence diagnostic site is at laboratory level. A definitive diagnosis can be reached at this stage.
Level III	Diagnostic activity includes specialized areas like virology, immunology, molecular biology and electron microscopy, etc. which require significant capital and training investments. It offers confirmatory diagnosis based on the principles of advanced diagnostic capabilities of the laboratory.

However, many of the Level III diagnostics based on immunological / serological methods comes as field kits at farm site (Level I), eg., Immunochromatographic kits against white spot syndrome virus (WSSV) indicating Level III diagnosis accessible to the field. It is also important to know the diagnostic capabilities of the each laboratory for Level II and III diagnosis before the dispatch of appropriate samples so that disease outbreaks are investigated readily and promptly.

3. MUD CRAB DISEASES IN INDIA AND OTHER COUNTRIES

Mud crab aquaculture has been practiced for many years in South-East Asian countries and India, and it is an important source of income by way of export. Traditionally, these activities were mainly based on stocking wild-caught juveniles and adults for grow-out culture (Fig. 3) and fattening of 'water crabs'. The traditional fattening is being done by two methods - in pens or enclosures erected in the shallow waters with bamboo and covered with fishing nets (Fig. 4), and in wooden or plastic cages with perforation (Fig. 5). With the diversification of farming activities, mud crab culture is gaining popularity, but the culture operations have not attained commercial

Fig. 3. Grow-out culture of mud crab

Fig. 4. Netted pens raised in coastal areas for crab fattening

Fig. 5. Fibre glass compartments used for crab fattening

Fig. 6. Diseased mud crab settling at the pond margin

status as in other crustaceans like shrimps and prawns. As the shrimp culture industry has come under the threat of viral diseases in the recent years, farmers have shown keen interest in crab farming. Culture of mud crabs is being practiced with low stocking density; hence many problems caused by diseases with potential economic impact might not have been observed. In India, the research on mud crab diseases has been minimal and largely remained in the shadow of other economically important and dominant culture species. Many diseases/abnormalities remain unreported or unresolved though they may affect marketability of products. Moreover, infected crabs may potentially transmit pathogens to various rearing facilities, adjoining farms and worse into the natural environments, though not much data are available. Recent experiences on grow-out culture of mud crabs revealed the occurrence of diseases leading to mortality, mainly when the quality of the water and the soil is poor (Fig. 6-8). Hence, the importance of biosecurity, of which surveillance for pathogens and diseases is an integral part, is gaining importance in crab farming.

Fig. 7. Dead crabs (*S. tranquebarica*) due to disease outbreak in a farm

Fig. 8. Mortality at pre-moult stage in mud crab

It is often believed that mud crabs are less susceptible to diseases than penaeid shrimps, might be due to the lower stocking densities followed in culture. However, a spectrum of pathogens and diseases are known to infect the eggs, larvae, juveniles and adult stages of mud crabs (Table 1). Some of these pathogens are of major biological and economic importance in the production of mud crabs and some of them occur incidentally. A recent review of diseases of mud crabs revealed the occurrence of fouling protozoans such as *Zoothamnium, Vorticella* and *Epistylis;* parasitic dinoflagellate such as *Hematodinium* sp. are reported to cause disease and death in a variety of crustacean species including the mud crab. Majority of the reports on metazoan parasites include barnacles like *Sacculina* sp. and *Loxothylacus* sp., fungal pathogens such as *Lagenidium* sp., *Haliphthoros* sp., *Halocrusticida* sp., *Atkinsiella* sp. and *Fusarium* sp., bacteria such as *Vibrio, Aeromonas* etc., viral infections, white spot syndrome virus, reovirus, muscle necrosis virus, baculovirus, many parasites and epibionts and also non-infectious pathogenic diseases such as stress and neurotic symptoms, blackening of gills, moult failure etc. have been reported. Infectious agents may be found at any stages of crab starting from eggs to adult stage. Loss of eggs in berried female crabs due to fungal infection, epibiotic fouling and luminescent bacteria are the most important manifestations encountered in hatchery.

Table 1. Common infections / diseases of mud crabs reported in India

Sl. No.	Etiology	Infection / Diseases
1.	Virus	White Spot Syndrome Virus
2.	Bacteria	Bacterial necrosis/shell disease Filamentous bacterial diseases Luminescent bacterial disease Other opportunistic bacterial pathogens
3.	Parasites / commensals	
	Protozoan	Peritrich ciliates Suctorian ciliates *Amylodinium* sp. infection *Hematodinium* sp. infection Microsporidian infection Gregarine infection
	Metazoan	
	Crustaceans	*Octolasmis* sp. infection *Balanus* sp. infection *Sacculina* sp. infection *Loxothylacus* sp. infection
	Helminths	Metacercarial stages of digeneans Cestodes Nematodes
4.	Fungus	*Fusarium* sp. *Lagenidium* sp. *Haliphthoros* sp. *Halocrusticida* sp. *Atkinsiella* sp.
5.	Non infectious and other diseases	Rust spot shell disease Stress Injury Nutritional Albinism Toxicity Deformities
6.	Behavioural aspects	Cannibalism

A possible new parasite causing 100% mortality in developing eggs of the mud crab has been reported from Australia. The parasite resembles protistan parasites and consists of a cluster of cells ranging from 3 to 6 µm with single nucleus and rhizoids that appear to function as an anchorage and a feeding organ. This parasite however, could not be classified to a phylum by its morphology alone.

Thus, it is imperative to have a detailed knowledge of the diseases and pathogens which are likely to infect mud crabs, as a basis for developing control strategies. The following section identifies those diseases which have occurred, and may impact adversely on the production of mud crabs in India. It is felt that, with the intensification of mud crab culture in India, it is likely to result in occurrences of known or previously unreported diseases or even exotic diseases. A brief description of each disease is given, together with possible treatment and/or control mechanisms that can be applied to contain and/or prevent the diseases.

3.1 VIRAL DISEASES

Although four viruses (*viz.,* White Spot Syndrome Virus, Muscle Necrosis Virus, Reovirus and Baculovirus) have previously been observed in mud crab, *S. serrata* in Asiatic region, only White Spot Syndrome Virus (WSSV) has been reported among wild and cultured mud crabs in India. Majority of them pertain to WSSV from naturally and experimentally infected mud crabs. So far, no other viral diseases of significance that affected shrimp aquaculture have been reported from mud crabs in the country.

Muscle necrosis virus, an icosahedral virus in cultured mud crabs causing 'sleeping disease' characterized by muscle necrosis, in China, is not a major concern in India. Similarly, a reovirus designated as mud crab reovirus (MCRV) from cultured mud crab, *S. serrata* with signs of 'sleeping disease', high mortality and heavy economic loss in Southern China was also reported. This cytoplasmic virus infects connective tissue cells of the hepatopancreas, gills and intestine in mud crab. Experimental infection with 80-100% mortality was observed by various routes of infection. RT-PCR detection method for the diagnosis of MCRV has been developed which can detect advanced stage of the disease in all tissues. A baculovirus infection in the form of intra-nuclear inclusion bodies in hepatopancreas epithelium of juvenile and mature mud crabs (*S. serrata*) without much clinical manifestation has been reported from the Northern Territory of Australia. The infection was reported to be refractory to penaeid shrimps suggesting that the mud crab baculovirus is unlikely pathogenic to crustaceans which are taxonomically diverse from mud crabs. These three viral diseases, however, have not been reported from India so far.

3.1.1 WHITE SPOT SYNDROME VIRUS (WSSV)

Mud crabs are known carriers and vectors of WSSV in shrimp culture facilities without showing any symptoms of the disease. Natural WSSV infections have been found in wild-caught and farmed mud crabs in various stages in many countries of Asia. WSSV was detected in around 60% of the benthic larvae of mud crab *S. serrata,* both under natural and experimental conditions. Although mud crab is known to be a carrier of viral organisms, in India studies are limited other than induced WSSV infections. Symptoms are in-apparent and the crab can maintain the experimental WSSV infection (Fig. 9 & 10) for many months, though moulting frequency gets reduced. In India, the natural prevalence of WSSV in crab is about 5% (Fig.11), while in culture ponds it is about 30%. WSSV infection could be either by vertical transmission from wild broodstock or horizontal transmission during monoculture as WSSV infected wild crabs are often found in culture ponds. Wild crustaceans (probably entering through creek water) serving as hosts for WSSV may act as natural reservoirs of the virus in the vicinity of culture ponds (crabs like *Uca, Thalamita, Sesarma, Metapograpsus,* etc. and shrimps like *Fenneropenaeus indicus, Penaeus monodon, Metapenaeus monoceros* and *M. dobsoni*). Many of the crab and shrimp species have been reported to carry very high viral loads in the absence of disease and may act as reservoirs, sustaining the virus in the natural environment as well as representing potential sources of

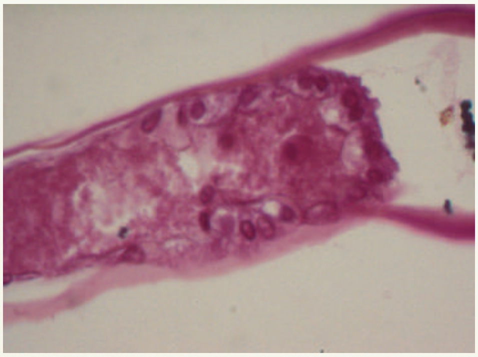


Fig. 9. Cowdry type A inclusions in gills of WSSV infected *S. tranquebarica* (H&E, 40X)

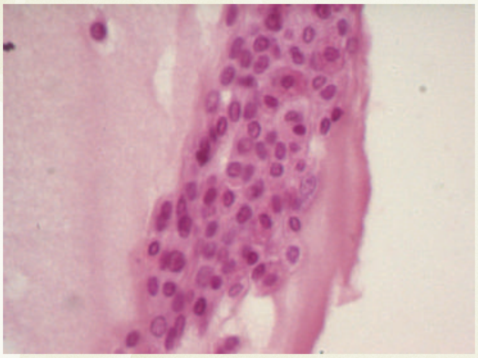
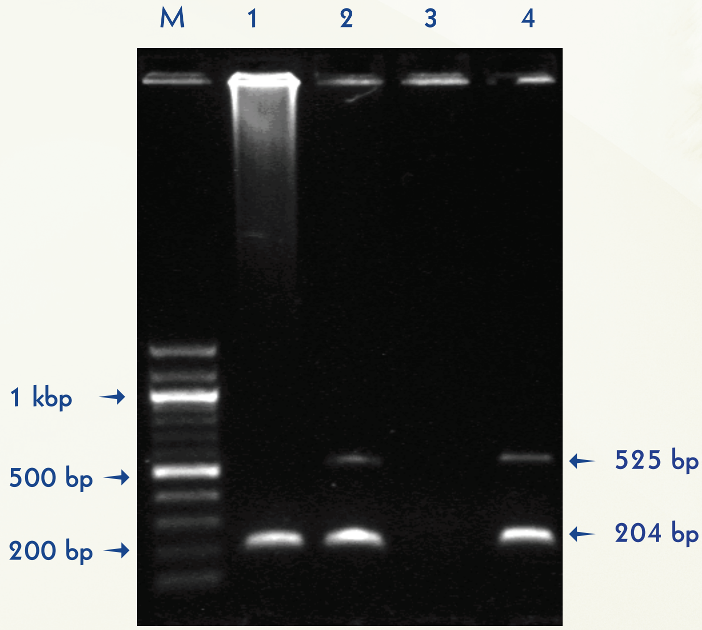


Fig. 10. Hypertrophied nuclei with basophilic inclusions near basal membrane of gills in WSSV infected *S. tranquebarica* (H&E, 100X)



Lane M 100 bp ladder

Lane 1 Sample (gill) from WSSV infected shrimp, *P. monodon*

Lane 2 Sample (gill) from mud crab, *S. tranquebarica*

Lane 3 Negative control (No DNA polymerase)

Lane 4 Positive control (10^3 copies /μl)

Fig. 11. Detection of WSSV in farmed mud crab showing heavy infection using single tube WSSV detection kit (Bangalore Genei)-Note two bands in case of crab sample as compared to shrimp

infection in shrimp ponds. However, the auto-entered *F. indicus* and *P. monodon* showed good growth in the system without showing clinical symptoms and/ or mortality.

To shrimp farmers, it is extremely important to confirm whether the mud crabs are the bonafide reservoirs of WSSV that can transmit the virus to farmed shrimp, as monoculture or polyculture of mud crab is being widely practiced in many shrimp farming areas. Studies conducted in the Aquatic Animal Health Laboratory of CIBA indicated that mud crab, *S. tranquebarica* can be infected with WSSV by injection, feeding or co-habitation using the WSSV infected shrimp or vice versa. Further, it is almost certain that WSSV can replicate in mud crabs at least in experimental conditions unlike some other species which are only mechanical carriers (eg. polychaetes, bivalves, rotifers, etc.). However, the epizootiology of WSSV remains complex due to the availability of wide range of potential hosts ranging from penaeid shrimps, wild crabs and more distantly related crustaceans such as copepods, amphipods and perhaps even aquatic insect larvae under culture conditions.

3.2 BACTERIAL DISEASES

The main problem in hatchery technology of mud crab still seems to be related to hygiene in the hatchery. Therefore, microbial infections (*i.e.* bacterial and fungal) have been the major concern of mud crab aquaculturists and researchers. Natural feed such as trash fish, molluscs (mussel / clam meat), farm waste, etc., also facilitate the entry of microbial pathogens in broodstock tank / grow-out ponds.

3.2.1 BACTERIAL NECROSIS

This is a common disease observed in larvae, post-larvae and adults. It is variously termed as 'black spot', 'brown spot', 'burnt spot', 'shell disease' or chitinolytic bacterial disease (Fig. 12). This is caused by the invasion of chitinolytic bacteria (gram -ve rods) such as *Vibrio* spp., *Pseudomonas* spp., *Aeromonas* spp., *Spirillium* spp. etc, which break down the chitin of the exoskeleton, leading to erosion and melanization (dark brown to black pigmentation) at the site of infection (Fig. 13 & 14). *Vibrio harveyi* is known to be pathogenic to zoeal stages of mud crab at 10^2 - 10^3 colony forming

Fig. 13. Chitinolytic bacterial infection (abdomen of female crab)

Fig. 12. Chitinolytic bacterial infection (abdomen of male crab)

unit per ml. Shell disease is rare in newly recruited crabs, but a common problem in crabs kept under captive conditions with the formation of a fuzzy mat composed of a multitude of organisms like blue green algae, bacteria, ciliates, flagellates and even nematodes. This disease reduces the value of the harvested crabs, apart from causing mortalities and can be controlled in captive and cultured mud crab population by reducing overcrowding, proper husbandry and system hygiene.

Fig. 14. Mature crab with blackening of abdominal flap

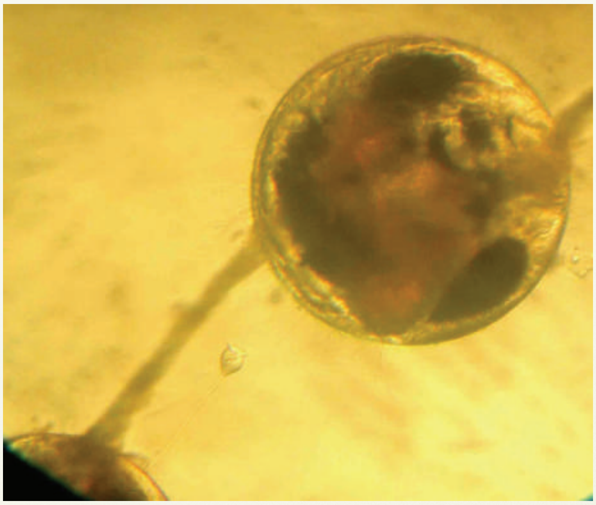


Fig. 15. *S.serrata* eggs with filamentous bacteria and *Vorticella* infection

3.2.2 FILAMENTOUS BACTERIAL DISEASE

Filamentous bacteria such as *Leucothrix mucor, Thriothrix* spp., *Flexibacter* spp. etc. sometimes cause mortalities by discolouration of gills and associated secondary infections. The larvae become moribund, with reduced activity, poor feeding and growth. In berried crab, the eggs may become infected with filamentous bacteria accompanied with other microbial infections, causing retarded embryonic development, and longer incubation time and egg mortality due to depleted oxygen exchange across egg membrane (Fig. 15). Adoption of better husbandry practices and hygiene measures will contain this infection.

3.2.3 LUMINESCENT BACTERIAL DISEASE

Luminescent bacterial disease is a severe, economically important bacterial infection caused by members of the genus *Vibrio* and other related genera. Vibriosis affects a diverse range of marine and estuarine shellfish species and is frequently secondary to other inciting causes, such as poor water quality, stress, poor nutrition. Adult animal often shows symptoms of loss of appetite, reduced growth, dark hepatopancreas and mortality in large numbers. *Vibrio harveyi* often infects the crab larvae reared in hatchery conditions. They spread very fast and poor hatchery conditions increase their virulence. The infected larvae become fluorescent in dark light, with reduced feeding and in severe cases mass mortalities occur. This can be treated by using specific antibiotics and disinfecting the intake water.

3.2.4 OTHER OPPORTUNISTIC BACTERIAL PATHOGENS

The co-infection of mud crabs with one or more bacterial species and / or other infectious agents like virus, fungus and parasites is the possibility in nature (Fig. 16-18). *Vibrio harveyi* and *V. campbellii* were found to be predominant often in WSSV infected mud crabs. Other *Vibrio* species found to occur were *V. vulnificus, V. nereis, V. fischeri* and *V. fluvialis.* Many opportunistic / secondary bacterial pathogens of mud crab *viz., V. campbellii, V. nereis, Shewanella loihica, S. woodyi, S. fidelis* and *S. hafniensis* were isolated and identified by 16s ribotyping from both haemolymph and hepatopancreas.

Fig. 16. Mud crab with severe microbial infections and loss of berried eggs

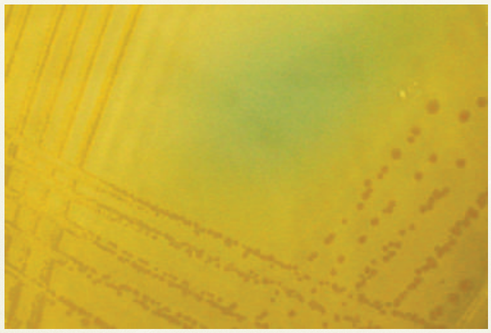


Fig. 17. *Vibrio sp.* (yellow colonies) on TCBS agar medium

Fig. 18. *Vibrio sp.* (green colonies) on TCBS agar medium

3.3 FUNGAL DISEASES

Three fungi, *Lagenidium, Atkinsiella* and *Haliphthoros* have been identified as possible agents of mud crab egg mortality in Japan and the Philippines. Fungal infection of the genus *Lagenidium* was found to be pathogenic to the eggs and larvae of mud crabs (*S. serrata*) in Indonesia.

3.3.1 EGG LOSS IN BERRIED FEMALE CRAB

Egg loss in berried female mud crabs due to fungal infection from aquatic environment has been a common problem. This infection has been observed in broodstock resulting in complete destruction and loss of egg mass during incubation period and partial hatching. *Haliphthoros* spp. was found to dominate the fungal population of *S. serrata* eggs leading to abortion / resorption of the egg mass. Some species may occur as saprotrophs on the surface of egg mass and may be non-pathogenic. Fertilized eggs are less susceptible to infection than unfertilized eggs probably due to the hardened membrane restricting fungal penetration. Bath treatment with formalin and fungicides were found to be effective to minimize the infection.

3.3.2 LARVAL MYCOSIS

Larval mycosis caused by *Fusarium* spp., *Lagenidium* spp. and *Sirolpidium* spp., leads to severe mortalities to crab larvae, often as a secondary infection. The fungus infects the dead or damaged tissue caused by wounds or other infections resulting in locomotory difficulties due to mycelial growth. In serious infections of *Lagenidium*, extensive non-septate highly branched mycelia invade through out the body, replacing all the tissues. Specialized hyphae protrude through the cuticle. Prophylactic doses of 5 to 10 µg/l formalin and 0.05 to 0.1 µg/l trifluralin applied on alternate day, were found to be effective in enhancing survival and larval development of infected megalopa compared with control.

3.4 PARASITIC DISEASES

Most parasitological work on portunid crab has focused on the American blue crab (*Callinectes sapidus*), green shore crab (*Carcinus maenas*), mud crab (*S. serrata*) and sand crab (*Portunus pelagicus*). Majority of crabs were found infected with protozoan or metazoan parasites or epicommensals. They belong to protozoans (*Haematodinium* sp., *Epistylis* sp. and *Acinata* sp.) and metazoans (helminths under microcephallid trematode metacercaria, *Levinseniella* sp., metacestodes such as *Polypocephalus* sp. and dorylaimoid nematode and two cirriped crustaceans, *Octolasmis* sp. and *Chelonbia* sp.). Symbionts belonging to the species of *Vorticella* oysters, polychaetes, hydrozoans, amphipods and turbellarians were also occasionally found in mud crabs.

3.4.1 PROTOZOAN PARASITES

Fouling protozoans such as peritrich ciliates (*Zoothamnium, Vorticella* and *Epistylis*) and suctorian ciliate (*Acineta* sp.and *Ephelota* sp.) on the gills may cause problem during the hatchery phase of mud crabs mainly on eggs and larval stages, especially if associated with poor water quality due to elevated nutrient and organic matter (Fig. 19 & 20). *Epistylis* sp. flourishes in low dissolved oxygen conditions. Once infested, cotton wool like growth attaches to the body and appendages and disrupt mobility and feeding.

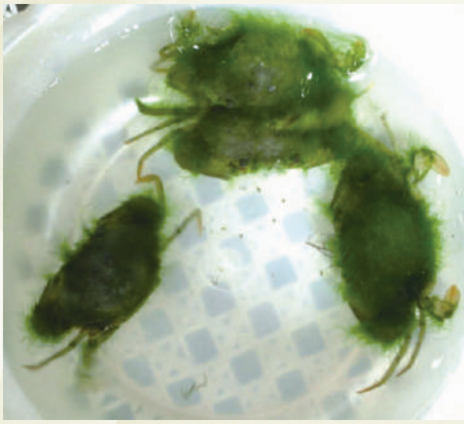


Fig. 19. *S. tranquebarica* baby crabs with algal mass and *Zoothamnium* sp. on exoskeleton

Fig. 20. *Zoothamnium* sp. infestation (40X)

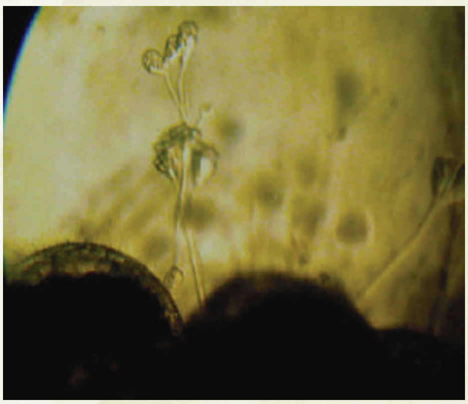


Fig. 21. *S. tranquebarica* eggs with *Vorticella* sp.

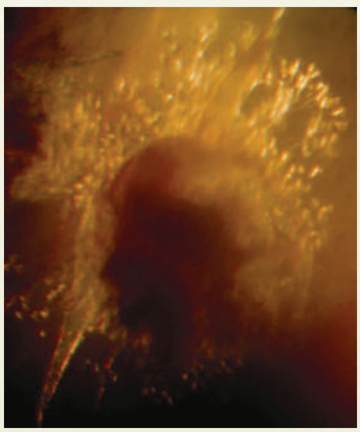


Fig. 22. *S. tranquebarica* Zoea V larva infected with *Vorticella* sp.

Suctorians feed mainly on other protozoans and in high numbers may interfere with respiration, while peritrichs interfere with locomotion, feeding and moulting of larvae causing stress and even death (Fig. 21 & 22). Usually ciliate infections are associated with stressful conditions, and as such, they are opportunistic pathogens and rarely found in wild caught crabs. Formalin treatment will save the affected crabs.

Dinoflagellates of the genus *Hematodinium* sp. that infects the hemolymph and other tissues of the crab, cause a disease condition known as 'milky disease' along Southern China with gross symptoms like moribund behaviour, opaquely discoloured carapace, cooked appearance, milky body fluid, unpalatable flavour and high mortality. These clinical signs are similar to those crabs suffering from bitter crab disease (BCD) or pink crab disease (PCD) caused by *Hematodinium* infection in other wild portunid crabs. Among sporozoan protozoa, histozoic microsporidian (*Thelohania* sp.) and enteric cephaline gregarines (*Nematopsis* sp.) are also encountered in mud crab, though not associated with any clinical disease. Cephaline gregarines of the genus *Nematopsis* utilize molluscs (bivalves, gastropods) as normal intermediate hosts and many estuarine crabs (*Metapograspus, Sesarma, Uca,* etc.) including *Scylla* spp. as final hosts. Feeding practice using fresh bivalves (mussels, clams, etc.) could possibly lead to *Nematopsis* sp. infection among cultured crustaceans. Pond reared mud crabs also may be infected with gregarine infection.

3.4.2 METAZOAN PARASITES

Most common metazoan parasites of mud crabs are barnacles (cirripedes) which are marine crustaceans either fixed or parasitic in their adult stage. The cirripedes are mostly commensal and tend to be predaceous while other cirripedes like *Sacculina* are exclusively parasitic on crabs. Two rhizocephalan parasites affecting mud crabs are *Sacculina* sp. and *Loxothylacus* sp. These infections seldom lead to mortality, but extensive shell erosion and perforation may lead to entry of other opportunistic pathogens. Typically, pedunculate (goose) barnacles of the genus *Octolasmis* spp. inhabit

Fig. 23. Gills infested with stalked barnacle *Octolasmis* sp.

the branchial chambers of mud crabs,especially on the ventral surfaces of the gills. The stalk bears, at its free end, the rest of the body known as the capitulum enclosed in a mantle formed by the carapace (Fig. 23 & 24).

Fig. 24. Goose barnacles on the gills of *S. tranquebarica* (photograph below 100 X)

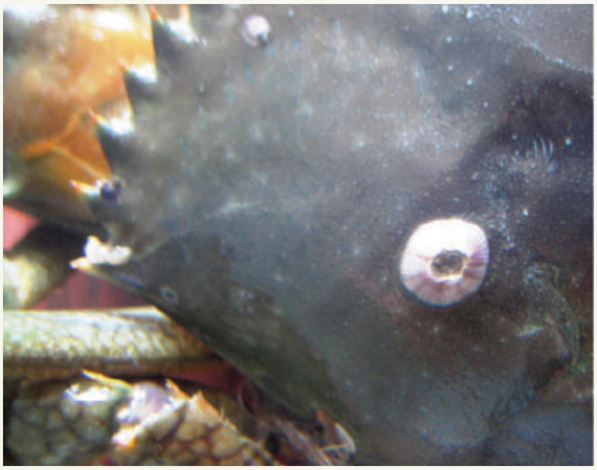


Fig. 25. Typical acorn barnacle, *Chelonbia* sp.

Balanus (acorn barnacle) is found attached to rocks below high water marks or bottom side of crab hideouts differing from *Octolasmis* sp. in having no peduncle; a set of shell is directly attached to the substratum. The set of shells form a sort of cone shaped case surrounding the body, and the opening is closed by a lid formed of four opercular plates (Fig. 25). Several species of balanid cirripedes (*Balanus* and other barnacles) live attached to the carapace, chelipeds of crabs or shells of molluscs and other objects available in culture ponds. The varieties of metazoans and intensity of infestation in pond condition are often correlated with the size of the crabs due to longer exposure and intermoult periods. Based on a study on portunid crab, *Portunus pelagicus,* some workers reported that female crabs possessed more species of parasites and symbionts than male crabs in terms of diversity and abundance. Similar situations also do exist in mud crabs.

Another crustacean leading parasitic life on decapods is *Sacculina* with extreme reduction in organization and has the appearance of a fleshy tumour attached by a peduncle to the abdomen of the crab on its ventral side (Fig. 26). At the hind end of the parasite is the cloacal aperture, which leads to the mantle cavity. There are no traces of segmentation or appendages or even alimentary canal. *Sacculina* is a unique parasite wherein in the initial stages, the peduncle sends numerous filamentous processes penetrating to various organs of the crab, even into legs and antennules for nourishment and disposal of waste products. The presence of parasite causes degeneration of tissues of the crab and hinders the formation of cuticle at the site of attachment during every successive moulting, and through it the body of *Sacculina* project freely as a fleshy mass. *Sacculina* is a typical example of parasite induced castration in which the infected male crab exhibits a tendency to develop characteristics of females; the abdomen becomes broader like females, the copulatory organs (pleopods) get reduced and become suited for carrying eggs whereas in female crabs the swimmerettes (pleopods) become shortened.

Fig. 26. *Sacculina* sp. on the abdominal flap

Crabs also act as intermediate hosts by harbouring metacercarial stages (in the hepatopancreas, musculature and internal connective tissues) of digenean trematodes of lower and higher vertebrates (mainly aquatic birds and mammals) but rarely any adult trematodes, cestodes or nematodes. *Scylla* spp., also act as paratenic hosts for the infectious larvae of many species of nematodes of higher vertebrates (eg. *Angiostrongylus* sp.). However, the perceived threats to other animals/man by way of eating mud crabs are largely unknown in India, as compared to many species of freshwater crabs.

3.5 NON-INFECTIOUS DISEASES

3.5.1 DEFORMITIES

In hatchery phase, a failure or delay in moulting from zoea to megalopa due to the attachment of the residual exoskeleton for several hours causes abnormal swimming behaviour and inability to consume feed. Environmental parameters and nutrient inadequacy, etc. are implicated in the delay or failure of moulting.

Fig. 27. Loss of limbs in *S. tranquebarica*

Fig. 28. Deformities and loss of chelate legs in *S. tranquebarica*

A range of deformities have been observed in grow-out culture (Fig. 27-30). These include moulting failure, missing legs, abdominal flaps, abnormalities of chelate legs, claws, etc. due to the attack of hard shelled crabs on freshly

Fig. 29. Deformities showing brocken claw in *S. tranquebarica*

Fig. 30. Ventral view of a growth in the first segment of cheliped in *S. tranquebarica*

moulted crabs, abnormal outgrowth, or injury due to various farming operations. All these factors enhance the entry of opportunistic pathogens and reduce the market value of harvested crabs. There is not much evidence that nutritional deficiencies or imbalances cause any disease in mud crabs including minerals, vitamins, essential fatty acids, as there is no study involving complete dependence on artificial diet in grow-out culture in India.

3.5.2 ALBINISM

A single report of dicolouration either on carapace or on limbs in American blue crab (*Callinectes sapidus*) is available. Another condition known as "hepatopancreas albinism" regarded as a nutritional disease as the reason for serious ecological and pathological problems in Chinese mitten crab (*Eriocheir sinensis*) in intensive rearing areas of Taihu Lake and other regions of China has also been reported. Partial albinism on carapace and legs has been observed in pond reared juveniles of *S. tranquebarica* in India (Fig. 31 & 32).

Fig. 31. Partial albinism in crablet of *S. tranquebarica*

Fig. 32. Left- normal crablet; right- complete albinism in juvenile *S. tranquebarica*

3.6 OTHER DISEASES

A new shell disease of non-infectious nature and uncertain etiology in *S. serrata* has been reported from Australia. This disease is characterized by irregularly shaped circular lesions commonly called 'rust spot shell disease' and unique histopathological alteration, and has the potential to damage markets of mud crab. However, this disease has not been reported from Indian waters.

Fig. 33. Discolouration of gills (right) in *S. tranquebarica* with multiple etiology.

Mud crabs also show symptoms arising out of any stress such as overcrowding, extreme temperature or pH, low dissolved oxygen, ammonia, etc. The condition is often reversible once the stressed condition is corrected. Blackening of gills (Fig. 33) may sometimes be found as a manifestation of several other disease syndromes, precipitation of dissolved chemicals, turbidity, Vitamin C deficiency, etc. General discoloration of gills may occur due to melanization of tissue and necrosis, which may be visible through the side of carapace.

The existence of any zoonotic diseases originating from mud crab is not known in India. However, *Vibrio cholerae* is a natural contaminant bacteria occurring in brackish and estuarine waters correlated with the epidemiology and transmission of cholera in the coastal environment. Crab or the crab meat is normally cooked before consumption; hence the risk of human infection is eliminated. However, contamination with bacteria that can cause human diseases may occur during the processing of crab meat, and food safety regulations should therefore be strictly followed.

3.7 BEHAVIORAL ASPECTS

3.7.1 CANNIBALISM

Cannibalism in crabs is a behavioural trait that may directly cause injury / death of the weaker / smaller- sized crabs often after moulting, and it is reported as a serious problem in mud crab grow-out ponds. This behaviour starts as early as megalopa stage in hatchery by devouring zoeae and accounted for a spike in mortality during metamorphosis. Thinning out the population and feeding of adequate live feed have been found useful in reducing the cannibalism. Young crabs, berried crabs and recently moulted crabs are often attacked by other crabs leading to loss of appendages such as periopods and chelipeds or even mortality. In hatchery, sandy substrate and/or PVC pipes are found to be ideal shelters (Fig. 34-37). Under farming conditions, cannibalism can be minimized by size grading and providing adequate shelter/housing areas,

Fig. 34. PVC pipe hide-out for juvenile mud crab

Fig. 35. Juvenile mud crab *S. trnquebarica* hiding among nylon threads

Fig. 36. Juvenile *S. tranquebarica* burying in the sand

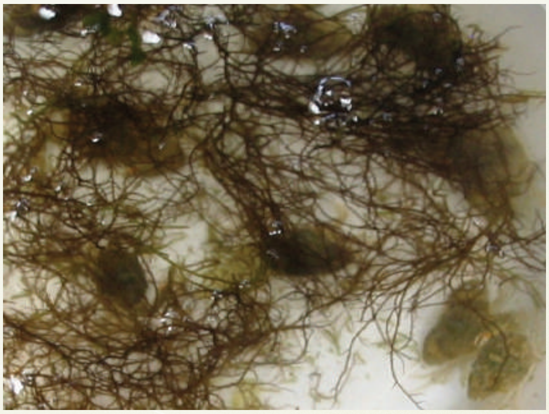


Fig. 37. Baby mud crab *(S. tranquebarica)* hiding among sea weeds.

Fig. 38. Nets, mounts, shelters in crab culture farm

as hiding place for the moulting crabs in ponds. This could include shallow areas, artificial shelters made of tiles / bricks / pipes or even mounts raised

Fig 39. Bricks and tiles as hide outs for grow-out culture

Fig 40. Roof tiles as hide-out in grow-out system

Fig. 41. Compartments made of bamboo for crab fattening

Fig. 42. Plastic containers for crab fattening

from the pond bottom (Fig. 38-40). In fattening, the crabs are kept individually in perforated compartments made of locally available materials like bamboo, nets, plastic containers/fibre glass cages, etc., that allows free flow of water (Fig. 41-44).

In some devastating parasitic dinoflagellate infections caused by *Hematodinium* sp., morbidity and mortality appear to depend on the burden of parasitic organisms in contrast to metacercaria, microsporidia, etc. Heavily

Fig. 43. Stocked crab in one of the compartments of cage

Fig 44. Fattened crab inside the plastic container

infected animals become lethargic and, if not preyed upon, succumb to overwhelming infection. Importance of cannibalism also lies in the fact that these weaker crabs encourage spiral built up of heavy parasitism in the healthy cannibalistic crabs.

3.8 DISEASE PREVENTION

Fig. 45. Congregation of mud crab in polluted water

Diseases generally progress quickly and result in high mortality leading to significant economic loss. From an economic and management view point, "prevention is better than cure" when it comes to disease in aquatic organisms at large. While discussing disease prevention, it is extremely important to understand the nature of disease and the route cause and its possible entry into production systems. Diseases may be infectious, *i.e.,* caused by living microbial (viral, fungal, bacterial) or parasitic organisms, or non-infectious, *i.e.,* caused by non-living factors, (nutritional deficiencies, behavioural problems and hostile environment or toxins). Diseases may also be primary, *i.e.,* caused by an infectious or non-infectious agent acting alone or they may be secondary, i.e., they may occur following or resulting from some other initiating cause. There are numerous examples of both primary and secondary diseases. The main routes of primary diseases may be through influent water, the use of infected feed materials (trash fish, clam, etc.) or exposure to other infected crabs. As such, primary diseases can be avoided by excluding the microbial organism or parasite from the culture system through the use of clean water, uninfected feedstuffs and avoidance of crab from uncertified sources. Water treatment using filtration, UV radiation, and biocontrol agents like non-virulent and beneficial organisms such as microalgae have been found useful to control the growth of pathogenic bacteria in both hatchery and grow-out ponds. Secondary diseases commonly accompany poor environmental conditions and/or stress and poor farm management (Fig. 45).

Invasion of wild aquatic organism in the culture system also pose stress to the cultured crabs especially large number of potentially harmful wild crabs (Fig. 46 a-f), gastropods (Fig. 47) and other crustaceans by harbouring pathogens of culture animals and disrupting local ecosystem. Thus, occurrence of disease in crabs as in case of other aquatic organisms is usually the result of a complex interaction between host and their environment, and the presence/absence of a given pathogen. The aim is to restrict the growth of potential pathogens, including virus, bacteria, fungi and parasites in the

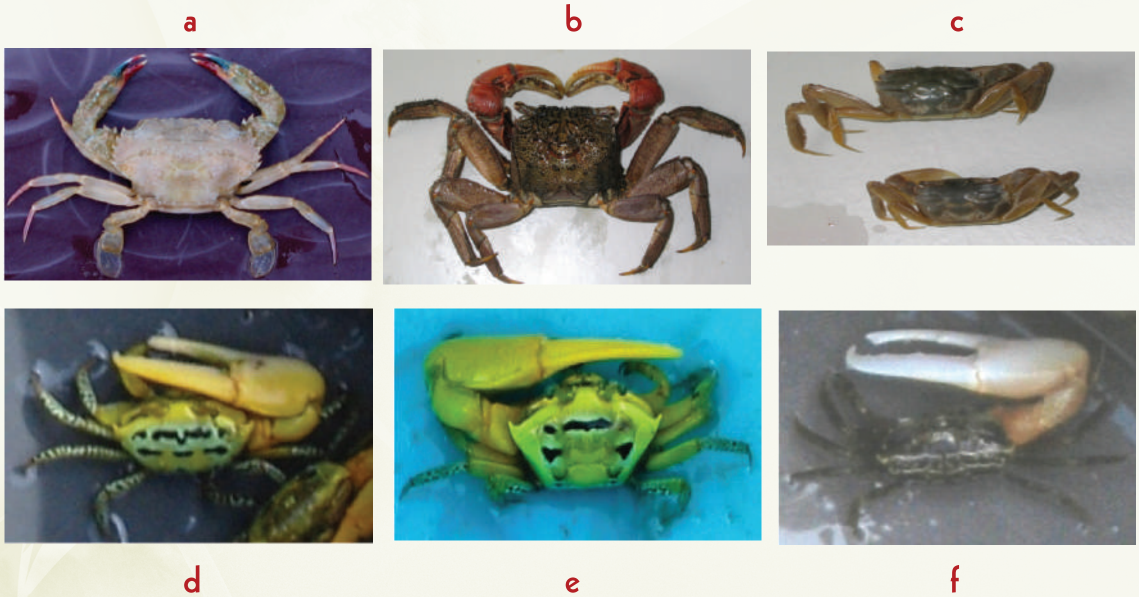


Fig. 46. a-f. Wild crabs found in mud crab culture ponds (a. *Thalamita crenata*, b. *Muradium tetragonum*, c. *Metapograpsus messor*, d-f. *Uca* (*Paraleptuca*) *annulipes*)

culture system. Serious disease conditions in crabs generally arise from two scenarios: i) sub-optimal growing conditions which render the animals more susceptible to opportunistic pathogens and ii) exposure of naive and susceptible individuals to infectious agents.

Fig. 47. Gastropod *Telescopium* sp.

3.8.1 WATER QUALITY

The incidence of disease is higher in low quality water. Sub-optimal or heavy algal blooms also affect the quality of environment. Mud crabs are prone to stress when the environmental conditions deteriorate. Mud crabs can tolerate a wide range of temperature (18 - 35°C) and salinity (6 - 35 ppt). However, under limiting conditions of oxygen, they leave the water and breathe atmospheric air. When crabs molt, they are unable to leave the water that is depleted of oxygen and consequently die. The tolerance of *S. serrata* larvae to total ammonia did not appear to increase with ontogenic development. Hence, environmental characteristics must be suitable and fit for crabs to tolerate and carry out their physiological functions. The optimum water conditions required for the crab culture are:

Water temperature (°C)	23-35
Salinity (ppt)	10-35
DO (ppm)	>4
pH	8.0-8.5
Water depth (cm)	>80
Desirable water colour	golden brown
Transparency (cm)	~30

Important ways to prevent crab diseases are to ensure high water quality in the rearing environment by regular water exchange or regular treatment to remove wastes and pollutants. The culture area (tank, pond or cage) must be kept free from accumulation of fish wastes and uneaten feed. Black gill disease generally follows an increase in the organic detritus. If necessary, some form of aeration device should be employed to maintain high dissolved oxygen levels. Stress resulting from low dissolved oxygen concentrations is responsible for many cases of mass mortality. Indicators of water quality (e.g. ammonia, nitrite, salinity, pH, water temperature and dissolved oxygen) should be measured on a regular basis.

Mud crab populations and their recruitments are reported to be declining due to pesticide pollution from agricultural operations, industrial and sewage effluents that often end up in rivers, estuaries and oceans. The aquatic system is therefore the most common target of heavy metals, pesticides and persistent organic pollutants contamination. Mud crab has a great potential as a tropical, biomonitoring species because its capacity to bioaccumulate a range of contaminants. Bioaccumulation of high levels of heavy metals (Hg, Pb, and Cd) in many aquatic animals including crab has been reported. Studies on *S. serrata* from Mahanadi estuary (Orissa) to determine the concentration of nine elements (K, Ca, Mn, Fe, Cu, Zn, Se, Br and Pb) in different tissues revealed marked difference in the elemental concentrations between sex of the mud crabs, which may be related to the growth rate and other biological activities. However, no significant differences in the concentration of elements (Ca, Mn, Fe, Cu and Zn) in the tissues of juveniles and adults of respective sex were observed, indicating the active regulation of these elements by *S. serrata.* However, no such study is available in case of *Scylla* spp. under farming conditions, as it is important for marketability and quality assurance.

3.8.2 FEED QUALITY

Feed must be stored correctly to prevent the introduction of infectious agents and to ensure that the nutritional value does not deteriorate. The use of trash fish or any live feed may readily introduce microbial organisms into the culture system. If whole fish, clam, mussel, squid and/or prawns are used, these should be snap frozen while fresh, and stored at -18 to -30°C for at least 10-21 days before use. This will minimize the transmission of certain parasites but will not necessarily inactivate infectious agents. Attempts to use formulated pellet feed for fattening and farming of mud crabs in earthen ponds showed encouraging results. Pelleted feed should also be kept cool, ideally at less than 20°C. In the dry season it is usually sufficient to keep the feed in a shaded building. In warm humid conditions, pelleted feed can quickly deteriorate. Fats become rancid, vitamins break down and mould can grow on the feed releasing toxins. Feed should not be stored for extended periods and good feed store management should be employed to keep track of stock and ensure that the feed fed to the crab is of the highest quality.

3.8.3 QUARANTINE

The seed and brood crabs may sometimes harbour pathogens without showing any apparent clinical symptoms. Unless previously tested and certified, any new lot of crabs brought onto the farm/hatchery should be quarantined for a minimum of two weeks to identify any diseases, pathogens or parasites. Bath treatment with formalin and fungicide during quarantine may be necessary to eliminate fouling microorganisms, parasites and fungal infections (Fig. 48). Advanced testing of crab for any specific agents may be undertaken during this period (Fig. 49).

Fig. 48. Prophylactic treatment of crab

Fig. 49. Compartments used for isolated rearing of mud crab in experiments

3.8.4 GENERAL QUARANTINE AND HEALTH REQUIREMENTS

Diseases generally affect the aesthetic look, public opinion and marketability of the any aqua-product including crab. Adherence of governmental regulations on minimum size and live shipping of crabs for export may enhance certain pathogens and inadvertent introduction to new regions. Hence, it is important that once crabs are observed to be sick or even if they have suddenly changed their behaviour, professional opinion should be sought. After a problem has been observed and before a diagnosis has been obtained, the farm must place itself under a voluntary quarantine with restrictions of all movements of culture crabs onto and off the farm. Failure to do so could jeopardize other farming operations, risk contamination of the surrounding aquatic environment and spread of infection to neighbouring farms.

3.9. DISEASE MANAGEMENT MEASURES

The disease control programmes in aquaculture must include examination of diseases and mortalities in holistic manner and consider various factors such as stocking densities, environment (turbidity, temperature, pH, salinity, dissolved oxygen of water and redox potential of soil), rate of water exchange, presence of bottom dwelling algae, the type of feed and its rate of consumption, phytoplankton bloom, physiological status of crabs, etc. These factors considered together go on long way in management of disease problems. Most of the disease control methods are based on preventive measures described above.

4. CONCLUSION

Diseases of mud crabs (*Scylla* spp.) may be caused by living agents like viruses, bacteria, fungi, parasites and epicommensals. In mud crabs, diseases occur in combination of pathogens and are often complicated by nutritional, environmental and management deficiencies. There is a need to understand disease and factors that contribute its development and outbreak. Further, magnitude of existing diseases and emergence of new diseases will continue with intensification of crab culture. The cross infections between mud crab and other cultured penaeid shrimp under field conditions and the purported role of mud crab as 'carriers' of pathogens also need further elucidation. The traditional strategy of 'stamping out the pathogens' is difficult to apply in aquatic environment. The characteristic feature of marketing of mud crab is the movement of live animals between production sites and market sites. Therefore, inherent potential for transmission of pathogens *in situ,* facilitating the spread to a relatively naive host and/or environment cannot be overlooked. Obviously, basic knowledge concerning the pathogens *vis-à-vis* of cultured mud crabs and how they interact with their hosts lags behind the needs of the industry. Hence a strict health management regimen revolving around scientific breeding, farming, and proper management of water, feed and drug usage is required to sustain mud crab farming.

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