Case Study of the Outbreak of White Spot Syndrome Virus at Shrimp Farms in Mozambique and Madagascar: Impacts and Management Recommendations

This report, prepared by the Responsible Aquaculture Foundation and funded by the World Bank, is Case Study #3 of a series entitled, "Lessons Learned in Aquaculture Disease Management".

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1 ABBREVIATIONS AND ACRONYMS

AAH	Aquatic Animal Health
AFD	Agence Française de Développement (French Development Agency)
APCM	Associação de Produtores Camarão de Moçambique (Mozambique Association of Shrimp Producers)
AQUAVETPLAN	Australian Aquatic Veterinary Emergency Plan
ASH	Autorité Sanitaire Halieutique (Aquatic Animal Health Authority of Madagascar)
CB-UEM	Centro de Biotecnologia da Universidade Eduardo Mondlane (Center for Biotechnology at Eduardo Mondlane University) - Maputo, Mozambique
DAFF	Department of Agriculture, Fisheries, and Forestry of Australia
DIRAQUA	Direction de l'Aquaculture (Directorate of Aquaculture, Madagascar Ministry of Fisheries and Marine Resources)
FAO	Food and Agriculture Organization of the United Nations
GAA	Global Aquaculture Alliance
GAPCM	Groupement des Aquaculteurs et Pêcheurs de Crevettes de Madagascar (Madagascar Shrimp Producer's Association)
IIP	Instituto Nacional de Investigação Pesqueira (National Fisheries Research Institute of Mozambique) - Mozambique
INAQUA	Instituto Nacional de Desenvolvimento da Aquacultura (National Institute of Aquaculture Development) - Mozambique
INIP	Instituto Nacional de Inspecção de Pescado (Mozambique National Intitute for Fish Inspection)
LES	Laboratoire d'Epidémio Surveillance (Laboratory for Epidemiological Surveillance) Antananarivo, Madagascar
LGA	Oso Farming – Les Gambas de l'Ankarana , Madagascar
MPRH	Ministere de la Pêche et des Ressources Halieutiques (Madagascar Ministry of Fisheries and Marine Resources)
OIE	Office International des Epizooties (World Organization for Animal Health)
PCR	Polymerase Chain Reaction (DNA amplification and identification technique)

PESAAQUA	Plano De Sanidade Dos Animais Aquáticos (Mozambique Aquatic Animal Health Plan)
RAF	Responsible Aquaculture Foundation
RLB	Rickettsia-like Bacteria
SPF	Specific Pathogen Free
UAZ	University of Arizona Aquatic Animal Health Laboratory
UEM	Universidade Eduardo Mondlane in Maputo, Mozambique
WSD	White Spot Disease
WSSV	White Spot Syndrome Virus

2 EXECUTIVE SUMMARY

White Spot Disease (WSD), caused by the White Spot Syndrome Virus (WSSV) is one of the most contagious viral diseases of penaeid shrimp and has had a multi-billion dollar economic impact since it first appeared in 1992 (Lightner et al. 2012). Until 2011 the shrimp farming industry in Madagascar and Mozambique remained free from the disease. The situation changed in September, 2011, when a shrimp farm in Mozambique experienced outbreaks of WSD at both its farm in Quelimane and its hatchery in Nacala. Surveillance studies subsequently showed that WSSV was widely distributed in wild shrimp populations along the Mozambican coast. Continued outbreaks of WSD in 2012 limited shrimp production to 41.4 MT, compared to 667 MT in the year before WSD first struck in Mozambique. The first case of WSD was reported in Madagascar in April, 2012, when a shrimp farm near Morondava began experiencing WSSV-related mortalities. This farm was shut down by the Competent Authority and remains closed one year later. In September and October of 2012 two more farms in Madagascar performed emergency harvests after detecting shrimp infected with WSSV.

It is not clear exactly how WSSV was introduced into the area, but genotypic analyses show the WSSV virus in the Mozambique Channel is genetically identical to a unique strain of WSSV that caused an outbreak of WSD in Saudi Arabia in January, 2011. It is possible that the WSSV from Saudi Arabia was transported to the Mozambique Channel either in ship ballast water or in infected shrimp from Saudi Arabia processed in Mozambique and Madagascar. Ocean currents may also have transported the WSSV into the area. The widespread prevalence of WSSV in wild populations on the Mozambican coast suggests that WSSV first became established in wild populations and then spread from the wild populations to the farms. There is no evidence to suggest that WSSV-infected broodstock or post-larvae were imported by shrimp growers from other areas.

Two common production practices used by farms in the region dramatically increased their vulnerability to WSSV infection: the use of unscreened wild broodstock in the hatcheries, and the reliance on high rates of water exchange to maintain water quality in the shrimp ponds. The lack of ongoing disease surveillance programs in either country prior to the outbreaks was another factor that contributed to the vulnerability of the shrimp farms. On the national level, there were problems in each country that limited the effectiveness of the governmental response to the outbreak. Prior to the WSSV outbreak neither Mozambique nor Madagascar had comprehensive aquatic animal health policies, or had functional institutions in place to provide coordinated responses to the crisis. Mozambique lacks legislation providing a regulatory framework for aquatic animal health, and there continues to be debate about which agency should serve as the Competent Authority. The lack of a national reference laboratory for aquatic animal health resulted in inadequate WSSV surveillance and PCR testing of broodstock prior to the outbreak. Inadequate funding of the government agencies responsible for aquatic animal health regulation resulted in the cancellation of a disease surveillance program only months before the outbreak occurred, and has limited the ability of the Competent Authority to form an effective response to the outbreak.

Recovery from the WSSV crisis will require several changes at the farm level. The single most important change is to eliminate the use of wild broodstock. This will require the establishment of breeding programs to develop Specific Pathogen Free (SPF) broodstock. As a long term strategy, SPF broodstock should be selected for resistance to WSSV. This is a time consuming and expensive process that may be beyond the means of individual farms to carry out on their own. The Expert Team recommends the establishment of a regional breeding center to produce SPF *Penaeus monodon* broodstock that are genetically selected for resistance to WSSV. The second most important change that farms can make is to reduce or eliminate their dependence on water exchange. The most effective way of accomplishing this is to install aeration systems in the ponds. Research has shown that 500 kg of shrimp can be supported without water exchange for each KW of aeration provided. The installation of 5 – 10 KW of aeration per hectare allows for modest increases in production rates that more than offset the installation and operating costs. Many of the shrimp farms in the region market their shrimp as organically grown. Unfortunately, the substitution of aeration for water exchange is a strategy that is incompatible with organic shrimp production standards. Biosecurity improvements will be needed to reduce the risk of horizontal transmission of WSSV. These improvements might include avoiding production during periods of low water temperature, improved filtration of incoming water, installation of crab fences and bird netting, and draining of water supply canals to eliminate WSSV vector populations of crabs and shrimp

At the national level the regulatory framework needs to be upgraded to provide comprehensive aquatic animal health (AAH) policies, and adequately funded regulatory agencies and national reference laboratories. National AAH plans should be developed to clearly identify the role of each stakeholder in a national biosecurity program and the strategies for responding to disease outbreaks. Disease surveillance programs consistent with OIE standards should be set up and funded nationally. There is a strong need for capacity building in the public sector with respect to aquatic animal health management. Priority should be given to promoting collaboration between the producer associations and the government ministries in the development of national biosecurity policies and programs.

The national AAH plans of Mozambique and Madagascar should be integrated to form a Regional AAH plan. Regular meetings between stakeholder groups of both countries should be scheduled to allow for the sharing of information and the discussion of cooperative projects, such as the development of a regional breeding center and the sharing of surveillance data.

3 TERMS OF REFERENCE

3.1 Background and Objectives

White spot disease (WSD) is a contagious viral disease of penaeid shrimp and is caused by the white spot syndrome virus (WSSV). WSSV was first reported from both Taiwan and the People's Republic of China in 1992. Since then, the disease has spread throughout Southeast Asia, India, Bangladesh, Asia, North, South and Central America. The economic losses due to WSSV have been devastating, totaling at least 8 billion dollars since 1992.

The shrimp industries in Mozambique and Madagascar remained free from WSD until September, 2011, when a shrimp farm in Quelimane, Mozambique experienced an outbreak of WSD. Since then, the shrimp industry in Mozambique has been virtually shut down. Eight months later, in May, 2012, there was an outbreak of WSD in Madagascar at a farm north of Morondava. This farm has remained out of service since the outbreak occurred. Within months, WSSV was diagnosed at two other Malagasy shrimp farms, forcing them to perform emergency harvests. After cleanup one of these farms was able to resume production while the other is operating only on a very small scale.

This report is the third case study of regional epizootic disease outbreaks affecting the aquaculture industry that has been sponsored by the World Bank and conducted by RAF. The RAF brought together an international team of experts to visit Mozambique and Madagascar to study the events surrounding the WSD outbreak. The objective was to develop a better understanding of factors that may have contributed to the outbreak and also to recommend actions the stakeholders in the Mozambique Channel shrimp industry can take to help the industry recover. According to the terms of reference, the aim of the study is to:

1) Identify needed changes in production systems and management strategies among private sector shrimp farm operators
2) Recommend needed capacity building among relevant public sector agencies
3) Identify needed regional cooperation and coordination in shrimp disease management
4) Estimate the cost and evaluate the feasibility of these interventions

Ultimately, the output of this study will be used to develop a fundable plan for recovery and growth of the shrimp farming industry in Madagascar, Mozambique (and Tanzania) following the outbreak of WSSV. The improved practices will also reduce the risk of future outbreaks due to other diseases.

3.2 Methodology

The international team of experts assembled by the RAF visited Mozambique and Madagascar on May 11-22, 2013. In each country the team interviewed representatives from shrimp farms, shrimp producer associations, and government ministries (Appendix 1) to understand the chronology of the White Spot crisis (Appendix 2 and 3). The team also visited the Sol y Mar farm in Mozambique and the Aqualma farm in Madagascar. On May 21 and May 22, a regional workshop was held in Antananarivo in which stakeholders from Mozambique and Madagascar and members of the RAF Expert Team presented their perspectives on the White Spot crisis.

3.3 Expert Team

Members of the RAF Expert Team included:

George W. Chamberlain - team leader
George Chamberlain received his Ph.D. in aquaculture from Texas A&M. University, USA. In 1990 he joined Ralston Purina Company, where he directed its international aquaculture program. In 1998, he joined Monsanto, where he directed its marine shrimp program on genetic selection, soy-based feeds, and sustainable pond systems. In 1999, he and Ken Morrison developed Black Tiger Aquaculture, a successful 170-ha integrated shrimp farm in Malaysia that had failed due to WSSV under previous ownership. They managed WSSV through development of an SPF population of *P. monodon*, family-based breeding, all-in/all-out larval rearing, and zero water exchange ponds. In 2004, they established Integrated Aquaculture International (later re-branded as iAqua), a breeding and technology company with white shrimp operations in Hawaii and black tiger shrimp operations in Brunei. Chamberlain served as President of the World Aquaculture Society in 1996. In 1997, he led the formation of the Global Aquaculture Alliance, an organization dedicated to the sustainability of aquaculture. In 2010, he assisted in the formation of the Responsible Aquaculture Foundation. He continues to serve as President of GAA, Director of iAqua, and Director and RAF.

Donald V. Lightner – shrimp pathologist
Professor Lightner's career in diseases of farmed aquatic animals spans more than four decades. After completing his M.S. and Ph.D. degrees in Fish Pathology in 1971, he began the first shrimp pathology program in the USA at the NMFS Laboratory in Galveston, Texas. In 1975 he accepted a research position at the University of Arizona where he applied shrimp disease management methods to a prototype super-intensive system. Since 1986, he has been a professor of Veterinary Science and Microbiology. He has authored or coauthored more than 500 publications and presentations on pathogen detection, disease diagnosis and pathobiology in penaeid shrimp. He has trained over 20 graduate students, and 1500 professionals from 59 countries have received formal training in UAZ shrimp pathology and diagnostic methods in 27

Shrimp Pathology Short Courses and 39 special international workshops. His laboratory became an OIE Reference Laboratory in 1993. He has served as a member or adviser to the Aquatic Animal Health Standards Commission for 12 years and contributed to the current editions of the Aquatic Animal Health Code and Manual of Diagnostic Tests for Aquatic Animals.

Richard (Dick) Towner – shrimp geneticist

Dick Towner is a genetics consultant working with major trout, shrimp, and tilapia companies to improve their stocks through genetic selection. He did his undergraduate work at Colorado State University and received his M.S. and Ph.D. degrees from the University of Wisconsin. Prior to starting his consulting company, Towner worked for a poultry breeding company, H&N, for 22 years. Positions he held at H&N included geneticist for the egg type breeding program, head geneticist for the broiler research program and Director of Genetics Research. From 1978 through 1999, Towner had an affiliate faculty appointment in the School of Fisheries at the University of Washington. Towner has extensive experience improving poultry, shrimp and fish aquaculture species through genetic selection.

Peter M. Van Wyk – aquaculture economist

Peter Van Wyk received an M.S. degree in Aquatic and Population Ecology from the University of California, Santa Barbara, in 1981 and a Master of Aquaculture degree from Auburn University in 1986. While at Auburn, Van Wyk trained as an aquaculture economist, manager, and analyst. During his 30 year career in aquaculture Van Wyk has designed, built, and managed shrimp hatcheries and growout facilities in the U.S., Latin America, and Malaysia. Van Wyk has spent much of the last 15 years developing technology to rear shrimp in biosecure indoor production facilities. As a project planner, he has used his expertise in production management, engineering, and aquacultural economics to develop sophisticated bioeconomic spreadsheet models to evaluate how changes in production strategies and performance parameters affect project costs and profitability. He has published several papers on the economics of recirculating shrimp production systems.

Marcos Villarreal – expert on WSSV management in Central America

Marcos Villarreal has a B.S. degree in Biology and a Master’s in Business Administration. He started his career in shrimp aquaculture in 1986 as Manager of the Nursery System at Agromarina de Panamá S.A. (Ralston Purina). He became its Operations Manager in 1994. In 1997, he was hired as General Manager of Industrias Acuimar S.A. In 2005, he moved to Indian Ocean Aquaculture in Pemba, Mozambique. In his role as Assistant General Manager, he managed the shrimp hatchery and assisted the GM in processing plant operations. From 2006 to 2012, Villarreal served as Acting General Manager of Arabian Shrimp Company in Gizan, Saudi Arabia. For the last year, Villarreal has served as General Manager of Altrix de Panama, S.A. (Grupo Calesa/CAMACO). He has also served as President of the Panamanian Shrimp Growers Association from 1995 to 1997.

Noriaki Akazawa – expert on WSSV management in Malaysia
Noriaki Akazawa graduated from Hokkaido University in Japan where he majored in Microbiology and Fish Diseases. From 1983 to 1998 he worked as a seafood purchaser and later as a seafood processing plant manager in Japan, Bali, and Vancouver. In 1999, Akazawa joined Song Cheng Enterprises Sdn. Bhd., a Malaysian shrimp farm operated by the Skylark Japan restaurant chain as Culturing and Processing Director. In 2000, he was promoted to Managing Director. Song Cheng was bought by Agrobest Sdn. Bhd. and Mr. Akazawa stayed on as Managing Director. He has now been managing the shrimp farm and processing plant for 15 years and has increased shrimp production from a few hundred tons to more than 11,000 mt, despite the presence of a variety of shrimp diseases including WSSV, HPV, MBV, and MSGS. In early 2011, Agrobest was hit by a new disease called Early Mortality Syndrome, which has swept through China, Vietnam, Malaysia, and Thailand. Akazawa has become a world leader in managing this disease and is completing his Ph.D. degree at Kinki University in Japan based on this research.

Adolfo Alvial - expert in public/private partnerships from the Chilean salmon industry
Adolfo Alvial is a Marine Biologist from the University of Chile, who received a Masters in Oceanography from Oregon State University and an MBA from Universidade Adolfo Ibáñez – Chile. He was Professor and Secretary General at the University of Chile – Iquique, where he conducted research on pelagic fisheries and El Niño. In 1987 he joined Fundación Chile where he was Director of Aquaculture. In that position he lead several projects directed to develop new business opportunities for the country such as turbot, abalone, and hake. In 2002 Alvial was appointed as General Manager of the Technological Institute of salmon, the technical branch of the Chilean salmon association. Between 2007 and 2010 Alvial was Technical Director of Marine Harvest of Chile. He has been President of the Business Incubator INER Los Lagos since 2006 and is presently General Director (Comandante) and co-owner of his own consulting company, Adolfo Alvial Consultancies. Alvial has participated in several initiatives to develop standards for aquaculture, such as BAP salmon standards for the GAA and greenhouse gas emission standards in the seafood industry for FAO and BSI. Alvial served as team leader for the first World Bank/RAF case study of the recovery of the Chilean salmon industry after the ISA epizootic.

4 MOZAMBIQUE CHANNEL SHRIMP INDUSTRY

4.1 General Description

Shrimp farming on the Mozambique Channel began in 1989 with the construction of a pilot-scale shrimp farm in Madagascar that later developed into Aqualma, a large integrated operation that stimulated regional development of the sector (Le Groumellec, et al. 2011). The industry is composed of a small number of commercial shrimp farms ranging in size from 174 – 800 Ha. There are currently 2 industrial shrimp farms operating in Mozambique with a total production area of 534 Ha, and 5 industrial shrimp farms in Madagascar with a total production area of 2,300 Ha. Unlike many regions where shrimp farms are highly concentrated in a small area, the farms in Madagascar and Mozambique are widely separated geographically.

Shrimp farming in the region is based primarily on the rearing of black tiger shrimp (*Penaeus monodon*) in semi-intensive earthen ponds of 2-10 Ha. Most ponds are stocked at relatively low densities (7 -12 shrimp/m2) with target production levels of 1.5 – 2.2 tons/Ha (Le Groumellec et al. 2011). The ponds are managed as flow-through systems, with water exchange rates as high as 20% per day. Little aeration is employed. Pond temperatures generally remain above 28°C from October – April, but during the colder winter months (June – August) temperatures can drop as low as 19°C. Because of this, some farms in the region harvest before the coldest months of the year, and produce just two crops per year. However, the largest farms in Madagascar operate year round, producing 2.3 – 2.5 crops per year. The summer months of December – April are the wettest months, and pond salinities often drop below 10 ppt during this period. The winter months are the driest months of the year, and pond salinities in some areas rise above 35 ppt.

Production costs for shrimp farms in Madagascar and Mozambique are higher than in most other areas of the world due to the isolation of the individual farms and the logistics of doing business in remote areas (Le Groumellec et al. 2011). In Madagascar, all electricity must be generated on site and the cost per kw-hr is high. Because of the high production costs, the product must be sold at premium prices. The shrimp farms in the Mozambique Channel region focus on producing high quality head-on shrimp for the European market. Many of the companies market their shrimp as organic or environmentally sustainable products. The farms in the region have successfully developed a unique identity for Madagascar and Mozambique shrimp in the European markets as a premium quality, environmentally sustainable product. The farms in this region are all vertically integrated, each with its own hatchery and processing plant.

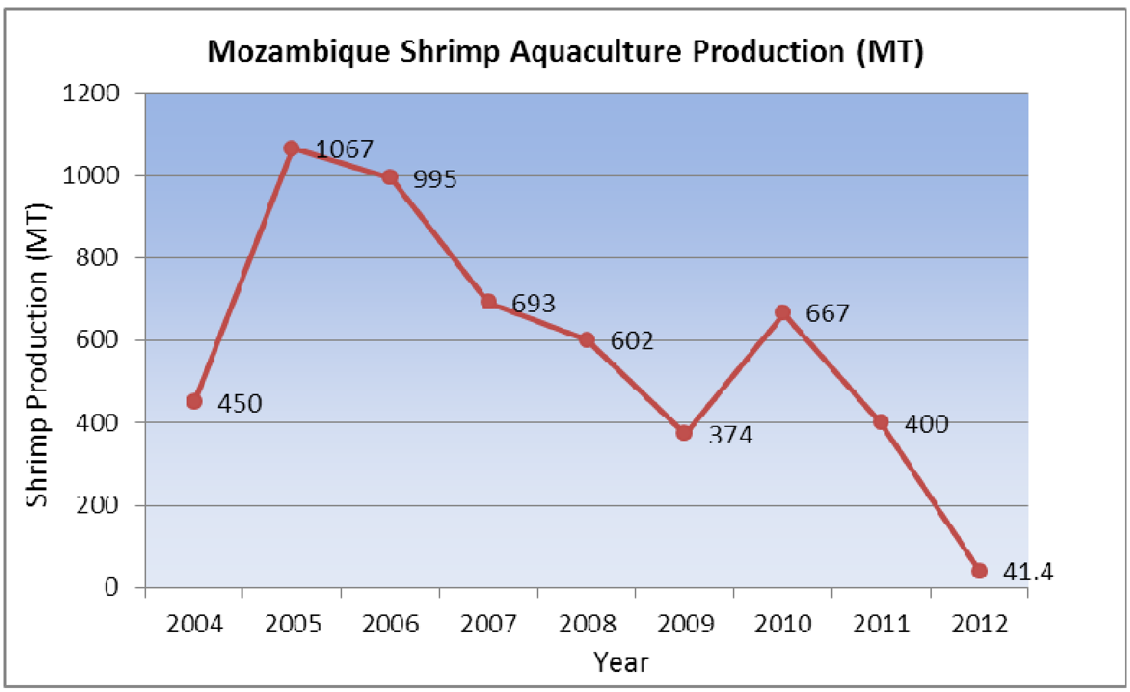
By virtue of its isolation, the Mozambique Channel shrimp industry was the only major shrimp farming region in the world that had never had a diagnosed case of any OIE listed shrimp diseases prior to 2011.

4.2 Mozambique Shrimp Industry

4.2.1 Mozambique Shrimp Farms

The shrimp industry in Mozambique is small, with only two industrial shrimp farms currently in operation. The total production area in these two farms is only 534 Ha. However, there is significant potential for further development. The Ministry of Fisheries recently surveyed coastal land in the country and concluded that there are 30,000 Ha suitable for development of industrial shrimp farms (Omar & Hecht, 2011).

The first industrial shrimp farm in Mozambique was built in 1994. By 2004 there were three large shrimp farms operating in the country. Production from these farms (Figure 1) peaked in 2006 at 1,067 MT/year (Blanc, 2012). In 2007 the largest farm, Indian Ocean Aquaculture, shut down due to technical and financial difficulties. Low market prices limited production output in 2008 and 2009 and one of the remaining shrimp farms suspended production for a period in 2010, when the farm was sold. Productivity was beginning to increase when WSSV hit the country in August, 2011. In 2012, aquaculture shrimp production in Mozambique dropped to 41.4 MT.



2001).**Figure 1:** Mozambique Shrimp Aquaculture Production, 2004 – 2012 (Omar, 2013)

There are currently two active commercial shrimp farms in Mozambique. The largest farm (350 Ha) is Aquapesca, located near the town of Quelimane in Zambezia Province (Figure 2). This is also the oldest farm in Mozambique and has been operating since 1994. The growout ponds at Aquapesca are mostly 10 ha earthen ponds that are stocked at low densities (7/m2). There are two production cycles per year, with a two month dry-out period from June – July. Annual production prior to 2011 was usually between 600-800 MT/yr. Post-larvae for stocking the farm are produced at their hatchery facility in Nacala. The majority of the broodstock for this hatchery are wild-caught. Aquapesca markets their shrimp as a head-on organic product, and the organic standards, established by the French AB-Bio label and EU Regulation 710-2009, require that within three years of obtaining organic certification, 50% of the broodstock must be domesticated. To comply with this requirement, Aquapesca began in 2009 selecting fast-growing shrimp from their growout ponds to use as broodstock, since there are no domesticated Specific Pathogen Free broodstock available in Mozambique. However, they continued to obtain a minority of their broodstock from the wild.

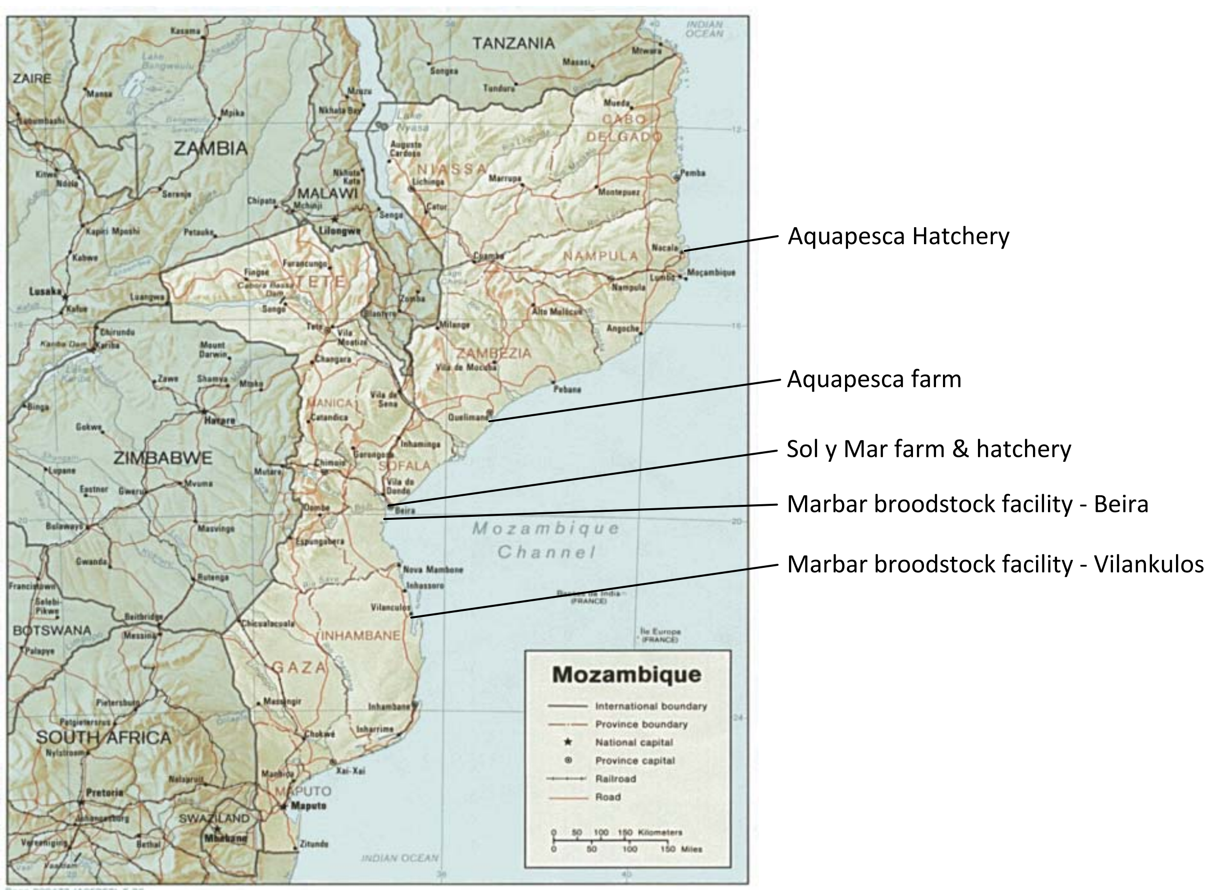


Figure 2: Location of shrimp aquaculture facilities in Mozambique

Prior to the WSSV outbreak in 2011, the Aquapesca risk management plan called for each batch of postlarvae stocked at the farm to be PCR tested for OIE listed viruses at PL15. Pleopod samples were preserved in 95% ethanol and submitted to the Centro de Biotechnologia da Universidade Eduardo Mondlane in Maputo and PCR tested for WSSV, MBV, YHV/GAV, TSV, IMNV, and IHHNV. Aquapesca also tested 30% of the broodstock brought into their hatchery.

The other industrial shrimp farm in Mozambique is Sol y Mar, located near Beira. This farm consists of 58 3-Ha growout ponds and two large reservoir ponds (100 ha total area). Like Aquapesca, the Sol y Mar farm is stocked at low density (7-10/Ha). The facility includes a hatchery that is operated when PLs are needed for stocking. The broodstock are wild-caught. Prior to 2010, the Sol y Mar farm was operated continuously, achieving 2.5 production cycles per year. In 2010 the farm was shut down and put up for sale. It was purchased by a Chinese company and was undergoing renovations when the outbreak of White Spot Disease (WSD) occurred at the Aquapesca facility in September, 2011.

4.2.2 Marbar Lda.

Marbar Lda. is a company based in Vilankulos that specializes in supplying wild *P. monodon* to shrimp hatcheries for use as broodstock. Marbar, which has been in operation since 1997, collects wild broodstock from several locations along the Mozambique coast. Marbar has a multi-step process for acclimating broodstock and preparing them for shipment to the hatcheries. Adult size shrimp are collected either from Beira in the north or Vilankulos in the south. After capture, the broodstock are held in a small scale quarantine system for several days near the collection site. If no abnormalities or unusual mortality is noted, the shrimp are then moved to one of two recirculating conditioning facilities, either in Beira or Vilankulos. In the conditioning facility, the shrimp are treated with antibiotics and fed with fresh clams and squid. Prior to 2012, samples were occasionally sent to UAZ for histology or PCR analyses. In 2012, Marbar began conducting their own PCR analyses, testing for WSSV, MBV, and HPV. Only a small percentage of the animals collected are tested, however, due to the high costs associated with the testing procedure. The company relies primarily on a stress-testing procedure to screen for healthy animals. Between 2009 and 2012 Marbar collected and sold slightly more than 12,000 *P. monodon* to hatcheries for use as broodstock. While the large majority of these shrimp were sold to hatcheries in Asia (mostly in Vietnam and Malaysia), about 12% of their sales were to shrimp hatcheries in Mozambique.

4.2.3 Shrimp Producers' Association of Mozambique (APCM)

The APCM (Associação de Produtores de Camarão de Moçambique) is a shrimp producer's advocacy group with representation from both of the shrimp farms in Mozambique, Marbar, and the Centro de Biotechnología. The APCM functions as the interface between the private shrimp producers and the public sector. The association represents the shrimp farms in discussions with the government regarding policies, regulation, and biosecurity. In 2009, the APCM received 1.5 M € in funding from the French Ministry of Economy and Finance and the French Development Agency (AFD). The funding was part of a Trade Capacity Building Program (PRCC) with the goal of improving the international competitiveness of the Mozambique shrimp farming industry. Mr. Blanc was hired by the APCM to administer this project. After the WSSV outbreak in Mozambique, the PRCC funds were re-directed towards funding of a WSSV surveillance program and helping to manage the crisis. One of the key objectives for the PRCC is to help strengthen the capacities of INIP as the Competent Authority for Aquatic Animal Health. The APCM is planning to provide training for technicians at the Centro de Biotechnología and INIP's Central Veterinary Laboratory to help them develop the capacity as AAH Reference Laboratories. Representing the APCM, Mr. Blanc has played a key role in managing the response of Mozambique to the WSSV crisis.

4.2.4 Ministry of Fisheries

The Ministry of Fisheries has overall responsibility for the management and administration of aquaculture in Mozambique. Two government bodies deal directly with aquaculture: the Instituto Nacional de Desenvolvimento da Aquacultura (INAQUA), and the Instituto Nacional de Inspección Pesquera (INIP).

INAQUA is a new agency that was created in 2008 by Decree No. 28/ 2008. INAQUA is the designated lead agency for all government projects related to aquaculture. It is responsible for strategic planning for aquaculture policy and for proposing legislation and regulations pertaining to aquaculture. It is also responsible for managing aquaculture licenses and authorizations for commercial projects. INAQUA conducts surveys and statistical analyses related to the Mozambique aquaculture sector. Prior to the outbreak, there was no formal national policy on aquatic animal health. INAQUA is now taking the lead role in developing a national policy to address aquatic animal health issues. Ms. Isabel M. Omar is the director of INAQUA. She was formerly the director of INIP, and has established strong communications between the two agencies.

INIP is the agency responsible for control of quality standards for all fisheries products. INIP is the designated Competent Authority for food safety and in March, 2012 INIP was designated as the OIE National Focal Point for Aquatic Animal Health for Mozambique. While the INIP team members are well-trained in HACCP, quality control and seafood safety, they do not have the training or equipment to serve as an Aquatic Animal Health Reference Laboratory. While INIP personnel are anxious to acquire the expertise necessary to take a more active role in aquatic animal health management, at present there is no legislation in Mozambique to provide a legal framework or funding for these activities. In Mozambique the Veterinary Authority is under the Ministry of Agriculture and INIP, the Competent Authority for aquatic animal health, is under the Ministry of Fisheries. This arrangement creates some challenges for the coordination between veterinary and fisheries authorities (Baloi et al, 2011).

4.2.5 Aquatic Animal Health Laboratories

In the absence of an official government-designated laboratory for AAH services, in-country diagnostic work for the shrimp farms is carried out by the Centro de Biotechnología, a laboratory at the Universidade Eduardo Mondlane (CB-UEM). The CB-UEM laboratory is a research and diagnostic laboratory shared by multiple departments at UEM. The laboratory began conducting PCR analyses on shrimp in 2008. They use IQ2000 PCR kits and can test for WSSV, IHHNV, MBV, TSV, IMNV, YHV/GAV, and HPV. The tests cost $22 US/sample. The lab is capable of processing 10 samples/day or 40 samples per week. Prior to the WSSV outbreak in 2011 the CB-UEM only tested about 150 samples per year for the shrimp industry. Most of the samples tested were post-larvae or broodstock pleopods submitted by the Aquapesca farm. Any positive test results are reported to the Ministry of Fisheries.

Histological work and PCR analyses on shrimp with suspected diseases are usually performed by the OIE Reference Laboratory located at UAZ. Some samples are also sent to other international diagnostic laboratories, such as the Concepto Azul laboratory in Ecuador.

4.3 Madagascar Shrimp Industry

The Madagascan shrimp industry is based on semi-intensive production of *Penaeus monodon* in 5-10 ha earthen ponds with little or no aeration. The ponds are managed as flow-through systems with water exchange rates peaking at about 15% of pond volume per day. Stocking rates are generally less than $12/m^2$. The average weight at harvest ranges from 20 – 30 grams. Yields average 1.5 – 1.8 MT/Ha. Most of the farms produce two crops per year with a dry-out period between crops during the coldest months of the year. The largest farm, however, operates on a continuous basis, obtaining 2.3 production cycles per year.

All of the farms in Madagascar are vertically integrated, with their own hatchery and processing plant. The two largest companies, Unima and Oso Farms, have developed SPF breeding programs and no longer rely on wild broodstock. The smaller companies use wild broodstock.

4.3.1 Madagascar Shrimp Farms

Commercial shrimp farming began in Madagascar in the early 1990's with the establishment of the Aqualma shrimp farm on Mahajamba Bay on the west coast. Within 10 years the industry had expanded to 6 farms and an annual production of nearly 6,000 MT per year. Annual production peaked at 8,354 MT/year in 2007 (Figure 3). However, production declined over the next several years due to a combination of rising production costs associated with higher fuel prices and falling shrimp prices due to increased production in Latin American and Asia. In

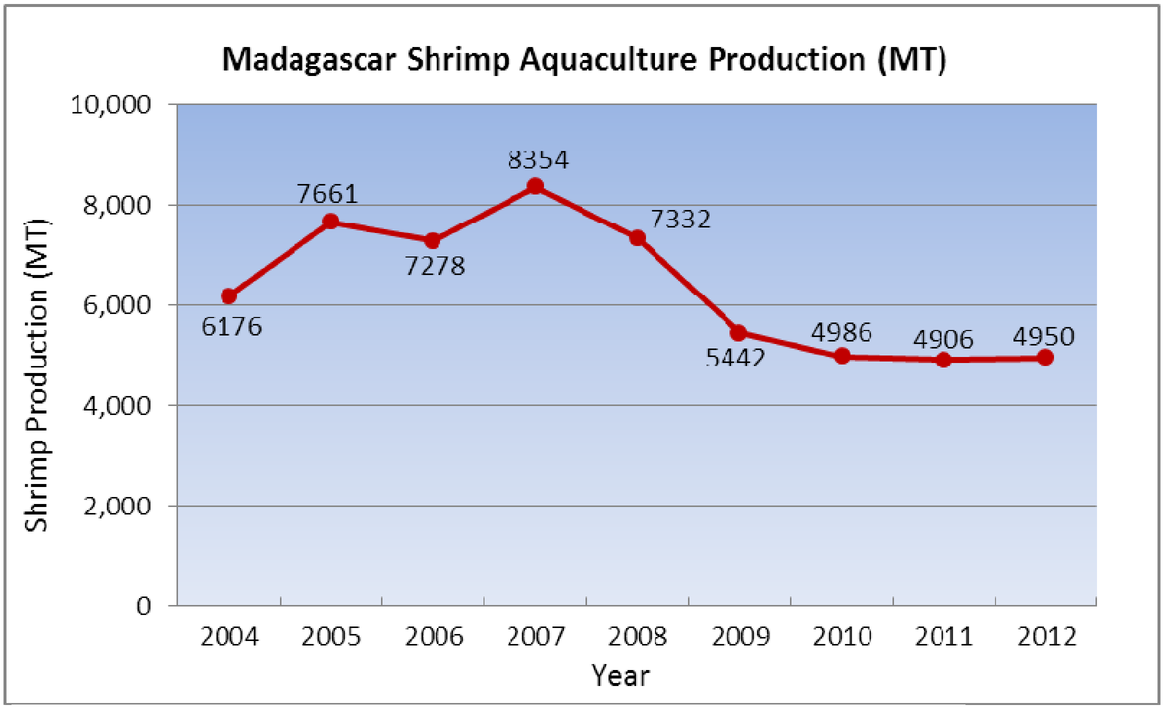


Figure 3: Madagascar shrimp aquaculture production, 2004 - 2012

2009, the difficult economic conditions resulted in the closure of two shrimp farms. One of these farms (Unima's Marima shrimp farm) re-opened in 2012 with the return of more favorable market conditions. Currently, there are four shrimp farming companies in the country operating 5 farms with a total production area 2,300 Ha.

The two largest shrimp farms in Madagascar are both owned by the Unima group. The oldest and largest farm is the Aqualma farm in Mahajamba, with a total production area of just under 800 Ha. The second Unima shrimp farm is the 450 Ha Marima shrimp farm, located in Besalampy. The Unima group operates a larval rearing facility in Mifoko, and leases a government hatchery in Mahajamba to increase their larval rearing capacity. They also operate a separate breeding center in Moramba. Unima initiated a broodstock domestication program in 1999 to eliminate their dependence on wild broodstock. Since 2003, 100% of the postlarvae stocked in Unima ponds were derived from captive-bred SPF broodstock. In addition to screening their broodstock for OIE listed pathogens, they also screen for some local pathogens, including two species of microsporidians, a Rickettsia-like intracellular bacteria, an iridovirus, and a local form of Monodon Slow Growth Syndrome. The Unima group markets their shrimp in the EU as a premium head-on product. In 2004, Unima obtained the "Label Rouge" for their shrimp from France's Ministry of Agriculture, certifying the superior quality of the product.

Is September, 2012 Unima's Marima shrimp farm detected WSSV in wild *F. indicus* shrimp sampled near the farm's pump station and initiated an emergency harvest of the farm. Subsequent PCR samples showed some of the shrimp on the farm were also positive for WSSV. The Marima farm was stocked with SPF PLs, which suggests that WSSV was horizontally transmitted from the wild carrier populations to the farmed shrimp population. Following a dryout period and installation of a microscreen filtration system, Marima has resumed production. Unima's Aqualma farm has not been infected by WSSV. The Unima group, which conducts their own PCR testing, is engaged in a large scale surveillance program to monitor the incidence of WSSV in wild crustacean populations on the west coast of Madagascar. The objective is to provide an early warning of the spread of WSSV in the wild before it reaches Mahajamba Bay. The company has devoted significant resources to surveillance of wild crustacean populations in near shore waters from the northern tip of Madagascar to south of Morombe. In the 12-month period from May, 2012 – April, 2013 the company has processed over 50,000 PCR samples.

The third largest shrimp farm in Madagascar is Oso Farming – Les Gambas de l'Ankarana (LGA). This farm is a subsidiary of R&O Seafood Gastronomy, headquartered in Paris. R&O Seafood Gastronomy is France's largest seafood distributor. LGA, located near the northwestern tip of the island, operates 42 growout ponds with a total water surface area of just over 400 hectares. The LGA farm is organically certified under the French AB-Bio label and EU Regulation 710-2009, which specifies standards for organic aquaculture products. Shrimp are stocked at a density of 11 shrimp/m^2 and grown to an average harvest size of 23 grams in approximately 150 days. Two crops per year are harvested with a 39 day dry-out period between crops. In keeping with organic standards, the ponds are not routinely aerated. Daily exchange rates average 7% of pond volume per day. LGA also stocks SPF post-larvae produced at their own breeding center. Broodstock are reared in specialized broodstock rearing ponds. The breeding center is reported to be capable of producing up to 5,000 broodstock every two months. LGA has a well-equipped laboratory with microbiology and PCR-testing capabilities. The lab can process up to 178 samples per day. No WSSV has been detected to date at the LGA facility or in nearby areas. However, the company has devoted considerable resources to surveillance of wild crustacean populations in near shore waters from the northern tip of Madagascar south to Mahajanga. In the 12-month period from May, 2012 – April, 2013 the company has processed over 37,000 PCR samples.

The Aquamen EF farm at Tsangajoly is located north of Morondava, and is the southernmost shrimp farm in Madagascar. The Aquamen farm consists of 110 ponds with a total water surface area of 400-ha. The production ponds average 3.6 ha in area. Like all the farms in the region, the Aquamen facility is vertically integrated, with a hatchery and processing plant. The Aquamen hatchery does not have an SPF breeding center, instead relying on wild broodstock.

In April, 2012 the Aquamen farm became the first farm in Madagascar to be infected with WSSV. The farm was shut down and disinfected, but has not yet been permitted to re-stock, pending submission and approval of a biosecurity plan.

The smallest farm in Madagascar is the 251-Ha Aquamas farm, located in Soalala, 150 km south of Mahajanga. This farm consists of 142 ponds ranging in size from 0.6 – 2.7 ha. Like the Aquamen hatchery, the Aquamas hatchery utilizes wild *Penaeus monodon* broodstock. These broodstock are not screened for viruses, but each batch of post-larvae is PCR-tested at the time of stocking. The testing is performed by the Pasteur Institute laboratory in Antananarivo. Since the outbreak of WSSV, the Aquamas facility has been experimenting with various management strategies to improve biosecurity, including chlorination of the water in their supply canal and filtering the seawater through 250 micron screens installed in specially constructed concrete gates located at the head of the secondary supply canals. Only 9 growout ponds with a total area of about 25-Ha have been stocked as part of the trial production runs with this new system.

4.3.2 Association of Shrimp Farmers and Fishermen of Madagascar (GAPCM)

The Association of Shrimp Farmers and Fishermen of Madagascar (GAPCM) is an advocacy group composed of both shrimp farmers and shrimp fishermen. The GAPCM was initially organized as an association of shrimp fishing boat operators in 1994, but its membership was expanded in 2001 to include shrimp farmers. The GAPCM has a total of 16 members, divided into two divisions: a shrimp fishing division with 11 members, and a shrimp aquaculture division with 4 members. Each of the shrimp farms in the country is represented in the GAPCM. The stated objectives for the association are to influence the development of rational policies for managing and regulating the shrimp farming and fishing sectors in the country, to represent the shrimp industry in discussions with the government, and to defend the common interests of its members. The GAPCM works closely with and has received funding from its institutional partners, including the Ministry of Agriculture, Livestock, and Fisheries (MAEP), and the French Development Agency (AFD). The GAPCM has also forged a partnership with the World Wildlife Fund (WWF) to promote sustainable shrimp farming practices that promote resource conservation, and preservation of biodiversity.

While the stated goal of the GAPCM is to serve as the unified voice for the shrimp aquaculture industry, in practice the GAPCM is not a unified group. Within the group there are deep divisions and lack of trust due to a long-standing rivalry between the group’s two most powerful and influential members: Unima and Oso Farming. The lack of unity within the GAPCM has the potential to interfere with the ability of GAPCM to develop a coordinated and cooperative response to the WSSV.

4.3.3 Ministry of Fisheries and Marine Resources

The Ministère de la Pêche et des Ressources Halieutiques (MPRH) is the agency with overall responsibility for the aquaculture sector in Madagascar. Within the MPRH the Directorate for Aquaculture is responsible for strategic planning for the aquaculture sector and for issuing aquaculture licenses and for proposing legislation and regulations for the aquaculture sector.

The Autorité Sanitaire Halieutique (ASH) is the Competent Authority for seafood certification and veterinary inspection for aquaculture facilities in Madagascar. ASH is also the designated OIE National Focal Point for Aquatic Animal Health in Madagascar. The director of ASH is Dr. Luc Josue D. Ralaimarindaza.

Like INIP in Mozambique, ASH is the agency responsible for control of quality standards for all fisheries products. Unlike the situation in Mozambique, the legal framework for AAH policy in Madagascar is much better defined. In 2001, the legislature passed the Development of Responsible Shrimp Aquaculture Act (Act 2001.020) which established a permitting process and prescribed basic biosecurity and environmental protection practices to be followed by the industry. In 2005, Decree No. 2005-185 established a National Pathogen List for aquatic animal diseases.

4.3.4 Laboratory for Epidemiological Surveillance

A 2006 convention between the GAPCM, the Malagasy government, and the French Development Agency (AFD) identified shrimp disease outbreaks as one of the most important risk factors for the future development of the shrimp aquaculture industry in Madagascar. The convention called for a national policy on aquatic health, an aquatic disease surveillance program, and the establishment of a national aquatic animal health laboratory. After the convention, the government issued Decree No. 20142/2006, allocating 1.4 million euro to create the Laboratory for Epidemiological Surveillance (LES) at the Pasteur Institute in Antananarivo. Additional funding was provided by the AFD. In 2010, LES was designated by the government as the official national laboratory for aquatic animal health monitoring. The LES is run by Dr. Iony Manitra Razanajatovo.

In 2009, Decree No. 33423 established a National Policy on Aquatic Health. As part of this national policy, a shrimp disease survey was commissioned for the west coast of Madagascar. The surveillance plan was designed by Dr. Angus Cameron, an epidemiologist with AusVet Animal Health Services. The plan called for sampling of wild and farmed shrimp by ASH personnel and PCR analyses by the LES. One of the original objectives of the lab was to survey diseases in the region to establish it as an OIE disease free zone. Aquamen volunteered to be the first farm sampled in the survey. The disease survey began in 2010 with samples being taken both from wild crustaceans at various locations on the west coast of Madagascar, and at the Aquamen farm. The sampling program was designed to detect viral diseases at a 1% incidence rate in the population. No WSSV was detected in 2010 or 2011. Funding from the AFD ended after 2010, and in 2011 government funding for the project also lapsed. The sampling program was discontinued in 2012 due to insufficient funds. ASH still owes the LES $20,000 for PCR sampling work that was done as part of the survey.

Since the WSSV outbreak began, the LES has not been an active participant in the WSSV surveillance efforts in Madagascar. This is only partly due to the lack of funding for this work. Other factors limiting their involvement include the lack of staffing to collect samples, and restrictions on reporting results to the farms of samples they submitted. The current rules require that all results must be reported first to ASH. This results in a time delay of about 3 weeks in reporting results back to the farms. Also, the cost per sample for PCR testing at the LES ($60/sample) is high, which is a significant deterrent for farms to use the LES for routine testing. Unima and LGA do their own PCR testing at a cost of $10/sample or less, rather than use the LES laboratory.

5 WHITE SPOT DISEASE

5.1 Etiology

White Spot Disease (WSD) is a lethal, contagious viral disease of penaeid shrimp and other decapod crustaceans. The causative agent of WSD is the white spot syndrome virus (WSSV). WSSV is the only member of the genus Whispovirus, and family, Nimaviridae. WSSV is a large, enveloped, double-stranded DNA virus, measuring 80-120 nm in diameter and 250-380 nm in length (Durand et al, 1997). The virions are rod-shaped to elliptical in form, and have a unique flagella-like appendage at one end. The virions replicate inside the nuclei of infected cells without the production of occlusion bodies. WSSV targets tissues of ectodermal (cuticular epidermis, foregut and hindgut, gills and nervous tissues), and mesodermal (connective tissue, lymphoid organ, antennal gland and hemopoietic tissue) origin (Wongteerasupaya et al. 1995).

5.2 Symptoms

WSD outbreaks in shrimp ponds are often accompanied by severe mortality. Acutely affected shrimp may be lethargic or anorexic and are often seen swimming erratically near the surface of the pond (Crockford, 2008). WSD takes its name from the characteristic white spots on the carapace, although this is not necessarily seen in all infected shrimp. The white spots are due to deposition of calcium salts by the cuticular epidermis. Moribund shrimp frequently develop a pink to red discoloration. Mortality rates among populations of shrimp showing these signs may approach 100% within 3 to 10 days of the onset of clinical signs (Momoyama et al. 1994; Sangamaheswaran & Jeyaseelan, 2001).

5.3 Transmission

WSSV can be transmitted either horizontally, or vertically. Horizontal transmission occurs through the ingestion of infected tissues or organisms (Lo & Kou, 1998; Durand & Lightner, 2002) or by direct contact with an infected individual. However, consumption of infected tissue is more than ten times as likely to result in transmission of the virus as cohabitation with an infected individual (Lotz and Soto, 2009). Vertical transmission from an infected female parent to her offspring has also been demonstrated (Lo et al. 1997).

5.4 Carriers

WSSV has a wide host range that includes virtually all decapod species and many other crustaceans (Lightner, 1996; Flegel, 1997; Lo and Kou, 1998). All life stages may be infected, including eggs, larval stages and adults (Venegas et al. 1999). Many non-decapod crustaceans, such as copepods (Huang et al. 1995), Liu, 2005), isopods (Lo and Kou, 1998, Overstreet et al. 2009), amphipods, and barnacles (Lei et al. 2002) have also been demonstrated to be carriers. It appears that WSSV infections in many of the non-decapod hosts are latent infections with no apparent pathology to the host (Lo and Kou, 1998).

WSSV has also been found in several non-crustacean carriers. Polychaete worms have been demonstrated to carry WSSV and are capable of transmitting the virus to shrimp broodstock fed with infected worms (Vijayan et al, 2005; Desrina et al. 2012). WSSV can be found in the gills and digestive tracts of oysters in areas where WSSV is present (Vazquez-Boucard, et al. 2010). Oysters have even been suggested to be sensitive bio-indicators of the presence of WSSV at low levels because they concentrate WSSV virions in their tissues (Vazquez-Boucard, et al. 2010).

5.5 Environmental Factors

Temperature has a profound effect (Figure 4) on the expression of disease in WSSV infected *L. vannamei*. Vidal et al. (2001) found that at temperatures above 32° C, WSD did not develop in WSSV-infected *L. vannamei*. However, when the same shrimp were cooled to 26° C, the disease would quickly develop with 100% mortality. Subsequent studies demonstrated that the hyperthermic phenomenon also occurred in other penaeids (Guan et al. 2003; Gunalan et al. 2010). Recent work has shown that replication of WSSV is significantly reduced or stopped under hyperthermic conditions (Du et al. 2006). These findings have helped to explain why WSD epizootics occur most often in the cooler seasons. In the Americas, that information has helped shrimp farmers manage WSD by avoiding stocking in the cool season or growing shrimp year-round in temperature-controlled greenhouses. Temperature fluctuations greater than ±3°C (Esparza-Leal et al. 2010; Tendencia & Verreth, 2011) are also conducive to outbreaks of WSD. This appears to be due to the combined effect of a reduced host immune response and an increase in the rate of viral replication at temperatures less than 28°C (Moser et al. 2012).

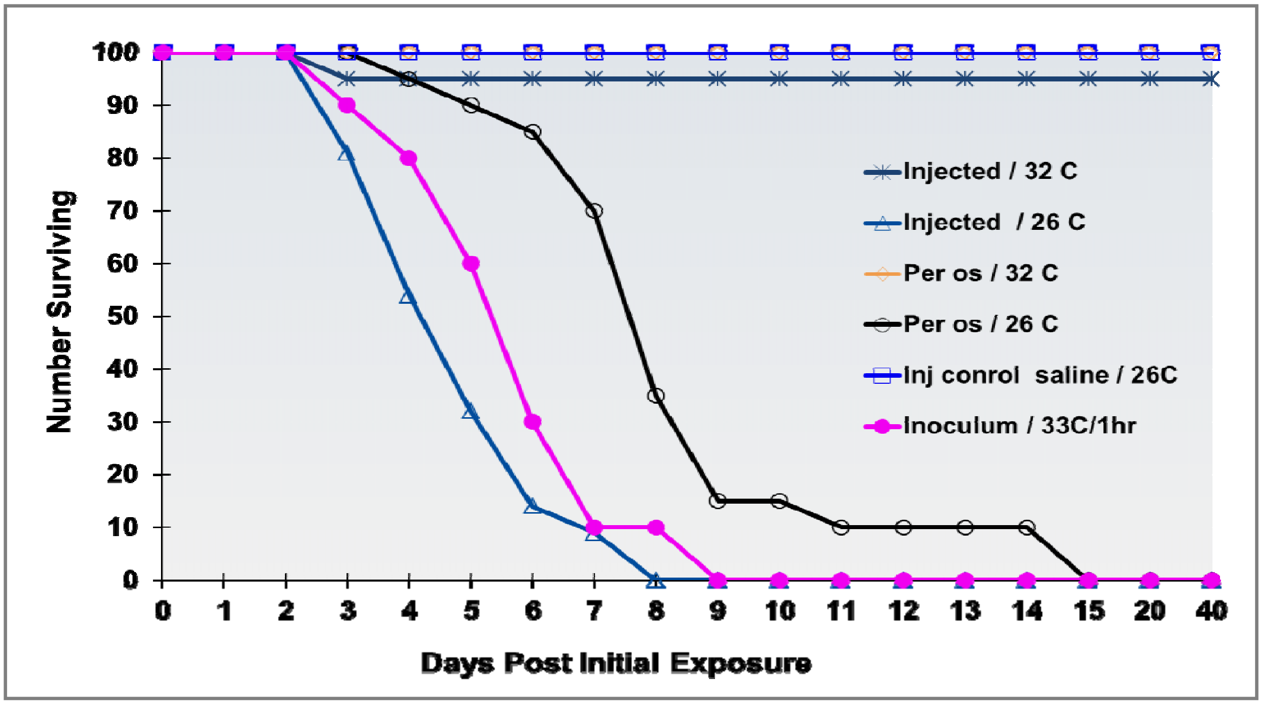


Figure 4: Effect of hyperthermia on WSD in L. vannamei. (Modified from Vidal et al. 2001).

Heavy rainfall events may also precipitate outbreaks of WSSV due to the combined effect of a rapid drop in both salinity and temperature (Tendencia et al. 2010).

5.6 HISTORY OF WSSV OUTBREAKS WORLDWIDE

The first known outbreak of WSD occurred in Taiwan in 1992, where farmed shrimp of three different species (*P. monodon*, *Marsupenaeus japonicus*, and *Fenneropenaeus penicillatus*) all experienced outbreaks of WSD (Chou et al. 1995). The disease spread to Japan in 1993 where it was reported from farmed *M. japonicus* (Inouye et al. 1994; Nakano et al. 1994) and the People's Republic of China (Huang et al. 1995). A variety of different names were applied to the virus causing these outbreaks, but all were describing a disease with similar gross signs and caused by a similar rod-shaped virus (Lightner and Redman, 2010). Over the next few years the disease became widespread throughout Southeast Asia, spreading to Vietnam, Thailand, Malaysia, Indonesia, and India, causing hundreds of million dollars of dollars in economic losses for the shrimp industry every year. At this time *P. monodon* was the dominant species cultured in Southeast Asia, and most of the postlarvae were produced from wild broodstock. As it became increasingly difficult to find disease-free broodstock, the Southeast Asia shrimp aquaculture industry began to switch to *Litopenaeus vannamei,* a species for which domesticated specific pathogen free (SPF) broodstock were readily available. Stocking disease-free PLs improved survivals, and the economics of growing *L. vannamei* were more favorable since *L. vannamei* could be stocked at higher densities (Briggs et al. 2005).

Despite the absence of live shrimp introductions in the western hemisphere, WSSV eventually spread to the Americas. Early in 1999, WSSV was diagnosed as the cause of serious epizootics in Central American shrimp farms. In January, 1999 WSSV first appeared in Panama and within two months the disease spread north to Honduras and Guatemala. By mid to late 1999, WSSV was causing major losses in Ecuador, then among the world's top producers of farmed shrimp. Exports of shrimp from Ecuador in 2000 and 2001 were down nearly 70% from pre-WSSV levels (Lightner, 2003). It has been proposed that the introductions of WSSV to the Americas were the result of importation of frozen shrimp products from WSSV-affected areas of Asia and the value-added re-processing of those frozen shrimp in coastal processing plants in the Americas (Nunan et al. 1998; Lightner, 2003), or possibly through the use of imported frozen WSSV-infected shrimp as bait by sport fishermen (Hasson et al. 2006).

WSSV also reached Spain and Australia in 2000-2001. In both cases, successful containment and eradication were reported and for both events, and the importation and use of infected frozen shrimp as a fresh feed for broodstock were implicated as the route of introduction (OIE 2013; Stentiford and Lightner, 2011).

In recent years WSSV spread to new areas of the world. In January 2011, shrimp farms in Saudi Arabia culturing *Fenneropenaeus indicus* began experiencing severe mortalities due to WSSV. In an attempt to determine the origins of the virus responsible for this outbreak, researchers at UAZ analyzed the genotypes of the WSSV isolated from *F. indicus* in Saudi Arabia. They identified three different genotypes from different farms (Lightner, 2012). Two of these differed from the strain of WSSV that originated in Asia and later spread to the Americas. The two Saudi Arabian WSSV genotypes differed from the Asian genotype by having a deletion of 1,522 base pairs from a specific section of the viral DNA (ORF 94); they differed from one another in the number of repeating base pair sequences in ORF 125 (Lightner, 2012; Tang et al. 2012). The evidence suggests that the new genotypes found in Saudi Arabia may have originated in wild *F. indicus* broodstock from the Red Sea (Tang et al. 2012).

6 WSD OUTBREAK IN THE MOZAMBIQUE CHANNEL

Soon after WSSV appeared in Saudi Arabia, WSSV began showing up in the Mozambique Channel. In September, 2011 WSSV was diagnosed at the Aquapesca shrimp farm in Mozambique. In April, 2012 WSSV was found at the Aquamen EF farm in Madagascar. In September, 2012 WSSV was found at the Marima farm in Besalampy. The genotypes of the WSSV isolated from the Aquapesca farm in Mozambique and at the Besalampy farm in Madagascar were the same as one of the new WSSV strains found in Saudi Arabia. The genotype of WSSV isolated from the Aquamen farm was identical to the other new WSSV strain from Saudi Arabia (Lightner, 2012). These results suggest that both strains of WSSV found in the Mozambique Channel have a common origin with the Saudi Arabian WSSV strains. It is not clear how the Saudi Arabian WSSV was transported to the Mozambique Channel. It could have been transported by ocean currents or in ship ballast water. It is also possible that WSSV-infected shrimp from Saudi Arabia were processed in shrimp processing facilities in Mozambique or Madagascar. Shrimp processing waste is a suspected route for introduction of WSSV into the Americas (Durand et al. 2000).

6.1 WSSV Outbreak in Mozambique

The following is a brief description of WSSV outbreak in Mozambique and the actions that were taken by the various stakeholders. A chronology of the key events can be found in Appendix 2.

6.1.1 Aquapesca

The first outbreak of WSD occurred at the Aquapesca shrimp farm in Quelimane. Following a significant temperature drop (>3°C), mortalities and moribund shrimp were observed in one pond and in the water inlet canal. The pleopod samples of moribund shrimp were sent to the Centro de Biotecnología da Universidad Eduardo Mondlane (CB-UEM) for PCR analysis. On September 3, CB-UEM reported the samples tested negative for WSSV and all other OIE listed diseases, despite the fact that the shrimp that were sampled had visible white spots on the carapace (Le Groumellec, 2011). There is some evidence that the samples had been fixed in Davidson's fixative rather than 95% ethanol. This would explain the negative PCR result. Unfortunately, the error allowed the disease to spread for another 10 days before it was properly diagnosed.

On September 3, managers began flushing the inlet canal. Believing the disease to be bacterial in origin, the managers began feeding the shrimp with medicated (OTC) feed. However, by September 5 two-thirds of the ponds on the farm were affected. INAQUA was notified of the disease outbreak on September 4.

On September 5 representatives from INAQUA and INIP (the OIE focal point for AAH) visited the shrimp farm to observe the problem firsthand. Pleopod samples collected on September 4th and 5th were sent to the UAZ OIE Reference Laboratory with a request that they be tested for Rickettsia-like bacteria (RLB). Despite the white spots on the shrimp, WSSV was discounted as a possible cause due to the negative PCR result from September 3. Additional samples were sent to CB-UEM. On September 9, UAZ reported the samples tested negative for RLB. Meanwhile, WSD continued to spread on the farm and mortalities were mounting. The inlet canal continued to be flushed daily. On September 12 the farm managers requested the UAZ and CB-UEM laboratories to test the samples sent on September 6 for WSSV. Later that day UAZ confirmed the samples were positive for WSSV. Flushing of the inlet canal was stopped immediately. CB-UEM confirmed the diagnosis on September 14 and 16.

Destruction of the shrimp and disinfection of the Aquapesca farm was carried out between September 16 and 29 under the supervision of representatives from INIP. The OIE was notified of the presence of white spot disease in Mozambique on September 22 by the National Director of Veterinary Services, Dr. Florencia Massanga Cipriano.

6.1.2 Aquapesca Hatchery in Nacala

WSSV hit the Aquapesca hatchery in Nacala at almost the same time as the farm was hit. On September 4, 2011 mortalities were observed among broodstock that had been captured from the Moma area and brought to the hatchery on September 3rd. The shrimp turned reddish, had difficulty molting, and then died. Handling stress was suspected. However, the mortalities continued until 100% of the shrimp had died. At least two new batches of broodstock from the Moma area were received at the hatchery over the next several days. These, too, developed the same symptoms and began dying. By September 18th broodstock that had been in the hatchery since early August and were housed in a different area in the hatchery also began dying.

On September 17th and 20th samples were collected from all broodstock groups at the hatchery and were sent to a private laboratory in Ecuador (Concepto Azul) for PCR testing. Results were not received back from this laboratory until October 27th, November 5th and November 8th. All samples were positive for WSSV.

The hatchery was inspected on September 29th, 2011 by INIP and INAQUA. Following the inspection, the Competent Authority ordered the destruction of all stocks, which began immediately.

6.1.3 Marbar

On November 20, 2011 a shipment of wild shrimp captured from the Nova Mambone area were brought to Marbar's Vilankulos facility where they began exhibiting clinical signs of WSD. These shrimp were quarantined and pleopod samples were taken and sent to the CB-UEM and UAZ laboratories for PCR analysis. Three additional batches of shrimp from the same area were brought to the facility over the next two weeks that also developed symptoms of WSD. On December 9 and 10 UAZ and CB-UEM both reported positive WSSV PCR results. The Competent Authority was notified, and the quarantined shrimp were destroyed under the supervision of INIP. Curiously, none of the shrimp at the facility other than the quarantined shrimp from Nova Mambone were tested. Nor did INIP request PCR testing of shrimp held at Marbar's Beira facility.

Following the WSSV outbreaks, Marbar has continued to collect wild broodstock and sell them to hatcheries in Asia after on-site testing using an IQ+ PCR diagnostic kit purchased for the company by the APCM. They prefer to perform their own testing due to the high cost

($20/sample) of PCR testing at CB-UEM. However, they only test shrimp they suspect of being infected after subjecting them to a stress test involving exposure to low temperature and dissolved oxygen. Shrimp that appear weak or which have reddish coloration or necrotic lesions are selected for PCR testing. About 10% of the shrimp that test positive to WSSV survive the stress tests. Dr. Chris Schnell, Technical Director at Marbar, believes this is evidence that the surviving shrimp may be resistant to WSSV. Dr. Schnell also reports that there has been a 90% reduction in the capture of wild shrimp since the start of the WSSV outbreak.

6.1.4 Sol y Mar

The Sol y Mar shrimp farm in Beira was not in operation at the time WSD hit the Aquapesca farm. However, Sol y Mar stocked their farm three times in 2012, and each time the farm experienced major losses, apparently due to WSD (Note: no PCR testing was done, but the symptoms were consistent with WSD). After stocking the farm in March, there was a period of heavy rainfall and cool temperatures in April. Soon after that, there was an outbreak of WSD causing 100% loss of the crop. The farm was drained, disinfected, and dried out over the winter months of May to September. In October and November, the farm was re-stocked, but soon experienced major mortalities due to WSD. The farm was dried out and re-stocked again in December. Although WSD disease again hit the farm, this time there were several ponds that did not have WSD outbreaks. The improved results may have been due to the warmer, drier weather conditions during this crop cycle. The farm is currently empty and drying out. Sol y Mar conducts its own PCR analyses on-site using an IQ+ detection kit. No shrimp samples were submitted to the UAZ or CB-UEM laboratories for PCR analysis. INIP did not supervise the destruction of shrimp stocks following the outbreaks, or inspect the farm prior to re-stocking.

Sol y Mar operates a small hatchery on-site using wild broodstock purchased from local fishermen. Samples of their broodstock are PCR tested prior to use. Despite the negative PCR test results, the broodstock may still have been the original source of the WSSV outbreak in March. Often shrimp with low levels of infection will test negative for WSSV prior to spawning, but test positive afterwards (Hsu et al. 1999). None of the broodstock was re-tested after spawning. After the March outbreak, WSSV may well have survived in populations of ghost shrimp and crabs on the farm, resulting in rapid infection of shrimp after re-stocking of the farm.

6.1.5 Aquapesca Outbreak in 2012

Following the disinfection and dryout of the farm and hatchery, Aquapesca set up a broodstock quarantine and PCR screening program at the Nacala hatchery. When wild broodstock are brought to the hatchery they are placed in individual holding tanks in a dedicated quarantine greenhouse. Pleopods are taken from each shrimp for PCR testing. Only shrimp with negative PCR test results are transferred to the maturation building. Broodstock are not, however, re-tested after spawning.

Aquapesca cautiously re-stocked the farm early in 2012 using PLs produced from the PCR-tested broodstock. Initially they ran a small-scale trial for only two months. Survival was 90%. Encouraged by the success of this trial they restocked the entire farm for the second cycle. Many of the ponds were again hit by WSD, and overall survival for the crop was less than 1%. The farm is currently empty and drying out.

6.2 WSSV Outbreak in Madagascar

The following account of the WSSV crisis in Madagascar is based on interviews with public sector stakeholders, including Dr. Luc Josue Ralaimarindaza, Executive Director of the Autorité Sanitaire Halieutique (ASH), Dr. Iony Razanajatovo, Director of the Laboratory for Epidemiological Surveillance (LES), and with private stakeholders, including representatives from the Unima group, Oso Farming LGA, and Aquamas. Appendix 3 contains a chronology of the key events associated with WSSV outbreak in Madagascar.

6.2.1 Aquamen

The first farm in Madagascar to develop WSD was the Aquamen EF shrimp farm, located north of Morondava. On April 10, 2012 the Aquamen farm became the first farm in Madagascar to be infected with WSSV. Approximately four months before WSSV was detected at the farm the LES suspended the surveillance program at Aquamen and surrounding areas due to lack of funding. This was unfortunate because it deprived Aquamen of an early warning that might have allowed them to take measures to prevent or mitigate the effects of WSSV on the farm. Shortly after mortalities were observed on the farm, the shrimp population on the farm was sampled and tested for WSSV. Prevalence of WSSV-infected animals was 10%. At the same time the prevalence in wild populations of shrimp near the farm was 5%. It was also reported (Dr. Luc Ralaimarindaza, personal communication) that WSSV was not detected along the coast except in the immediate vicinity of the Aquamen farm. It is not clear when these prevalence data became available as there was not an ongoing surveillance program in effect in May, 2012. Mortalities increased and within 2 weeks about 75% of the shrimp on the farm were dead. The UAZ reference laboratory officially confirmed the WSSV diagnosis on May 9, 2012. The Competent Authority ordered Aquamen to destroy all shrimp on the farm without releasing water from the ponds.   Aquamen was also ordered to shut down their hatchery and destroy all broodstock and seedstock. On April 21 Aquamen began collecting and burying the remaining shrimp on their farm. They stopped pumping, closed the discharge gates, and held the water in their ponds for three months until it had evaporated. The ponds and canals were then plowed, limed, and dried out. Over one year later Aquamen remains closed, because the regulatory policy of the Competent Authority does not permit re-stocking until an approved biosecurity plan has been submitted by Aquamen.

6.2.2 Marima

The Marima shrimp farm in Besalampy was the next farm to experience an outbreak of WSD. In early September, 2012, Unima's own surveillance program collected some wild *F. indicus* shrimp from near the Marima pump intake and inside the farm's water supply canal that tested positive for WSSV. Following their contingency plan, Marima stopped all pumping at the farm and began emergency harvesting of the ponds. All ponds were harvested within two weeks. PCR-testing of shrimp within the farm showed that some of the ponds were infected with WSSV, but most of the ponds were salvaged.   The Marima ponds were dried and disinfected. Unima previously had developed a plan for upgrading the biosecurity at the farm with the installation of microscreen drum filters at the farm's pump station and installation of an ozone system to disinfect the water before it entered the ponds. This biosecurity plan was submitted to and approved by the Competent Authority. After a two-month dry-out period during which the biosecurity modifications were implemented, the farm was able to resume production.

6.2.3 Aquamas

The Aquamas shrimp farm is located less than 150 km to the north of Marima.   WSSV was detected on the Aquamas shrimp farm one month after it was found at Marima. Aquamas immediately initiated an emergency harvest of all their ponds.   Aquamas dried out the facility for 5 months before stocking 9 ponds in March, 2013 to test the effectiveness of some biosecurity enhancements to the farm.

6.2.4 Aqualma and LGA

As of May, 2013 neither the Aqualma farm nor the Oso Farming LGA farm has been affected by WSSV. Surveillance of wild shrimp populations has yet to detect WSSV north of the city of Mahajanga. Mahajanga is nearly 100 km to the south of Mahajamba Bay, where Aqualma is located, and nearly 600 km to the south of the Oso Farming LGA farm.

7 NATIONAL LEVEL RESPONSES TO THE WSSV CRISIS:

7.1 Control options as a function of WSSV distribution

On the national level, there are three broad control options for dealing with a new outbreak of White Spot Disease (DAFF, 2005):

1) Eradication
2) Zoning and Containment
3) Control and Mitigation

The appropriate response is a function of the how widely distributed the infection is in the wild population.

Eradication is possible only in the earliest stages of introduction of WSSV to a new area, when the virus is not yet established in the wild population. Eradication requires immediate destruction and disposal of all stocks in facilities where the disease has been detected, disinfection and retention of water at the infected facility, and creation of a quarantine buffer zone around the facility. Widespread surveillance is required to demonstrate that WSSV has not spread beyond the infected facility. The eradication option was not applicable in the case of Mozambique and Madagascar, because the disease appeared to originate from infected wild shrimp detected in multiple locations in the Mozambique Channel and possibly originating from Saudi Arabia.

If the pathogen has a localized distribution in the wild, then the objective of the management program is containment of the pathogen so that it does not spread. Policies to contain the spread of WSSV may include:

1) PCR testing of broodstock and postlarvae
2) Pond level monitoring for WSSV and destruction of shrimp in infected ponds
3) Restrictions on discharge of water from infected facilities without prior disinfection
4) Zoning to define disease-free and infected zones
5) Quarantine and restrictions on the movement of shrimp out of the infected zone
6) Regional surveillance monitoring of wild populations to determine distribution and movements of the virus and to provide early warning to farms in disease-free zones

Once WSSV becomes endemic to a region and broadly distributed in wild populations, the strategy then shifts from containment to mitigation. Governments can assist by conducting routine disease surveillance, training in disease management procedures, financial assistance to farms implementing biosecurity enhancements, and support to cooperative efforts to produce

SPF and disease-resistant seedstock. Individual farms must take responsibility for implementing management strategies and biosecurity procedures to minimize the impact of WSSV.

7.2 Response of the Mozambique Government

After receiving notification from the CB-UEM and UAZ laboratories that the Aquapesca disease outbreak was caused by WSSV, a high level meeting was called on September 15th, 2011 that included representatives from APCM, INAQUA, INIP and the IIP (Fisheries Research Institute). The objectives of this meeting were to inform the Competent Authority (INIP) of the situation and to formulate a plan on how to respond to the outbreak. A technical committee was formed with members from each of the organizations represented at the meeting. The committee was tasked with planning and coordinating the response to the WSSV outbreak. The response to WSSV included legislation, development of a WSSV surveillance program, setting up a national diagnostic laboratory for aquatic animal diseases, and training for INIP personnel in diagnosis of diseases of aquatic organisms. In addition, INAQUA and the APCM invited experts from Thailand to Mozambique to share their experience in management of WSSD, and regulatory measures taken by the Thai government to help improve biosecurity at the national level. These experts visited Mozambique in March, 2013.

7.2.1 Ban on the Transport of Crustaceans

The first official response to the outbreak of WSD in Mozambique was the issuing of a decree banning the transport of live and frozen crustaceans between provinces. The goal of this ban was to prevent the spread of WSSV from the zone of active infection to non-infected areas. The Ministry of Fisheries based this policy on the recommendations contained in the Australian Aquatic Veterinary Emergency Plan (AQUAVETPLAN) developed for controlling WSD by the Australian Department of Agriculture, Fisheries and Forestry (DAFF) (2005). AQUAVETPLAN recommends that as soon as WSD is diagnosed in a new region the following zones should be set up and enforced:

- Restricted areas — areas around infected premises or areas
- Control areas — buffer zones between the restricted areas and free areas
- Free areas — areas that are free from infection or are of unknown status

All movements of potential vectors for WSSV, especially live and frozen crustaceans, should be contained within the restricted and control areas.

The effectiveness of this strategy depends on the degree to which the disease is established in wild populations and the geographic distribution of the infected population. This strategy can be very successful when a WSD outbreak results from a recent, point source introduction such as happens when WSSV is imported with purchased broodstock or PLs. The strategy of preventing the spread of disease through restriction of commercial transport of potential carriers is less likely to be effective if reservoirs of WSSV have already become established in wild host populations. The fact that shrimp can be infected with levels of WSSV below the detection limit for PCR testing may allow WSSV to spread and become established in reservoir populations. In Mozambique surveillance testing conducted in late 2011 revealed that WSSV was widely distributed along the Mozambican coast. However, the distribution of WSSV in the wild was unknown at the time the Ministry of Fisheries banned the transport of crustaceans between provinces.

7.2.2 Legislation

At the time of WSSV outbreak there was no legislation in Mozambique establishing policies on aquatic animal health. The WSSV technical committee recognized the need for a policy framework for aquatic animal health and began work on two legislative documents related to aquatic animal health:

- **Aquatic Animal Health Plan – Strategy For Control Of White Spot Disease**

The Aquatic Animal Health Plan (Omar, 2011), also known by its Portuguese acronym "PESAAQUA", is closely modeled on the Australian AQUAVETPLAN disease strategy for controlling White Spot Disease (DAFF, 2005). PESAAQUA outlines disease control principles to be followed by the Competent Authority in the case of an outbreak of WSD. Included in the emergency plan are chapters discussing various response strategies to WSD outbreaks: confirmation of infection, destruction and disposal procedures, decontamination procedure, containment and control strategies, and principles for setting up a surveillance plan. PESAAQUA will be submitted to the Ministry of Fisheries for approval in July, 2013.

- **Health Regulations For Farmed Aquatic Animals**

This document will specify the aquatic animal health regulations that each aquaculture operation must adhere to and will be based on the OIE Aquatic Animal Health Code (OIE, 2011). This document was presented to the Ministry of Fisheries on May 18, 2013. The Ministry decided that the aquatic animal health regulations should be included as part of the existing terrestrial animal health laws and that the Competent Authority should be under the Veterinary Services. While this makes sense from an organizational standpoint, the change will further delay the development of a functional aquatic animal health authority in the country due to the lack of trained personnel, organizational structures and laboratory facilities with the Veterinary Services.

7.2.3 Epidemiological Surveillance Plan

The WSSV technical committee also recognized the need to determine the prevalence of WSSV in wild populations of crustaceans along the entire Mozambican coast. The APCM technical assistant, with input from INAQUA and INIP, designed and implemented an epidemiosurveillance program. There was no money in the Ministry of Fisheries budget for such a program, so the AFD funded the program in 2011 using funds diverted from an aquaculture sector capacity building project. Wild shrimp and crabs were sampled in all coastal provinces and sent to a private lab in Ecuador for PCR analyses. When the results of the first 500 samples were reported by testing laboratory in December (Figure 5), it became clear that WSSV was well-established in most areas along the Mozambican coast, with prevalence reaching as high as 32% on the coast of Nampula province (Pereira and Omar, 2013). The Nacala hatchery is in Nampula. The surveillance program continued in 2012 with funding from the Ministry of Fisheries.

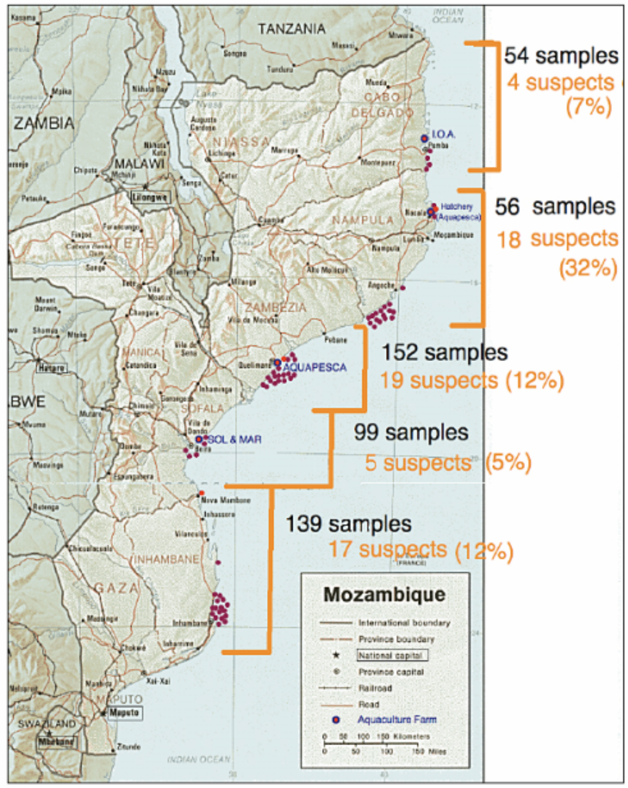


Figure 5: Prevalence of WSSV in crustacean samples, Sept. 28 – Oct. 10, 2011. (Blanc, 2012)

7.2.4 OIE Mission on White Spot Disease in Mozambique

At the request of the Mozambique government, the OIE scheduled a Performance of Veterinary Services (PVS) mission to Mozambique from November 10-16, 2011. The OIE PVS missions are designed to assist the veterinary services of OIE member countries to establish their current level of performance and to identify gaps and weaknesses in their ability to comply with OIE international standards (OIE, 2013). The PVS was scheduled prior to the outbreak of WSSV in the country. The objectives of the mission were expanded to include evaluation of the ongoing WSSV crisis in Mozambique: origins of disease, actions of private sector stakeholders, actions of public sector stakeholders, and public/private stakeholder cooperation. The OIE PVS mission report (Le Groumellec, 2011) provides a detailed account of the events associated with WSSV outbreak, as well as offering excellent recommendations for strengthening Mozambique's ability to manage aquatic animal health issues. The OIE examiner, Dr. Marc Le Groumellec, is a veterinarian specializing in shrimp pathology who also happens to be employed by the Unima group in Madagascar.

7.3 Government Response in Madagascar

The following actions were taken by the Madagascan government in response to the outbreak of White Spot Disease in Madagascar:

7.3.1 Inspection of the Aquamen facility

On April 23, 2011 the Competent Authority for aquatic animal health diseases in Madagascar, ASH, inspected the Aquamen facility. Dr. Marc Le Groumellec was present during the inspection as a representative for the GAPCM. Samples were collected and submitted to the UAZ Aquatic Animal Health Laboratory for PCR analysis. On May 9, 2011 the UAZ laboratory confirmed that the shrimp samples were positive for WSSV. On May 9 the Competent Authority reported the outbreak to the OIE.

7.3.2 Stamping out of WSSV at Aquamen

After confirmation of the diagnosis of WSSV, the Competent Authority ordered a program of stamping out of the WSSV infection following guidelines prescribed in the OIE Aquatic Animal Health Code (OIE, 2011). Specific stamping out measures ordered by the Competent Authority included:

- Discontinuation all pumping activities and blocking off of drain gates to avoid releasing any contaminated water into the environment.
- Collection and destruction of all shrimp stocks on the farm, including hatchery broodstock and larval shrimp, by incineration and/or burial with quicklime (CaO).
- Dryout and disinfection of the farm.
- Dryout and disinfection of the hatchery.

Although WSSV infection was not demonstrated in the broodstock and postlarvae, OIE guidelines for stamping out of infections (OIE Aquatic Animal Health Code, 2011) recommend the killing of all aquatic animals on an infected site that are suspected of being infected or which may have been exposed to infection by direct or indirect contact. ASH has not allowed Aquamen to resume operations pending submission and approval of a biosecurity plan.

7.3.3 Ban on crustacean imports

ASH issued a decree banning the importation of crustacean species that might infect Madagascar shrimp. This was done to prevent shrimp that were caught elsewhere from being brought to Madagascar for processing. It was also intended to prevent WSSV infected processed shrimp from entering the country.

7.3.4 Factors Limiting Ability of Malagasy Government to Respond

Except for the actions listed above, the Competent Authority in Madagascar has been willing but unable to respond to the WSSV crisis. The Executive Director of ASH cited the following reasons for their limited response to the crisis (Ralaimarindaza, 2013):

1. Insufficient financial resources to establish a functional emergency plan.
2. Lack of financial resources to assist farmers' efforts to fight the disease.
3. Difficulties in finding and hiring scientists specialized in shrimp diseases.
4. Lack of communication between private sectors carrying out surveillance programs and ASH makes it difficult for ASH to respond to new cases. (However, representatives from Unima stated that they systematically reported positive WSSV cases from their surveillance program to the Competent Authority.)
5. Delays in reporting of diagnostic results do not allow for rapid response to new cases.
6. The remote location of farms and the difficulties in communication hamper regulatory efforts.

Although ASH is the legal authority and is empowered to take the necessary steps to limit the disease outbreak, it is paralyzed by lack of financial resources. It is hesitant to impose regulatory constraints, because it ASH recognizes that the private farms are often better funded and have better access to international experts to assist in managing the crisis.

7.4 Private Sector Response to the WSSV Crisis

7.4.1 GAPCM Working Group on WSSV

A working group on WSSV was established within the GAPCM members immediately after the WSSV outbreak in Mozambique in September, 2011. This technical group represented the GAPCM in several meetings with the public sector (notably Competent Authorities like DSV and ASH). A detailed action plan was defined and regularly updated from November 2011 until May 2012. However, disagreements between GAPCM members as regarding strategies to deal with the crisis led to dissolution of the working group after November, 2012.

7.5 Private Sector Surveillance Program

In July, 2012 the GAPCM proposed the organization of a WSSV surveillance program as a joint effort of the LES and the private PCR labs operated by the Unima Group and Oso Farming LGA. Despite recognition by all stakeholders of the critical importance of such a program, the Ministry of Fisheries had no funds available to support surveillance activities. The private sector has had to shoulder both the workload and the cost of WSSV surveillance sampling and testing. Since September 2012, Unima has collected and PCR tested more than 50,000 samples for WSSV. Since May of 2012, the LGA has conducted more than 37,000 PCR tests on samples collected for their own surveillance program. Unfortunately, there is little communication between these two companies, resulting in potential duplication of effort. At the concluding workshop of this mission on May 21-22, Unima and LGA agreed to share their PCR results with the other shrimp farms in the country and with ASH.

8 REGIONAL RESPONSES TO THE WSSV CRISIS

8.1 FAO Sub-Regional Strategy

The FAO and World Bank sponsored a regional workshop in Maputo on April 2-4, 2013 to begin development of a sub-regional strategy for improving aquatic biosecurity in the Mozambique Channel sub-regional countries (Omar et al. 2013). The participants in this workshop included representatives from Mozambique (INAQUA, INIP, and the APCM), Madagascar (ASH), Tanzania (National Animal Aquatic Health Coordinator), and the FAO Aquaculture Service. The principle objective for the workshop was to develop the framework for a sub-regional aquatic program to improve aquatic animal health capacity in the sub-regional countries of the Mozambique Channel. This program should identify which activities should be addressed at the national level, and which activities require sub-regional cooperation. Among the guiding principles for the program is recognition that the countries share a common marine environment. Serious aquatic animal pathogens introduced to the waters of one country have the potential to spread and negatively affect aquaculture and/or the wild fisheries of another country. Therefore, the countries have a shared responsibility to prevent the introduction of exotic pathogens and to implement sound and sustainable aquaculture practices.

The sub-regional strategy for improving aquatic biosecurity developed by the participants is presented in ANNEX 1. The program contains 8 components and 12 elements.

The key objectives of the program are:

1. To develop a governance system that promotes biosecurity, national strategies for aquatic animal health should be developed and national legislation regarding aquatic animal health should be reviewed to make sure it is consistent with international standards.

2. To promote sub-regional preparedness for AAH crises, individual countries should develop emergency operational response plans and train personnel in their implementation.

3. To improve disease diagnostics regional reference laboratories for diagnostic testing should be recognized; reference laboratories should participate in proficiency testing; costs should be standardized.

4. To improve disease surveillance, regional surveillance programs should be designed and personnel trained to implement the surveillance programs; surveillance data should be used to contain pathogens in infected areas and protect non-infected areas.
5. To minimize risk from new or exotic pathogens, minimum biosecurity standards and best management practices should be agreed upon and farms should be required to meet those standards and trained in best management practices.
6. To promote sustainable aquaculture development and responsible investment in shrimp aquaculture each country must create an enabling environment by providing AAH services, disseminating information on regional aquaculture practices, facilitate the formation of farmer associations, and develop mechanisms for risk management.
7. To promote the strengthening of national aquaculture institutions, governments should support students seeking degrees in AAH, and should invest in strengthening national diagnostic and research infrastructure.
8. To promote regional collaboration, networking and sharing of information and resources, a web portal for AAH should be developed in which surveillance data and other AAH information is shared; there should also be regional collaboration and sharing of resources such as genetic resources, and feed.
9. Regular and special or emergency meetings should be held between regional stakeholders to promote regional cooperation and collaboration.

8.2 World Bank-Sponsored Study and Workshop on WSSV Management Strategies

On the initiative of the GAPCM, a video conference was organized in September, 2012 between representatives of the producers associations of both Madagascar (GAPCM) and Mozambique (APCM), the French Development Agency (ADF) and aquaculture experts at the World Bank to discuss regional approaches to manage the WSSV crisis. As a result of the video conference World Bank agreed to sponsor a study of WSSV management alternatives by a team of international experts. They also agreed to sponsor a regional workshop at the conclusion of the visit by the Expert Team to discuss the findings of the Expert Team and to devise a regional strategy for addressing the white spot crisis.

8.2.1 WSSV Study by an International Team of Experts

The World Bank contracted the Responsible Aquaculture Foundation to assemble a team of international experts to study the WSSV outbreak in the Mozambique Channel and to deliver a report on their recommendations for strategies for restructuring the shrimp sector. This report is the product of Expert Team's study of the WSSV crisis in Mozambique and Madagascar.

8.3 Regional Workshop on a White Spot Management Plan

At the conclusion of the country visits by the World Bank Mission Expert Team, a regional workshop on a White Spot management plan was held in Antananarivo on May 21-22, 2013. The workshop was attended by public and private stakeholders from both Mozambique and Madagascar. The workshop included presentations by members of the Expert Team on their findings and recommendations, as well as presentations on the WSSV situations in Mozambique and Madagascar by the directors of INAQUA (Mozambique) and ASH (Madagascar). Representatives from the GAPCM and APCM gave presentations on farm level responses to the WSD outbreaks. In their presentations, members of the Expert Team emphasized the critical importance of developing SPF (certified specific pathogen free) and SPR (genetically selected for resistance to specific diseases) broodstock, upgrading the biosecurity on the farms, and maintaining rigorous disease surveillance programs. The team also stressed the importance of a strong cooperative effort between public and private stakeholders to create effective national and regional biosecurity plans.

The workshop concluded with the adoption of a conceptual plan for managing white spot in the region that included four main elements:

- Development of national and regional surveillance plans, beginning with the sharing of existing surveillance data through the creation of an online database
- Development of national biosecurity plans with minimum biosecurity requirements for individual farms, well-defined procedures to follow in response to disease outbreaks, and criteria for re-starting farms affected by outbreaks
- Transitioning from wild broodstock to Specific Pathogen Free broodstock selected for resistance to White Spot Disease
- Improving cooperation among industry stakeholders at the national and regional level through the creation of technical and strategic committees on aquatic animal health and the holding of regular meetings between the committees and stakeholders

9 FARM LEVEL IMPLEMENTATION OF BIOSECURITY PLANS

9.1 Mozambican Shrimp Farm Biosecurity Plans

9.1.1 Aquapesca

The following changes have been implemented at the farm to improve biosecurity:

- Production has been limited to a single cycle per year coinciding with the warm season to minimize the temperature-related effects of WSSV

- Stocking density has been reduced to 3 PL/m^2 to minimize stress and water exchange requirements
- Filtration of the incoming water supply has been improved by installation of a triple screen at the head of the supply canal (1.2 mm pre-filter + two 700 micron screens)
- Installation of a double screen system in each inlet gate consisting of a 700 and 500 micron screen, followed by a 300 micron bag filter.
- Implementation of a farm surveillance program in coordination with INIP
- A new contingency plan has been developed and approved outlining steps to be taken in case of new outbreaks or positive PCR tests

Aquapesca's new biosecurity plan is influenced by their commitment to produce shrimp organically. Because of this, Aquapesca has chosen to reduce stocking densities rather than install aeration systems, as a means of reducing water exchange requirements. The organic certification program allows only emergency aeration.

Aquapesca's Nacala hatchery has also improved their biosecurity practices. They no longer collect broodstock from the Moma area, where there is a high incidence of WSSV-infected shrimp. Now they collect their broodstock from the northern coast of Mozambique where the prevalence of WSSV is much lower. In addition, Aquapesca has constructed a broodstock quarantine facility at the Nacala hatchery. All of the broodstock brought to the facility are now quarantined and PCR tested before being brought into the hatchery's maturation area (Figure 6). Water treatment at the hatchery has been improved so that all water entering the hatchery is now chlorinated. Every lot of PLs is now PCR-tested following a stress test before shipment to the farm.

Figure 6: Broodstock quarantine system at the Aquapesca Nacala hatchery. Photo credit: P.P. Blanc)

Aquapesca understands that the long-term solution WSSV is to develop a breeding facility to develop WSSV-resistant shrimp. François Grosse, Director of Aquapesca, expressed his desire for the development of a national breeding facility funded by World Bank. The breeding facility would be operated as a business, but 10% of the PLs would be made available to small scale Mozambican shrimp farmers free of charge. This would satisfy the government's goal of supporting the development of small-scale aquaculture.

9.1.2 Sol y Mar

At the time of our visit in May, 2013 Sol y Mar was not operating. They are considering several modifications of the farm to improve biosecurity, including the installation of 5 aerators per pond to allow the ponds to be operated with minimal water exchange, and the installation of a 70-m deep seawater well for each of the 58 growout ponds. They are also planning to clean and re-contour the dikes for the ponds which will allow them to do a better job of controlling crabs in the ponds. The dikes are also in need of maintenance from erosion over the years. The total budget for the renovations is $2.66 million dollars. Sol y Mar believes that by moving to a biosecure, zero or low exchange production system with 10 hp/ha of aeration they can increase their production to 5 mt per hectare per year. The additional revenue generated at this level of production would justify the cost of the renovations.

9.2 Madagascan Shrimp Farm Biosecurity Plans

9.2.1 Unima Group Farms

The Unima Group has a comprehensive biosecurity plan to protect their farm from WSD. The main elements of the plan are as follows:

- Early detection through surveillance of WSSV infections in wild carrier populations along the Madagascan coast and near the farm.
- A contingency plan when WSSV is detected near the farm that calls for stopping of all pumping and immediate emergency harvest of shrimp larger than 15 g
- Installation of 1 mm pre-filters, settling ponds, and 35-micron microscreen drum filters to remove most WSSV carriers before they enter the water supply canal.
- Installation of an ozone water treatment system to kill water-borne WSSV and planktonic carriers.
- Construct a drainable concrete-lined canal system on top of the pond levees.
- Reducing the water exchange requirements by adding additional aerators to the ponds, bringing the total aeration to 10 hp/ha
- Dividing the 10-ha ponds in half lengthwise to improve water circulation patterns.
- Improving water quality in the ponds through extensive use of probiotics.

The Unima Group hatcheries already produce SPF post-larvae and have been engaged in selective breeding since 2003 (Le Groumellec et al. 2011). Unima believes these capital improvements will allow them to improve production capacity from 2 MT/crop to 3.5-4.0 MT/crop. The increase in production capacity will require increases in the hatchery production capacity and processing capacity. Unima estimates the proposed upgrades will cost nearly $30 million dollars for the two farms.

9.2.2 Oso Farming LGA

The Oso Farming biosecurity plan is a management-based plan. The key elements of the plan include:

- Early detection of WSSV by mounting massive surveillance of WSSV in wild populations on the northwest coast of Madagascar
- Contingency plans, including the emergency harvesting and processing of marketable shrimp if WSSV detected near the farm or anywhere in Northern Madagascar
- Strict enforcement of biosecurity policies on the farm with respect to personnel
- Stocking of SPF postlarvae produced at the LGA hatchery and derived from certified specific pathogen free broodstock.
- Breeding program to SPR stocks with genetic resistance to White Spot Disease
- Reduced stocking densities during the winter months
- Application of an advanced environmental management system they refer to as the "Oso Cube of Comfort", in which pH, temperature, salinity, and redox potential are closely monitored and controlled.
- Exclusion of carriers by equipping ponds with double screens that allow filtration down to 200 microns

Because Oso Farming's business model is based upon marketing their shrimp as an organic product, the use of aeration as a means to reduce water exchange is not an option for them. The management believes that their strategy of stocking PLs bred for resistance to WSSV, and maintaining an optimal culture environment will prevent the manifestation of WSD. While they do not as yet have breeding lines with demonstrated resistance to WSSV, they believe that they will achieve this goal within months. However, due to the incremental nature of genetic selection improvements, it seems unlikely that dramatic improvements in resistance to White Spot can be made over such a short time frame.

9.2.3 Aquamas

The Aquamas biosecurity plan includes the following elements:

- Quarantine and screen broodstock for WSSV before moving them into the maturation section of their hatchery.

- PCR testing of postlarvae before stocking
- Conversion of a 50 m x 800 m section of the main water supply reservoir into a chlorination reservoir. Seawater will be disinfected with 30 ppm of chlorine; the seawater will remain in the chlorination reservoir for four days to allow the chlorine to dissipate.
- Filtration of water through 250 micron screens mounted concrete gates at the entrance to lateral branches of the water supply canals.
- Avoid stocking during the cold season

A section of the farm has been modified and production trials are currently underway to test the system.

9.2.4 Aquamen EF

In May 2013, ASH told Aquamen they would be permitted to resume operations if they agreed to a biosecurity plan similar to the Unima's plan (D. Chauty, personal communication). The Unima biosecurity plan is outlined in Section 9.2.1. The company does not have the financial resources to follow this plan. In the meantime, Aquamen remains closed.

10 MANAGEMENT OF WSSV OUTBREAKS WORLDWIDE

The path to recovery has not been the same for Asia and Latin America. The production strategies that predominate in these two regions have always differed. In Asia, shrimp ponds are typically 1 ha or less, and stocked with densities of 50 – 120 shrimp/m^2. Ponds are aerated continuously and water exchange rates are low. Latin American farms typically consist of earthen ponds averaging 2-10 Ha and stocked at densities of 20/m^2 or less. Latin American farms use little aeration but water exchange rates of 10-15%/day are common. The differences in farm design and production strategy have led to different approaches to managing WSD.

10.1 Asian WSSV Management Approach

In Asia, the approach to managing WSSV is to eliminate all potential sources of infection. Vertical transmission is prevented by stocking SPF post-larvae. Prevention of horizontal transmission requires a variety of measures. By increasing the amount of aeration in the shrimp ponds, water exchange can be largely eliminated (Hopkins et al. 1993). Each kW of aeration can support an additional 500 kg of shrimp production (Boyd, 1998). Shrimp ponds in Asia often have between 10 and 20 kW/Ha of aeration, allowing them to produce 5-10 MT/Ha of shrimp with little or no water exchange. The low rates of water exchange significantly reduce the risk of introducing carriers of WSSV into the shrimp ponds. The low volume of exchange also allows for economical disinfection of the water that is pumped into the farm. After filling a pond for stocking, most Asian farms treat the water with either chorine (20-30 ppm) or a crustacide (eg. Trichlorfon) to kill the crustacean carriers of WSSV. Many also utilize dedicated treatment ponds to treat water used for exchange with chlorine or crustacides.

10.2 Latin American WSSV Management Approach

The strategy of heavily aerating the ponds and eliminating water exchange is not a practical strategy in Latin America, where ponds are often 10 ha or larger. In Latin America the strategy adopted included stocking only SPF PLs, operating only during the warm months of the year, improved filtration (200 microns) of incoming water, and better management of pond bottoms and water quality. As a long term strategy, several of the larger farms invested in breeding programs in an effort to develop shrimp stocks with significant resistance to WSSV.

Like the farms in Latin America, most of the shrimp farms the Mozambique Channel region are semi-intensive shrimp farms with large ponds stocked at relatively low stocking densities. Water quality is maintained through water exchange, rather than by aerating the ponds. Because of this, the Latin American strategies for managing WSSV are of great interest to producers in the region.

11 HATCHERY LEVEL STRATEGIES FOR CONTROLLING WSSV

Stocking post-larvae produced from wild broodstock is the single biggest risk factor for the development of WSD in shrimp farms. Infected broodstock transmit WSSV to their offspring. Once WSSV becomes established in wild populations, the use of unscreened wild broodstock in the hatchery is likely to result in outbreaks of WSD on the farm.

11.1 PCR Testing of Wild Broodstock

If domesticated broodstock are not available, the risk of vertical transmission of WSSV can be mitigated by quarantining and PCR testing of broodstock for WSSV and other OIE-listed viruses. For this to be effective the broodstock must be quarantined in individual holding tanks and each shrimp must be individually tested. Any shrimp testing positive should be destroyed. However, a negative PCR test does not guarantee that the shrimp is not infected with WSSV. The viral load in shrimp with latent infections may be below the detection limit, especially if PCR samples are pooled. The stress of spawning may weaken the host immune system allowing the virus to replicate. Shrimp that test negative for WSSV may test positive after spawning (Hsu et al. 1999). If wild broodstock are used, it is essential that the female breeders be re-tested for WSSV after each spawn. A sample of PLs should also be stressed and PCR-tested and only PLs with negative test results should be stocked on the farms.

11.2 SPF Broodstock

The use of screened wild broodstock should be seen only as an interim strategy for obtaining disease free seedstock. The long term strategy for ensuring the disease free status of seedstock is to replace wild broodstock with Specific Pathogen Free (SPF) broodstock. The replacement of wild broodstock with SPF broodstock has been a key factor in the recoveries of both the Asian and Latin American shrimp industries from WSSV. In a 2006 report on the state of world aquaculture, the FAO concluded that without the importation and use of SPF broodstock, it is unlikely that Asia's major shrimp producing countries could have recovered from outbreaks of WSSV and other viral diseases, given the severe shortage of healthy wild-caught broodstock (FAO, 2006).

11.2.1 Definition of SPF

Specific Pathogen Free refers to a stock of shrimp that has been free of a specified list of pathogens (typically the seven OIE listed marine shrimp pathogens) for a minimum of 24 months of continuous testing and is subject to an ongoing PCR surveillance program. The term SPF has often been misused and misunderstood. SPF status is not a heritable trait nor is it a lifetime condition. SPF shrimp can become infected when exposed to a pathogen. SPF shrimp have neither innate resistance nor innate susceptibility to a particular pathogen. The advantage of using SPF seedstock is that they are free from disease at the time they are stocked. If the pathogen can then be excluded from the culture environment, disease caused by that pathogen can be avoided.

11.2.2 Development of SPF Broodstock

The development of SPF broodstock is an involved and time-consuming process (Lotz, 1992; Moss, et al. 2003; Lightner, 2011). This involves collecting shrimp from the wild and transferring them to a primary quarantine facility (Figure 7) where they are analyzed for specifically listed pathogens. If they test negative, they are transferred to a secondary quarantine facility where they are spawned to produce an F1 generation of captive shrimp. If shrimp from the F1 generation test negative for specifically listed pathogens after several successive screenings, they are transferred to a nucleus breeding center where they become part of the SPF breeding population. The process of developing SPF broodstock requires at least two years.

There are two companies in the region (Unima and Oso Farming LGA) that have already developed SPF *P. monodon* broodstock. It would be a tremendous advantage for the region if a means can be found to make SPF breeders or seedstock from these two companies available to the other producers in the region.

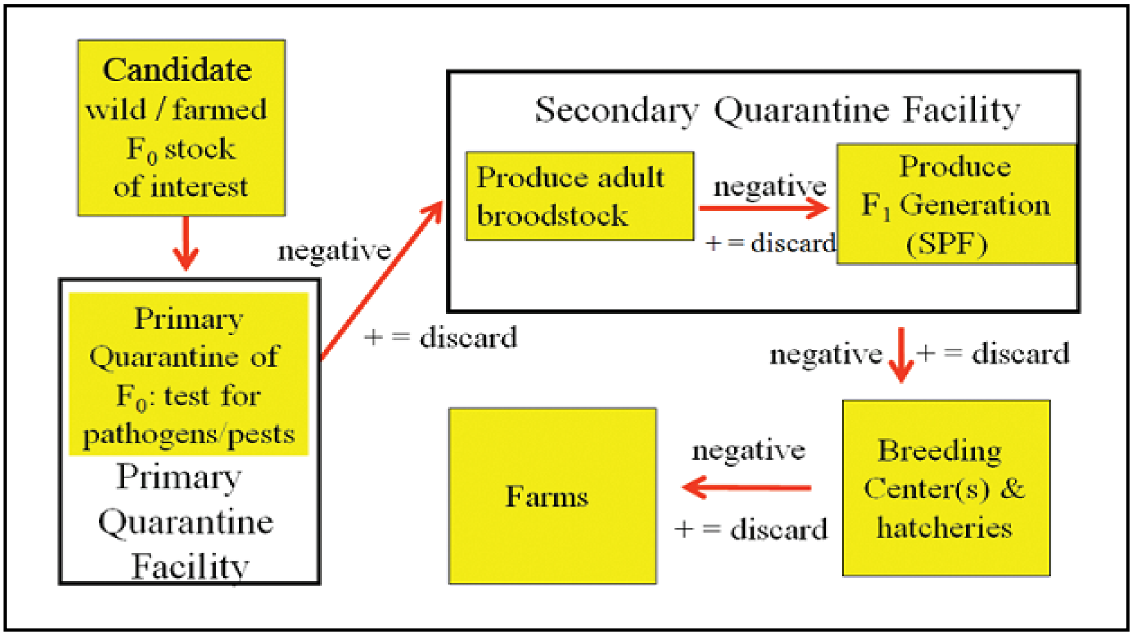


Figure 7: Steps to SPF stock development as developed by the US Marine Shrimp Farming Program (after Lightner, 2011).

11.2.3 WSSV-RESISTANT BROODSTOCK

Once a sufficient number of genetically distinct families are developed for the SPF breeding program, it is not necessary to continue collection of new families from the wild. At that point, the SPF development program transforms into a domestication program. Careful attention will need to be paid to the families that are being created to prevent inbreeding. Ideally a few important traits will be selected for to improve the performance characteristics of the shrimp. The three most important characteristics of any culture species are its growth rate, its breeding fecundity, and its survival in the culture system. In an environment where viral disease is a constant threat, breeding for disease resistance can substantially improve survivability in the culture system.

For example, a selective breeding program initiated by a Panamanian shrimp company in 2001 has resulted in the development of significant resistance to WSSV in three selected lines of *L. vannamei* (Cuéllar-Anjel et al. 2012). In trials where shrimp from different genetic lines were challenged *per os* with WSSV, survival was 23%, 26%, and 57% 17 days after exposure in shrimp from families selected for WSSV-resistance, compared to 0% in unselected controls (Figure 8).

In Latin America development of WSSV-resistant stocks has been an important part of the strategy for industry survival now that WSSV is endemic in the environment. However, the benefits of selective breeding for disease resistance generally require several years of effort.

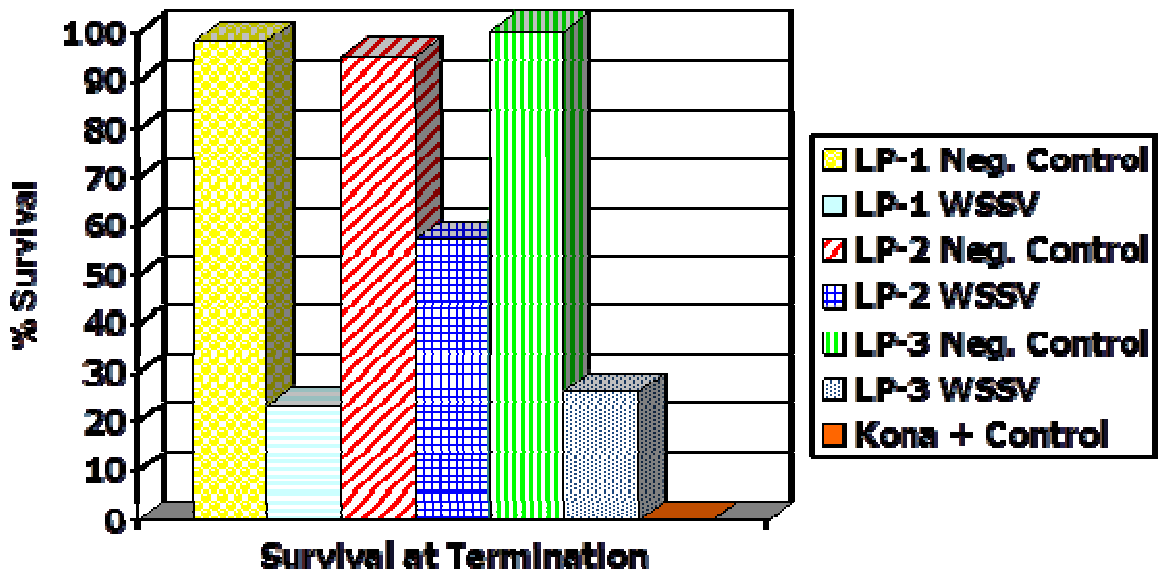


Figure 8. Survival by family in a WSSV challenge study of genetic lines selected for resistance to WSSV by a Panamanian shrimp company. (Cuéllar-Anjel, 2012)

The resistance to WSSV presented in the Panamanian example is the result of ten years of selection for WSSV resistance.

Selective breeding programs are expensive. Annual costs to operate a small breeding center would likely be between $500,000 and $1,000,000 per year. This makes operation of a selective breeding center too expensive except for large shrimp companies. However the cost of PLs produced from the selected broodstock declines as the number of PLs produced increases (Table 1). For a program that costs $1,000,000/year to operate, the breeding cost per

No. of PLs Produced/Yr from Breeders	Breeding Center Annual Budget	
	$500,000	$1,000,000
50 million	$10.00	$20.00
100 million	$5.00	$10.00
200 million	$2.50	$5.00
300 million	$1.67	$3.33

Table 1: Breeding center cost per 1000 PLs as a function of the number of PLs produced per year from the breeders and the Breeding Center annual budget.

thousand PLs drops from $10/1000 PLs to $4/1000 PLs as PL production increases from 100 million to 250 million PLs per year. The estimated annual demand for PLs for the entire Mozambique Channel shrimp industry is estimated to be between 850 and 1100 million PLs per year, depending on the stocking density used. This demand could easily be met by one breeding center. Sharing the cost of a single regional breeding center would be a cost effective option for the farms in the region.

12 FARM LEVEL STRATEGIES FOR CONTROLLING WSSV

12.1 Avoid Stocking during the Cold Season

The expression of WSSV infections in shrimp are temperature dependent. High water temperature (>32°C) prevents the onset of WSD and significantly reduces mortality of WSSV-infected shrimp (Rahman et al. 2006). WSSV infection is much more likely to cause mortality when water temperatures are 27°C or less. Because of this relationship between water temperature and WSSV virulence, many shrimp farmers in areas where WSSV is endemic avoid operating their farms during the coldest months of the year.

In Madagascar and Mozambique pond water temperatures are coldest from mid-May to the end of September (Figure 9). During this time period water temperatures are likely to average less than 27°C. These are the months when the risk of WSD outbreaks is highest. Shrimp farms

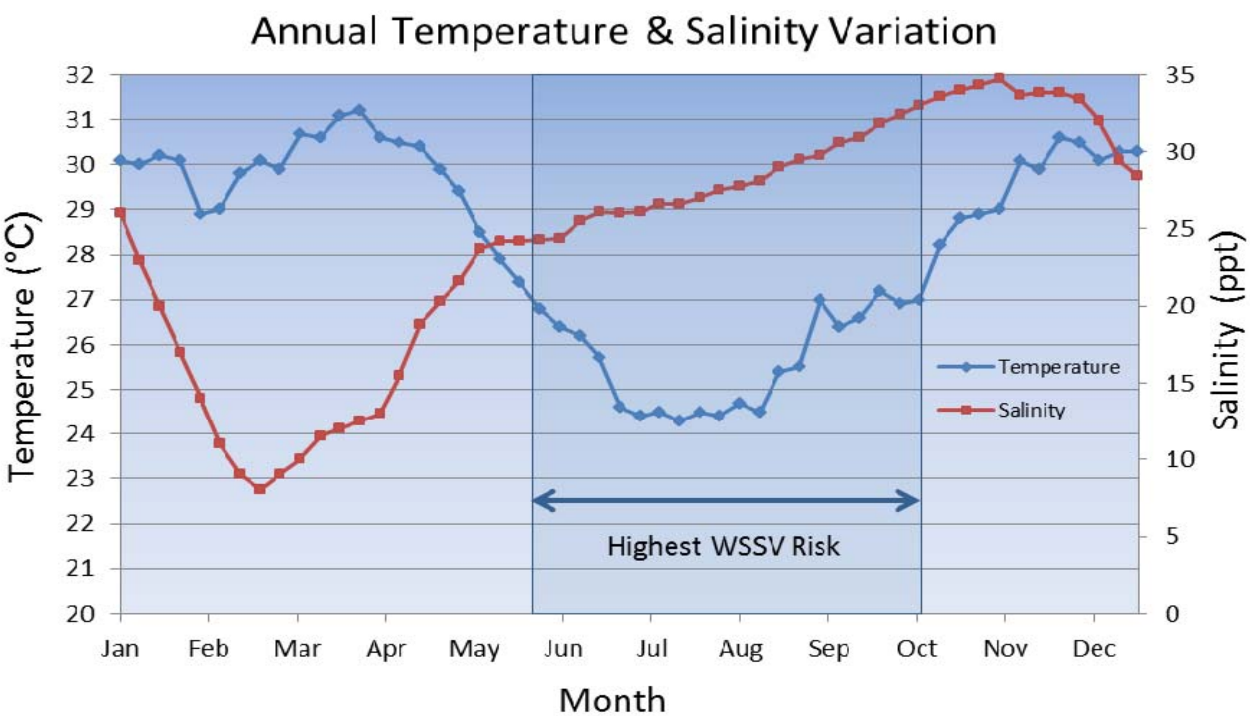


Figure 9: Annual temperature and salinity variation for a Madagascar shrimp farm. Shaded area is the time period when water temperatures are less than 27°C. (Adapted from Corpron, 2005)

can reduce their risk of WSD outbreaks by not operating the farm during this time period. That leaves 226 days between October 1 and May 15. Allowing 21 days between crops, there are only 205 growing days per year for two crops of shrimp. While it may seem that this strategy would reduce the annual productivity of shrimp farms, it should be noted that avoiding production during the coldest months has been one of the keys to the recovery of the Latin American shrimp industry from the White Spot epidemic.

12.2 Head-starting PLs in Greenhouse-Covered Nursery

Some shrimp farms in Latin America have begun using indoor nursery systems (Figure 10) to head-start their crops to re-gain the production days lost by avoiding the cold season. An indoor raceway system provides a biosecure production environment with warm water temperatures. Subsequent survival in the growout pond will generally be improved by stocking an advanced juvenile. *L. vannamei* PLs are typically stocked at densities of up to 2,000-3,000 PLs/m^2 and grown to a size of 2.0-2.5 g in lined raceways. Optimal stocking densities for *P. monodon* nursery raceways would be lower, perhaps about 1000 PLs/m^2 for a 50 day nursery period (Briggs, 1991). Four 7 m x 50 m raceways stocked at 1000/m^2 and harvested with 85% survival would provide enough juveniles to stock one 10-ha pond at a density of 12/m^2.

Figure 10: Indoor nursery raceway system for head-starting PLs (Photo credit: Larry Drazba)

12.3 Reduce Water Exchange

One of the most effective strategies for minimizing risk of WSD on farms is to operate the farm with little or no water exchange. Water exchange provides an opportunity for carrier organisms such as shrimp and crabs to enter the farm. Even filtered seawater may contain planktonic carriers such as copepods and crustacean larvae. In areas where there are active WSD outbreaks, free WSSV virions in the seawater will pass through even the finest screens and are capable of infecting shrimp in the ponds (Esparza-Leal et al. 2009). Adoption of production strategies that will allow overall water exchange rates to be reduced should be a central element of every farm's strategy to reduce their risk of WSSV.

Water is exchanged in shrimp ponds to reduce the buildup of organic matter and nitrogenous wastes in the pond. Simply reducing water exchange rates is not a viable strategy since water quality will deteriorate and the carrying capacity of the pond will be reduced. However, there are many studies that show that water exchange can be reduced or eliminated in shrimp ponds by aerating the pond (Hopkins, et al. 1993; Hopkins, et al. 1995). Each kW of aeration can support an additional 500 kg of shrimp production (Boyd, 1998). Shrimp ponds in Asia often have between 10 and 20 kW/Ha of aeration, allowing them to produce 5-10 MT/Ha of shrimp with little or no water exchange.

12.4 Pond Aeration

In Asia aeration has been applied to intensify production in small ponds. Shrimp farmers in Madagascar and Mozambique have little interest in intensification of their culture systems. They have differentiated their shrimp in the market-place by emphasizing the quality of their shrimp which they attribute to the outstanding environmental conditions in their low density ponds. The goal of aerating the ponds in this situation is not to intensify production, but to

Item	Units	Qty	Unit Price	Total
Paddlewheel Aerator, 2.5 hp	ea	800	$1,000	$800,000
Starter Panel	ea	800	$200	$160,000
Power cabling	ha	400	$200	$80,000
Electrical Distribution - Power Lines	ha	400	$2,000	$800,000
500 KVA Generators – (2 KVA/KW)	ea	8	$50,000	$400,000
Total Cost	**ha**	**400**	**$5,600.00**	**$2,240,000**

Table 2: Estimated cost of adding 5 hp/ha of paddlewheel aeration for a 400 ha shrimp farm. The cost includes the installation of generators and power lines to each pond.

maintain current production levels with much lower rates of water exchange. In addition, aeration should help maintain higher dissolved oxygen levels to avoid stressing the shrimp. The addition of 5 kW/ha of aeration should allow stocking densities to be increased from 10 to 15 shrimp/m^2 without compromising product quality. The capital cost associated with adding 5 hp of aeration capacity to a farm is estimated at $5,600/ha, including the cost of power generation and distribution (Table 2). The additional production would pay for the cost of installing aerators and generators on the farm (see Appendix 5). Much of the additional operating cost associated with running paddlewheel aerators in the ponds is offset by the savings in reduced pumping costs.

12.5 Probiotics

Regular probiotic usage can improve the pond environment in several ways. Probiotics compete with pathogenic bacteria, such as *Vibrio harveyi* and *V. parahaemolyticus,* reducing the counts of the pathogenic bacteria in the water (Garriques and Arevalo, 1995; Moriarty, 1998). Several studies have demonstrated a relationship between the counts of bacteria that form green colonies on TCBS agar plates (*V. harveyi, V. parahaemolyticus,* and *V. vulnificus*) and outbreaks of WSD (Gunalan et al. 2010; Tendencia and Verreth, 2011). In addition probiotics are able to consume toxic nitrogenous wastes (Avnimelech, 1999). Probiotics are a useful tool that can help maintain healthy conditions in a pond even under restricted water exchange. Regular probiotic usage will add about $300/ha/cycle in operating costs.

12.6 Exclusion of carriers by filtration

Exclusion of carriers of WSSV should be a critical component of any farm level strategy for preventing WSD (Clifford, 1999). There is no broad agreement in the industry with respect to the size of filter screen that should be used. To be effective, the water should be filtered down to at least 200 microns. From a biosecurity standpoint, WSSV risk decreases with screen size. That consideration must be balanced against the practicality of obtaining the required flow rates and frequency of cleaning.

12.6.1 Microscreen drum filters

Ideally all seawater entering the farm should be filtered before it is discharged into the water distribution canal. However, filtering the large volumes of water pumped onto the farms (6-20 m^3/sec) presents a challenge. A large amount of filtration surface area is required, and screens can become clogged very quickly. Microscreen drum filters provide a practical solution to these problems. Microscreen drum filters are mechanical, self-cleaning filters designed to filter fine suspended solids from the water at flow rates. A drum filter consists of a horizontally mounted cylindrical drum with fine-mesh screen wrapped around it. Water enters the front of the drum and passes through the screen. Suspended solids are deposited on the inner surface

Description	Quantity	Unit Price	Total Cost
Microscreen Drum Filter - 100 micron screen, .50 m^3/sec capacity	12	$50,000	$600,000
Concrete weir and drum filter support structure	12	$40,000	$480,000
Electrical Installation	12	$10,000	$120,000
Total estimated cost of microscreen drum filter and weir			**$1,200,000**

Table 3: Estimated cost for installing a microscreen drum filtration system with filtration capacity of 6 m^3/sec.

of the screen. The drum rotates slowly and solids are continually washed off the screen by a high pressure spray bar. Drum filters can be fitted with filter screens from 10 – 500 microns, and can handle flow rates of up to 500 L/sec with a 100 micron screen.

Filling a 400-ha shrimp farm in 30 days with 12 hours a day available for pumping requires a total pumping capacity of almost 7 m^3/sec. To filter this flow through 500 L/sec drum filters would require 14 units. The capital requirements for this filtration option are very high (Table 3). Large drum filters can cost more than $50,000 each. Including the cost of the concrete structures needed to mount and direct the flow through the drum filters, the final installed cost could reach $100,000 per unit. While this option may be the ideal filtration option from a biosecurity standpoint, the cost will be prohibitive for most farms.

12.6.2 Bag Filtration of Seawater Entering a Pond

An affordable alternative to filtering the water before it enters the distribution canals is to filter it at the inlet gates for each pond. The traditional concrete inlet gate uses one or two flat 500 micron screens to exclude fish and crabs. Copepods and crustacean larvae easily pass through these screens. Using a finer 200-micron screen in the existing frames is not a good filtration option because the screens would require constant cleaning to keep them from clogging. In Latin America this problem has been overcome by using 4-m long filter bags. Typically the filter bags are set up with an inner and an outer bag. The inner bag has a course mesh (1 mm), while the outer bag is a finer mesh, usually 200 micron. The filter bags are attached to a frame that is mounted on the pond side of the inlet gate. The end of the filter bags are tied off. The length of the filter bag provides a large amount of surface area for filtration. The bags are self-cleaning in the sense that trapped solids are continually washed down to the end of the filter bag by the water flow, leaving most of the length of the filter clean for filtration. The accumulated solids need to be emptied from the end of the bag two or three times per day.

Materials for the filter bags cost about $250 per inlet gate. Assuming one inlet gate for every 5 ha of pond area, the cost would be about $50 per hectare of farm ponds.

12.7 Install Water Distribution Canal Drain Structures

Water distribution canals on many shrimp farms are rarely drained, and many even lack drainage structures. Over time they are colonized by a wide range of organisms, including fish, shrimp, crabs, oysters, and other crustaceans. The presence of a large biomass of potential carriers of WSSV represents a significant biosecurity risk for the shrimp farm. A simple and relatively inexpensive solution to this problem is to construct one or more drainage gates to facilitate regular draining of the distribution canal. After draining the distribution canal should be dried out thoroughly before refilling to eliminate kill potential vectors living in burrows.

The estimated cost of constructing concrete water control structures for draining the distribution canal is about $7,000 each.

12.8 Crab Fencing

Crabs can be an important reservoir host for WSSV (Lo et al. 1996; Kanchanaphum, et al. 1998) and are abundant in the mudflats where most shrimp farms are built. The ability of crabs to travel over land means special measures are needed to exclude crabs from shrimp ponds. When properly maintained, crab fencing has proven to be an effective means of excluding crabs from shrimp ponds. Crab fences are plastic barriers typically about 50 cm high erected around the perimeter of a farm (Figure 11).

Figure 11: Crab fencing

Crab fencing is inexpensive, costing about $500/km of fence. Crab fencing is only needed on farm perimeter levees and on levees between ponds and canals.

12.9 Bird Netting

Birds have long been suspected as vectors for transmission of WSSV. Following disease outbreaks, large numbers of seabirds are often attracted to the affected pond to feed on the dead and dying shrimp. It has been hypothesized that after feeding on infected shrimp birds can transmit WSSV from one pond to another either by defecating or regurgitating. A study by Van Patten et al. (2004) demonstrated that while WSSV isolated from the feces of birds is non-infective, regurgitated WSSV remains infective. Many seabirds regularly regurgitate non-digestible food items.

In areas where WSSV is endemic, many shrimp farms now cover the ponds with bird netting or monofilament scare lines to exclude birds from shrimp ponds. Data from a farm in Malaysia shows that bird netting can effectively prevent the spread of WSSV from infected ponds to other ponds on the farm (Akazawa, 2013). Even very large ponds can be covered with monofilament netting supported on cables strung between support posts anchored in the pond bottom (Figure 12). The cost for covering a shrimp pond with monofilament netting is approximately $2,000/ha.

Figure 12: Bird netting deployment system (Photo credit: Larry Drazba)

12.10 Disinfection of Seawater Entering the Farm

Filtration systems are effective at preventing vectors larger than the mesh size of the screen, but it is still possible for WSSV to enter a pond either as free virions or in planktonic carriers such as copepods. Disinfection of the pond water with chlorine or ozone can be an effective way of inactivating WSSV that passes through the mechanical filtration systems. WSSV has been shown to be inactivated by exposure to 200 ppm of sodium hypochlorite for 10 minutes (Balasubramanian et al. 2006). In pond applications the OIE (2013) recommends maintaining a minimum free chlorine level of 10 ppm for 24-48 hours after filling. Free chlorine should be monitored at regular intervals and calcium hypochlorite should be re-applied as necessary to maintain this minimum concentration. An initial application rate of 30 ppm of free chlorine will usually be sufficient to maintain the required 10 ppm of chlorine for 24 hours. After treatment the pond should be allowed to sit for 4 or 5 days before stocking to allow the chlorine to dissipate.

A total of 462 kg of granular chlorine (65% chlorine) is required to treat 1 hectare of pond area filled to a depth of 1 m. Assuming a cost of $1.20/kg for granular chlorine, the cost for disinfecting a pond prior to stocking is $554/ha. For a farm producing 2,000 kg/ha per crop, disinfecting the pond prior to stocking would add $0.28/kg to the production cost.

Chlorinating the water within the shrimp pond disinfects the initial fill of the pond, but a separate treatment reservoir is required to chlorinate water used for water exchanges. If the total time required to treat the water is 4 days, two treatment ponds will needed to ensure a continuous supply of disinfected seawater. Each of the ponds should have a volume of 4 times the daily farm water requirement. If the farm is exchanging 5% of the pond volume per day, the total volume of the treatment ponds would equal 40% of the volume of the production ponds. This is not a cost effective use of pond area.

13 AFFORDABILITY OF BIOSECURITY IMPROVEMENTS

A financial analysis was conducted to determine the affordability of investing in biosecurity upgrades to the farm facilities. In our interviews with representatives of the different farms, the team gathered information on typical production parameters such as stocking densities, survivals, length of crop cycles, number of crop cycles per year, average weight of shrimp harvested, water exchange rates and FCRs. We also gathered information on prices received for the shrimp and costs of labor, management, feed, diesel consumption, and processing costs. Finally, we gathered information on investment costs and costs for various upgrades such as bird netting, paddlewheel aeration, generators, microscreen drum filters, etc.

Using the information gathered, an enterprise budget was developed for a “typical” 400-ha Mozambique Channel shrimp farm. This model assumed no investment in biosecurity improvements. We then calculated the investment requirements for implementing different biosecurity upgrades. To simplify the analysis we examined the financial consequences associated with three biosecurity strategies or scenarios (Table 4). Stocking SPF PLs was a common element to all three strategies. We assumed this increased the cost of PLs from $10.00/thousand to $14.00/thousand. Other improvements common to all plans included crab fencing, bird netting, probiotic usage, and drain structures to allow drainage of seawater distribution canals. The main distinguishing feature between Biosecurity Strategy #1 and the other two strategies is aeration. Strategy #1 assumes no aeration is added to the ponds while Biosecurity Strategies #2 and #3 both include the addition 5 hp/ha of aeration. Water exchange without aeration can only be reduced by lowering stocking densities. The addition of 5 hp of aeration per hectare should allow water exchange to be nearly eliminated. With 5-hp of aeration per hectare it should be possible to produce approximately 2,500 kg/ha without water exchange (Boyd, 1999). The addition of aeration allows stocking rates to be increased from $9/m^2$ to $13.5/m^2$. Production under this scenario would be 2,363 kg/ha, assuming 70% survival and a harvest weight of 25 g. Biosecurity Strategies #2 and #3 differ from one another in the technology selected for seawater filtration. Biosecurity Strategy #2 utilizes 200 micron bag filters attached to the inlet structures while Biosecurity Strategy #3 uses microscreen drum filters.

The costs and returns for each of the four scenarios are presented in Appendix 4.

Table 4: Assumed features for three different biosecurity improvement strategies compared with the features of a typical farm with no biosecurity improvement strategy.

Feature	No Biosecurity Strategy	Biosecurity Strategy #1	Biosecurity Strategy #2	Biosecurity Strategy #3
Stock SPF PLs from breeding center		X	X	X
Drainage gates on SW distribution canal		X	X	X
Bird netting over ponds		X	X	X
Crab fencing		X	X	X
Regular probiotic treatments of ponds		X	X	X
Aeration – 5 hp/ha			X	X
Water Exchange Rate	15%/day	10 %/day	0 %/day	0 %/day
Stocking Density	$9/m^2$	$6/m^2$	$13.5/m^2$	$13.5/m^2$
Increased capacity of processing facilities			X	X
200-micron bag filters on inlet gates		X	X	
100-micron Microscreen drum filters				X

These are the key conclusions drawn from this analysis:

- Reducing stocking densities to allow for lower water exchange rates is not a viable biosecurity strategy. The gains in biosecurity are minimal, and the reduced productivity of the farm may very well make the farm unprofitable.
- The addition of 5-hp/ha of aeration should allow for a significant increase in productivity from 1.57 MT/ha/crop to 2.36 MT/ha/crop, while minimizing the need for water exchange.
- Biosecurity Strategy #2 (aeration plus bag filtration) increase in productivity reduces overall operating costs and improves the profit margin. Net returns per kg of shrimp produced are estimated at $1.25/kg with no biosecurity plan, and $2.00/kg under Strategy #2.
- The most biosecure strategy, in which aeration and microscreen drum filtration is used, is very capital intensive, with an expected investment cost of about $14 million dollars for a 400 ha farm. Despite the high cost, the profit per kg of shrimp is reduced by only $0.12/kg.

14 CONCLUSIONS

14.1 The Cause of the Outbreak

The first epidemiological survey that was carried out in late 2011 demonstrated that shortly after the first outbreak at the Aquapesca farm WSSV was already widely distributed along the entire length of the Mozambican coast, infecting both shrimp and crabs. This is strong evidence that WSSV was already established in the Mozambique Channel before the first farm outbreak.

The genotype of the WSSV in the Mozambique Channel is closely related to that of the WSSV found in Saudi Arabia, and is genotypically distinct from WSSV found elsewhere in the world. This strongly suggests a common origin for the Saudi Arabian and Mozambique Channel strains of WSSV. The WSSV outbreak in Saudi Arabia began in January, 2011, nine months before the outbreak in Mozambique. It seems likely that the WSSV in the Mozambique Channel originated in the Red Sea.

What is less clear is how WSSV was transported between the two areas. Both Mozambique and Madagascar prohibited the importation of live shrimp into their countries, so it seems unlikely imported live shrimp were the source of WSSV in the Mozambique Channel. It is possible that WSSV was somehow transported from the Red Sea to the Mozambique Channel, either in ship ballast water or by ocean currents. Another possibility is that shrimp fished from the Red Sea were transported to processing plants in Beira, Inhassunge, Maputo or Mahajanga.

The widespread distribution of WSSV in wild populations of shrimp along the coast of Mozambique, and the use of wild shrimp as broodstock in the Nacala hatchery strongly suggests that infected broodstock was the route by which WSSV infected the Aquapesca farm. Further support for this hypothesis is the fact that there was an outbreak of WSD in newly captured broodstock simultaneous with the outbreak on the Aquapesca farm. Broodstock brought to the hatchery before the initial outbreak also developed WSD. Before the WSSV outbreak in September, wild broodstock were not routinely quarantined and PCR-tested prior to being introduced into the hatchery. Another possibility is that the disease was introduced to the farm by infected wild crustaceans entering through the seawater pumping system.

It is not clear whether the WSSV outbreak at the Aquamen EF shrimp farm originated by vertical transmission from infected wild broodstock or by horizontal transmission from infected carriers in the seawater system. Like the Nacala hatchery, the Aquamen hatchery relied on wild broodstock. The Aquamen hatchery normally quarantined, stress tested, and PCR tested their broodstock prior to moving them into the hatchery. However, Aquamen relied on the LES to do their PCR testing. Due to lack of funding the LES discontinued PCR testing at the Aquamen facility several months before the WSSV outbreak. The lack of access to PCR testing may have resulted in the use of asymptomatic WSSV-infected broodstock. Despite the fact that broodstock samples sent to the UAZ lab tested negative for WSSV, the high rate of infection on the farm is suggestive of vertical transmission. According to the Immediate Notification of WSSV infection sent to the OIE (OIE, 2012), the morbidity rate on the farm was 95%. However, the presence of WSSV-infected wild shrimp in the coastal areas near the farm makes horizontal transmission of WSSV an equally likely source for the infection.

14.2 Contributing Factors at the Farm Level

14.2.1 Reliance on wild broodstock

While two of the shrimp farming companies in Madagascar have shrimp breeding programs and stock SPF post-larvae, the rest of the shrimp industry in the region relies on wild broodstock or non-SPF farm-reared broodstock. None of the companies using wild broodstock employed strict quarantine and PCR screening of their broodstock prior to the outbreak in 2011. Reliance on wild unscreened broodstock is perhaps the biggest disease risk factor for the aquaculture industry. Vertical transmission of viral diseases through infected wild broodstock provides a direct path for a viral disease to infect the shrimp on a farm, and can result in widespread infection. Historically the use of wild broodstock and seedstock has fostered the spread of viral disease in shrimp aquaculture and in wild populations (Lightner, 2009). The shrimp farming industry globally has recognized this and begun to make the transition from wild to domesticated broodstock and seedstock. This transition is critical to the long term sustainability of shrimp farming.

14.2.2 Reliance on water exchange

All of the shrimp farms in the Mozambique Channel region are semi-intensive shrimp farms featuring large earthen ponds managed as open systems with high rates water exchange. Little or no aeration is employed on most of these farms. Instead, water quality is maintained by exchanging up to 15% of the pond volume per day. This practice dramatically increases the risk of WSSV infecting the shrimp stocks in the ponds by horizontal transmission. Filtration of the incoming water is primarily done for the purpose of predator control using 500 micron screens. This mesh size, however, allows the passage of WSSV carriers such as crustacean larvae. The water distribution canals on these farms are rarely drained and contain considerable biomass of shrimp, crabs, ghost shrimp, oysters, and barnacles. This reservoir of susceptible hosts and mechanical hosts increases the vulnerability of farms to WSSV outbreaks.

One of the lessons learned from the viral pandemics of the last 20 years is that open systems are extremely vulnerable to disease outbreaks. Only by eliminating water exchange can the risk of horizontal transmission be eliminated. Substitution of aeration for water exchange is the most effective way to eliminate water exchange. Where the demands of organic certification make that impossible, farms should adjust stocking densities to minimize their water exchange requirements.

14.2.3 Lack of surveillance programs

Prior to the WSSV outbreak in September, 2011 no surveys of disease prevalence in wild crustacean populations had been conducted in Mozambique. A disease surveillance program was initiated in Madagascar in 2010, but was discontinued the following year due to funding issues. Disease surveillance programs provide early warning to shrimp farmers of the presence of pathogens in the nearby coastal environment, allowing them to take appropriate measures to minimize the potential for a catastrophic disease outbreak. The lack of surveillance programs in both countries resulted in the shrimp farms being unprepared when WSSV appeared in the Mozambique Channel. The two companies hit hardest by WSSV were the first companies to become infected in each country.

Both Mozambique and Madagascar now have surveillance programs in place. However neither is sufficiently funded by the government or is as effective as it should be. The surveillance program in Mozambique was initially funded by the French Development Agency, and organized by the APCM with input from INIP and INAQUA. While the program is now funded by the Ministry of Fisheries, the government still has not taken full control of the program. In Madagascar there is no funding available for a surveillance program due to the governmental crisis. The private sector has had to carry out and fund its own surveillance programs. While the efforts of the two companies conducting surveillance activities are commendable, the lack of coordination between the two programs has led to inefficiency. The surveillance data gathered by the two companies has not been available to other stakeholders in the country, reducing the overall value of the data gathered.

14.2.4 Lack of resources to implement needed biosecurity improvements

The recovery of the industry from the WSSV epidemic is dependent upon producers investing in improvements in the biosecurity of their operations. Farms that are currently dependent upon wild broodstock will need to invest in programs to develop domesticated SPF broodstock. Prevention of horizontal transmission will require investments in aeration systems, filtration systems, crab fencing, and bird netting. The total cost of these investments will be at least 5-10 million dollars for each farm. This cost may be too high for some of the farms to bear.

14.3 Weaknesses in aquatic animal health regulatory framework

On the national level in each country, there were problems that limited the effectiveness of the governmental response to the outbreak. Prior to the WSSV outbreak neither Mozambique nor Madagascar had developed a comprehensive aquatic animal health policy, or functional institutions in place to provide a coordinated response to the crisis.

14.3.1 Mozambique

In Mozambique the regulatory framework for the aquaculture industry is still being developed. INAQUA, the government agency responsible for overseeing the aquaculture industry was only created 2008 and when the WSSV outbreak occurred in 2011 the agency was still in the process of recruiting personnel to complete its structure (Le Groumellec, 2011). INIP is the designated Competent Authority for aquatic animal health, but lacks a reference laboratory or personnel with training in aquatic animal disease diagnostics.

There is a lack of legislation regarding aquatic animal health clearly defining the roles each stakeholder (Baloi and Le Groumellec, 2012). The WSSV crisis made it clear to all stakeholders in Mozambique the importance of developing a national strategy for aquatic animal health supported by legislation. Work began immediately on drafting a set of aquatic animal health regulations and a national strategy for dealing with WSSV and other disease outbreaks. The process, however, is time-consuming and nearly two years after the initial outbreak of WSSV neither piece of legislation has been approved. Even after the legislation is approved it will take more time for the new organizational structure to become fully functional.

14.3.2 Madagascar

In Madagascar, the regulatory framework for the aquaculture industry is slightly better developed than in Mozambique, at least on paper. There is a national pathogen list for aquatic animal diseases, and there is a legislated aquatic animal health policy. Madagascar also has a designated official reference laboratory for aquatic animal diseases. Nevertheless, the lack of funding for aquatic animal health programs has crippled ASH and LES to the point that they are unable to function in a meaningful capacity. When the WSSV crisis struck the country in 2012, the Malagasy government was unable to mount a coordinated response to the disease outbreak.

15 LESSONS LEARNED

- **Physical isolation does not assure biosecurity.**

  By virtue of its physical isolation, the shrimp industry surrounding the Mozambique Channel had been free from OIE listed diseases. This freedom from disease resulted in many of the farms lagging behind the rest of the world in the adoption of biosecure production practices such as the elimination of dependence on wild broodstock, and the continued reliance on high rates of water exchange to manage water quality in the shrimp ponds. When WSSV did reach the area, these farms were vulnerable.

- **Surveillance programs are critical for national biosecurity**

  The fact that WSSV was found in a high percentage of the samples taken in Mozambique shortly after the first outbreak suggests that WSSV may have been present in the area for months before the first outbreak. If a national surveillance program had been sampling the wild populations on a regular basis before the outbreak occurred, producers could have taken appropriate measures to upgrade biosecurity before WSSV appeared on their farms.

- **Breeding programs to produce SPF disease-resistant stocks should be a regional priority**

  The reliance on unscreened wild broodstock is the biggest biosecurity risk for the industry as a whole. The risk of vertical transmission can be minimized by stocking SPF PLs, but SPF shrimp are still vulnerable to horizontal transmission after they are stocked. As a long term strategy, the region needs to develop SPF stocks that have been selected for resistance to WSSV. However, it is not economical or feasible for each individual producer to maintain their own breeding center to produce SPF disease-resistant stocks. While a single regional breeding center would be the most cost effective strategy for eliminating the use of wild broodstock, establishing one national breeding center in each country might be a better alternative from a political standpoint.

- **High rates of water exchange are a major risk factor for horizontal transmission of WSSV.**

  Substitution of aeration for water exchange can be cost effective with only modest intensification of production.

- **Strong national aquatic animal health policies and institutions are critical for national biosecurity**

  The absence of strong national aquatic animal health policies and institutions increases the vulnerability of the region to epizootic disease outbreaks. Aquatic animal health policies should clearly define the responsibilities of the various stakeholders in maintaining national biosecurity, as well as the procedures that must be followed when a disease outbreak does occur.

- **National and regional biosecurity requires cooperation of all stakeholders**

  The investment required to manage farm biosecurity increases with disease prevalence. Consequently, it is in the interest of all stakeholders to avoid outbreaks in the region through implementation of biosecurity practices that meet or exceed minimum standards. Weak biosecurity on individual farms weakens the biosecurity for all of the farms in the region. Producer associations and governments should work together to develop standards for minimum biosecurity practices and assure that they are implemented at each facility.

16 RECOMMENDATIONS

At the conclusion of the Regional Workshop on White Spot in the Mozambique Channel, workshop participants identified four main areas to be addressed by the region:

1. Development of national and regional biosecurity protocols, including procedures for normal operation, procedures to respond to disease outbreaks, and procedures for re-start of farms following a disease outbreak
2. Transition from the use of screened wild broodstock to the use of Specific Pathogen Free Broodstock and eventually to broodstock genetically selected for disease resistance
3. Design and implementation of national disease surveillance programs with collaboration between Competent Authorities of countries in the region and sharing of results between all stakeholders
4. Promotion of regional cooperation between all stakeholders by setting up technical and strategic committees to address region-wide aquatic animal health issues such as, regional breeding programs, disease surveillance and regional responses to disease outbreaks.

The following are some specific measures recommended by the Expert Team to promote aquatic biosecurity in the region:

16.1 Recommendations for Producers

1) Develop a Regional Breeding Center to produce SPF broodstock

The replacement of wild broodstock with SPF domesticated should be given the highest priority. A single breeding center for the entire region would be the most economical alternative. Without a base to build upon, it typically takes 2 years to develop an SPF population and several additional years of captive breeding to achieve domestication. However two farms in the region already have SPF breeding centers that can serve as a foundation for a regional breeding center. If there is cooperative effort on the part of all stakeholders in both Mozambique and Madagascar, the entire region could have access to SPF seedstock within a year.

For Mozambique, the quickest route for the replacement of wild broodstock would be to permit the importation certified SPF stocks from Madagascar. This is prohibited under current law. Unless this law is modified to permit the importation of certified disease free stocks, Mozambique will have to develop their own SPF breeding program from scratch.

2) Breed for WSSV-resistance

After the establishment of SPF populations in the regional breeding center, priority should be given to breeding for resistance to WSSV. The feasibility of this strategy has been demonstrated with *L. vannamei*. With a well-designed breeding program, gains in WSSV resistance of 2-5% per generation should be possible.

3) **Follow strict PCR screening procedures if use of wild broodstock is unavoidable.** If wild broodstock must be used, they should be quarantined in individual tanks and individually tested by PCR. Females should be tested by PCR and histology after each spawn, and PLs should be PCR tested prior sending them to the farm.

4) **Avoid stocking during the cold season**
Outbreaks of WSD are much more likely to occur when water temperatures are low. Avoiding stocking during the coldest months of the year has proven to be an effective strategy for mitigating WSD outbreaks. The strategy is most effective when all shrimp farms adapt their stocking strategies to avoid production during the coldest months.

5) **Upgrade farm biosecurity to minimize horizontal transmission**
Farm biosecurity must be upgraded to minimize risk of mortality due to horizontal transmission of WSSV. Various technologies are available depending on the appropriate balance of risk tolerance and capital availability at each facility. The risk reduction associated with a particular strategy must be weighed against its cost. For example, installing a self-cleaning microscreen system to filter incoming seawater to less than 100 microns before it enters the distribution canal might improve biosecurity to a greater extent than passing the water through a static 200-micron filter bag as it enters the pond, but the cost is at least 30 times higher. For a farm that has limited capital resources, the most biosecure option may not make sense financially. Farms that are producing for organic markets have other constraints on the allowable technologies that they can adopt. So clearly, one size does not fit all. Each farm will have to develop a biosecurity plan that is appropriate for their situation. Collaboration between the individual farms, the producer's associations and the Competent Authority would be helpful in defining best practices to achieve a minimum standard of biosecurity.

5) **Explore alternatives for providing financial assistance to farms for biosecurity upgrades**
An outbreak of WSSV at a given farm in the region will heighten the prevalence of the disease in the environment and increase the risk of transmission to others. Consequently, it is in the interest of the all stakeholders for farms to upgrade their biosecurity infrastructure. Therefore there should be a concerted effort on the part of all stakeholders to identify mechanisms to finance biosecurity upgrades.

16.2 Recommendations for Public Sector Improvements

1) Review national legislation pertaining to aquatic animal health policy

Aquatic animal health policy should be written into national law. The law should clearly identify the institutions responsible for overseeing aquatic animal health policy and should define the relationships between each institution. The legislation should identify who in the government will assume the role of Competent Authority for aquatic animal health and clearly define the powers and authority for that position. The laws pertaining to aquatic animal health should define policies concerning import and export of aquatic animals, quarantine and health certification procedures, and responses to disease outbreaks. New and existing legislation should be reviewed to make sure it is consistent with international standards and obligations, such as the OIE's International Aquatic Animal Health Code.

2) Designate a National Reference Laboratory for Aquatic Animal Health

Each country should designate a National Reference Laboratory for aquatic animal health and provide sufficient funding to equip the laboratory with state of the art equipment for histopathology and PCR testing. Lab personnel should receive the training needed to accurately diagnose the range of aquatic animal diseases, and labs should participate in ring test proficiency exercises. The laboratories should be adequately staffed to enable quick turn-around times on sample processing.

3) Develop national aquatic disease surveillance programs to OIE standards

Disease surveillance programs should be coordinated and funded by the ministry of the Competent Authority, rather than being left to the initiative of the private sector. Surveillance programs provide early warning of disease hazards and provide producers with the opportunity to take early action to avoid catastrophic losses. Results of surveillance testing should be made public quickly to all national and regional stakeholders. A website should be created for posting of results. The creation of a website for surveillance data should be given high priority so that the surveillance data from the private sector surveillance efforts in Madagascar and the surveillance program in Mozambique can be rapidly shared among all stakeholders.

4) Develop national response plan for aquatic animal health emergencies

Each country should develop a national response plan for aquatic animal health emergencies. The Australian AquaVetPlan (DAFF, 2005) is an excellent model that many countries have used for crafting their own aquatic animal health plans.

5) Strengthen partnership between public and private sectors

Long term sustainability and growth of the shrimp industry in the Mozambique Channel can only be achieved in a biosecure environment. National and regional biosecurity requires close cooperation of producers and national institutions responsible for coordinating and implementing aquatic animal health policy. The producer associations in each country (the APCM in Mozambique and the GAPCM in Madagascar) are the interface between the producers and the government ministries. Priority should be given to promoting collaboration between the producer associations and the government ministries in the development of national biosecurity policies and programs. A good starting point would be to schedule quarterly meetings between the producer associations and the government ministries responsible for aquatic animal health. Strategic and technical committees composed of representatives from both the public and private sector would be very productive way to identify biosecurity strategies that will benefit the entire sector. The private sector representatives would provide the technical expertise and intimate knowledge of the needs of private sector. The public sector representatives would provide expertise on program organization and management, and would make sure the public interest is represented. Building cooperative working groups would build trust between the public and private sector and would ensure that all stakeholders are working together towards a common goal.

16.3 Regional Level Cooperation

1) Develop a regional response plan for aquatic animal health emergencies

As an ultimate goal, the national AAH plans of Mozambique and Madagascar should be integrated to form a Regional AAH plan. The regional plan would identify mechanisms for cooperation between the Competent Authorities in each country. An excellent starting point for the regional plan would be to schedule regular meetings (annual or twice a year) between stakeholder groups of both countries to share information and to discuss cooperative projects. Two areas where regional cooperation will be critical are in the sharing of surveillance data and the establishment of a regional breeding center.

16.4 Regional Biosecurity Plan

The reliance on unscreened wild broodstock is the biggest biosecurity risk for the industry as a whole. The risk of vertical transmission can be minimized by stocking SPF PLs, but SPF shrimp are still vulnerable to horizontal transmission after they are stocked. As a long term strategy, the region needs to develop SPF stocks that have been selected for resistance to WSSV. However, it is not economical or feasible for each individual producer to maintain their own breeding center to produce SPF disease-resistant stocks. While a single regional breeding center would be the most cost effective strategy for eliminating the use of wild broodstock, for political reasons a national breeding center in each country might be the best alternative.

- **Surveillance programs are critical for national biosecurity**

  The fact that WSSV was found in a high percentage of the samples taken in Mozambique shortly after the first outbreak suggests that WSSV may have been present in the area for months before the first outbreak. If a national surveillance program had been sampling the wild populations on a regular basis before the outbreak occurred, producers could have taken appropriate measures to upgrade biosecurity before WSSV appeared on their farms.

- **Strong national aquatic animal health policies and institutions are critical for national biosecurity**

  The absence of strong national aquatic animal health policies and institutions increases the vulnerability of the region to epizootic disease outbreaks. Aquatic animal health policies should clearly define the responsibilities of the various stakeholders in maintaining national biosecurity, as well as the procedures that must be followed when a disease outbreak does occur.

- **National and regional biosecurity requires cooperation of all stakeholders**

  The investment required to manage farm biosecurity increases with disease prevalence. Consequently, it is in the interest of all stakeholders to avoid outbreaks in the region through implementation of biosecurity practices that meet or exceed minimum standards. Weak biosecurity on individual farms weakens the biosecurity for all of the farms in the region. Producer associations and governments should work together to develop standards for minimum biosecurity practices and assure that they are implemented at each facility.

17 SUB-REGIONAL BIOSECURITY PLAN

The White Spot crisis has illustrated that, despite its geographic isolation, the shrimp aquaculture industry in the Mozambique Channel region (Mozambique, Madagascar, and Tanzania) is vulnerable to epizootic disease outbreaks. It must be recognized that all of the shrimp producers in the Mozambique Channel region operate on a common body of water, and that the biosecurity of each farm is dependent on the biosecurity practices of all of the other farms and shrimp processors in the region. A coordinated regional response to the White Spot disease outbreak is needed to allow the shrimp industry to return to profitability. A regional approach to biosecurity is also the best defense against future introductions of other OIE listed diseases.

In April, 2013 the FAO convened a workshop in Maputo for the purpose of developing a sub-regional strategy to improve aquatic animal health and biosecurity in the Mozambique Channel.

The participants in this workshop included representatives from Mozambique (INAQUA, INIP, and the APCM), Madagascar (ASH), Tanzania (National Animal Aquatic Health Coordinator), and the FAO Aquaculture Service. At the conclusion of the workshop the participants drafted a document outlining a strategy for improving aquatic biosecurity and aquatic animal health for the Mozambique Channel sub-region (see Annex I). The strategy identifies policy measures to be implemented at the national and regional level to promote aquatic animal health in the region. While additional work will be needed to fill in the details, the plan provides an excellent framework for addressing the biosecurity needs of the region. Rather than propose a separate Regional Biosecurity Plan, The World Bank Mission Expert Team endorses the regional biosecurity strategy proposed by the FAO working group, but would like to recommend the following additional program activities:

PROGRAMME COMPONENT 1 – *Governance*

1. Legislation should clearly identify the Competent Authority, and a National Reference Laboratory for aquatic animal disease diagnoses.
2. Each country in the region should develop a detailed Aquatic Animal Health Plan, identifying the Competent Authority, National Reference Laboratory, listed pathogens, key biosecurity policies, and emergency plans for disease outbreaks.
3. The National Plans should specify how information on Aquatic Animal Health will be shared between the Competent Authorities of all the countries in the sub-region.

PROGRAMME COMPONENT 2 – *Sub-regional preparedness/response and contingency plan for shrimp disease emergencies*

1. Clear procedures should be developed specifying the actions farms must take when a listed disease is diagnosed, including immediate discontinuation of water exchange, procedures for destruction and disposal of existing shrimp stocks, and disinfection of the farm.
2. The criteria for shrimp farms to start back up again following a disease outbreak should also be clearly identified**.**
3. Legislation should include an exception to the ban on importation of live aquatic animals to allow for the importation of veterinarian-certified Specific Pathogen Free seedstock and broodstock from other countries in the Mozambique Channel sub-region.

PROGRAMME COMPONENT 3 – *Diagnostics, Surveillance and Reporting*

1. Surveillance programs for OIE-listed shrimp pathogens should be a cooperative effort undertaken by the governments of the Mozambique sub-region countries.
2. A regional surveillance program should be designed with the assistance of an OIE-designated consultant to ensure both wild and farmed populations are effectively sampled. A sampling program should also be developed for shrimp processing facilities.

3. A regional authority should be designated to oversee the surveillance program, including sample collection, sample submission, disease diagnostic work, collection and analysis of data, and reporting of the findings.
4. National Reference Laboratories should be designated for each country in the sub-region
5. Reference Laboratories should be provided with state-of-the-art diagnostic equipment with sufficient sample processing capacity to enable timely processing of samples and reporting of results.
6. Reference Laboratories should participate in ring-testing exercises to validate the accuracy and reproducibility of the laboratories' diagnostic procedures.
7. Results of the surveillance program should be posted quickly to a web-site to permit immediate access by all stakeholders. Data collected by privately sponsored surveillance programs should also be posted to this web site. Positive results should generate alerts to be sent out to the competent authority and to designated representatives for each farm.
8. Designation of the sub-region or zones within the sub-region as disease free should be based on evidence provided by sample evidence and in accordance with OIE standards.
9. Funding of the surveillance program is the responsibility of the governments of the sub-region countries. However, a concept note should be prepared for possible funding by international agencies and/or private donors detailing the costs, needs and benefits of the surveillance program.

PROGRAMME COMPONENT 4 – *Prevention and Management of Risks from Exotic, Emerging and/or Unknown Aquatic Pathogens*

1. The shrimp industry must make the transition from reliance on wild broodstock to captive-reared Specific Pathogen Free broodstock. During the transition period, wild broodstock should be used only if they have been shown to be disease free by a rigorous quarantine and PCR testing protocol.
2. A shrimp breeding center should be established to produce Specific Pathogen Free broodstock and seedstock and made available to all shrimp farms in the Mozambique Channel sub-region. This breeding center should be developed as a cooperative effort of the governments and shrimp producers. (Note: The details of where the breeding center is located, how it is managed, and how it is funded should be determined by a working group consisting of public and private sector representatives from each country in the sub-region.)
3. As a long term strategy, SPF broodstock at the breeding center should be selected for resistance to WSSV to reduce vulnerability of shrimp stocks to horizontal transmission.
4. A minimum standard for farm biosecurity should be developed by a working group to include public and private stakeholders from each country in the sub-region. (Note: It should be recognized that every farm is different and that biosecurity plans must be tailored to the needs and resources for each farm.)

5. Each farm should develop and implement a biosecurity plan. The Competent Authority should review the biosecurity plan for each farm to make sure the plan meets the minimum standards for biosecurity as defined by the sub-regional working group.
6. Prepare regional minimum standards for importing crustaceans (live and products).
7. Legislation should include an exception to the ban on importation of live aquatic animals to allow for the importation of veterinarian-certified Specific Pathogen Free seedstock and broodstock from other countries in the Mozambique Channel sub-region.

PROGRAMME COMPONENT 5 – *Promotion of Sustainable Aquaculture Development and Responsible Investment in Shrimp Aquaculture*

No changes or additions recommended.

PROGRAMME COMPONENT 6 – *Assessment of socio-economic benefits/potential and risks, technical feasibility and environmental impacts of further shrimp aquaculture development in the Indian Ocean sub-region*

No changes or additions recommended.

PROGRAMME COMPONENT 7 – *Institutional Strengthening (human and financial resources, diagnostic and research infrastructure) and targeted capacity building on aquatic biosecurity (aquatic animal health)*

1. Training should be provided to Reference Laboratory technicians in both PCR and histological procedures so that they are able to accurately diagnose all of the OIE listed aquatic animal diseases.
2. Budgets for agencies responsible for AAH should include the cost of maintaining surveillance programs, Reference Laboratories, and other costs associated with maintaining a pro-active Aquatic Animal Health Program.

PROGRAMME COMPONENT 8 – *Regional Collaboration, Communication and Networking on Information and Shared Resources*

1. Regional strategic and technical committees should be organized with stakeholder representatives from all countries in the sub-region to ensure regional collaboration and information sharing in the development of AAH national plans, and regional surveillance programs.
2. The regional strategic and technical committees should meet on a quarterly basis to promote communication between stakeholder groups and to review progress on regional AAH initiatives.
3. Disease outbreaks within the region will require a region-wide response. Regional strategic and technical committees should develop procedures for a regional response to aquatic animal health emergency.

The Expert Team believes that with the addition of the recommended activities, the Strategy for Improving Aquatic Biosecurity for the Mozambique Channel Sub-Region provides an outstanding blueprint for recovery of the shrimp farming industry from the White Spot Disease crisis and for preventing future disease outbreaks.

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19 APPENDIX 1 - World Bank/RAF Mission Daily Activities & Meetings

Saturday, May 11

- Arrived in Maputo, Mozambique

Sunday, May 12

- Met with Pierre-Philippepe Blanc (APCM - Associação de Produtores Camarão de Moçambique, Technical Assistant for the Shrimp Aquaculture Sector)
- Farm visit – Sol y Mar (Director – Mr. Zhao Chanhui)

Monday, May 13

- Met with representative from Aquapesca (François Grosse – Director)
- Visited the Centro de Biotecnologia da Universidade Eduardo Mondane (Dacia Correia, Sub-director of the center, & Olivia Pedro, laboratory director)
- Met with Chris Schnell, Technical Director of Marbar, Lda., a wild monodon broodstock supplier based in Vilanculo

Tuesday, May 14

- Meeting with Dr. Maria Isabel Omar – National Director of Aquaculture, Instituto Nacional de Desenvolvimento da Aquacultura (INAQUA) (National Institute of Aquaculture Development)
- Met with Dr. Moisses Massinga, President of the APCM
- Meeting with Pierre-Philippe Blanc, APCM Technical Assistant

Wednesday, May 15

- Flew to Antananarivo, Madagascar

Thursday, May 16

- Met with Dr. Luc Ralaimarindaza, Executive Director of the Autorité Sanitaire Halieutique
- Met with Jean Edmond Robilahy, Cabinet Director for Ministere de la Peche et des Ressources Halieutiques
- Also participating in meeting were Harilalao "Zoelys" Raboanarijaona, Director of Aquaculture & Vero Rahantarimalala, Chief of Service in Marine Aquaculture
- Met with Dr. Iony Razanajatovo at the Pasteur Institute's Laboratory for Epidemiological Surveillance (Laboratoire de Epidémio Surveillance)

Friday, May 17

- Flew to Majahanga
- Met with Management of Unima - (Amyne Ismail – Director General; Rao Manavendra Vemulapalli – Manager of Farm Operations; Marc Le Groumellac – Hatchery and Disease Lab Manager; Vincent Rigolet, Aqualma Farm Manager; Padge Beasley, Engineering Consultant for farm re-design.

Saturday, May 18

- Visited Unima's Aqualma shrimp farm in Mahajamba

Sunday, May 19

- Met with Jean-Paul Robson – Manager of Quality Control for Aquamas Shrimp Farm
- Flew back to Antananarivo
- Met with representatives of the Oso Farming group: Salim Ismail, Chairman & CEO; Mathias Ismail, Managing Director; Eric Douheret, Director of Operations; Maryse Andriamampianina, Administrative and Financial Director.

Monday, May 20

- George met with Eulalie Ranaivoson of the GAPCM (Groupement des Aquaculteurs et Pêcheurs de Crevettes de Madagascar)

Tuesday, May 21

- Regional workshop on WSSV management plan

Wednesday, May 22

- Regional workshop on WSSV management plan

APPENDIX 2 - Chronology of Mozambique Outbreak

The following is a chronology of the WSSV outbreak in the Mozambique Channel was compiled from a variety sources, including a from an OIE-sponsored mission to Mozambique to study the WSSV outbreak (Le Groumellec, 2012), as well as interviews with representatives from each of the farms in the region, representatives of the APCM and with Mozambique government officials .

Chronology of Mozambique WSSV Outbreak

Date	Event
Aug. 31, 2011	• First mortalities from WSSV observed at Aquapesca shrimp farm in Quelimane, Mozambique
Sept. 1, 2011	• Pleopods samples sent to Center for Biotechnology Laboratory for emergency PCR analysis for OIE listed diseases • Samples fixed in Davidson's, not 95% ethanol.
Sept. 3, 2011	• Negative PCR test results for OIE listed diseases reported by CB-UEM. • Daily flushing of inlet canal started at Aguapesca
Sept. 4, 2011	• INAQUA notified of disease outbreak at the Aquapesca farm • Mortalities observed at Aquapesca Hatchery in Nacala within a group of broodstock recently brought to hatchery from Moma area. All shrimp in this group were dead within 2 weeks. • No broodstock tissue samples sent to laboratory – handling stress suspected
Sept. 5, 2011	• Most of ponds on farm with dead or moribund shrimp. • INIP (Compentent Authority) and INAQUA officials visit farm and observe the mortalities.
Sept. 6, 2011	• Samples of moribund shrimp with white spots sent to CB-UEM and UAZ for PCR Analysis. • Requested testing for Rickettsia–like bacteria due to negative PCR test results from CB-UEM on Sept. 2 sample.
Sept. 12 -14, 2011	• Positive WSSV test results on samples from Sept. 6 reported by UAZ and CB-UEM.

Sept. 15, 2011	• Meeting of Aquaculture sector to develop an action plan for dealing with the WSSV crisis • Technical commission created to study the WSSV problem. • Meeting with INIP (OIE focal point) to report the situation
Sept. 18, 2011	• Mortalities in Nacala hatchery spread to rest of broodstock tanks in hatchery. • Samples from all groups of broodstock sent to Concepto Azul lab in Ecuador.
Sept. 21 -29, 2011	• Official stamping out (collection, incineration, destruction, fallowing initiated) under supervision of the Competent Authority.
Sept. 22, 2011	• OIE immediate notification of WSSV report submitted by Dr. Florencia A. Massango Cipriano, National Director of Veterinary Services
Sept. 23, 2011	• First meeting of the technical commission, with representative of INAQUA, INIP, IIP, LCA, DCA and APCM (see "list of acronyms"). • Validation and organization of the national sampling plan.
Sept. 28 - Oct. 10, 2011	• APCM conducts sampling of crustaceans in different zones along the Mozambique coast to test for prevalence of WSSV
Sept. 29, 2011	• All remaining broodstock and larvae at Nacala hatchery are destroyed under supervision of INIP officials.
Nov. 20, 2011	• Shrimp from Nova Mambone area and exhibiting clinical signs of WSSV brought to Marbar's V Vilankulos recirculating facility. • The shrimp was eliminated and pleopod samples were sent to CB-UEM and UAZ for PCR analysis. • Remaining shrimp from that group were kept in quarantine.
Nov. 25, 30, & Dec. 4, 2011	• Additional groups of shrimp from Nova Mambone area developed clinical signs of WSSV after being brought to Vilankulos.
Dec. 9 & 10, 2011	• Both CB-UEM and UAZ report samples sent by Marbar tested positive for WSSV. Official provincial representatives of INIP informed. • INIP representatives sent to Vilankulos to supervise the destruction of the shrimp and disinfection of the quarantine system. • No samples were taken from any other group of shrimp at the facility.

December, 2011	• Quarantine system set up at Nacala hatchery; 100% of broodstock PCR tested prior to transfer to maturation facility (see photo 2 in Appendix (3).
Dec., 2011 - Feb., 2012	• Aquapesca conducts short two month trial in production ponds with 90% survival.
Jan. 23- Feb. 2, 2012:	• Training of laboratory technicians on PCR methods
Feb. – Mar., 2012	• Aquapesca stocks rest of farm with PLs from PCR-tested broodstock; nearly 100% lost to WSSV in March.
March, 2012	• Second positive WSSV result from Marbar Vilanculos facility and destruction of affected stocks
March, 2012	• Sol y Mar stocks ponds for first time since WSSV outbreak began
Late April, 2012	• Following period of heavy rain & cool weather, ponds at Sol y Mar break with WSSV, causing heavy mortality. Ponds drained and farm dried out.
May, 2012	• Second survey of WSSV in wild populations, focusing on Sofala province
Jun. – Jul., 2012	• Third survey of WSSV in wild populations, focusing on Nampula and Zambezia provinces.
Oct., 2012	• Sol y Mar re-stocks ponds but experiences WSSV outbreak soon after stocking, resulting in 100% mortality.
Nov., 2012	• Fourth sampling of wild animals (in Sofala, Inhambane, Cabo Delgado, Gaza, Maputo).
Dec., 2012	• Sol y Mar re-stocked after a short dry-out period. Some ponds suffer mortalities from WSSV, some do not. Warmer temperatures may have helped.
Dec., 2012	• Portable field PCR labs set up in four Mozambican provinces: Nampula (in Nacala), Zambezia (in Quelimane), Sofala (in Beira), Inhambane (in Vilanculos).

APPENDIX 3 – Chronology of WSSV Outbreak in Madagascar

Date	Event
2010	• Shrimp disease surveillance program initiated by the LES. The Aquamen shrimp farm is the only farm to participate in the disease surveillance program.
Dec., 2010	• LES disease surveillance program terminated due to lack of funds and limited participation by the shrimp farms.
January, 2012	• APMF prohibiting all international vessels from emptying their ballast tanks in Malagasy waters following a request from GAPCM acting within the framework of the fight against the "white spot"
Apr. 4, 2012	• First mortalities from WSSV observed at Aquamen shrimp farm in Tsangajoly, Madagascar.
April 24, 2012	• GAPCM Executive Committee to discuss WSSV situation at Aquamen • Development of an action plan
April 25-30, 2012	• All Aquamen ponds were emptied of their populations and the liming of such ponds began. • Action plans to fight against the "white spot" were formed before the official confirmation by the reference laboratory of the Office International des Epizooties (OIE) that it is of a case of "white spot."
May 9, 2012	• Official OIE initial notification of WSSV made.
May 23 & 28, 2012	• Meetings to discuss WSSV crisis between GAPCM and officials Competent Authority (ASH), Ministry of Fisheries and Marine Resources, Pasteur Institute (LES), French Development Agency (AFD), EU, World Bank, and FAO. Dr. Lightner of the OIE References Laboratory at UAZ was also present.

July 4, 2012	• At a meeting of the GAPCM executive committee it was decided that the LES surveillance program was not sufficient to meet the requirements for monitoring the spread of WSSV. The committee resolved to ask the Competent Authority to organize a new surveillance program relying on a cooperative public/private surveillance program using both the LES laboratory and GAPCM member's laboratories for analyzing the samples. GAPCM met the same afternoon with the Competent Authority to discuss the surveillance program.
Sept., 2012	• WSSV found in samples outside of the Besalampy farm. Emergency harvests were initiated immediately. Some of the ponds were infected with WSSV, but most of the ponds were salvaged. Ponds were dried and disinfected.
Sept., 2012	• Plan developed to hold an International Workshop on Whitespot in Antananarivo to include a World Bank team of experts, members of GAPCM, APCM, and public sector stakeholders from both Mozambique and Madagascar. The workshop was tentatively scheduled for the end of November, 2012.
Oct., 2012	• WSSV found on the Aquamas farm in Soalala.
Oct. 9 & 16, 2012	• Following a request from GAPCM, public-private special commission to deal with the crisis of the "white spot" was created and chaired by the Prime Minister. The commission had held meetings on 9 and 16 October with the participation particularly by representatives of the Ministry of Fisheries and Marine Resources and those of the Ministry of Livestock and other members the "Aquaculture" Division GAPCM.

20 APPENDIX 4 - Biosecurity Investment Analysis

Investment analysis of three different strategies for improving farm biosecurity.

ITEM	No Biosecurity Strategy	Biosecurity Strategy # 1	Biosecurity Strategy # 2	Biosecurity Strategy #3
Capital Investments				
Total Farm Investment before biosecurity upgrades	$12,000,000	$12,000,000	$12,000,000	$12,000,000
Proceessing Plant Investment before upgrades.	$8,000,000	$8,000,000	$8,000,000	$8,000,000
Investment in Biosecurity Upgrades	$0	$864,800	$6,104,800	$14,060,000
Total capital investments	**$20,000,000**	**$20,864,800**	**$26,104,800**	**$34,060,000**
Production Assumptions				
Total farm production pond area	400 ha	400 ha	400 ha	400 ha
Stocking rate	9.0 PLs/m2	6.0 PLs/m2	13.5 PLs/m2	13.5 PLs/m2
Survival rate	70%	70%	70%	70%
Shrimp harvest weight	25 g	25 g	25 g	25 g
Average yield per ha per cycle	1,575 kg/ha	1,050 kg/ha	2,363 kg/ha	2,363 kg/ha
Growing days per production cycle	110 days	110 days	110 days	110 days
Feed conversion rate (FCR)	1.80	1.80	1.80	1.80
Number of production crops per year	2 crops/yr	2 crops/yr	2 crops/yr	2 crops/yr
Annual production per year	1,260,000 kg	840,000 kg	1,890,000 kg	1,890,000 kg
Revenues	**$/kg**	**$/kg**	**$/kg**	**$/kg**
Annual revenues from shrimp sales	$11.00	$11.00	$11.00	$11.00
Variable Costs	**$/kg**	**$/kg**	**$/kg**	**$/kg**
Shrimp Postlarvae	$0.57	$0.80	$0.80	$0.80
Feed (kg)	$2.52	$2.52	$2.52	$2.52
Fertilizer & Lime	$0.16	$0.24	$0.11	$0.11
Probiotics	$0.00	$0.14	$0.06	$0.06
Supplies	$0.16	$0.24	$0.11	$0.11
Diesel Fuel for Pumping	$0.38	$0.39	$0.09	$0.09
Diesel Fuel for Aeration	$0.00	$0.00	$0.70	$0.70
Wages & Benefits	$1.00	$1.50	$0.66	$0.66
Processing Cost	$1.75	$1.75	$1.75	$1.75
Repair & Maintenance	$0.40	$0.60	$0.26	$0.26
General & Administration	$1.15	$1.73	$0.77	$0.77
Total Variable Costs/kg	**$8.09**	**$9.90**	**$7.83**	**$7.83**
Fixed Costs	**$/kg**	**$/kg**	**$/kg**	**$/kg**
Depreciation on Farm Investment (15 yr straight line)	$0.63	$0.95	$0.42	$0.42
Depreciation of Processing Plant Investment	$0.63	$0.95	$0.08	$0.42
Interest on original capital investment	$0.40	$0.60	$0.26	$0.26
Depreciation on Biosecurity Capital Improvements	$0.00	$0.10	$0.32	$0.74
Interest on Biosecurity Capital Improvements	$0.00	$0.03	$0.08	$0.19
Total Fixed Costs	**$1.67**	**$2.63**	**$1.17**	**$2.04**
TOTAL COST	**$9.75**	**$12.53**	**$9.00**	**$9.87**
Net Returns Above Variable & Fixed Costs	**$1.25**	**-$1.53**	**$2.00**	**$1.13**
Simple Return (Net Returns ÷ Total Investment x 100%)	**7.9%**	**-6.2%**	**12.0%**	**6.3%**

ANNEX I - Strategy for Improving Biosecurity in the Sub-regional Countries of the Mozambique Channel (Madagascar, Mozambique and Tanzania)[1]

SUMMARY

This document outlines a Strategy for Improving Aquatic Biosecurity (Aquatic Animal Health) in the Sub-regional countries of the Mozambique Channel (Madagascar, Mozambique and Tanzania), intended to be presented during a shrimp consortium meeting being organized by the World Bank in May 2013 in Madagascar. This strategy may also be used to approach international organizations such as the Technical Cooperation Department of FAO, the World Organisation for Animal Health (OIE) and other regional and bilateral mechanisms, as well as the participating governments for possible funding and/or organizational support.

This Strategy is part of a concerted effort to address transboundary issues related to aquatic animal health management in the aforementioned countries. The preparation of the full implementation plan of the Strategy will be an ongoing process. A brief description is provided at the end of the document.

The major sections of this Strategy outlined in this document include:

- Background
- SWOT Analysis
- Purpose
- Vision
- Guiding principles
- Programme components
- Implementation strategy

Each Programme Component may be accomplished by completion of a number of activities. These include actions to be taken by individual countries in support of their national aquatic animal health strategies and typically supported by the government and essential to successful completion of the regional activities. Sub-regional activities will be undertaken jointly by countries. A coordinating mechanism needs to be established, e.g. a Regional Aquatic Animal Health Advisory Group consisting of regional and international experts or other mechanism/s that may be appropriate for the region.

BACKGROUND

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[1] This document contains the main outcomes of a workshop convened by FAO and hosted by INAQUA from 2-4 April 2013 in Maputo, Mozambique. The workshop was supported by the World Bank. The document was jointly prepared by all workshop participants, namely: Ms. Isabel Omar (INAQUA – Mozambique), Dr. Luc Josué Ralaimarindaza (ASH, Madagascar); Dr Ana Paula Baloi (INIP – Mozambique), Mr Philip-Pierre Blanc (ACPM – Mozambique); Dr Hamisi L. Nikuli (National Animal Aquatic Health Coordinator – Tanzania); and Dr. Melba B. Reantaso (FAO).

White spot syndrome virus (WSSV), the most serious pathogen of cultured shrimp had affected almost all shrimp producing countries in Asia beginning in the 1990s including 9 countries in the Americas as of 1999. Most recent outbreaks include that of Brazil (2005), the Kingdom of Saudi Arabia (2010-2011), Mozambique (2011), Brunei (2012), and Madagascar (2012). Losses from WSSV outbreaks in Asia alone was estimated at USD 6 billion during 1992/1993 outbreaks; in the Americas, about USD 1-2 billion during 1999 outbreaks.

A consortium of organizations and institutions (interested in providing solutions and interventions to this current shrimp disease situation in the sub-region) has been formed by the World Bank. A regional stakeholder consultation is being planned to be held in Madagascar in May 2013. As a preparatory work towards the May consultation, FAO has been requested to technically assist in the development of a sub-regional strategy on aquatic biosecurity; this strategy is intended to be presented in the consultation. A 3-day workshop (referred to as the Maputo Workshop in this document) was convened by FAO and hosted by the Instituto Nacional de Desenvolvimento da Aquacultura (INAQUA) from 2-4 April 2013 in Maputo, Mozambique. The workshop was supported by the World Bank.

The preparation of a sub-regional strategy on aquatic biosecurity involved two main activities, namely: firstly is the conduct of an aquatic animal health performance and capacity assessment in the three countries using an FAO survey questionnaire; and secondly, a 3-day sub-regional meeting facilitated by FAO and participated by representatives from each of the three countries to discuss the results of the survey and use these as basis for developing a sub-regional strategy.

The FAO survey questionnaires contain 18 sections pertaining to: (1) international trade in live aquatic animals and national border controls; (2) control of domestic movement of live aquatic animals and other domestic activities that may spread pathogens; (3) policy and planning; (4) legislation; (5) disease surveillance/monitoring; (6) disease diagnostics; (7) emergency preparedness and contingency planning; (8) extension services; (9) compliance/enforcement; (10) research; (11) training; (12) expertise; (13) infrastructure; (14) linkages and cooperation; (15) funding support; 23 (16) current challenges; (17) constraints; and (18) additional information (a blank Survey Questionnaire is appended as Annex I). The survey was conducted from February to March 2013.

The Maputo Workshop was informed by the following:

- Summary and analysis of the FAO survey on aquatic animal health performance and capacity assessment for the 3 countries
- Introduction to SWOT analysis
- Role of crustacean fisheries and aquaculture global food security: past, present and future
- Status of crustacean fisheries and aquaculture in Madagascar
- Status of crustacean fisheries and aquaculture in Mozambique
- Status of crustacean fisheries and aquaculture in Tanzania

MOZAMBIQUE CHANNEL SUB-REGIONAL STRENGTHS, WEAKNESSES, OPPORTUNITIES AND THREATS (SWOT)

A SWOT analysis exercise (Box 1) was conducted during the workshop in order to better understand the shrimp aquaculture sector. The results were used in drawing the different programme components of the Strategy.

Box 1: Results of SWOT analysis

STRENGTH ***(Internal, Favourable)***
1. Availability of aquatic resources suitable for crustacean aquaculture investment (marine and fresh water) 2. Organizational structure present at all levels of administration 3. Available human resources that can be trained on AAH 4. Presence of national legislation (laws, guidelines, plans) addressing issues concerning aquaculture development 5. Stakeholder participation during preparation of legislation at all levels 6. Existence of fisheries research and training institutes for technology development and transfer 7. Existence of shrimp farms exist in the sub-region 8. Presence of regulatory boards at the Ministry level 9. Consistent government revenue collection from fisheries and aquaculture resources 10. Shared water body - Mozambique channel thus sharing same ecological conditions and crustacean species and thus sharing same AAH issues 11. Similar environmental legislations regarding aquaculture activities and their impacts to the environment

WEAKNESS ***(Internal, Unfavourable)***
1. Low priority on AAH activities of government during sectoral programme financial planning and budget allocation 2. Available legislations not clearly address issues pertaining AAH and when addressed, are not fully operational nor enforced 3. Weak competence to perform disease diagnosis due to lack of AAH laboratory 4. Low capacity to undertake aquatic animal disease surveillance and reporting due to lack of expertise, facilities and design/methods 5. Lack of comprehensive aquafarms registration and database development (information system) 6. Lack of national pathogen list for Mozambique and Tanzania and sub- regional list of pathogens 7. Low capacity for emergency preparedness to aquatic disease outbreaks 8. Lack of national AAH action plan and strategies 9. Inadequate communication/networking on aquatic AH issues 10. Inadequate compliance with international standards (e.g. WTO SPS Agreement, OIE Code and Diagnostic Manual) 11. Unavailability of vaccines against shrimp viral pathogens

OPPORTUNITIES ***(External, Favourable)***
1. Ongoing public sector reforms process 2. Existence of public private sector partnership in shrimp aquaculture development and existence of well-defined working modality 3. Increasing need for aquaculture sector development for the growing human population and declining capture fisheries 4. AAH is a major sustainability issue that should be prioritized for efficient allocation of funding resources which need to be highlighted to governments, investors, donors and aid agencies 5. Huge aquaculture resource base are suitable for investment 6. Enthusiastic stakeholders willing to participate in the development of the sector 7. Increasing domestic and export market demands for crustacean products 8. Increasing market trend provides opportunity for development of effective AAH protection programme that is one of the major requirements for national and international markets 9. Except for WSSV, Sub- region is still free from major shrimp pathogens, thus giving it a significant trade advantage, and requires stringent protection measures 10. Governments currently recognize the weakness in the AAH management and strong willingness to improve as demonstrated by ongoing efforts to address WSSV. 11. Growing coastal population that can have socioeconomic benefit from further sustainable aquaculture development especially in remote and rural areas 12. The sector is currently operating at small-scale level and thus offering great opportunity and good timing for development and adaption of required systems for efficient development

THREATS ***(External, Unfavourable)***
1. Difficulty in recruiting qualified and experienced staff on AAH issues 2. Conflicting interests resulting from impacts of globalization and on-going changes on macro policies 3. Irresponsible sectoral development will not allow maximum realization of the potential contribution and investment opportunities 4. Unavailability of budgetary allocation and when available, untimely disbursement of funds 5. Weather uncertainties accompanied with climate changes can have impacts, for example, on: 6. the susceptibility of aquatic hosts (including vectors) to certain pathogens, the viability of pathogens, etc. 7. disruption on production and capture fisheries harvests, and 8. general development of the sector 9. Expected land and water resource user conflicts that goes with sectoral development 10. Introduction of exotic, emerging and/or unknown shrimp pathogens and inability to contain the spread 11. Weak implementation of good aquaculture practices, farm level biosecurity, good farming practices, etc. 12. Lack of cooperation between shrimp farmers 13. Reactive response/action to aquatic disease emergencies 14. Low priority given to biosecurity governance and AAH management

STRATEGY FOR IMPROVING AQUATIC BIOSECURITY (AQUATIC ANIMAL HEALTH) FOR THE MOZAMBIQUE CHANNEL SUB-REGIONAL COUNTRIES (MADAGASCAR, MOZAMBIQUE AND TANZANIA)

PURPOSE

This Strategy outlines a long-term, agreed-upon plan of activities to improve aquatic animal health capacity in the sub-regional countries of the Mozambique Channel, i.e. Madagascar, Mozambique and Tanzania. The Programme identifies the activities of sub-regional and national interests and importance that can be addressed jointly by the sub-regional countries and the national aquatic animal health activities that must be accomplished by individual countries in order to accomplish the Programme itself.

It is intended that the Strategy will be presented during the WB-organized consultation in May 2013 in Madagascar. It may also be used to approach international organizations such as the Technical Cooperation Department of FAO, the World Organisation for Animal Health (OIE) and other regional and bilateral mechanisms, as well as the participating governments for possible funding and/or organizational support.

This Strategy includes a **Vision** and set of **Guiding Principles** for aquatic animal health in the Mozambique Channel and consists of eight **Programme Components**, within which are 12 **Programme Elements** containing a total of 42 **Programme Activities**. The eight Programme Components address the broad themes of:

1. Biosecurity governance
2. Sub-regional preparedness/response and contingency plan for shrimp disease emergencies
3. Diagnostics, surveillance and reporting
4. Prevention and management of risks from exotic, emerging and/or unknown aquatic pathogens
5. Promotion of sustainable aquaculture development and responsible investment in shrimp aquaculture
6. Assessment of socio economic benefits/potential and risks, technical feasibility and environmental impacts of further shrimp aquaculture development in the indian ocean sub-region
7. Institutional strengthening and targeted capacity building on aquatic biosecurity
8. Regional collaboration communication and networking on information and shared resources

The Strategy recognizes the importance of human capacity building, and this is addressed primarily in the form of training programmes and workshops for the various areas of aquatic animal health. Development of research capacity is also highly important; however, this generally involves post-graduate training and thus is to be addressed by the national governments.

VISION

The long-term vision of the Strategy for Improving Aquatic Biosecurity in the Mozambique Channel sub-regional countries of Madagascar, Mozambique and Tanzania is:

"*To develop and maintain aquatic animal health capacity in Madagascar, Mozambique and Tanzania that will be able to support the sustainable development and management of the crustacean aquaculture sector while protecting sub-regional biodiversity and aquatic ecosystems from the impacts of exotic pathogens and epizootic disease*".

GUIDING PRINCIPLES

The following principles served as guidance in the preparation of this Strategy[2].

- Countries require a minimum level of national and regional aquatic animal health capacity in order to protect their living aquatic resources (including aquaculture), natural aquatic environments and aquatic biodiversity from the negative impacts of pathogens and disease.
- Increased aquatic animal health capacity should enable aquaculture to make a greater contribution to the economies of these countries through healthy aquatic production, increased competitiveness in international markets and improved economic viability at the national level.
- Countries share a common marine environment and thus serious aquatic animal pathogens introduced to the waters of one country have the potential to spread and negatively affect aquaculture and/or the wild fisheries of another country. Thus, countries have a shared responsibility to prevent the introduction of exotic pathogens and to implement sound and sustainable aquaculture practices.
- Movement of living aquatic animals within and across their national boundaries (transboundary movement) is important for economic, social, development and public resource purposes. The benefits of such movements must be weighed against the potential risks, and authorities should implement informed decisions.
- National and regional aquatic animal health strategies, plans and programmes should be consistent with countries' obligations as members of the World Organisation for Animal Health (OIE) and/or the World Trade Organization (WTO) and other relevant treaties and agreements. Countries reserve the right to take sanitary and phytosanitary measures necessary for the protection of human, animal or plant life consistent with these obligations.

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[2] Adapted mainly from: FAO. 2007. Aquaculture development. 2. Health management for responsible movement of live aquatic animals. *FAO Technical Guidelines for Responsible Fisheries.* No. 5, Suppl. 2. Rome, FAO. 31 pp. (available at: ftp://ftp.fao.org/docrep/fao/010/a1108e/a1108e00.pdf).

- Countries are encouraged to develop and formalize national aquatic animal health strategies and health management procedures that adhere to international and regional standards and be harmonized on as wide a basis as possible.
- Countries should encourage industries to use preventative measures to limit their exposure to pathogens and disease. Such measures include but are not limited to the use of better management practices (BMPs), health certification, specific pathogen free (SPF) and high health (HH) stocks, quarantine, and vaccination protocols, if applicable.

PROGRAMME: COMPONENTS, ELEMENTS AND ACTIVITIES

PROGRAMME COMPONENT 1 – Governance

Programme Element 1: Legislation and regulation

Programme activities:

1) Review and update of national legislation pertaining to all aspects of Aquatic Animal Health and shrimp aquaculture
2) Harmonization of national legislation to international standards
3) Enhanced compliance to WTO SPS Agreement and trading partner requirements
4) Harmonization of implementation of WTO SPS Agreement at sub-regional level
5) Training on the implementation of international standards

Programme Element 2: Policy and planning

Programme activities:

1) Develop National Strategies on Aquatic Animal Health (competent authority, national pathogen list, diagnostics, surveillance, use of veterinary medicines, emergency preparedness, prevention and management of risks from aquatic pathogens/diseases, Aquatic Animal Health information system, responsible movement of live aquatic animals, risk analysis, capacity building, cooperation, etc.) including guidance on development, implementation and capacity development mechanisms
2) Regional priorities and collective action (minimum requirements and action on Aquatic Animal Health)

PROGRAMME COMPONENT 2 – Sub-Regional Preparedness/Response and Contingency Plan For Shrimp Disease Emergencies

Programme Element 3: Emergency fund

Programme activities:

1) Prepare a concept note to define this element and detailed mechanisms/guidelines, estimating resources for implementation referring to existing mechanism or similar mechanisms in other sectors or create a mechanism specifically for aquatic emergencies Assessment of national needs for diagnostic capability by an international expert assisted by national focal points. Enhanced compliance to WTO SPS Agreement and trading partner requirements

Programme Element 4: Emergency response and contingency plans

Programme activities:

1) Training on the design and preparation of emergency response and contingency plans
2) Preparation of operational plans and technical manuals
3) Simulation exercise at farm level and national level (including planning and actual simulation)

PROGRAMME COMPONENT 3 – Diagnostics, Surveillance and Reporting

Programme Element 5: Methods, Design and Costing

Programme activities:

1) Harmonization of diagnostic methods and regional agreement on costs
2) Access to laboratory facilities that can provide quick and reliable diagnostic service
3) Recognition of a regional laboratory for reference, confirmation and other assistance
4) Proficiency testing
5) Preparation of a regional list of pathogens
6) Design of a regional surveillance programme
7) Training on implementation of diagnostics and surveillance

PROGRAMME COMPONENT 4 – Prevention and Management of Risks from Exotic, Emerging and/or Unknown Aquatic Pathogens

Programme Element 6: Capacity Building on Best Practices

Programme activities:

1) Training of shrimp farmers/producers/operators and government on good shrimp aquaculture and biosecurity practices
2) Training on risk analysis (different levels, public and private sectors)

Programme Element 7. Minimum regional sanitary control

Programme activities:

1) Minimum biosecurity checklist (farm, national, regional levels) including legislation
2) Prepare regional minimum standards for importing crustaceans (live and products)

PROGRAMME COMPONENT 5 – Promotion of Sustainable Aquaculture Development and Responsible Investment in Shrimp Aquaculture

Programme Element 8 : Enabling environment

Programme activities:

1) Disseminate and exchange information about regional aquaculture practices (organic shrimp farming, certification, etc.)
2) Promote aquaculture as a business model and provide guidance
3) Provision of Aquatic Animal Health services and other services (extension, etc)
4) Develop mechanisms for incentives and compensation and risk management schemes, e.g. insurance
5) Coordinate effective actions to guarantee reliable business operation
6) Facilitate and assist in the formation of farmer association/cooperative/community-based organizations and provide support to relevant activities. Training on risk analysis (different levels, public and private sectors)

PROGRAMME COMPONENT 6 – Assessment of socio-economic benefits/potential and risks, technical feasibility and environmental impacts of further shrimp aquaculture development in the Indian Ocean sub-region

Programme Element 9 : Assessment studies

Programme activities:

1) Technical feasibility studies, EIA or risk analysis of new ventures on shrimp aquaculture
2) Socio-economic assessment of the impacts of aquatic pathogen introduction (e.g. retrospective analysis of WSSV in Madagascar and Mozambique)
3) Socio-economic assessment of the benefits of good aquaculture and biosecurity practices

PROGRAMME COMPONENT 7 – Institutional Strengthening (human and financial resources, diagnostic and research infrastructure) and targeted capacity building on aquatic biosecurity (aquatic animal health)

Programme Element 10 : Institutional strengthening

Programme activities:

1) Education on Aquatic Animal Health (academic degrees)
2) Training (see also other sections)
3) Develop and/or improve national diagnostic and research infrastructure
4) Targeted capacity building (refer to other sections)
5) Manuals, operating procedures, protocols
6) Allocation of sufficient financial resources to Aquatic Animal Health based on needs and priorities

PROGRAMME COMPONENT 8 – Regional Collaboration, Communication and Networking on Information and Shared Resources

Programme Element 11 : Aquatic animal health information system

Programme activities:

1) Regional web portal for an Aquatic Animal Health Information System covering all relevant information aspects of Aquatic Animal Health
2) Early warning system
3) GIS for surveillance data
4) Regular and special/emergency meetings (all levels face to face, teleconference

Programme Element 12 : Shared resources

Programme activities:

1) Collaboration on shared resources (feed, laboratory, shrimp genetic resources, etc.)

IMPLEMENTATION STRATEGY

The implementation strategy of the Strategy will be done at two levels, i.e. national level and regional level (Table 1). The implementation strategy emphasizes the need for national-level action to complete a number of essential activities that address national issues and priorities in support of the Elements of the Strategy. Completion of these national activities is essential to implementation the regional activities of the Strategy, which tackle issues and priorities with a regional dimension.

National level

National strategies on aquatic animal health (including compliance with international treaties and agreements)

The preparation of a National Aquatic Animal Health Strategy (National Strategy) by each country and an associated implementation plan will support national aquatic animal health and attainment of the objectives of the Regional Strategy. A National Strategy provides a comprehensive framework that will allow countries to protect aquatic animal health, ensure healthy aquatic production, comply with international agreements, etc. Associated national implementation plans will contain each government's individual action plans at the short, medium and long-term. The implementation of a National Strategy should use the concept of "*phased implementation based on national needs and priorities*". Thus it is expected that the National Strategy of the different countries will vary depending on the level of aquaculture development, the importance of the aquaculture sector, socio-economic status and other relevant factors. Nevertheless, a National Strategy presents a number of essential elements, and it will be up to the governments to determine which of these elements are relevant to their individual circumstance. The National Strategy should be supported by legislation and regulation, institutional, human, and financial and other resource requirements.

Examples of national strategies on aquatic animal health exist (including formulation and development process) and they can be used as reference. The National Strategy contains many of the essential elements for a successful aquatic animal health protection programme. These include: (i) policy, legislation and enforcement; (ii) risk analysis; (iii) pathogen list; (iv) information system; (v) health certification and quarantine; (vi) surveillance, monitoring and reporting; (vii) zoning; (viii) emergency preparedness and contingency planning; (ix) research; (x) institutional structure; (xi) human resource development; and (xii) regional and international cooperation. The competent authority or responsible entity that will drive the process of national strategy formulation and development needs to be identified or designated. National-level coordination and stakeholder consultation and priority setting are essential activities that need to be undertaken as part of the process.

The formulation of a National Strategy is a government responsibility and may be done through various ways, e.g. national workshop with expert assistance, regional workshop to build capacity in developing such strategy, expert contract, etc. The Regional Strategy is developed to assist countries in accomplishing this task. Furthermore, the National Strategy should be integrated into the appropriate fisheries and aquaculture development plans, biosecurity programmes or rural livelihood programmes and should include planning for monitoring and evaluation of its implementation.

Regional level

As aquatic animal health management involves many issues that are transboundary in nature, an effective aquatic animal health protection programme has to be supported by regional and international cooperation. Table 1 lists a number of activities that will be undertaken at the regional level and activities of the Regional Strategy whose completion is the responsibility of the national governments. In all cases regional activities will provide guidance towards accomplishing these national activities. National governments also have responsibilities towards completion of regional activities outlined in the Regional Programme.

As many of these activities require considerable planning and financial support, more detailed proposals will be prepared separately. Key implementation activities include:

- Integration into national plans and other sub-regional or regional programmes
- Focal points or national coordinators on aquatic animal health supported by a regional advisory group on aquatic animal health

Table 1: Summary of Mozambique Channel sub-regional strategy for aquatic biosecurity showing responsibility for implementation (national or sub-regional), time frame for implementation (short, medium, or long), and priority level (low, medium or high).

Programme Component 1: Biosecurity governance									
Programme Elements	Activities	Implementation		Time-Frame			Priority		
		National	Sub-regional	Short	Medium	Long	Low	Medium	High
1 Legislation and regulation	1 Review and update of national legislation pertaining to all aspects of AAH and shrimp aquaculture	x							
	2 Harmonization of national legislation to international standards	x	x						
	3 Enhanced compliance to WTO SPS Agreement and trading partner requirements		x						
	4 Harmonization of implementation of WTO SPS Agreement at sub-regional level		x						
	5 Training on the implementation of international standards	x	x						
2 Policy and planning	6 Develop National Strategies on AAH[1]	x	x						
	7Regional priorities and collective action (minimum requirements and action on AAH)		x						

Programme Component 2: Sub-regional Preparedness/ Response and Contingency Plan for Shrimp Disease Emergencies									
Programme Elements	Activities	Implementation		Time-Frame			Priority		
		National	Sub-regional	Short	Medium	Long	Low	Medium	High
3 Emergency fund	8 Prepare a concept note to define this element and detailed mechanisms/guidelines, estimating resources for implementation referring to existing mechanism or similar mechanisms in other sectors or create a mechanism specifically for aquatic emergencies		x						
4 Emergency response and contingency plans	9 Training on the design and preparation of emergency response and contingency plans	x	x						
	10 Preparation of operational plans and technical manuals	x	x						

Programme Component 3: Diagnostics, Surveillance and Reporting									
Programme Elements	Activities	Implementation		Time-Frame			Priority		
		National	Sub-regional	Short	Medium	Long	Low	Medium	High
5 Methods, Design and Costing	12 Harmonization of diagnostic methods and regional agreement on costs		x						
	13 Access to laboratory facilities that can provide quick and reliable diagnostic service		x						
	14 Recognition of a regional laboratory for reference, confirmation and other assistance		x						
	15 Proficiency testing		x						
	16 Preparation of a regional list of pathogens		x						
	17 Design of a regional surveillance programme		x						
	18 Training on implementation of diagnostics and surveillance	x	x						
	19 Use surveillance data to contain identified pathogens in infected areas and protect non-infected areas	x							

Programme Component 4: Prevention and Management of Risks from Exotic, Emerging and/or Unknown Aquatic Pathogens									
Programme Elements	Activities	Implementation		Time-Frame			Priority		
		National	Sub-regional	Short	Medium	Long	Low	Medium	High
6 Capacity building on best practices	20 Training of shrimp farmers/producers/operators and government on good shrimp aquaculture and biosecurity practices	x	x						
	21 Training on risk analysis (different levels, public and private sectors	x	x						
7 Minimum regional sanitary control	22 Minimum biosecurity checklist (farm, national, regional levels) including legislation	x	x						
	23 Prepare regional minimum standards for importing crustaceans (live and products)	x	x						

Programme Component 5 Promotion of Sustainable Aquaculture Development and Responsible Investment in Shrimp Aquaculture									
Programme Elements	Activities	Implementation		Time-Frame			Priority		
		National	Sub-regional	Short	Medium	Long	Low	Medium	High
8 Enabling environment	24 Disseminate and exchange information about regional aquaculture practices (organic shrimp farming, certification, etc.)	x	x						
	25 Promote aquaculture as a business model and provide guidance	x	x						
	26 Provision of AAH services and other services (extension, etc)	x							
	27 Develop mechanisms for incentives and compensation and risk management schemes, e.g. insurance	x							
	28 Coordinate effective actions to guarantee reliable business operation	x	x						
	29 Facilitate and assist in the formation of farmer association/cooperative/community-based organizations and provide support to relevant activities	x							

Programme Component 6 Assessment of socio-economic benefits/potential and risks, technical feasibility and environmental impacts of further shrimp aquaculture development in the Indian Ocean sub-region									
Programme Elements	**Activities**	**Implementation**		**Time-Frame**			**Priority**		
		National	Sub-regional	Short	Medium	Long	Low	Medium	High
9 Assessment studies	30 Technical feasibility studies, EIA or risk analysis of new ventures on shrimp aquaculture	x	x						
	31 Socio-economic assessment of the impacts of aquatic pathogen introduction (e.g. retrospective analysis of WSSV in Madagascar and Mozambique)	x	x						
	32 Socio-economic assessment of the benefits of good aquaculture and biosecurity practices	x	x						

Programme Component 7 Institutional Strengthening (human and financial resources, diagnostic and research infrastructure) and targeted capacity building on aquatic biosecurity (aquatic animal health)									
Programme Elements	**Activities**	**Implementation**		**Time-Frame**			**Priority**		
		National	Sub-regional	Short	Medium	Long	Low	Medium	High
10 Institutional strengthening	33 Education on AAH (academic degrees)	x	x						
	34 Develop and/or improve national diagnostic and research infrastructure	x	x						
	35 Targeted capacity building (refer to other sections)	x	x						
	36 Manuals, operating procedures, protocols	x	x						

Programme Component 8 Regional Collaboration, Communication and Networking on Information and Shared Resources									
Programme Elements	**Activities**	**Implementation**		**Time-Frame**			**Priority**		
		National	Sub-regional	Short	Medium	Long	Low	Medium	High
11 Aquatic animal health information system	37 Regional web portal for an AAH Information System covering all relevant information aspects of AAH		x						
	38 Early warning system		x						
	39 GIS for surveillance data		x						
	40 Regular and special/emergency meetings (all levels face to face, teleconference)		x						
12 Shared resources	41 Collaboration on shared resources (feed, laboratory, shrimp genetic resources, etc.)		x						