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The Paradox of Progress: Why Shrimp Diseases Are Rising Despite Better Technology

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Abstract

Technological advancements have revolutionized shrimp aquaculture, enabling higher productivity, improved monitoring, and better resource management. However, the industry continues to face an increasing number of disease outbreaks, including emerging conditions affecting early life stages of *Penaeus vannamei*. This paradox highlights the complex interaction between intensification, microbial imbalance, pathogen evolution, and environmental stress. This article explores why diseases are increasing despite better technology and emphasizes the need for a more holistic and ecosystem-based approach to aquatic animal health management.

Introduction

Shrimp aquaculture has undergone a remarkable transformation in recent years, driven by innovations in hatchery systems, feed formulation, water quality monitoring, and biosecurity practices. Species such as *Penaeus vannamei* have become the backbone of global shrimp production due to their adaptability and fast growth. Despite these advancements, disease outbreaks remain a persistent and growing challenge, causing significant economic losses worldwide. Diseases such as EHP, WFS, WSSV, TSV, Acute Hepatopancreatic Necrosis Disease and newer conditions like Transparent Postlarval Disease have raised concerns about the sustainability of intensive shrimp farming systems. The increasing frequency of such diseases suggests that technological progress alone is insufficient to control health challenges in aquaculture. Understanding this contradiction requires examining the deeper biological and ecological dynamics within farming systems.

The Intensification Trap

One of the primary reasons for the rise in shrimp diseases is the intensification of farming practices. Modern technology allows farmers to stock more shrimp in smaller areas,

increasing overall production. However, high stocking densities create stressful conditions that weaken the immune system of shrimp and facilitate rapid transmission of pathogens. The accumulation of waste and uneaten feed further deteriorates water quality, creating an environment conducive to the proliferation of opportunistic pathogens such as *Vibrio parahaemolyticus*. In such systems, even minor imbalances can quickly escalate into severe disease outbreaks.

Microbial Imbalance: The Hidden Problem

Another critical factor is the disruption of microbial balance within aquaculture systems. Shrimp ponds and hatcheries are complex microbial ecosystems where beneficial and harmful microorganisms coexist. Technological interventions such as excessive disinfection or indiscriminate use of antibiotics may reduce pathogen loads temporarily but often eliminate beneficial microbes as well. This creates ecological niches that are rapidly occupied by opportunistic and often more virulent bacteria. Such microbial imbalances, commonly referred to as dysbiosis, are now recognized as a major driver of emerging diseases in shrimp culture.

Rapid Pathogen Evolution

The rapid evolution of pathogens also contributes significantly to the problem. Bacteria such as Vibrio parahaemolyticus have demonstrated a remarkable ability to acquire new virulence factors through genetic exchange mechanisms. This has led to the emergence of strains capable of causing different disease syndromes, often with complex and multifactorial pathogenic mechanisms. As a result, diseases are becoming harder to diagnose and control, outpacing the development of effective management strategies.

Environmental and Climate Stress

Environmental and climate-related factors further complicate disease dynamics. Rising temperatures, salinity fluctuations, and increased pollution levels can stress shrimp and compromise their immune responses. At the same time, these conditions may enhance the growth and virulence of pathogens. Even with advanced monitoring tools, sudden environmental changes can trigger outbreaks, highlighting the limitations of technology in fully controlling biological systems.

Globalization and Disease Spread

The global nature of shrimp aquaculture has also facilitated the spread of diseases. The movement of broodstock, larvae, and aquaculture inputs across regions increases the risk of introducing new pathogens into previously unaffected areas. This globalization has

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accelerated the emergence and dissemination of diseases, making local outbreaks a global concern.

Host Susceptibility and Early-Life Vulnerability

Additionally, the focus on rapid growth and high productivity in selective breeding programs may have inadvertently reduced genetic diversity and disease resistance in cultured shrimp populations. Early life stages, particularly larvae and postlarvae, are inherently vulnerable due to their underdeveloped immune systems. Emerging diseases often target these stages, leading to high mortality rates and significant production losses.

Overdependence on Technology

Another important aspect is the overdependence on technological solutions without adequate understanding of ecological principles. While aerators, sensors, and automated feeding systems have improved efficiency, they cannot replace fundamental management practices such as maintaining water quality, balanced feeding, and proper pond preparation. In some cases, misuse of technology can even exacerbate problems, for instance, overfeeding in automated systems, increasing organic load and promoting pathogen growth.

Conclusion

The increasing incidence of shrimp diseases in the face of technological advancement reflects the complex and dynamic nature of aquaculture systems. While technology has enhanced production capacity and operational efficiency, it has also intensified farming conditions, altered microbial ecosystems, and inadvertently supported pathogen evolution. Addressing this challenge requires a shift from a purely technology-driven approach to a more holistic strategy that integrates ecological balance, microbial management, environmental sustainability, and host health. Future success in shrimp aquaculture will depend not only on technological innovation but also on a deeper understanding of the biological systems that underpin aquatic animal health.

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