Biosecurity and Major Diseases in Shrimp Culture

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Abstract: The global shrimp aquaculture has passed its 30th year as a significant and rapidly growing and now represents a multi-billion dollar a year industry. More than half of the global shrimp supply now comes from farms. Recent statistics show that in 2008, 3,399,105 metric tons (MT) of the total world supply of 6,519,671 MT of shrimp (or 52%) were produced from aquaculture. However, shrimp farmers have suffered significant economic losses over the last decade, largely from viral diseases that have plagued the industry. In Asia, mortalities of cultured shrimp due to White Spot Syndrome Virus (WSSV) and Yellow Head Virus (YHV) have resulted in significant economic losses, and Taura syndrome virus (TSV) is now spreading throughout this region. Similarly, in the Western Hemisphere, both WSSV and TSV have caused catastrophic losses on shrimp farms. In Ecuador alone, WSSV was responsible for an estimated 53% decline in shrimp production from 1998 to 2000, resulting in a loss of export revenue in excess of $516 million. It is believed that these diseases are transferred between regions through the importation of hatchery broodstock, postlarvae and shrimp products. Once new pathogens are imported to an area, infection of wild stock appears to be inevitable, eliminating future possibilities of using uncontaminated wild stock to culture. Good biosecurity measures are vital to maintaining healthy animals, to reducing the risk of acquiring diseases in aquaculture facilities and to harvest high quality good yield. Thus, biosecurity measurements for a shrimp farming facility includes; disease prevention, disease monitoring, effectively managing disease outbreaks, cleaning and disinfection between production cycles and general security precautions.

Key words: Shrimp, Culture, Biosecurity, Disease, Prevention,

1. Introduction

The global shrimp farming industry has passed its 30^{th} year as a significant and rapidly growing industry. More than half of the global penaeid shrimp supply now comes from farms. Recent statistics (FAO, 2010) show that in 2008, 3,399,105 metric tons (MT) of the total world supply of 6,519,671 MT of shrimp (or - 52%) were produced from aquaculture. The huge scale of the shrimp farming industry represents fourteen of billions of dollars of physical assets and hundreds of thousands of jobs. Two species are dominant in the global shrimp farming industry. These are the black tiger shrimp *Penaeus monodon* and the Pacific white shrimp *Litopenaeus vannamei.* In Asia, the dominant species of choice was the Giant Tiger shrimp P. monodon native to tropical, coastal regions of the Indo-Pacific basin. In the West, the principal farmed species was P. vannamei, the Pacific White shrimp which is native to the tropical Pacific coast of Latin America. In the early 1990s, Asian shrimp farmers contributed more than 90% of total world production while farmers in the West contributed less than 10% of the total. Development of specific pathogen-free SPF stocks of P. vannamei in the U.S. in the early 1990s and their industry-wide use caused a doubling of U.S. industry production. Subsequent introduction of the domesticated non-native SPF P. vannamei to Asia in the late 90^{s}, produced dramatic increases in shrimp production and rapid spread through Southeast Asia. Rapid and sustained increases in Asian shrimp production resulted from P. vannamei's widespread adoption and these drove global shrimp production to double since 2000. By 2004, P. vannamei emerged as the leading shrimp species in worldwide production contributing more than 50% of total world farmed-shrimp production. In 2008, P. vannamei production accounted for more than 70% of total world production and was the dominant species farmed in China, Thailand, and Indonesia the world's three leading production countries.

The vast majority of shrimp culture in the world is conducted in outdoor earthen ponds that are typically located in coastal zones and exposed to a variety of pathogens. The worldwide experience of the shrimp farming industry is that pathogens, especially viruses, are a serious threat to the productivity and even survival of the industry. Although farmed shrimp now represent more than 50% of the global penaeid shrimp supply, farmers have suffered significant economic losses over the last decade, largely from viral diseases that have plagued the industry (Table 1. Lightner, 2005). In Asia, mortalities of cultured shrimp due to White spot syndrome virus (WSSV) and Yellow head virus (YHV) have resulted in significant economic losses (Flegel and Alday-Sanz 1998), and Taura syndrome virus (TSV) is now spreading throughout this region. Similarly, in the Western Hemisphere, both WSSV and TSV have caused catastrophic losses on shrimp farms (Lightner, 2003). In Ecuador alone, WSSV was responsible for an estimated 53% decline in shrimp production from 1998 to 2000, resulting in a loss of export revenue in excess of $516 million (Rosenberry, 2000).

Virus	Year of emergence to 2001	Product loss (US dollars)
WSSV - Asia	1992	4-6 billion
WSSV - Americas	1999	> 1 billion
TSV	1991-1992	1-2 billion
YHV	1991	0.1-0.5 billion
IHHNV	1981	0.5-1.0 billion

Table 1. Estimated Economic Losses Since The Emergence of Certain Diseases in Penaeid Shrimp Aquaculture

The pandemics due to the penaeid viruses WSSV and TSV, and to a lesser extent to IHHNV and Yellow Head Virus (YHV), have cost the penaeid shrimp industry billions of dollars in lost crops, jobs, and export revenue. In response to these viral pathogens, the global shrimp farming industry is changing the way shrimp aquaculture is practiced. The social and economic impacts of the pandemics caused by these pathogens in countries in which shrimp farming constitutes a significant industry have been profound. In the wake of the viral pandemics the shrimp culture industry has sought ways to restore the industry's levels of production to the "pre-virus" years. The application of biosecurity to shrimp farming is central to those efforts (Lightner 2005). At the shrimp farm level, biosecurity refers to producing healthy shrimp in a well-controlled environment that excludes the introduction or propagation of unwanted organisms and includes the prevention or escape of organisms back into the natural environment. The primary goal of a biosecurity program in shrimp farming is to prevent the introduction of any infectious organism into a shrimp farming system. In this study a brief review was given of basic farm management strategies to improve the outlook for more biosecure production and control of disease in shrimp culture. A series of standard operating procedure recommendations was presented including farm location and design, pond preparation, stocking strategies, water exchange, feed management, health monitoring, and disease exclusion.

2. Biosecurity in Shrimp Farming

Biosecurity, as it is being applied to shrimp aquaculture, may be defined as the practice of exclusion of specific pathogens from cultured aquatic stocks in broodstock facilities, hatcheries, and farms, or from entire regions or countries for the purpose of disease prevention (Lightner 2003). Lightner (2003), discussed ways of excluding pathogens from stock (i.e., post larvae and broodstock), especially through the use of quarantine and specific pathogen-free (SPF) certified stocks, and restricting imports of live and frozen shrimp. Excluding vectors and external sources of contamination and preventing internal cross contamination were suggested methods for excluding pathogens from hatcheries and farms. In the poultry industry, biosecurity has been defined as an essential group of tools for the prevention, control, and eradication of economically important infectious diseases. While biosecurity in this context may have many facets, central to its application in shrimp farming are the concepts of stock control and pathogen exclusion. This has been accomplished through the practice of stocking farms only with shrimp that are free of the diseases of concern into farms with controlled water sources. The latter issue of controlled water sources is being accomplished through better farm siting, farm design and water management through the use of such strategies as inland shrimp farming, "zero" water exchange, and the use of water treatment devices that remove potential vectors from the source water (Browdy et al. 2001). Horowitz and Horowitz (2003) described physical, chemical, and biological precautionary measures to be taken as well as a second line of defense against potential disease outbreaks. Physical measures are those that aim at preventing the intrusion of disease-carrying vectors to the farm site, and include physical barriers, water treatment, and quarantine. Chemical measures are those used to treat materials before they enter the facility.

Chlorination and ozonization are often used to treat incoming water, and iodine and chlorine are used to treat other potential vectors such as tools, footwear, and clothing. Biological measures include the use of SPF shrimp, which are readily available commercially. A second line of defense for the shrimp industry is to use specific pathogen-resistant shrimp, which, in addition to being disease-free, are resistant to specific diseases. Since shrimp do not develop a specific immune response, common immunostimulants, such as β-1-3 glucan, lipopolysaccharides, and peptidoglycans are used to improve the ability of the shrimp to prevent infection.

The pathogens WSSV and IHHNV are considered to have been introduced into the Americas from Asia with live shrimp or with frozen infected commodity shrimp (FAO 2003; Tang et al. 2003). Both WSSV and IHHNV have been demonstrated in wild penaeid shrimp in the Americas (Motte et al. 2003) and Asia (Fegan and Clifford 2001). The establishment of these and other pathogens in wild shrimp stocks in the Americas has changed the way shrimp are farmed. Gone are the days when broodstock and postlarvae could be collected from the wild without concern that they might be carrying disease. Also gone are the days when shrimp farms, in all but the most geographically isolated locations, could be designed and operated without a biosecurity program. In the decade following the emergence and spread of WSSV throughout Asia and into the Americas and the emergence and spread of TSV throughout the Americas and into Asia, the industry has begun to adopt a variety of biosecurity measures and programs as its best defense against these and other diseases. In some shrimp farming regions, the application of the principles of biosecurity has helped farms in those regions to reduce losses due to disease and to improve production (Fegan and Clifford 2001).

If a disease presents itself at a particular pond, effective biosecurity measures should prevent the complete loss of the crop and the spread of disease to other ponds. Lightner (2003) recommended an approach to eliminating pathogens at the stock level and partial disinfection at the facility level. To eliminate pathogens in post-larvae and broodstock, affected tanks and ponds should be depopulated, disinfected, and restocked with SPF shrimp. It may, however, be necessary to depopulate the entire stock and to fallow the entire facility if partial disinfection (using lime, chlorine, or drying) is not successful. Horowitz and Horowitz (2003) suggested providing better environmental and biological conditions to the infected population to increase its ability to resist diseases. They discussed the following steps: a) effect physical measures (increase aeration, control temperature, improve the feeding regime, remove sludge and organic matter, and treat wastewater) to improve the environmental conditions, b) effect chemical measures, including control of pH and salinity, reduction of ammonia and nitrite, and application of antibiotics, and c) to use effective biological measures, consisting mainly of the use of probiotics containing a mix of bacterial species to establish beneficial microbial communities under culture conditions.

2.1. Control of Shrimp Stocks

The single most important principle of biosecurity is stock control, which may be simply defined as the use of captive or domesticated stocks, cultured under controlled conditions, and which have been the subject of an active disease surveillance and control program (Lightner 2003). While numerous methods have been incorporated into the operational design and management of shrimp farms previously affected by TSV and WSSV to eradicate them and to insure that they are not reintroduced, none can be expected to provide much protection against crop losses in farms that use seed stock derived from wild stock sources. The use of only domesticated shrimp stocks that have a known history of being free of pathogens of concern can help to mitigate this risk. However, an SPF history comes only from a long-term captive breeding and disease surveillance program at a facility that has a fully functional and effective biosecurity plan (Fegan and Clifford 2001). The successful application of the SPF concept is dependent upon the absence of the pathogen(s) of concern in the stocks being reared (or that are present), on the availability of sensitive and accurate detection and diagnostic methods for the pathogen(s), and the presence of an effective barrier (i.e., facility design and geographic location, government mandated import restrictions, etc.) to prevent the introduction of the specific pathogen(s) intended to be excluded. The International Council for the Exploration of the Sea (ICES) Guidelines (Code of Practice to Reduce the Risks of Adverse Effects Arising from the Introduction on Nonindigenous Marine Species, 1973, as reviewed in Sindermann (1988, 1990) was followed for the development of these stocks (Table 2).

Original ICES Guidelines	Adapted to SPF Shrimp Development
1. Conduct comprehensive disease study in native habitat	1. Identify stock of interest (i.e., cultured or wild)
2. Transfer {founder stock} system in recipient area	2. Evaluate stock's healtlddisease history.
3. Maintain and study closed system population	3. Acquire and test samples for specific listed pathogens (SLPs) and pests.
4. Develop broodstock in closed system	4. Import and quarantine founder (F0) population;

	monitor F0 stock.
5. Grow isolated F1 individuals; destroyoriginal introductions	5. Produce F1 generation from F0 stock.
6. Introduce small lots to natural waters - continue disease study.	6. Culture F1 stock through criticmonitor general health and test for SLPs. al stage(s);
	7. If SLPs, pests, other significant pathologies are not detected, F-1 stock may be defined as SPF and released from quarantine.

Table 2. Recommended Steps in The ICES Guidelines for Risk Reduction in Aquatic Species Introductions

2.2. SPF and SPR Shrimp Stocks

Stock control requirements are being addressed in at least three ways. Where the industry has remained dependent upon wild (adult or postlarval = PL) stocks as its source of "seed," routine polymerase chain reaction (PCR) testing of broodstock and PLs for important pathogens like WSSV, TSV, YHV, and IHHNV has been adopted. Other components of the industry have chosen to attempt to develop and use specific pathogen resistant stocks (SPR) when pathogen exclusion from other sources such as the water supply is not a practical option (Lightner and Redman 1998). Nonetheless, the development and use of "specific pathogen free" (SPF) stocks is emerging as perhaps the best management strategy for stock control in farms, regions or countries with biosecurity programs. Although marketers commonly use the term "disease-free" to describe the live shrimp products in commerce, they are in reality marketing shrimp that are free of specific disease causing agents. Because nothing that is living is completely free of some sort of disease, such "disease free shrimp" are more correctly referred to as being free of certain specific pathogens or SPF.

The term SPF implies that the stock of interest is free of one or more specific pathogens (Fegan and Clifford 2001). To the USMSFP, SPF means the stock of interest has at least 2 yr of documented historical freedom of the disease agents listed on its working list of specific pathogens, that the stock has been cultured in biosecure facilities, and that the stock was either cultured under conditions where the listed disease agents would have produced recognizable disease if any were present and/or that the stock has been subjected to routine surveillance and testing for the listed pathogens. Those pathogens on the USMSFP SPF list have also met certain criteria including: 1) the pathogen(s) must be excludable; 2) adequate diagnostic and pathogen detection methods are available; and 3) the pathogen(s) poses significant threat of disease and production losses (Lotz et al. 1995; Lightner 2003), which are also among the criteria required for disease listing by the Office International des Epizooties, OIE **(**OIE 2003a, 2003b)

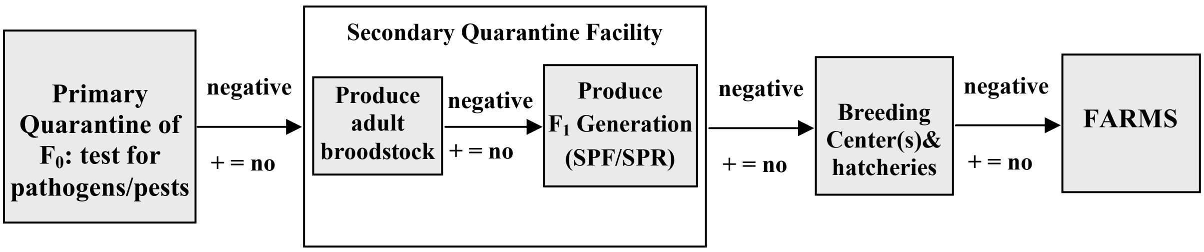

Figure 2. Schematic of The Steps in Developing Specific Pathogen Free Breeding Lines.

Specific pathogen free stocks developed by the USMSFP were developed in the spirit of the ICES Guidelines (Table 2; Fig. 1). To begin the process, each "SPF candidate population" of wild or cultured shrimpstocks of interest was identified. Samples of the stock were taken and tested using appropriate diagnostic and pathogen detection methods for the specific pathogens of concern. If none were found, a founder population (F,) of the "candidate SPF" stock was acquired and reared in primary quarantine. During primary quarantine, the F, stock was monitored for signs of disease, sampled, and tested periodically for specific pathogens. If any pathogens of concern were detected, the stock was destroyed. Those stocks that tested negative for pathogens of concern through primary quarantine (which ran from 30 d to as much as 1 yr for some stocks) were moved to a separate secondary quarantine facility for maturation, selection, mating, and production of a second (F,) generation. The F, stocks were maintained in quarantine for further testing for specific pathogens of concern. Those that tested negative were designated as SPF, and used to produce domesticated lines of SPF and "high health" shrimp (Wyban et al. 1992; Brock and Main 1994; Pruder et al. 1995; Lotz et al. 1995)

3. Major Diseases in Shrimp Culture

Farmed shrimp are infected by a range of disease agents including bacteria, viruses, fungi and protozoa. This overview focuses mainly on viral and bacterial diseases that have had a significant impact on the shrimp farming industry. There are a number of viruses that infect shrimp, but not all of them cause fatal diseases. Infectious hypodermal and hematopoietic necrosis virus (IHHNV) has been observed in most commercially farmed shrimp species. It appears to be harmless in some species such as the Asian tiger shrimp, *Penaeus monodon*, but malicious in others causing mortality and growth retardation. There are a number of other viruses such as the monodon baculovirus (MBV), hepatopancreatic parvo-like virus (HPV), and baculovirus penaei (BP) that damage the cells of the hepatopancreas and make the shrimp susceptible to other disease agents. It is believed that infection by these viruses causes a reduction in growth rates. As noted earlier, the three viruses that cause acutely fatal diseases in shrimp farming are the white spot syndrome virus (WSSV), yellow head virus (YHV) and Taura syndrome virus (TSV). All three viruses can cause extensive mortality within a few days of the first clinical signs of the disease. As discussed below, the severity of a viral disease typically subsides in about two years after the first incidence of the given disease. This apparently indicates some type of an adaptive response to the disease agent. However, the viruses are never completely eliminated. They resurface periodically, particularly at times of stress, to cause large-scale mortalities. Furthermore, growth retardation often coincides with viral infections resulting in economic losses.

The most important diseases of cultured penaeid shrimp, in terms of economic impact, in Asia, the Indo-Pacific, and the Americas have infectious agents as their cause (Tables 3, 4). Among the infectious diseases of cultured shrimp, certain viruscaused diseases stand out as the most significant. The impact of White Spot Disease (WSD) due to white spot syndrome virus (WSSV) has been particularly noteworthy. Rosenberry (2001) estimated that disease due to WSSV "robbed the industry" of approximately 200,000 MT of production in 2000 worth more than $1 billion. The viral disease pandemics caused by WSSV and Taura Syndrome Virus (TSV) that began in 1992 and caused billions in lost revenue have forever changed the shrimp farming industry (Table 1; Lightner 2005). The social and economic impacts of the pandemics caused by these pathogens in countries in which shrimp farming constitutes a significant industry have been profound. In the wake of the viral pandemics the shrimp culture industry has sought ways to restore the industry's levels of production to the "pre-virus" years. The application of biosecurity to shrimp farming is central to those efforts. Some of the most important diseases (and their etiological agents) were once limited in distribution to either the Western or Eastern Hemisphere and many of the most significant shrimp pathogens were moved from the regions where they initially appeared to new regions even before the "new" pathogen had been recognized, named, proven to cause the disease, and before reliable diagnostic methods were developed. The diseases, due to the shrimp viruses IHHNV (infectious hypodermal and hematopoietic necrosis virus), TSV, and WSSV, were all transferred with live shrimp stocks from country to country and from one continent to another well before their etiology was understood (Lightner 2003).

Viral diseases	Bacterial and fungal diseases	Other diseases
White Spot Syndrome Virus	Vibriosis:	Epicommensals and parasites:
Yellow head Virus group	-septic HP necrosis	-*Leucothrix mucor*
Taura Syndrome Virus	-hatchery vibriosis	-peritrich protozoans
MBV group	-luminescent vibrio	-gregarines
IHHNV	Other bacteria:	-microsporidians
HPV group	-Rickettsia	Nutritional imbalances
RE0 group	Fungal:	Toxic syndromes
	-Larval mycosis	and environmental extremes
	-Fusariosis	

Table 3. Major Diseases of IndoPacific and East Asian Penaeid Shrimp (Lightner, 2005)

Viral diseases	Bacterial and fungal diseases	Other diseases
White Spot Syndrome Virus	Vibriosis:	Epicommensals and parasites:
Taura Syndrome Virus	-Sindrome Gaviota”	-*Leucothrix mucor*
IHHNV	-hatchery vibriosis	-peritrich protozoans
BP group	-luminescent vibrio	-gregarines
HPV group	-shell disease	-microsporidians
IMNV	-septic HP necrosis	Nutritional imbalances
RE0 III	Other bacteria:	Toxic syndromes
LOVV	-NHP bacterium	and environmental extremes
RPS	Fungal:	Zoea II syndrome
	-Larval Mycosis	
	-Fusariosis	

Table 4. Major Diseases of The American Penaeids **(**Lightner, 2005)

3.1. Yellow Head Virus

Yellow head virus was first reported in Thailand in 1991. A related virus called Gill Associated Virus (GAV) was reported from Australia in 1996. Yellow head virus caused severe disease outbreaks in Thailand until 1994. The disease typically occurs in juveniles or sub-adults. A spurt in feed consumption followed by loss in appetite, lethargy and erratic swimming are the gross signs first observed. Pale yellow coloration of the gills and cephalothorax is often noted. Mortalities start within a few days and can reach as high as 100% in 3-5 days after the gross signs are observed. Sporadic disease outbreaks still occur, mainly in Asia, but the mortalities are less severe than past **(**Lightner, 2005).

3.2. White Spot Syndrome Virus

White spot syndrome virus was first reported in Japan in 1993, although it might have originated in China. This virus has caused the most damage to the shrimp farming industry. It spread to almost all shrimp farming countries of Asia in a span of three years. It was reported in the United States in 1995, and spread to Central and South American countries in a span of four years. Almost all shrimp species have been affected. Further, most crustaceans can be infected with the virus and become carriers. The characteristic feature of WSSV infection is the presence of white spots or patches under the carapace, although this may not be present in all diseased shrimp. Soon after showing general signs of ill-health such as reduced feed intake and erratic swimming, mortalities occur. Mortality up to 100% may occur within seven days after the first sign of problems. The infection may occur at any stage in the life cycle of the shrimp. Stressful conditions such as sudden changes in environmental conditions, particularly lowered temperatures, trigger disease. Frequent WSSV disease outbreaks still occur worldwide, but there are more and more cases of shrimp populations escaping severe mortality in spite of WSSV infections **(**Lightner, 2005; Wyaban, 2009).

3.3. Taura Syndrome Virus

Taura syndrome was reported first in 1992 in Ecuador. Presence of TSV was reported in 1995. TSV spread throughout the Pacific coast of Central and South America and mainly affected the Pacifc White Shrimp, P. vannamei. Distinguishable gross signs of TSV are pale reddish coloration of the body, red tail fans, necrosis of the cuticular epithelium, and soft shells. Mortality during molting is common. Sometimes, the shrimp are affected only transitionally: gross signs of the disease may occur, but the shrimp may behave and feed normally. While TSV still occurs, the catastrophic losses suffered in the early years of TSV infection are less common now.

3.4. Vibriosis

Infection by *Vibrio* spp. is the most common bacterial disease problem in shrimp culture. *Vibrio* spp. are ubiquitous and naturally present in most aquatic ecosystems. Infections occur when shrimp are stressed or unhealthy. Infections may also occur as a result of high concentrations of Vibrio spp. in the culture system. Some species and strains, particularly *V. harveyi*, are more infectious than others. Shell lesions, black coloration of gills and discoloration of shells occur as a result of vibriosis. Severe mortalities may follow acute infections.

Chronic infections may result in erratic swimming behavior, abnormal coloration, external fouling and less severe, but sustained mortalities (Lightner 2003, 2005).

4. Biosecurity Protocol for Shrimp Farming

Biosecurity protocol for shrimp farming included three main management strategies focusing on: (a) pond bottom preparation and water management prior to stocking, (b) seed selection and stocking, and (c) post-stocking management (Clifford and Cook, 2002; Wyaban 2009).

4.1. Pond Bottom Preparation and Water Management Prior to Stocking

- Removal of bottom sludge, Particularly in ponds stocking higher densities (up to 8 PL/m^2).
- Plowing on wet soil if the sludge has not been removed completely.
- Use of lime in pond preparation.
- Disinfection of pond water
- Fertilization reduces the risk of disease outbreak in lower stocking density farms.
- Water filtration using twin bag filters of 250 μm mesh size.
- Water conditioning for 10–15 days before stocking.

4.2. Seed Selection and Stocking

- Uniform size and color post-larvae (PLs), actively swimming against the water current. Stocking of poor quality of seed (less active, more mortality during transportation and size of less than 16 mm in case of nursery reared juveniles increases the risk of shrimp disease outbreak.
- Stocking Pathogen Free (SPF) Larvae (SPF shrimp stocks are avaible in some countries)
- Longer transport time (>6 hours) of the seed from hatchery or nursery to the pond also increases the likelihood of a subsequent disease outbreak.
- Weak PL elimination before stocking using formalin (100 ppm) stress for 15–20 minutes in continuously aerated water.
- On-farm nursery rearing of PLs for 15–20 days.
- Stocking into green water and avoiding transparent water during stocking.

4.3. Post Stocking Management

- Perform a visual inspection of the pond on a daily basis.
- Sampling for growth and survival
- Monitor shrimp health and the appearance of disease using animals collected in the weekly growth and population samples
- Gut content and their color.

In general, 80% or more of the shrimp randomly sampled from a healthy, well nourished, recently fed pond should display the intestinal tract (mid-gut) running the length of the tail to be full of food. In addition to quantifying gut fullness and using it to detect under-feeding or predict the onset of disease, the color of the shrimp's gut contents can also be very informative (Table 5).

Gut Content Color	Probable Food Item	Probable Cause(S)
Black, dark brown	Benthic detritus, sediment	Under-feeding; inadequate feeding
Light or golden brown	Manufactured feed	Normal
Red, pinkish	Cannibalized body parts from dead shrimp	Disease event in pond
Green	Benthic algae	Under-feeding
Pale, whitish	None (disease condition)	Gregarines, or some other disease

Table 5. The Color of The Shrimp's Gut Contents and Predict The Onset of Disease

- Use of water reservoirs, and 10–15 days aging before use in grow out ponds.

- Water filtration-ponds using water filter nets of fine mesh have better production.
- Aeration-ponds using aeration tend to have higher shrimp production.
- High salinity and pH (>8.5) have an affect on risk of disease outbreaks
- Green water (pond color) ponds have better production and lower risk of disease outbreak.
- Clear water with bentic and filamentous algae lead to lower production.
- Regular use of agricultural lime, especially after water exchange and rain.
- No use of any harmful/banned chemicals.
- Use of feed check trays to ensure feeding based on shrimp demand.
- Feeding across the pond using boat/floating device to avoid local waste accumulation.
- Regular removal of benthic algae.
- Water exchanges only during critical periods.
- Weekly checking of pond bottom mud for blackish organic waste accumulation and unpleasant odor.
- Regular shrimp health checks, and weekly health and growth monitoring using a cast net.
- Removal and safe disposal of sick or dead shrimp.
- Emergency harvesting after proper decision-making.
- No draining or abandoning of disease-affected stock

4.4. A Biosecure Farm Model

A drawing showing a 100-ha farm comprised of fifty 2.0-ha ponds with a centralized pumping and ozone contact facility is presented in Fig. 2. The gross farm area of 182 ha includes 18 ha of pond surface area committed to a series of sedimentation, aeration, and retention ponds (Schuur, 2003).

The mechanical area includes a forebay or pumping basin that is accessed by gates for selecting water supply from either the treatment pond in a recirculation mode, or the raw water source in an exchange replenishment mode. From the forebay the water is pumped through an ozone injection device and then through a contact channel with sufficient volume to allow a minimum of 10 min retention time in a maximum flow situation. The effluent from the contact chamber is discharged into the primary supply channel that encircles the entire perimeter of the farm. The pump lift from the forebay is about 3 m in order to provide a sufficient hydraulic gradient for gravity distribution by the supply channel network to all of the ponds. The supply channel has cross-sectional area sufficient to carry peak flows to the furthermost ponds with only a minor loss of head.

The nearly square configuration is optimal for reducing the farm perimeter to a minimum for biosecurity purposes. There is an all-weather dike-top roadway outside the supply channel encircling the farm perimeter of roughly 5.4 km. For security purposes the farm perimeter can be circuited in about 10 min at a modest vehicle speed. The external roadway traffic naturally inhibits plant growth and cover for terrestrial crabs that might seek access. A further barrier to intrusion inside the roadway is a short fence constructed with metal or plastic sheet material embedded in the ground and suspended by stakes. This barrier is a common feature of many intensive farms in combination with lime and pesticide application. The roadway also provides a 'killing zone' before the barrier where any potential carriers can be detected and eliminated.

About 18% of the production pond surface is allocated to serial treatment ponds that provide sedimentation, aeration, and retention in order to improve water quality within the farm. The two sedimentation areas can be used in series or parallel flow, or in some cases one at time while the other is being dried and reconditioned. Additional retention time improves the water quality by providing additional area for autotrophic and/or heterotrophic processes to absorb and digest ammonia and organic matter. Mechanical aeration applied in the series provides more efficient oxygen transfer efficiency to the farm as a whole. This is due to the additional driving force provided by the difference between oxygen-depleted water from sedimentation ponds and the effluent concentration at the discharge of the aeration lagoon.

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