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Diseases of mud crabs (*Scylla* spp.): an overview

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ABSTRACT

Mud crabs (*Scylla* spp.) are the most promising group for diversification of coastal aquaculture. However, the health management *vis-a-vis* diseases of mud crabs attracted less attention of researchers, and therefore, there is distinct lack of description of their pathogens as compared to other commercially exploited crustacean and finfish species. Culture of mud crab is largely extensive with extremely low input; hence diseases with potential economic impact have not been widely observed and caused problems. However, intensification of mud crab culture is likely to result in occurrences of known or previously unreported or even exotic diseases. Many new pathogens and diseases are being reported with significant pathogenicity and adverse effect on the production of mud crabs across the world. In the present review, the viral, bacterial, fungal, protozoan and metazoan pathogens of mud crabs and their impact on the health of individuals and aquaculture are discussed.

Keywords: Disease, Infection, Mud crab, Pathogen, *Scylla serrata*, *Scylla* spp., *Scylla tranquebarica*

Introduction

Mud crabs (*Scylla* spp.) are the most traded seafood commodity in India and elsewhere (Fielder and Allen, 2004; Kathirvel *et al*., 2004). Aquaculture of these crabs has been practised for several decades in many Asian countries including India (Kathirvel *et al*., 2004). In India, mud crab culture mainly depends on fattening of soft-shelled or water crabs. This is the simplest form of aquaculture practice where recently molted crabs are held in confinement for a short period to enhance marketable attributes. This form of culture now forms the basis of a small but vibrant seafood industry in south-east Asian countries. In India, farming of mud crab is gaining impetus as a species for diversification of coastal aquaculture (Kathirvel, 1993; Marichamy, 1996; Marichamy and Rajapackiam, 2001; Patterson and Samuel, 2005; Sakthivel and Francis, 2006). Several aspects of aquaculture of this species have been the basis of intensive research during the last two decades (Keenan, 1999; Srinivasagam *et al.,* 2000; Kathirvel *et al*., 2004; Quinitio *et al*., 2002; Shaji *et al*., 2006). However, disease in cultured crab populations and seed production facilities received little attention (Jithendran *et al*., 2009), though mass mortality of farmed mud crab stocks have been reported frequently (Poornima *et al*., 2008). Furthermore, infected crabs may potentially transmit pathogens to various rearing facilities, adjoining farms, and even to natural environment, although much data are not available (Jithendran *et al.,* 2009). With increasing interest in mud crab aquaculture and growing requirements to manage the health of mud crab populations, it is pertinent to consider the effect of disease as a mortality driver in cultured and wild population to ensure long term sustainability of this resource. Therefore, improved understanding of the pathogen profile of mud crab is crucial. Against this background, the present compilation is an overview of the potential diseases encountered in mud crab *Scylla* spp. based on the currently available literature besides the work carried out by the researchers of Central Institute of Brackishwater Aquacutlure (CIBA), Chennai, over a period of one decade. Keenan *et al*. (1998) reviewed the taxonomy and nomenclature of mud crab species, and identified four species of *Scylla viz., S. serrata, S. oceanica, S. tranquebarica* and *S. paramamosain*. However, taxonomy and species status of mud crabs in India are yet to be characterised. Therefore, in the present review we adopt the nomenclature suggested by Kathirvel and Srinivasagam (1992).

Mud crab diseases in India and other countries

A brief description of diseases affecting mud crabs, together with possible treatment and/or control measures that can be adopted are presented. The types of diseases found in mud crabs are summarised in Table 1.

Viral diseases

Four types of viruses *viz*., white spot syndrome virus (WSSV), muscle necrosis virus, reovirus and baculovirus have been reported in mud crab *Scylla* spp. Most works on viral infection in mud crabs pertain to WSSV from naturally

Table 1. Important diseases/infections of mud crabs in India and other countries

Diseases/infections	Reference (s)
Viral diseases	
White spot syndrome virus (WSSV)	Lo *et al*. (1996) Flegel (1997) Kanchanaphum *et al*. (1998) Kou *et al*. (1998) Supamattaya *et al*. (1998) Otta *et al*. (1999) Rajendran *et al*. (1999) Chen *et al*. (2000) Chakraborty *et al*. (2002) Sahul Hameed *et al*. (2003) Lavilla-Pitogo and de la Pena (2004) Flegel (2006) Escobedo-Bonilla *et al*. (2008)
Muscle necrosis virus (Muscle necrosis)	Song *et al*. (2003)
Reovirus (Sleeping disease)	Weng *et al***.** (2007)
Baculovirus infection	Anderson and Prior (1992) Humphrey *et al*. (2009)
Bacterial diseases	Lavilla-Pitogo *et al*. (2001) Lavilla-Pitogo and de la Pena (2004)
Bacterial necrosis/shell disease Filamentous bacterial disease Luminescent bacterial disease Other opportunistic bacterial pathogens Red sternum syndrome	
Fungal diseases	Salaenoi *et al*. (2006)
Fusarium sp *Lagenidium* sp. *Haliphthoros* sp. *Halocrusticida* sp. *Atkinsiella* sp.	Areekijseree *et al*. (2010) Bian *et al*. (1979) Bian and Egusa (1980) Lio Po *et al*. (1982) Nakamura *et al*. (1995) Roza and Hatai (1999) Leano (2002) Lavilla-Pitogo and de la Pena (2004) Shaji *et al*. (2006)
Parasitic infections	Devi (1985) Hudson and Lester (1994) Lavilla-Pitogo *et al*. (2001) Kathirvel *et al*. (2004) Lavilla-Pitogo and de la Pena (2004) Jithendran *et al*. (2009)
Protozoan parasitic infections	
Peritrich ciliates Suctorian ciliates *Amyloodinium* sp. infection	
Hematodinium sp. infection	Li *et al*. (2008)
Microsporidian infection Gregarine infection	

Metazoan parasitic infections	
Crustaceans	Jeffries *et al*. (1991)
Octolasmis sp.	Jeffries *et al*. (1992)
Balanus sp.	Voris *et al*. (1994)
Sacculina sp.	Knuckey *et al*. (2006)
Loxothylacus sp.	
Helminths	
Metacercarial stages of digeneans	
Cestodes	
Nematodes	
Non-infectious and other diseases	Lavilla-Pitogo and de la Pena (2004)
Rust spot shell disease	Jithendran *et al*. (2009)
Stress	Andersen *et al*. (2000)
Injury	
Nutritional	
Albinism	
Toxicity	
Deformities	

and experimentally infected mud crabs (Otta *et al*., 1999; Rajendran *et al*., 1999; He *et al*., 2003; Sahul Hameed *et al*., 2003). A study in Thailand reveals that mud crab (*S. serrata*) and other wild crab species (*viz*., *Uca vocans*, *Sesarma mederi*) can be experimentally infected with Taura syndrome virus (TSV) by injection and by feeding with TSV-infected shrimp carcass, and that the resulting infections can persist for up to 50 days and may act as carriers of TSV and can pose potential risk to shrimp aquaculture (Kiatpathomchai *et al*., 2008). However, natural infections of these species in wild caught crab have not been reported so far. Experimental infection of other shrimp virus like yellow head virus (YHV) in various species of crabs including mud crabs revealed inability for multiplication (Longyant *et al*., 2006).

White spot syndrome virus (WSSV)

Mud crabs are known carriers and vectors of WSSV in shrimp culture facilities (Lo *et al*., 1996) without showing any signs of the disease. Natural WSSV infections have been found in wild-caught and farmed mud crabs in various stages in many countries of Asiatic region (Lo *et al*., 1996; Flegel, 1997, 2006; Kanchanaphum *et al*., 1998; Kou *et al*., 1998; Otta *et al*., 1999; Lavilla-Pitogo *et al*., 2001; He *et al*., 2003). WSSV was detected in 60% of the benthic larvae of mud crab, *S. serrata* both under natural and experimental conditions (Chen *et al*., 2000). Although mud crab is known to be a carrier of viral organisms in India, studies are limited other than induced WSSV infections (Rajendran *et al*., 1999; Sahul Hameed *et al*., 2003). Signs are inapparent and the crab can maintain the experimental WSSV infection for many months, though moulting frequency was found to be reduced (Lavilla-Pitogo *et al*., 2007). In India, the natural prevalence of WSSV in crab is about 5.06%, while in culture ponds it is about 30% (Poornima *et al*., 2008). WSSV infection could be in either way; by vertical transmission from wild broodstock or even horizontal transmission during monoculture as culture ponds often witnessed presence of WSSV infected wild crabs. Studies conducted in our laboratory indicate that mud crabs (*S. tranquebarica*) can be infected with WSSV by injection, feeding or co-habitation using the WSSV infected shrimp or *vice versa*. To shrimp farmers, it is extremely important to confirm whether the mud crabs are 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.

Muscle necrosis virus

Song *et al*. (2003) reported an icosahedral virus, 150 nm in diameter, in cultured mud crab causing a disease characterised by muscle necrosis in China.

Reovirus

Recently, 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 reported. This cytoplasmic icosahedral non-enveloped virus (70 nm diameter) 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 (Weng *et al*., 2007). An RT-PCR detection method for the diagnosis of MCRV has been developed and could be detected in all tissues in advanced stage of the disease (Guo *et al*., 2008).

Baculovirus infection

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 (Anderson and Prior, 1992; Humphrey *et al*., 2009). The infection was reported to be refractory to penaeid shrimps suggesting that the mud crab baculovirus is unlikely to be pathogenic to crustaceans taxonomically diverse from mud crabs. Mud crab baculovirus infection has not been recorded from India.

Bacterial diseases

The main problem in hatchery technology of mud crab still seems to be related to hygiene. 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.

Bacterial necrosis

This is a common disease observed in larvae, post-larvae or adults. It is variously termed as 'black spot', 'brown spot', 'burnt spot', 'shell disease' or chitinolytic bacterial disease. This is caused by the invasion of chitinolytic bacteria, which break down the chitin of the exoskeleton, leading to erosion and melanisation (dark brown to black pigmentation) at the site of infection. Several chitinolytic bacteria (Gram negative rods) such as *Vibrio* spp., *Pseudomonas* spp., *Aeromonas* spp., and *Spirillium* spp. are involved. *Vibrio harveyi* is known to be pathogenic to zoeal stages of mud crab at 10^2 -10^3 cfu ml^{-1}. 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 (Lavilla-Pitogo *et al*., 2001). This disease reduces the value of the harvested crabs, apart from causing mortalities. The disease can be controlled in captive and cultured population by reducing overcrowding and by adopting proper husbandry and system hygiene.

Filamentous bacterial disease

Filamentous bacteria such as *Leucothrix mucor, Thriothrix* spp. and *Flexibacter* spp. 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, longer incubation time and egg mortality due to depleted oxygen exchange across egg membrane.

Luminescent bacterial disease

Luminescent bacterial disease is a severe, economically important bacterial infection caused by members of the genus *Vibrio* and other related genera (Shanmuga Priya, 2008). Vibriosis affects a diverse range of marine and estuarine shellfish species and is frequently secondary to other inciting causes *(e.g.*, poor water quality, stress and poor nutrition). Adult animal often shows symptoms of loss of appetite, reduced growth, dark hepatopancreas and morality in large numbers. *V. harveyi* often infect 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.

Other opportunistic bacterial pathogens

Co-infection with one or more bacterial species and/or other infectious agents like viral, fungal and parasitic infection is a common occurrence. *V. harveyi* and *V. campbellii* were found to be predominant often in WSSV infected mud crabs (Poornima *et al*., 2008). Other *Vibrio* species found were *V. vulnificus, V. nereis, V. fischeri* and *V. fluvialis* (Shanmuga Priya, 2008). Many opportunistic/ secondary bacterial pathogens were also isolated and identified by 16S ribotyping from both haemolymph and hepatopancreas of mud crabs under culture conditions and from wild (*viz*., *V. campbellii, V. nereis, Shewanella loihica, S. woodyi, S. fidelis* and *S. hafniensis*).

A disease entity with characteristic red sternum in mud crab with uncertain etiology was reported (Salaenoi *et al*., 2006). Areekijseree *et al.* (2010) reported bacterial etiology of red sternum syndrome in cultured mud crab (*S. serrata*) from Thailand. Infected crabs were characterised by hard carapace, red chelipeds and joints, pale hepatopancreas, gills, and soft muscles almost immobile before succumbing to death. The haemolymph revealed three stages of the syndrome, namely orange, orange-white and milky-white in color. The disease is suspected to be bacterial in nature due to the isolation of five different types of bacteria from the infected tissues by conventional microbiology and electron microscopy and is associated with the stages and severity of the disease.

Fungal diseases

Three fungi, *viz., Lagenidium*, *Atkinsiella* and *Haliphthoros* have been identified as possible agents of mud crab egg mortality in Japan and the Philippines (Bian *et al*., 1979; Bian and Egusa, 1980; Lio Po *et al*., 1982; Leano, 2002). *Lagenidium* spp. was found to be pathogenic to the eggs and larvae of mud crabs (*S. serrata*) in Indonesia (Nakamura *et al.,* 1995).

Egg loss in berried female crab

Egg loss in berried females due to fungal infection from aquatic environment has been a common problem (Quinitio *et al*., 2002). The problem has been observed in broodstocks resulting in partial hatching or complete destruction and loss of egg mass during incubation period. Leano (2002) reported that *Haliphthoros* spp. was found to dominate the fungal population of *S. serrata* eggs leading to abortion/resorption of eggs mass. Some species may occur as saprotrophs on the surface of egg mass and may be non-pathogenic. Fertilised eggs are less susceptible to infection than unfertilised eggs probably due to the hardened membrane restricting fungal penetration (Shaji *et al*., 2006).

Larval mycosis

Larval mycosis due to *Fusarium* spp., *Lagenidium* spp. and *Sirolpidium* spp. cause severe mortalities to crab larvae often as a secondary infection. 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 throughout the body replacing all the tissues. Specialised hyphae protrude through the cuticle. Prophylactic doses of 5 and 10 µg l^{-1} formalin and 0.05 and 0.1 µg l^{-1} trifluralin applied every alternative day were found to be effective in enhancing survival and larval development to megalopa compared with control (De Pedro *et al*., 2008).

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*). Hudson and Lester (1994) observed that no crabs were free from parasites or symbionts of either internal or external parasites. They belong to protozoans (*Hematodinium* 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 *Chelonibia* sp.). Symbionts belonging to the *Vorticella* sp., oysters, polychaetes, hydrozoans, amphipods and turbellarian were also occasionally found in mud crab. A possible new parasite causing 100% mortality in developing eggs has been reported from Australia (Kvingedal *et al*., 2006). The parasite resembles protistan parasites and consists of a cluster of cells ranging from 3 to 6 mm with single nucleus and rhizoids that appear to function as an anchorage and a feeding organ. The parasite could not be classified to a phylum by morphology alone.

Protozoan parasites

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

Dinoflagellates of the genus *Hematodinium* sp. that infects the hemolymph and tissues of the crab, cause a disease condition known as ‘milky disease’ along the southern China with gross symptoms such as moribund behaviour, opaquely discoloured carapace, cooked appearance, milky body fluid, unpalatable flavour and high mortality. These clinical signs are similar to those of 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 are encountered in mud crab though not associated with any clinical disease. Cephaline gregarines of the genus *Nematopsis* utilise molluscs (bivalves, gastropods) as normal intermediate hosts and many estuarine crabs (*Metapograspus*, *Sesarma* and *Uca*) as final hosts (Prasadan and Janardanan, 2001; Tuntiwaranuruk *et al*., 2004). Feeding practice using live bivalves (mussels, clams *etc.*) could possibly lead to *Nematopsis* sp. infection among cultured crustaceans. Tuntiwaranuruk *et al.* (2004) also opined that pond reared commercial crustaceans including mangrove crab *S. serrata* may be infected with gregarines.

Metazoan parasites

Most common metazoan parasites of mud crabs are cirripedians, either fixed or parasitic in their adult stage. Barnacles or cirripedes are mostly commensals and tend to be predaceous while others like *Sacculina* are exclusively parasitic on crabs. Two rhizocephalan parasites affecting mud crabs are *Sacculina* sp. and *Loxothylacus* sp. (Boschma, 1949; Knuckey *et al*., 2006). These infections seldom lead to mortality, but extensive shell erosion and perforation may lead to entry of opportunistic pathogens. Typically, pedunculate barnacles of the genus *Octolasmis* spp. inhabit the branchial chambers of mud crabs, especially on the ventral surfaces of the gills (Jeffries *et al*., 1991; 1992). The stalk bears at its free end, the rest of the body known as the capitulum enclosed in a mantle formed by the carapace. *Balanus* (acorn barnacle) is found attached to rocks below high water marks or bottom side of crab hide-outs differing from *Octolasmis* sp. in having no peduncle and the shell is directly attached to the substratum. The shells form a sort of cone shaped case surrounding the body, and the opening is closed by a lid formed of four opercular plates. 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 variety of metazoans and intensity of infestation in pond condition is often correlated with the size of the crab due to long standing exposure and longer intermoult periods. Based on a study on portunid crab, *Portunus pelagicus,* Shields (1992) reported that female crabs possessed more species of parasites and symbionts than did male crabs in terms of diversity and abundance. Similar situations also do exist in mud crabs.

Sacculina is a crustacean parasite of decapods with extreme reduction in organisation and has the appearance of a fleshy tumour attached by a peduncle to the abdomen of the crab on its ventral side. At the hind end of the parasite is an opening, 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 in that in the initial stages, peduncle sends numerous filamentous processes penetrating to the 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, through which the body of *Sacculina* project freely as a fleshy mass. *Sacculina* is a typical example of parasite induced castration in that 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) becomes reduced.

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 acts as paratenic hosts for the infectious larvae of many species of nematodes of higher vertebrates (*e.g., Angiostrongylus* spp.). However, the perceived threat to other animals/man by way of eating mud crab is largely unknown in India, as compared to many species of freshwater crabs.

Non-infectious diseases

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 are implicated in the delay or failure of moulting (Quinitio and Parado-Estepa, 2003).

A range of deformities have been observed in grow-out culture. These include moulting failure, missing legs, abdominal flaps, abnormalities of chelate legs, claws *etc.* when hard shelled crabs attack the freshly moulted crab, 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 crab. There is not much evidence that nutritional deficiencies or imbalances cause any diseases in mud crab including minerals, vitamins, essential fatty acids, as there is no study involving complete dependence on artificial diet in grow-out culture in India.

Albinism

Dicolouration either on carapace or on limbs described as partial albinism in American blue crab (*Callinectus sapidus*) has been reported by Sims and Joyce (1965). Song *et al.* (2007) reported 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. Partial albinism on carapace and legs has been observed in pond reared juveniles of *S. tranquebarica* (Jithendran *et al*., 2009; Kathirvel, personal communication).

Other diseases

A new shell disease of non-infectious nature and uncertain etiology in *S. serrata* has been reported from Australia. The potential of this shell disease to damage mud crab markets has been reported as well (Andersen *et al*., 2000). This disease is characterised by irregularly shaped circular lesions commonly called 'rust spot shell disease' and unique histopathological alteration. However, this disease has not been reported from Indian waters.

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 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 melanisation 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 cholera* 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 crab meat is normally cooked before consumption, so the health risk is low. 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.

Diseases caused by various pathogens of fish and shrimp have been well documented, while little is known of its effect on mud crab (*Scylla* spp.) both under hatchery and farming conditions. Mud crabs are traditionally considered as quite hardy organisms to many infectious diseases and the occurrence of diseases under culture condition is on the rise with the intensification of crab culture. Much research is needed to understand the pathogens, host and environmental interaction under hatchery and farming conditions to increase the productivity and conservation of mud crab as a sustainable aqua-resource. We have limited understanding of pathogen profile of mud crab in hatchery and grow-out culture, how these pathogens are transmitted and their potential for transmission to other commercially exploited and cultured species. The cross infections between mud crab and other cultured penaeid shrimps under field conditions and the reported role of mud crab as 'carriers' of pathogens also need further elucidation. This is important as culture operation of mud crab still relies on wild caught 'water crabs' or crablets. The traditional strategy of 'stamping out the pathogens' is difficult to apply in aquatic environment. A significant feature of marketing of mud crab involves the movement of live animals between capture/culture sites and market sites with potential for transmission of pathogens *in situ*, facilitating the spread to a relatively naïve host and / or environment. The basic knowledge concerning the pathogens *vis-à-vis* of cultured mud crab and how they interact with their hosts lags behind the needs of the industry.

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References

Anderson, I. G. and Prior, H. G. 1992. Baculovirus infections in the mud crab, *Scylla serrata*, and a freshwater crayfish, *Cherax quadricarinatus*, from Australia. *J. Invert. Pathol.,* 60: 265-273.

Andersen, L. E., Norton, J. H. and Levy, N. H. 2000. A new shell disease in the mud crab *Scylla serrata* from Port Curtis, Queensland (Australia). *Dis. Aquat. Org*., 43: 233-239.

Angell, C. A. 1992. The mud crab. *Report of the seminar on the mud crab culture and trade*. Surat Thani, Thailand, November 5-8, 1991. Bay of Bengal Program, BOBP/ REP/ 51, Madras, India, 246 pp.

Areekijseree, M., Chuen-Im, T. and Panyarachun, B. 2010. Characterization of red sternum syndrome in mud crab farms from Thailand. *Biologia*, 65: 150-156.

Bian, B. Z. and Egusa, S. 1980. *Atkinsiella hamanaensis* sp. nov. isolated from cultivated from cultivated ova of the mangrove crab*, Scylla serrata* (Forsskal). *J. Fish. Dis*., 3: 373-385.

Bian, B. Z., Hatai, K., Po. G. L. and Egusa, S. 1979. Studies on the fungal diseases in crustaceans. I. *Legenidium scyllae* sp. nov. isolated from cultivated ova and larvae of the mangrove crab (*Scylla serrata*). *Trans. Mycol. Soc. Jpn*., 20: 115-124.

Boschma, H. 1949. *Sacculina beauforti* and *Loxothylacus ihlei*, two rhizocephala of crab *Scylla serrata* (Forsskal). *Bijdr. Dierkd*., 28: 41-46.

Chakraborty, A., Otta, O. K., Joseph, B., Kumar, S., Hossain, M. S., Karunasagar, I., Venugopal, M. N. and Karunasagar, I. 2002. Prevalence of white spot syndrome virus in wild crustaceans along the coast of India. *Curr. Sci.,* 82: 1392-1397.

Chen, L. L., Lo, C. F., Chiul, Y. L., Chang, C. F. and Kou, G. H. 2000. Natural and experimental infection of white spot syndrome virus (WSSV) in benthic larvae of mud crab *Scylla serrata. Dis. Aquat. Org.,* 40: 157-161.

De Pedro, J. B., Quinitio, E. T. and Parado-Estapa, F. D. 2008. Formalin as an alternative to trifluralin as prophylaxis against fungal infection in mud crab *Scylla serrata* (Forsskal) larvae. *Aquacult. Res*., 38: 1554-1562.

Devi, S. L. 1985. The fishery and biology of crabs of Kakinada Region. *Indian J. Fish*., 32: 18-32.

Escobedo-Bonilla, C. M., Alday-Sanz, V., Wille, M., Sorgeloos, P., Pensaert, M. B. and Nauwynck, H. J. 2008. A review on the morphology, molecular characterization, morphogenesis and pathogenesis of white spot syndrome virus. *J. Fish Dis*., 31: 1-18.

Fielder, D. and Allan, G. 2004. Executive summary and recommendations. In: Allan, G. and Fielder (Eds.), *Proceedings of scoping study and workshop, ACIAR working paper*, No. 54, p. 7-9.

Flegel, T. W. 1997. Special topic review: Major viral diseases of the black tiger prawn (*Penaeus monodon*) in Thailand. *World J. Microbiol. Biotechnol*., 13: 433-442.

Flegel, T. W. 2006. Detection of major penaeid shrimp viruses in Asia, a historical perspective with emphasis on Thailand. *Aquaculture,* 258: 1-33.

Guo, Z. X., Weng, S. P., Li. G., Chan, S. M. and He, J. G. 2008. Development of an RT-PCR detection method for mud crab reovirus. *J. Virol. Methods*, 151: 237-241.

He, J. G., Chen, Y. G., Deng, M., Yao, P., Zhou, H. M., Weng, S. P., Jiang, S. G., Long, Q. X. and Chan, S. M. 2003. Natural host range and pathogenicity of white spot syndrome virus infection in shrimp and crab species in China. In: Phillips, B., Megrcy, B. A. and Zhou, Y. (Eds.), *Proceedings of the Third World Fisheries Congress*: *Feeding the World with Fish in the Next Millennium-the Balance between Production and Environment*. American Fisheries Society, Symposium, Vol. 38. Bethesda, Maryland, USA, p. 195-203.

Hudson, D. A. and Lester, R. J. G. 1994. Parasites and symbionts of wild mud crabs *Scylla serrata* (Forsskal) of potential significance in aquaculture. *Aquaculture,* 120: 183-199.

Humphrey, J. D., Williams, G. and Needham, E. 2009. The occurrence of baculovirus in mud crab at Darwin Aquaculture Centre and in regional areas of the Northern Territory: Characterisation, pathological significance and impact on proposed mud crab aquaculture. Technote, No. 126. Northern Territory Government (http://www.nt.gov.au/d).

Jeffries, W. B., Voris, H. K. and Poovachiranon, S. 1992. Age of the mangrove crab *Scylla serrata* at colonization by stalked barnacles of the genus *Octolasmis*. *Biol. Bull*., 182: 188-194.

Jeffries, W. B., Voris, H. K. and Yang, C. M, 1991. Species recognition among the pedunculate barnacles (Cirripedia: Thoracica) on the mangrove crab, *Scylla serrata*. *Raffles Bull. Zool*., 32: 141-154.

Jithendran, K. P., Poornima, M., Balsubramanian, C. P. and Kulasekarapandian, S. 2009. *Diseases of mud crabs in India*. *Bull. Cent. Inst. Brackishwat. Aquacult.*, No. 20: 28 pp.

Kanchanaphum, P., Wongteerasupaya, C., Sitidilokratana, N., Boonsaeng, V., Panyim, S., Tassanakajon, A., Withyachumnarnkul, B. and Flegel, T. W. 1998. Experimental transmission of white spot syndrome virus (WSSV) from crabs to shrimp *Penaeus monodon*. *Dis. Aquat. Org.,* 34: 1-7.

Kathirvel, M. 1993. Mud crab. In: *Handbook on aqua farming of shrimps, lobsters and crabs*, MPEDA Publication, Cochin, 72 pp.

Kathirvel, M. and Srinivasagam, S. 1992. Taxonomy of the mud crab, *Scylla serrata* (Forsskal), from India. In: Angell, C. A. (Ed.), *The mud crab. A Report of the seminar on the Mud crab culture and trade,* held at Surat Thani, Thailand, 5-8 November, 1991, Bay of Bengal Program, Madras, India, p. 127-132.

Kathirvel, M., Kulasekarapandian, S. and Balasubramanian, C. P. 2004. *Mud crab culture in India*. *Bull. Cent. Inst. Brackishwat. Aquacult.*, No. 17 : 60 pp.

Keenan, C. P. 1999. Aquaculture of the mud crab, genus *Scylla*-past, present and future. In: Keenan, C. P. and Blackshaw, A. (Eds.), *Mud crab aquaculture and biology*. ACIAR proceedings No. 78 : 216 pp.

Keenan, C. P., Davie, P. J. F. and Mann, D. L. 1998. A revision of the genus *Scylla* De Haan, 1833 (Crustacea: Decapoda: Brachyura: Portunidae). *Raffles Bull. Zool.,* 46: 217-245.

Kiatpathomchai, W., Jaroenram, W., Arunrut, N., Gangnonngiw, W., Boonyawiwat, V. and Sithigorngul, P. 2008. Experimental infections reveal that common Thai crustaceans are potential carriers for spread of exotic Taura syndrome virus. *Dis. Aquat. Org*., 79: 183-190.

Knuckey, I. A., Davie, P. J. F. and Cannon, L. R. G. 2006. *Loxothylacus ihlei* Boschma, (Rhizocephala) and its effects on the mud crab, *Scylla serrata* (Forsskål), in northern Australia, *J. Fish. Dis.,* 18: 389-395.

Kou, G. H., Peng, S. E., Chiu, Y. L. and Lo, C. F. 1998. Tissue distribution of white spot syndrome virus (WSSV) in shrimp and crabs. In: Flegel, T. W. (Ed.), *Advances in Shrimp Biotechnology*, National Center for Genetic Engineering and Biotechnology, Bangkok, p. 267–271.

Kvingedal, R., Owens, L., and Jerry, D. R. 2006. A new parasite that infects eggs of the mud crab, *Scylla serrata*, in Australia. *J. Invert. Pathol*., 93:54-59.

Lavilla-Pitogo, C. R. and de la Pena L. D. 2004. *Diseases in farmed mud crabs Scylla* spp.: *diagnosis, prevention and control*. SEAFDEC Aquaculture Department, Iloilo, Philippines, 89 pp.

Lavilla-Pitogo, C. R., de la Pena L. D., and Catedral, D. D. 2007. Enhancement of white spot syndrome virus load in hatchery-reared mud crab *Scylla serrata* (Forsskal, 1775) juveniles at a low temperature. *Aquacult. Res*., 38: 1600-1603.

Lavilla-Pitogo, C. R., Marcial, H. S., Pedrajas, S. A. G., Quinitio, E. T. and Millamena, O. M. 2001. Problems associated with tank-held mud crab (*Scylla* spp.) broodstock. *Asian Fish. Sci*., 14: 217-224.

Leano, E. M. 2002. *Haliphthoros* spp. from spawned eggs of captive mud crab, *Scylla serrata*, broodstocks. *Fungal Diversity,* 9: 93-103.

Li, Y. Y., Xia, X. A., Wu, Q. Y., Liu, W. H. and Lin, Y. S. 2008. Infection with *Hematodinium* sp. in mud crabs *Scylla serrata* cultured in low salinity water in southern China. *Dis. Aquat. Org*., 82: 145-150.

Lio Po, G. D., Sanvictores, M. E. G., Baticados, M. C. L. and Lavilla, C. R. 1982. *In vitro* effect of fungicides on hyphal growth and sporogenesis of *Lagenidium* spp. isolated from *Panaeus monodon* larvae and *Scylla serrata. J. Fish. Dis.,* 5: 97-112.

Lo, C. F., Ho, C. H., Peng, S. E., Chen, C. H., Hsu, H. C., Chiu, Y. L., Chang, C. F., Liu, K. F., Su, M. S., Wang, C. H. and Kou, G. H. 1996. White spot syndrome baculovirus (WSBV) detected in cultured and captured shrimp, crabs and other arthropods. *Dis. Aquat. Org.*, 27: 215- 225.

Longyant, S., Sattaman, S., Chaivisuthangkura, P., Rukpratanporn, S., Sithigorngul, W. and Sithigorngul, P. 2006. Experimental infection of some penaeid shrimps and crabs by yellow head virus (YHV). *Aquaculture*, 257: 83-91.

Marichamy, R. 1996. Mud crab culture and hatchery. *Bull. Cent. Mar. Fish. Res. Inst.*, 48: 103-107.

Marichamy, R. and Rajapackiam, S. 2001. The aquaculture of *Scylla* species in India. *Asian Fish. Sci*., 14: 231-238.

Nakamura, K., Nakamura, M., Hatai, K. and Zafran 1995. *Lagenidium* infection in eggs and larvae of mangrove crab (*Scylla serrata*) produced in Indonesia. *Mycoscience*, 36: 399-404.

Otta, S. K., Shubha, G., Joseph, B., Chakraborty, A., Karunasagar, I. and Karunasagar, I. 1999. Polymerase chain reaction (PCR) detection of white spot syndrome virus (WSSV) in cultured and wild crustaceans in India. *Dis. Aquat. Org*., 38: 67-70.

Patterson, J. and Samuel, V. D. 2005. Participatory approach of fisherwomen in crab fattening for alternate income generation in Tuticorin, south-east coast of India. *Asian Fish. Sci.*, 18: 153-159.

Poornima, M., Kathirvel, M., Kulasekharapandian, S., Santiago, T. C., Kalaimani, N., Jithendran, K. P., Alavandi, S. V. and Saraswathi, R. 2008. Occurrence of white spot syndrome virus in cultured mud crab *Scylla tranquebarica.* In: *Compendium of International Conference on 'Emerging infectious diseases of animals and biotechnological applications'* , 28-29 July, 2008, Tamil Nadu Veterinary and Animal Sciences University, Chennai, India. p. 94.

Prasadan, P. K. and Janardanan, K. P. 2001. Three new species of gregarines (Apicomplexa: Sporozoea: Porosporidae) in the estuarine crabs from Kerala, India. *Acta Protozool.*, 40: 303-309.

Quinitio, E. T. and Parado-Estepa, F. D. 2003. *Biology and hatchery of mud crabs Scylla* spp. SEAFDEC, Aquaculture Department, Tigbauan, Iloilo, Philippines, p. 42.

Quinitio, E. T., Parado-Estepa, F. D. and Rodriguez, E. 2002. Seed production of mud crab *Scylla* spp. *Aquacult. Asia,* 7 (3): 29-31.

Rajendran, K. V., Vijayan, K. K., Santiago, T. C., and Kroll, R. M. 1999. Experimental host range and histopathology of white spot syndrome virus (WSSV) infection in shrimp, prawns, crabs and lobsters from India. *J. Fish. Dis*., 22: 183-191.

Roza, D. and Hatai, K. 1999. Pathogenicity of fungi isolated from the larvae of the Mangrove crab, *Scylla serrata* in Indonesia. *Mycoscience*, 40: 427-431.

Sahul Hameed, A. S., Balasubramanian, G., Syed Musthaq, S. and Yoganandhan, K. 2003. Experimental infection of twenty species of Indian marine crabs with white spot syndrome virus (WSSV). *Dis. Aquat. Org*., 57: 157-161.

Sakthivel, M. and Francis, H. O. 2006. A successful mud crab farming in a Nellore village pond, Andhra Pradesh. *Fishing Chimes*, 26 (4): 12-14.

Salaenoi, J., Sangcharoen, A., Thongpan, A. and Mingmuang, M. 2006. Morphology and haemolymph composition changes in red sternum mud crab (*Scylla serrata*). *Kasetsart J. (Nat. Sci.)*, 40: 158-166.

Shaji, M., Quinitio, E. T., Samraj, T., Kandan, S., Ganesh, K., Kumar, D., Arulraj, S., Pandiarajan, S., Ismail, S. and Dhandapani, K. 2006. Seed production of mud crab *Scylla serrata* at the Rajiv Gandhi Centre for Aquaculture, Tamil Nadu, India. *Aquacult. Asia*, 11 (1): 17-21.

Shanmuga Priya, U. 2008. *Phenotypic and genotypic characterization of Vibrio harveyi isolates from mud crab, Scylla tranquebarica.* M. Phil. Dissertation, Dhanalakshmi Srinivasan College of Arts and Science for Women, Perambalur, (Bharathidasan University), Tamilnadu, 120 pp.

Shields, J. D. 1992. Parasites and symbionts of the crab *Portunus pelagicus* from Moreton Bay, eastern Australia. *J. Crust. Biol.*, 12: 94-100.

Sims Jr., H. W. and Joyce Jr., E. A. 1965. Partial albinism in a blue crab. *Quart. J. Florida Acad. Sci.,* 28: 373-374.

Song, Z. R., Ni., Z. M., Huo, Z. H., Li, W. S., Peng, Q. M. and Peng, H. C. 2003. Pathology study on muscle necrosis tissue necrosis of mud crab *Scylla serrata*. *J. Jimei Univ. (Natural Science)*, 8: 301-304 (in Chinese, English Abstract).

Song, X. H., Cheng, J. X., Zhu, M. X., Cai, C. F., Yang, C. G. and Shen, Z. H. 2007. Pathogenic factors of albinism in hepatopancreas of Chinese mitten crab *Eriocheir sinensis* (Decapoda: Grapsidae). Chinese electronic periodical services (http://www.ceps.com), 14: 762-769 (in Chinese, English Abstract).

Srinivasagam, S., Kathirvel, M. and Kulasekarapandian, S. 2000. Captive broodstock development, induced breeding and larval stages of mud crabs (*Scylla* spp.). *Bull. Cent. Inst. Brackishwat. Aquacult.*, No. 12: 26 pp.

Supamattaya, K., Hoffman, R. W., Boonyaratpalin, S. and Kanchanaphum, P. 1998. Experimental transmission of white spot syndrome virus (WSSV) from black tiger shrimp *Penaeus monodon* to the sand crab *Portunus pelagicus*, mud crab *Scylla serrata* and krill *Acetes* sp. *Dis. Aquat. Org*., 32: 79-85.

Trino, A. T. and Rodriguez, E. M. 2001. Mud crab fattening in ponds. *Asian Fish. Sci.,* 14: 211-216.

Tuntiwaranuruk, C., Chalermwat, K., Upatham, E. S., Kruatrachue, M. and Azevedo, C. 2004. Investigation of *Nematopsis* spp. oocysts in 7 species of bivalves from Chonburi Province, Gulf of Thailand. *Dis. Aquat.Org*., 58: 47–53.

Voris, H. K., Jeffries, W. B. and Poovchiranon, S. 1994. Patterns of distribution of two barnacle species on the mangrove crab, *Scylla serrata*. *Biol. Bull*., 187: 346-354.

Weng, S. P., Guo, Z. X., Sun, J. J., Chan, S. M. and He, J. G. 2007. A reovirus disease in cultured mud crab, *Scylla serrata*, in southern China. *J. Fish. Dis*., 30: 133-139.

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