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Minireview

The role of selective breeding and biosecurity in the prevention of disease in penaeid shrimp aquaculture

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ABSTRACT

About 3.5 million metric tons of farmed shrimp were produced globally in 2009 with an estimated value greater than USD$14.6 billion. Despite the economic importance of farmed shrimp, the global shrimp farming industry continues to be plagued by disease. There are a number of strategies a shrimp farmer can employ to mitigate crop loss from disease, including the use of Specific Pathogen Free (SPF), selectively bred shrimp and the adoption of on-farm biosecurity practices. Selective breeding for disease resistance began in the mid 1990s in response to outbreaks of Taura syndrome, caused by Taura syndrome virus (TSV), which devastated populations of farmed shrimp (*Litopenaeus vannamei*) throughout the Americas. Breeding programs designed to enhance TSV survival have generated valuable information about the quantitative genetics of disease resistance in shrimp and have produced shrimp families which exhibit high survival after TSV exposure. The commercial availability of these selected shrimp has benefitted the shrimp farming industry and TSV is no longer considered a major threat in many shrimp farming regions. Although selective breeding has been valuable in combating TSV, this approach has not been effective for other viral pathogens and selective breeding may not be the most effective strategy for the long-term viability of the industry. Cost-effective, on-farm biosecurity protocols can be more practical and less expensive than breeding programs designed to enhance disease resistance. Of particular importance is the use of SPF shrimp stocked in biosecure environments where physical barriers are in place to mitigate the introduction and spread of virulent pathogens.

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1. Introduction

Shrimp belonging to the family Penaeidae include commercially important species inhabiting tropical and sub-tropical waters around the world (Bailey-Brock and Moss, 1992). These shrimp are cultured primarily in Asia and the Americas and generate significant foreign exchange. According to the Food and Agriculture Organization of the United Nations (FAO), an estimated 3.5 million metric tons of farmed penaeid shrimp were produced in 2009 with an estimated value greater than $14.6 billion (FAO, 2011). Despite the economic importance of farmed shrimp, the global shrimp farming industry continues to be plagued by diseases resulting in production inefficiencies and reduced profits for shrimp farmers.

Historically, commercial farmers have relied on the capture of wild shrimp to stock their ponds (Moss et al., 2001; Lightner et al., 2009). Shrimp are caught as postlarvae from coastal nursery habitats and stocked directly into ponds for growout or are collected offshore as broodstock and spawned in captivity to

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Table 1
United States Marine Shrimp Farming Program working list of "specific" and excludable pathogens for penaeid shrimp for 1990, 2004, and 2010. This list will be revised and expanded as new pathogens are identified and new disease diagnostic tools become available.

Virus	1990	2004	2010
Infectious hypodermal and hematopoietic necrosis virus (IHHNV)	X	X	X
White spot syndrome virus (WSSV)		X	X
Yellow head virus complex (YHV, GAV, LOV)		X	X
Taura syndrome virus (TSV)		X	X
Baculovirus penaei (BP)	X	X	X
Monodon baculovirus (MBV)		X	X
Baculoviral midgut gland necrosis (BMN)		X	X
Hepatopancreatic parvovirus (HPV)	X	X	X
Infectious myonecrosis virus (IMNV)		X	X
Penaeus vannamei nodavirus (*Pv*NV)			X
Prokaryote			
Necrotizing Hepatopancreatitis (NHP)		X	X
Rickettsia-like bacteria-Milky Hemolymph Disease (RLB-MHD)			X
Protozoan			
Microsporidians	X	X	X
Haplosporidians	X	X	X
Gregarines	X	X	X
Number of pathogens or pathogen groups	6	13	15

produce postlarvae for stocking. Wild-caught shrimp pose a serious risk to the industry because they may be infected with pathogens which can spread throughout a shrimp culture facility or a shrimp farming region. Pandemics caused by shrimp viruses have resulted in significant economic losses in major shrimp farming regions of the world and these losses can be attributed, in part, to the use of infected, wild-caught shrimp (Lightner et al., 2009; Lightner and Redman, 2010).

Another disadvantage in culturing wild-caught shrimp is the inability of the farmer to benefit from selective breeding to improve commercially important traits. Selective breeding of terrestrial animals has resulted in significant improvements in growth, feed conversion efficiency, and reproductive performance over successive generations (Boyle, 2001), and fish have been bred for enhanced resistance to viral (Wetten et al., 2007) and bacterial (Silverstein et al., 2009) pathogens. However, the benefits of selective breeding for shrimp lag far behind those realized in more mature meat-producing industries, despite the fact that several penaeid species have been bred in captivity for decades and most exhibit high fecundity and a relatively short generation time.

As the global shrimp farming industry matures, integrated approaches will be needed to mitigate the impacts of disease and to ensure the industry's long-term sustainability. These approaches will include the use of Specific Pathogen Free (SPF), selectively bred shrimp and the adoption of on-farm biosecurity practices. Each of these approaches is reviewed below.

1.1. Specific Pathogen Free shrimp

Over the past decade, there has been an increasing trend among shrimp farmers to stock their ponds with postlarvae produced from healthy, domesticated broodstock in an effort to mitigate crop loss from disease (Crocos and Moss, 2006; Lightner et al., 2009). The disease status of captive broodstock can be controlled, to a significant extent, using Specific Pathogen Free (SPF) shrimp (Lotz, 1997; Lightner et al., 2009). SPF shrimp are free of one or more specific pathogens which meet the following criteria: (1) the pathogen can be reliably diagnosed, (2) the pathogen can be physically excluded from a facility, and (3) the pathogen poses a significant threat to the industry (Lightner et al., 2009). Currently, there are SPF populations of shrimp which are free of White spot syndrome virus (WSSV), Yellow head virus (YHV), Infectious hypodermal and hematopoietic necrosis virus (IHHNV), Taura syndrome virus (TSV), and Infectious myonecrosis virus (IMNV). These viruses have cost the global shrimp farming industry billions of dollars in lost crops, jobs, and export revenue over the past decade (Lightner and Redman, 2010). The current list of specific pathogens for SPF penaeid shrimp used by the US Marine Shrimp Farming Program and several commercial broodstock suppliers in the US includes ten viruses or viral groups, two prokaryotes, and certain classes of parasitic protozoa (Table 1, USMSFP, 2010). It is important to note that this list is dynamic and will be revised and expanded as new pathogens are identified and new disease diagnostic tools become available.

Currently, only SPF populations of Pacific white shrimp, *Litopenaeus vannamei*, are commercially available on a large scale, and this factor has played a major role in *L. vannamei* usurping the giant tiger prawn, *Penaeus monodon*, as the most commonly cultured shrimp species worldwide. In 2000, an estimated 630,984 metric tons (MT) of farmed *P. monodon* were produced globally, whereas only 146,362 MT of farmed *L. vannamei* were produced during the same year (FAO, 2011). However, in 2009, farmed *L. vannamei* production increased to 2,327,534 MT and this represents a 1,490% increase over 9 years. During the same period, farmed production of *P. monodon* increased to 769,219 MT representing only a 22% increase. Historically, shrimp farmers in the Americas have cultured *L. vannamei*, so this dramatic species shift has occurred primarily in Asia where more *L. vannamei* are now produced than in the Western Hemisphere where it is indigenous.

Although SPF shrimp are, by definition, free of specifically listed pathogens, SPF shrimp may not be disease free. They may, for example, be infected with a known pathogen that is not included on the SPF list of the shrimp supplier, or they may be infected with an unknown pathogen that has not yet been described. Although bacteria from the genus *Vibrio* can cause significant shrimp disease problems and can be reliably diagnosed (two of the criteria that need to be met for a pathogen to be considered for inclusion on an SPF list), they are not included on SPF lists. This is because they cannot be physically excluded from a facility due to their ubiquity as members of the shrimp's normal gut flora. Also, it is important to note that SPF shrimp have no innate resistance to a particular pathogen, nor are they innately susceptible. Disease resistance or susceptibility can be bred into a line of shrimp through selective breeding, but these characteristics have no bearing on SPF status.

1.2. Breeding for disease resistance

Following the initial establishment of an SPF population of *L. vannamei* by the US Marine Shrimp Farming Program in the early 1990s (Wyban et al., 1993; Lotz et al., 1995), family based shrimp breeding programs began to emerge. These programs generated