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Investigating disease prevalence in India's shrimp farming industry

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Abstract
Global demand for seafood has driven the rapid rise of shrimp farming, which now produces more than traditional wild-caught fishing. However, this growth has come at a cost; the high-density, stressful, and artificial environments typical of modern farms make shrimp highly vulnerable to viral diseases. Today, managing these outbreaks is the biggest hurdle for farmers worldwide. To better protect their stock, producers need to move beyond simple solutions like vaccination and embrace a more diverse, integrated approach that addresses all aspects of farm health and biosecurity.

Keywords: WSSV, yellow head, vibriosis, viral, white gut, farming

Introduction
Commercial shrimp cultivation in India did not emerge until the mid-1980s, a period when many neighbouring Asian nations notably China and Taiwan had already hit the ceiling of their production capacity and were beginning to struggle with disease outbreaks and ineffective management techniques. The Indian industry experienced a rapid surge in the 1990s, only to collapse between 1995 and 1996 due to a widespread viral epidemic. This decline was largely exacerbated by the inexperience of coastal states, which lacked both established best practices and technical support systems for commercial-scale operations. Despite this turbulent history, India possesses enormous untapped potential for aquaculture across its marine, freshwater, and brackishwater ecosystems. With a massive 8,118 km coastline, complemented by 3.5 million hectares of estuaries and 3.9 million hectares of backwaters, the country is well-positioned for growth. Experts suggest that roughly 1.2 million hectares are ideal for brackishwater aquaculture; however, the majority of this land remains dormant, particularly in West Bengal (34%) and Gujarat (32%).

Currently, Andhra Pradesh leads the nation in aquaculture development, driven by proactive farmers who have utilized nearly half of their available potential land. Nationally, however, the industry remains in its early stages, with only 190,000 hectares developed, representing a mere 16% of the total available brackishwater area.

The aquaculture sector has seen substantial global development, with shrimp cultivation emerging as a cornerstone of the industry. India, in particular, has witnessed an extraordinary surge in productivity, with output climbing from 35,500 tonnes in the early 1990s to over 843,633 tonnes by 2020–21 (MPEDA, 2022). Currently, frozen shrimp is the nation's most valuable seafood export, accounting for approximately 40% of the total export volume and over 66% of its US dollar earnings. Within this landscape, Kerala remains a key contributor, utilizing a blend of ancestral and contemporary farming practices. The state leverages its vast network of backwaters comprising over 46,000 hectares, with nearly 3,000 hectares utilized for shrimp production to generate an annual yield of roughly 1,550 tonnes (MPEDA, 2022). Despite this success, the industry contends with significant pathological challenges, most notably six prevalent diseases: WSSV, WFS, BGD, LSS, RMS, and EHP.

Shrimp aquaculture worldwide faces significant challenges from a diverse array of viral, bacterial, and parasitic agents. Pathogens such as acute hepatopancreatic necrosis disease (AHPND), Necrotising hepatopancreatitis bacterium (NHPB), Enterocytozoon hepatopenaei (EHP), yellow head virus (YHV), hepatopancreatic parvovirus (HPV), infectious myonecrosis virus (IMNV), monodon baculovirus (MBV), white spot syndrome virus (WSSV), infectious hypodermal and hematopoietic necrosis virus (IHHNV), and Taura syndrome virus (TSV) are widespread (Oie, 2021; Tandel, 2017) [24]. Furthermore, the emergence of newer threats, including decapod iridescent virus (DIV1) and covert mortality disease (CMD), presents a growing risk to global production (Qiu *et al*., 2017; Zhang *et al*., 2017) [19].

Within India, documented outbreaks have specifically involved IMNV, IHHNV, EHP, HPV, MBV, and WSSV (Tandel, 2017; Sahul *et al*., 2017; Babu *et al*., 2021) [1, 24]. While other major pathogens—such as YHV, TSV, NHPB, and AHPND have not yet been officially recorded in the country, there is a strong concern that these transboundary or emerging diseases may already be circulating within Indian culture systems. The lack of formal reports is likely attributed to insufficient farmer awareness, a dearth of data surrounding novel pathogens, and the absence of adequate diagnostic infrastructure to detect them.

White spot syndrome virus (WSSV)
The White Spot Syndrome Virus (WSSV), which triggers White Spot Disease (WSD), represents a primary challenge to the global shrimp aquaculture sector, having severely impacted industries in Asia starting in 1992 and Latin America by 1999. This pathogen is highly aggressive and possesses a broad host range, capable of infecting a vast array of decapod crustaceans, including lobsters, crabs, crayfish, freshwater prawns, and various marine shrimp species.

The clinical presentation of an acute WSD infection is often marked by an abrupt cessation of feeding, sluggish movement, and the development of distinctive white lesions ranging from 0.5 to 2.0 mm in diameter that appear under the shell. Other symptomatic indicators include a shift in body coloration toward pink or reddish-brown, caused by the expansion of chromatophores. While these white spots are common, they are sometimes absent or less prominent in infected *P. vannamei* populations in the Americas.

WSSV typically targets the ectodermal and mesodermal tissues, such as the epithelium residing beneath the cuticle, often resulting in rapid and unpredictable mortality. The virus is highly contagious, moving through both horizontal channels such as water-borne exposure and the consumption of infected carcasses and vertical transmission. Furthermore, the virus can infiltrate pristine habitats through contaminated wastewater, while various carriers, including copepods, aquatic insect larvae, and other invertebrates, serve as persistent reservoirs for the infection.

Yellow head disease (YHD)

Yellowhead disease (YHD) is triggered by the Yellow Head Vvirus (YHV) genotype 1, a rod-shaped, enveloped virus containing single-stranded positive-sense RNA that is classified under the *Roniviridae* family (Ganjoor, 2015) [7]. As its name suggests, the infection often causes the cephalothorax of the shrimp to take on a bleached or yellowish hue. Clinical indicators frequently involve an initial surge in feeding activity followed by a total loss of appetite, with dying shrimp often congregating near the pond embankments (Stentiford *et al*., 2009; Walker and Mohan, 2009) [22, 25]. Additionally, affected shrimp may display an unusual reddish coloration.

While Gill-associated virus (GAV) typically results in lower mortality rates, YHV is more virulent, leading to tissue necrosis within the ectodermal and mesodermal layers, particularly impacting the gills and lymphoid organs (Walker and Mohan, 2009) [25]. The disease was first documented in 1990 in Thailand among *Penaeus monodon* populations, from which it rapidly disseminated throughout the nation's aquaculture industry (Cowley *et al*., 2000). Since then, YHD outbreaks have been documented across various shrimp-farming regions, including Vietnam, Mexico, Indonesia, Taiwan, India, Sri Lanka, and Malaysia (Mohan *et al*., 1998; Wang and Chang, 2000; Walker and Mohan, 2009) [25].

Vibriosis

Vibriosis remains a pervasive challenge within *Litopenaeus vannamei* aquaculture operations worldwide. This bacterial condition is primarily attributed to pathogenic Gram-negative strains, most notably *V. harveyi*, *V. parahaemolyticus*, *V. vulnificus*, *V. penaeicida*, and *V. alginolyticus* (Brock and Lightner, 1990; Ishimaru et al., 1995) [2, 9]. Furthermore, research by Lightner (1996) [16] identifies additional culprits, including *V. damsela*, *V. fluvialis*, and various other unclassified *Vibrio* species.

Infected shrimp typically exhibit erratic swimming patterns and may be seen drifting near the water's surface. A noticeable decline or complete cessation of feeding is another hallmark of the disease. Physical indicators often include clipped antennae, redness in the appendages and uropods, and a coarse, rough texture when stroking the antennae. Internally, the hepatopancreas undergoes a visible transformation, progressing from an initial cloudiness to a distinct red or brownish hue.

Outbreaks frequently escalate into mass mortality when environmental stressors compromise the animals' immune systems. Key trigger factors include deteriorating water quality, high thermal levels, excessive stocking densities, insufficient water exchange, and depleted dissolved oxygen concentrations (Lewis, 1973; Lightner and Lewis, 1975; Brock and Lightner, 1990) [2, 12, 14].

Taura Syndrome Virus

The first documented outbreak of Taura syndrome occurred in June 1992[10], affecting farm-raised *Penaeus vannamei* populations situated near Ecuador's Taura River (Jiminez, 1992) [10]. The causative agent, Taura syndrome virus (TSV), is characterized as a non-enveloped, icosahedral, positive-sense single-stranded RNA virus measuring roughly 31–32 nm in diameter. It shares biological commonalities with the *Apavirus* genus of the *Dicistroviridae* family, bearing a resemblance to insect viruses such as the cricket paralysis virus and the *Drosophila* C virus (Christian *et al*., 2005) [3].

TSV primarily targets juvenile *P. vannamei* (ranging from 0.1 to 5 g), typically manifesting within 14 to 40 days after the shrimp are introduced to nursery or grow-out facilities, though infections are also possible in post-larvae and mature shrimp (Lightner *et al*., 1995) [15]. The progression of the disease is categorized into three distinct stages: acute, transition, and chronic. During the acute phase, shrimp display a reddish hue most notably in their pleopods and tail fans due to the expansion of red chromatophores. This stage is marked by empty digestive tracts, soft shells, and extreme mortality, which can reach 95% during the molting process.

Should the shrimp survive into the transition phase, they develop dark, irregularly shaped melanized lesions on their appendages, cephalothorax, and tail, largely resulting from the accumulation of hemoglobin. Despite these markings, their behavior often returns to normal. In the chronic stage, the shrimp appear asymptomatic. Although some data suggests the virus may eventually be cleared, the infection can persist within the population for a year or even longer. TSV is known to infect tissues derived from the mesoderm and ectoderm, specifically targeting the lymphoid organ, hematopoietic tissue, striated muscle, antennal glands, subcuticular connective tissue, and the epithelium of the cuticle (Hasson *et al*., 1999) [8].

Running mortality syndrome (RMS)

Running Mortality Syndrome (RMS) is a chronic health issue affecting *P. vannamei* shrimp in India, a problem first observed in 2001. It is characterized by persistent daily die-offs occurring 30 to 60 days after stocking, which intensify toward the end of summer cultivation cycles. The syndrome presents unique symptoms such as tail and appendage reddening and opaque abdominal muscles that do not match known disease profiles. Data from Suguna (2022) [23] highlights the severity of the issue, noting that some farmers have suffered losses of 50–70% over four consecutive crops. Although the specific cause is unknown, experts believe it may be linked to various conditions, including CMNV and white muscle disease. To combat RMS, industry best practices involve strict biosecurity, intensive pond management, and critical screening of seed stock for quality assurance (Suguna, 2022) [23].

White gut / faeces syndrome (WFS)

White Faeces Syndrome (WFS) has been documented in both *P. monodon* and *P. vannamei* aquaculture. A clinical hallmark of this condition is the emergence of string-like, fecal-like structures within the digestive tract. These vermiform (worm-shaped) bodies are typically found embedded in the midgut, the hepatopancreatic tubules, and the area connecting the hepatopancreas, stomach, and midgut.

The syndrome typically emerges after the shrimp have been in culture for roughly two months. Early investigations often misidentified the causative agents as gregarines, leading to the name "White Faeces Syndrome." The economic impact of this condition is significant, often resulting in production losses between 10% and 15% and sometimes as high as 20% to 30% due to stunted growth rates and increased mortality.

While the exact etiology remains a subject of debate, more recent research such as the study by Sriurairatana *et al*., (2014) [21] suggests that WFS is actually caused by the shedding and cellular transformation of hepatopancreatic microvilli. These degraded tissues clump together to form vermiform structures that look like protozoan parasites, potentially weakening the shrimp and making them more susceptible to secondary infections.

Because the underlying cause and effective pharmaceutical treatments for WFS remain unclear, management strategies focus on prevention. Maintaining optimal water quality through consistent exchanges, lowering stocking densities, and implementing rigorous overall farm management are currently the most effective methods for mitigating the risks associated with this syndrome.

Conclusion

As the global population swells and wild-capture fisheries struggle to keep pace with soaring seafood demand, the rapid growth of the aquaculture sector has inadvertently escalated the threat of infectious disease outbreaks. Even with recent innovations in shrimp cultivation, persistent pathogenic challenges underscore the critical necessity for robust biosecurity protocols. To protect the industry from significant financial instability, it is imperative to adopt proactive management strategies. Such efforts must prioritize the implementation of systematic disease surveillance, the refinement of molecular-based early detection systems, and continued investment into cutting-edge solutions including vaccines, RNA interference, probiotics, and immunostimulants to fortify aquatic health regimes.

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