White Spot Syndrome Virus in Shrimps: Aquatic Impact and Potential Human Health Implications

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Abstract

Shrimp populations throughout the world are afflicted by the deadly and extremely contagious White Spot Syndrome Virus (WSSV). The worldwide shrimp business has suffered large financial losses as a result of WSSV since it first appeared in the 1990s. In addition to having an effect on aquatic environments, this virus can be harmful to human health if consumed by infected shrimp. The most common viral infection, WSSV, can kill a very high percentage of *Litopenaeus vannamei*. Still unknown, nevertheless, are the alterations in intestinal flora brought on by WSSV. While WSSV had little effect on the microbiota's richness and diversity, it did dramatically increase the abundance of dominating taxa like Proteobacteria and Fusobacteria and significantly decrease Bacteroidetes and Tenericutes in infected shrimp infected. It concludes that WSSV poses a significant threat to shrimp aquaculture due to high mortality rates and rapid spread, affecting intestinal microbiota and necessitating further research for effective management and health effects.

Keywords: Morphology, Transmission, Clinical, White spot, Syndrome, Shrimps

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Introduction

According to (*Wu, 2020)*, Viruses are submicroscopic infectious entities that replicate within an organism's live cells, infecting all living things. They are the most common living organisms and are found in almost every environment on Earth. Viruses exist as independent viral particles, or virions, composed of genetic material, a capsid, and an outer lipid envelope shown in Figure 1 (Pumpens and Pushko, 2022).

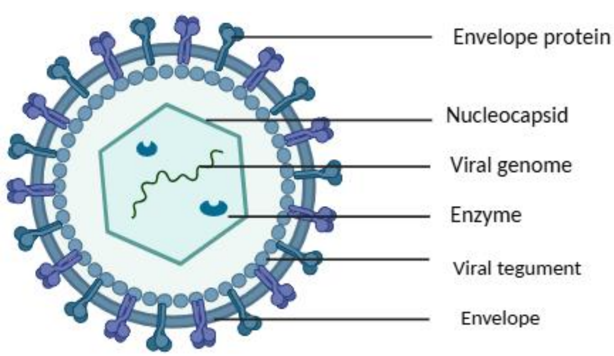

Fig. 1: Basic Virus Structure

The origin of viruses in life's evolutionary history is unknown, but plasmids may be ancestors. Since 1959, the term "virion" (plural "virions") has also been used to describe a single viral particle that is discharged from the cell and has the ability to infect other cells of the same type (*Casjens, 2010)*. Although they lack essential traits like cell structure, some biologists believe they are life forms due to their role in reproduction and evolution through natural selection (Koonin et al., 2016). Viruses spread through various pathways, including vectors. The host range of a virus varies, from narrow to broad (Robilotti et al., 2015). Crustaceans like shrimp are among the many creatures that viruses can infect, and the following discussion will center on this interaction (Grinin, 2025).

An Overview of Shrimps

A shrimp, also known as a shrimp in the US or UK, is a long-bodied shellfish that swims ability, typically affiliated to the Decapoda order shown in Figure 2. Shrimp are generally considered stalk-eyed swimming crustaceans with long, narrow tails, long whiskers, and slender legs. They swim forward by paddling with swimmerets on their abdomens. Shrimps have delicate legs for perching, while lobsters and crabs possess robust legs (Rudloe, 2009). Their lifespan is typically one to seven years. Shrimp species range from 2 cm to 25 cm, with larger ones being more commercially targeted in the Commonwealth of Nations and former British territories (Rudloe, 2009).

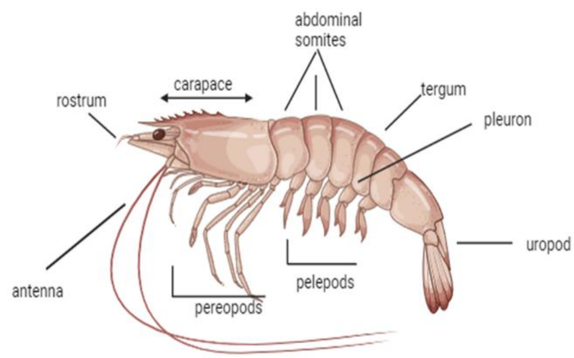

Fig. 2: Shrimp structure (Retrieved from bio render)

A Habitat Perspective

Commonly found at seafloor of most beaches, as well as in rivers and lakes, are shrimp. There are a number of species, and usually one species is localized (Rudloe, 2009). The majority of shrimp species are marine, while more than 25% of the known species are found in freshwater (De Grave, 2008). Marine life can be found in depths of up to 5,000 meters (16,000 feet) from the tropics to the Polar Regions (Raturi, 2025). Lifecycle of shrimps shown in Figure 3.

White spot syndrome

White spot syndrome virus was first identified in Japanese-farmed Penaeus japonicus, it is thought to have been introduced using live infected post-larvae from Mainland China's Fujian Province in 1992 (Jiang et al., 2017). The virus was detected in North America, South Carolina, USA, and Texas, USA, after one year, it may have 1995 marked the entry into the Pacific Ocean. a result of the spread of infected post-larvae (Rosenberg, 2000). Since farmers raised wild shrimp as a side crop in tidal ponds for generations, shrimp farming has been practiced on a limited scale throughout Southeast Asia (Dey et al., 2023). White Spot Syndrome Virus (WSSV) is a microbe causing white spot disease in cultured penaeid shrimp (Pradeep et al., 2012). It causes 100% mortality within 3-10 days of infection (Oakey et al., 2019). Symptoms appear after the animal is almost dead (Saravanan et al., 2017), leading to the development of successful immunological and molecular diagnostic techniques.

It has been estimated that the disease condition has cost the shrimp industry between eight and fifteen billion dollars globally since it first appeared (Shinn et al., 2018). The annual growth rate of the financial losses was already 1 billion USD (FAO, 2014). WSSV was found to be responsible for 80% of the losses in shrimp production in China (Salehi, 2021), and it also had a significant impact on farmed shrimp output (Lucien-Brun, 2017). WSSV poison affects various crustaceans and can be found in natural populations. Research has focused on identifying the causes and solutions for disease control in confined crustaceans (Sánchez-Paz, 2010). Cultured shrimp have a maximum lifespan of four to five months, and they must withstand various conditions, including changes in salinity and temperature. Techniques to prevent WSSV introduction include domestication of microbe's free shrimp brood stock, minimal water exchange, and culture pond dry-out procedures (Dieu et al., 2021).

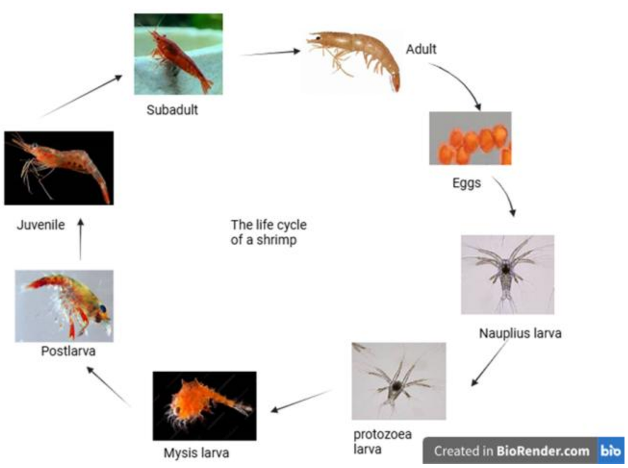

Fig. 3: Life cycle of shrimp (Retrieved from Biorender)

WSSV Genome

The most well sequenced viral genome is WSSV, which is a circular dsDNA molecule (Vlak et al., 2004). The size of the genome differs to the viral isolate. According to three total WSSV variants (accession numbers AF369029, AF332093, and AF440570), the genome sizes of Thailand, China, and Taiwan were 292,967, 305,107, and 307,287 bp, respectively (Sablok et al., 2012). Researchers concentrate on statistically examining genetic materials, particularly the function of components of the viral envelope, subsequent to achieving assuring the genome DNA sequence of WSSV (Guevara-Hernandez et al., 2012) have identified and described a limited number of DNA metabolic and functional genes.

WSSV Virion Protein

Virions are macromolecules that transport and preserve viral DNA, with structural proteins crucial for targeting cells and activating defenses (Tsai et al., 2004). WSSV's unique morphology may be explained by virion proteins' structural role, allowing for diagnostic tests targeting specific biological components. Non-structural proteins regulate DNA replication, viral multiplication, and transcriptional regulation (Liu et al., 2006). There are five proteins in the tegument, ten in the nucleocapsid, and twenty-one in the envelope. Non-essential proteins in WSSV genome are essential for replication of the viral genome, and suppression of cell function. These proteins are therefore excellent options for both medical research and the creation of vaccines. Investigations revealed VP9 is a prevalent protein in host tissue, despite the fact that its precise physiological function is unknown (Liu et al., 2006). According to studies employing X-rays and NMR, VP9 has a unique zinc ion active site that contains a DNA-binding fold (Islam et al., 2023). These results imply that VP9 might be involved in the transcription of WSSV. The tegument proteins VP36A and the nucleocapsid proteins VP664 (Tsai et al., 2004) and VP136A (Islam et al., 2023) also have the single-cell attachment motif. One such protein that has been found to be essential for viral penetration is VP466. One of the suspense linked to the genes is P466—a glutathione S-transferase protein indicated ORF151 (Xie et al., 2006).

Morphology and Structure of WSSV

WSSV is 80–120 nm in diameter and 250–380 nm in length. The virions are rod-shaped to elliptical and have a characteristic flagella-like appendage at one end (Walker and Mohan, 2009). According to (Tsai et al. 2004), virions contain at least 45 structural proteins that are arranged into three morphologically distinct layers. The WSSV virus targets mesodermal and ectodermal tissues. The stacking ring components of the nucleocapsid proteins consist of a large protein (VP664) and a basic DNA-binding protein (VP15) (Witteveldt et al., 2005). The cellular structure of the viral envelope is 6–7 nm thick and contains 35 different proteins shown in the Figure 4 (Sánchez-Paz, 2010).

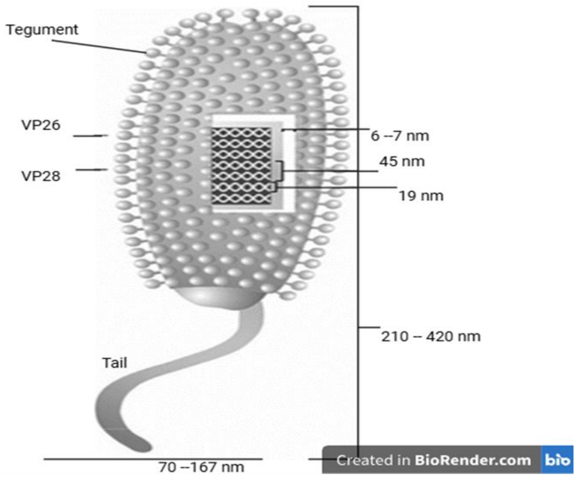

Fig. 4: Morphology and Structure of WSSV (Biorender)

The facts provided in morphological section has been used to draw WSSV nucleocapsid structure. (a) Electron microscopy was used to analyze the WSSV nucleocapsid, which has 15 noticeable vertical helices. (b) A side view cross section of a single, 70 nm-diameter nucleocapsid helix. (c) A side view of an empty nucleocapsid (cross section) with a diameter of 80 nm. One trait that distinguishes WSSV is the cross-hatched structure of the nucleocapsid (Verbruggen et al., 2016).

The Lifecycle of WSSV

There are various phases in the w*hite spot syndrome virus (WSSV)* life cycle, ranging from infection to replication and spread. With its high virulence, WSSV mostly infects crustaceans, especially shrimp shown in Figure 5 (Tribamrung et al., 2023). It targets mesodermal and ectodermal cells, including the lymphoid organs, cuticular epithelium, and gills, once inside. When the viral DNA reaches the nucleus of the host cell, it uses the host's biological resources to replicate and conduct *DNA-templated transcription (*López et al., 2024). Cell lysis frequently results from the release of newly formed viral particles into the cytoplasm from the nucleus. Both *horizontally (*via water, cannibalism, or contaminated equipment) and *vertically* (from infected broodstock to offspring), WSSV can spread (Cox et al., 2024). The virus is extremely contagious and challenging to contain since it may survive in the environment. Outbreaks can be made worse by stressors such as temperature swings, high stocking densities, and poor water quality. WSSV has been found in wild shrimp populations as well, especially in coastal areas close to aquaculture zones, even though it is primarily linked to farmed shrimp (Islam et al., 2023).

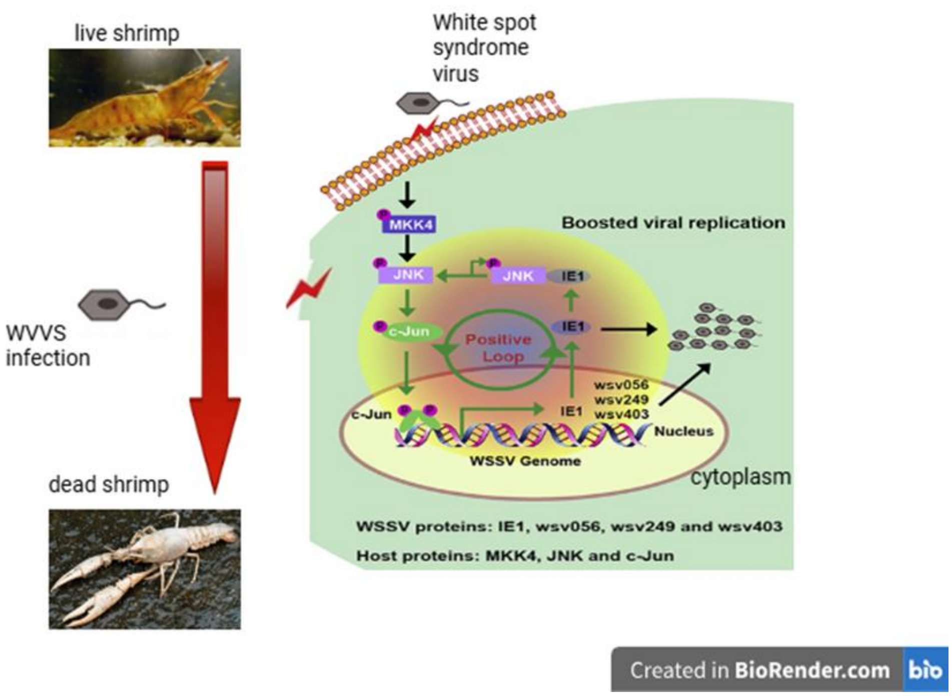

Fig. 5: Viral replication of WVVS

Clinical Sings

Virus can infect various hosts, including shrimp and crustaceans. Cultivated penaeid shrimps are highly virulent, causing 100% mortality rates in a few days. Nonpenaeid shrimp also face severe infection. External stressors like temperature, salinity, bacterial diseases, and pollutants can also cause variable severities in infection. WSS is characterized by white patches, decreased food intake, lethargy, loose cuticle, and reddish discoloration on the carapace, appendages, and abdominal segments (Lee et al., 2022).

Pathological Changes

WSSV infects various host cells, causing histological alterations in intestinal, gill and connective tissues. Infected cells display cytoplasmic clearing, hypertrophied nuclei and occlusions. White spots on a diseased shrimp's shell, ranging from 0.3 to 3.0 mm in diameter, (Li et al., 2016) appear as dome-shaped areas on the carapace and smaller specks on the cuticle surface, possibly due to cuticular epidermis anomalies. Following virus infection, biochemical changes are observed, including increased glucose consumption and lactate concentration, increased glucose 6-phosphate dehydrogenase activity, decreased triglyceride concentration, and upregulation of mitochondrial voltage-dependent anion channel.

Human Exploitation

Seafood: Fishing and Food Production

Otter trawls, seines and shrimp baiting are commercial methods for capturing wild shrimp, with baited traps being prevalent in the Pacific Northwest region. Prawn trawling can lead to high accidental catch rates of non-target species, with up to 20 pounds of shrimp discarded for every pound sold (Khan, 2018). This practice kills finfish and cetacean species, altering natural balance in abandoned areas and producing over one-third of the world's bycatch (Morgan et al., 2003). Marketing shrimp involves promoting appearance, grading, color, and homogeneity classifications; selling frozen, low-mercury, and high omega-3 fatty acids and occasionally selling whole shrimp. Shrimp, low in food energy but high in protein, calcium, and iodine, contains 122 to 251 mg of cholesterol per 100 g. Consuming shrimp benefits the circulatory system by increasing the cholesterol ratio and decreasing triglycerides (Kumar et al., 2018). Ebiko, or shrimp roe, is a crucial ingredient in sushi making, often referred to as "shrimp flakes. Shrimp substitutes derived from plants, produced since the early 2020s, have demonstrated rapid improvement (Kateman et al., 2023).

Aquaria

Home aquariums feature various shrimp species, including bamboo, Japanese marsh, cherry, ghost, and glass shrimp, as well as saltwater shrimp like harlequin, fire, and cleaner. These species help with debris removal and algae control.

Target Organizations and Transmission Mechanisms

WSSV can infect various organs, including skin, gills, and neurological cells, but not endodermal organ epithelial cells (Lee et al., 2024). Late stages can cause severe damage, leading to organ failures and even death. The entrances to shrimp remain unknown Studies show WSSV development in young *P. monodon* is most frequent in stomach subcuticular epithelial cells and hepatopancreas' gills, integument, and connective tissue when challenged with WSSV damaged tissue (Lee et al., 2022). The epithelium in the midgut body may provide a temporary location for WSSV duplication, allowing the virus to evade the around basement membrane, according to another research conducted on *Marsupenaeus japonicus*. However, WSSV dificult by absorption showed that hemoglobin migrating to the midgut and gills at the end of infection was WSSV negative (Arts et al., 2015).

When shrimp were exposed to high infectious doses of viral proteins, it was discovered that the antennal gland cells, the gill cells, and the foregut epithelial cells were the sites of WSSV replication (Bonilla et al., 2008). To detect virus, a number of diagnostic techniques have been developed. In situ hybridization (Lightner et al., 2012), gross observation, cytological techniques (López et al., 2009), scientific methods, such as nitrocellulose-enzyme immunoblot study and Western blotting methods , and polymerase chain reaction based approaches have recently become more sensitive, and dependable. A loose cuticle with white patches that range in width from 0.5 to 2.0 mm is frequently seen on the interior of the shell of highly contaminate shrimp (Hossain et al., 2015).

The Fundamental Nature of WSSV and its Clinical Manifestations

Although WSSV takes a long time to show symptoms, upon its completion, the fatality rate is higher because contaminated animals die within 3 to 8 days. Cumulative death may surpass 100% within 10 days of the disease onset. Although young shrimp of all sizes and ages are harmful in grow-out ponds, substantial mortality happens one to two months after restocking (Mishra at al., 2005). The most typical symptom of WSSV infection is the development of round white spots or patches that range in diameter from 0.5 to 3.0 mm. Among the symptoms of a bacterial WSS infection are white to reddish-brown /pinkish/to discoloration, over the head and carapace, decreased appetite, and congregation near the embarkation, among other symptoms. This disease also results in decreased boasting and mediocre response to a stimulus, loose cuticle , enlargement of *branchiostegites*, thinning and delayed clotting of hemolymph (Wang et al., 2001). The disease also causes the skin and appendages to turn red.

WSSV'S Effect on Shrimp Farming

The largest significant threat to Asia's shrimp farming industry at the moment and for some time has been WSSV describe in Table 1. This illness is extremely virulent and can infect a wide variety of hosts. The prevalence and effects of white spot in wild shrimp groups in affected regions are poorly understood, but it is primarily found in Asia and Latin America (Mohan et al., 2009). Among the ectodermal and mesodermal tissues infected by WSSV are the tissues lining the cutis, as well as the neuronal, muscular, lymphoid, and hematopoietic systems. Shrimp's carapace, limbs, and internal body parts develop Spots virus (red and white) with a diameter of 1-2 mm due to the hepatopancreas.

P. monodon latent carriers have caused outbreaks in Thailand due to environmental changes, most likely caused by seawater pressure through salt levels or toughness, or sudden temperature changes (Vega et al., 2009). Temperature variations have also been demonstrated to kill infected *P. vannamei* in Latin America and North America. However, WSSV fatality rate at 18 or 22°C and cause 100% fatalities at 32°C in the United States, while in Ecuador, it would cause death rate at a lower than 30°C and prevent it at much higher temperatures than 30°C. For instance, once WSSV arrived in 1999, Ecuador's exports decreased to 38,000 metric tons in 2000 from 115,000 metric tonnes in 1998. Since then, Ecuador has bounced back, and in 2003, it exported an estimated 50,000 metric tons (Cuéllar-Anjel et al., 2012).

Aquatic Impact and Potential Human Health Implications

The White Spot Syndrome Virus (WSSV) affects human health, aquatic environments, and shrimp populations in profound ways.

Effect on Populations of Shrimp

Infected shrimp populations can die from WSSV up to 100% of the time. Farmers may experience financial losses if infected shrimp show decreased growth rates. Shrimp infected with WSSV may become more vulnerable to other illnesses (Millard et al., 2021).

Table 1: Shrimps farming production in for coastal provinces over the 1993-2007 in south Iran

Province	1993	1995	1997	1999	2000	2001	2002	2003	2004	2005	2006	2007	References
Khuzestan	8.6	35	114	491	850	2,054	0	26	21	0	17	70	(Rosenberry, 2002).
Bushehr	0.6	63	296	1,062	1,955	3,334	3,788	3,585	5,600	476	1,623	876	(Rosenberry, 2002).
Homozgan	6.6	32	106	205	850	1,2131	872	1,737	2,004	1,284	1,560	1,538	(Salehi, 2002)
Sistan and Balochistan	0.5	5	03	69	355	1,0213	1,300	2,114	1,278	1,800	2,500	16	(Lightner, 2010)
Total	16.3	135	517	1,858	4,010	7,624	5,960	7,462	8,903	3,560	5,700	2,500	(Salehi, 2003)

Effects on Aquatic Environments

WSSV outbreaks may cause modifications to aquatic food webs and ecosystem functions. WSSV can change the makeup of aquatic communities and lead to the extinction of native shrimp species (Angnunavuri et al., 2023). Shrimp infected with WSSV may discharge nutrients and toxins into the water, which can worsen the water's quality.

Effect on Human Health

If eaten raw or undercooked, WSSV-infected shrimp can endanger human health. Shrimp farmers, processors, and merchants may suffer financial losses as a result of WSSV outbreaks, which may have a domino effect on people's ability to make a living. The possibility of WSSV spreading to people by zoonotic transmission is uncommon, but it does exist, especially for those who handle contaminated shrimp (Bernstein et al., 2021).

WSSV Management Techniques

To prevent nauplii and PLs from virus contamination, avoid buying from contaminated sources, use iodine and water washes, inspect animal batches, uphold biosecurity standards, and build a hatchery to prevent illness entry. WSSV should be diagnosed and screened using reliable diagnostic tests (Powell et al., 2006), such as PCR and ISH, and tissue lesions examined. Sample hatcheries twice, save samples for testing, and buy animals with stress testing and PCR checks (Sterchi, 2008). Screen later-stage animals for *P. japonicus* virus, as it may not become harmful until after PL6. Reduce shrimp tension by extending acclimatization periods, using supplemental diets and NSIS, stocking during certain times, maintaining a healthy diet throughout life, using lower-density stock, identifying carriers of WSSV in ponds, collecting zooplankton and phytoplankton for PCR testing, and collecting frequent pond samples for histology and PCR.

Diagnoses, Treatment and Prevention

WSSV infection's histological findings differ from other penaeid infections like yellowhead virus and infectious hypodermal and hematopoietic necrosis virus due to lower tissue specificity and intranuclear occlusions. Quantitative PCR, or nested PCR, can be used to diagnose the virus quickly and precisely (Kubiś et al., 2013). In order to stop an outbreak, shrimp farms and hatcheries utilize a lot of disinfectants. Useful management strategies include stocking uninfected shrimp seeds and raising them carefully to avoid contamination away from environmental stressors. Shrimp raised at water temperatures over 29°C and in regions with comparatively modest temperature swings were more resistant to WSSV (Bauer, 2023).

Conclusion

The White Spot Syndrome Virus (WSSV) poses a serious threat to the global shrimp farming business. Contaminated sources are the major causes of WSSV. It is important to remove the contamination with wash because WSSV can spread between those people who exposed with the contaminated shrimps. WSSV caused dangerous effects on human health. Shrimp afflicted with this extremely contagious virus die quickly, causing significant financial losses. Shrimps are used as a food. They have economic importance. WSSV impacts the global food supply system, livelihoods, and shrimp production. The creation of efficient and sustainable control methods is still essential to ensuring the survival of shrimp aquaculture, even as research endeavors continue to deepen our understanding of WSSV and create mitigating techniques. It is very necessary to follow up the preventions which are given above because there is no defined treatment or therapies for the White Spot Syndrome Virus. We can face this major problem but caution is essential to protect the human health and environment.

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