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FAO Technical Assistance Efforts to Deal with Acute Hepatopancreatic Necrosis Disease (AHPND) of Cultured Shrimp

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Abstract

The authors briefly describe the efforts of the Food and Agriculture Organization of the United Nations (FAO) between 2011 and 2017 in providing assistance to member countries in dealing with Acute hepatopancreatic necrosis disease (AHPND) of penaeid shrimp, through two Technical Cooperation Project (TCP), which lead to the production of this volume of collected papers. The first project TCP/VIE/3304 was an emergency TCP project, Vietnam as recipient country. The second project TCP/INT/3502 was an interregional TCP project with Colombia, Ecuador, Guatemala, Honduras, Mexico, Panama and Peru from the Latin America and the Caribbean (LAC) region, and India, the Islamic Republic of Iran, the Philippines and Sri Lanka from the Asian region as recipient countries.

A significant concern to the shrimp aquaculture sector, AHPND will continue to hamper the continuity of food supply, impact livelihoods and reduce national export earnings. This special issue of Asian Fisheries Science on AHPND contains some of the technical papers that were delivered during the Viet Nam, Panama and Bangkok EMS/AHPND events between June 2013 and June 2016. This volume contains 23 contributions on a range of topics aimed at continuously updating the knowledge and experiences in dealing with AHPND and related topics from the perspectives of the government, academe and producer sectors.

Keywords: AHPND, EMS, disease response, FAO projects, TCP/INT/3502

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Introduction

In July 2011, based on a request from the Government of Viet Nam for technical assistance, the Food and Agriculture Organization of the United Nations (FAO) fielded a Rapid Deployment Team (RDT) through the Crisis Management Centre – Animal Health (CMC-AH) and made a quick assessment of an unknown disease affecting cultured shrimp in the Mekong Delta provinces of Viet Nam. Based on epidemiological observations and other relevant field data, the CMC-AH mission confirmed that a serious disease outbreak of unknown etiology had begun in early 2010 and continued into 2011, with high mortalities among cultured giant tiger prawn (*Penaeus monodon*) and whiteleg shrimp (*P. vannamei*).

The pattern of disease spread was consistent with an infectious agent, i.e. starting in one pond in one location and subsequently spreading to several ponds within the same farm, followed by spread to neighbouring farms. The pattern of spread and the clinical signs of the disease were not similar to those of any known major shrimp viral or bacterial disease previous reported in Viet Nam or elsewhere in the world.

FAO/MARD Project TCP/VIE/3304

Following the recommendations of the RDT, the FAO project “TCP/VIE/3304 (E) Emergency assistance to control the spread of an unknown disease affecting shrimps” was developed and implemented from 2012–2013. This project provided emergency technical support to Viet Nam’s Ministry of Agriculture and Rural Development (MARD). The project achieved its objectives of: (1) identifying the causative agent of the unknown disease; (2) building the capacity of farmers on biosecurity and good aquaculture practices (GAPs); and (3) developing a National Aquatic Animal Health Strategy (NAAHS) for Viet Nam. Toward the end of the project, the FAO/MARD Technical Workshop on “Early Mortality Syndrome (EMS) or Acute Hepatopancreatic Necrosis Syndrome (AHPNS) of Cultured Shrimp” was held in Hanoi, Viet Nam from 25 to 27 June 2013 (Viet Nam EMS/AHPNS June 2013, the first event).

The workshop was attended by 63 participants consisting of key personnel involved in the TCP/VIE/3304 project, members of the MARD National Task Force on Shrimp Diseases, and key experts involved in the work on early mortality syndrome/acute hepatopancreatic necrosis syndrome (EMS/AHPNS) in other countries (Peoples Republic of China, Malaysia, Thailand) and other resource experts from FAO and the United States of America. The participants concluded that the technical workshop significantly improved their understanding of AHPND, and that the process taken by the FAO/MARD TCP/VIE/3304 project could serve as a good model for conducting similar unknown disease investigations in the future.

FAO Inter-regional Project TCP/INT/3502

Upon completion of TCP/VIE/3304, the FAO continuously received requests from member countries for technical assistance in dealing with EMS/AHPNS. Thus, an interregional Technical Cooperation Project (TCP), TCP/INT/3502 “Reducing and Managing the Risks of Acute Hepatopancreatic Necrosis Disease (AHPND) of Cultured Shrimp” was developed to further generate a better understanding of the disease. The FAO inter-regional project, which was implemented from 2015 to 2017, had two major project outputs:

- Output 1: Awareness and technical knowledge on AHPND at national, regional and interregional levels enhanced.
- Output 2: Intersessional activities at country level to support the development of national strategies and/or other relevant instruments.

The project had 11 participating countries, namely: Colombia, Ecuador, Guatemala, Honduras, Mexico, Panama and Peru from the Latin America and the Caribbean (LAC) region, and India, the Islamic Republic of Iran, the Philippines and Sri Lanka from the Asian region. One of the expected outcomes of this project under Output 1 was enhanced knowledge and strengthened capacities for dealing with AHPND in the Asian and LAC regions. In view of this, the convening of two international technical seminars/workshops involving resource experts from the government, academe and the private sector was one of the mechanisms that contributed to achieving this goal.

The International Technical Seminar/Workshop: “EMS/AHPND: Government, Scientist and Farmer Responses”, held from 22–24 June 2015 in Panama City, Panama (referred to as Panama AHPND June 2015 in this document) was implemented jointly with the *Organismo Internacional Regional de Sanidad Agropecuaria* (OIRSA, the International Regional Organization for Plant and Animal Health). The Panama AHPND June 2015 provided a platform to improve the understanding of the disease through the lens of governments, scientists and producers and collectively generate practical management and control measures.

Two delegates from each of the 11 FAO member countries officially participating in the interregional TCP, representatives from two FAO member countries participating on a non-FAO funded basis (i.e. Nicaragua and the Kingdom of Saudi Arabia), members of the private sector from Asian and Latin America and the Caribbean (LAC) countries, invited scientists and other experts, representatives from FAO (technical officers from FAO headquarters in Rome and the Subregional Office for Mesoamerica, and international consultants) and OIRSA, comprised a total of 105 attendees drawn from 21 countries. The Second International Technical Seminar/Workshop on AHPND: “There is a Way Forward”, held from 23–25 June 2016 in Bangkok, Thailand (referred to as Bangkok AHPND June 2016 in this document)was implemented jointly with the Network of Aquaculture Centres in Asia-Pacific (NACA).

The Bangkok AHPND 2016 updated knowledge and exchanged experiences in dealing with AHPND. It also validated current concepts and models under different systems and environmental conditions, and generated actions and responsibilities targeting different sectors (i.e. government, producers and academe) as a way forward to deal with AHPND. The Bangkok AHPND 2016 event was attended by 84 participants, including attendees from ten of the project’s 11 participating countries (6 participating countries from LAC: Columbia, Ecuador, Guatemala, Honduras, Mexico, Panama) and 4 participating countries from Asia (India, the Islamic Republic of Iran, the Philippines, Sri Lanka), as well as from 11 non-participating FAO member countries (Australia, Bangladesh, Brazil, Indonesia, Japan, the Kingdom of Saudi Arabia, People's Republic of China, Singapore, Thailand, the United Kingdom, Viet Nam) and representatives of four international and regional organizations (NACA, OIRSA, the World Organisation for Animal Health (OIE) and the Southeast Asian Fisheries Development Center – Aquaculture Department (SEAFDEC-AQD)).

In addition to the above, under major Output 2, the project also provided detailed guidance and a framework for the development of country National Action Plans (NAPs) on AHPND. This was facilitated by participating countries completing the FAO Aquatic Animal Health Capacity and Performance Questionaire Survey (a national self-assessment survey) which identified strengths, weaknesses and needs related to national aquatic animal health and biosecurity. This was followed by the holding of national stakeholder consultations in the majority of countries, where the national competent authorities had the opportunity to engage with relevant stakeholders from academia and the private sector regarding their draft NAPs and to disseminate the knowledge gained from participation in this project, particularly in the Panama AHPND June 2015 and Bangkok AHPND June 2016. By the end of the project, six countries (Columbia, Guatemala, India, the Islamic Republic of Iran, Philippines, Sri Lanka) had prepared NAPs for AHPND, while another four countries (Ecuador, Honduras, Mexico, Nicaragua) had prepared comprehensive documents in a different format (e.g. national aquatic animal health plans) that incorporated many of the key points contained in the FAO AHPND action plan framework.

The highlights of the three events are summarized below:

Highlights of the Viet Nam EMS/AHPND June 2013

The workshop highlighted the following:

- A period of relatively trouble-free shrimp production has resulted in complacency in the shrimp aquaculture sector. This laxity made the sector vulnerable to any newly emerging pathogen that might arise unexpectedly, as was the case of EMS/AHPNS.
- Poor management practices, including weak compliance with biosecurity standards and good aquaculture practices (GAPs) were evident at both farms and hatchery facilities.
- Shrimp aquaculture needs to improve and to continue to develop into a sector that implements responsible and science-based farming practices.

- With the current understanding that EMS/AHPNS has a bacterial aetiology and is caused by a strain of *Vibrio parahaemolyticus*, the workshop recommended that a proper name should now be given to EMS/AHPNS, i.e. acute hepatopancreatic necrosis disease (AHPND).
- The sector was asked to consider a number of recommendations for specific and generic actions and measures for reducing the risk of AHPND. These recommendations were directed to the wider community of shrimp aquaculture stakeholders in both the public and private sectors and were pertinent to important areas such as:
    - AHPND diagnosis;
    - AHPND notification/reporting;
    - international trade of live shrimp, shrimp products (frozen, cooked), and live feed for shrimp;
    - advice to countries affected and not affected by AHPND;
    - measures at farm and hatchery facilities;
    - advice to pharmaceutical and feed companies and shrimp producers;
    - actions on knowledge and capacity development;
    - AHPND outbreak investigation/emergency response; and
    - Specific AHPND-targetted research on various themes (i.e. epidemiology, diagnostics, pathogenicity and virulence, public health, mixed infections, non-antimicrobial control measures, environment, polyculture technologies).

Highlights of Panama AHPND June 2015

The Panama EMS/AHPND June 2015 event presented the latest information available at that time (June 2015) about AHPND, including the current state of knowledge about the causative agent, the host and geographical distribution, detection methods, risk factors, management efforts, and the actions taken by regional and international organizations. The information summarized below is based on the 21 technical presentations given by resource experts.

The causative agent of AHPND*:* The causative agent was discovered in 2013 as unique isolates of *Vibrio parahaemolyticus* (VP_{AHPND}) that carry a plasmid (pAP1) of approximately 69 kbp. This plasmid contains two genes that produce toxins (one 12.7 kDa and one 50.1 kDa) that are capable of acting together to cause AHPND. The Pir A/B toxin genes that code for the two toxin proteins that induce AHPND in shrimp have been reported to be similar to PirA/B toxin genes known from *Photorhabdus* spp. (Gram-negative, luminescent, rod-shaped bacteria that are members of the Family Enterobacteriaceae). In nature, *Photorhabdus* spp., which live in an obligate, symbiotic relationship with the entomopathogenic nematode *Heterorhabditis* spp. and a closely-related genus, *Heterorhabditis* spp., are parasites of insect larvae. These nematodes have a wide geographic distribution and since the 1980s, have been researched extensively for application in insect control.

Possible public health implications*:* The genome of *V. parahaemolyticus* has several clusters of genes that have been acquired by horizontal gene transfer. Some of them (the tdh and trh gene clusters) are associated with pathogenicity to humans. However, the AHPND-causing strains lack the gene clusters involved in pathogenicity to humans and thus, fortunately, the VP_{AHPND} isolates characterized so far pose no threat to human health.

Host and geographical distribution: AHPND infects mainly whiteleg shrimp (*Penaeus vannamei*), but has also been reported from giant tiger prawn (*P. mondon*) and fleshy prawn (*P. chinensis*). AHPND first appeared in the People's Republic of China around 2009 and was called covert mortality disease. It has since been recorded from Viet Nam (2011), Malaysia (2011), Thailand (2012), Mexico (2013) and the Philippines (2015), and is suspected to be present in in India. It is also suspected to be present in, but unreported from other countries in both Asia and LAC.

Current status of detection methods: The presumptive gross signs of AHPND in penaeid shrimp include an empty stomach and midgut, a pale and shrunken hepatopancreas, and mortality within approximately 35 days after stocking of postlarvae (PL). However, similar gross signs may occur with other diseases and thus, confirmation requires histological examination of the hepatopancreas to reveal the unique feature of the acute stage of AHPND, i.e. massive sloughing of cells of the tubule epithelium in the absence of any clear evidence of a causative agent. To aid in the identification of reservoirs and potential transmission routes, two interim polymerase chain reaction (PCR) detection methods based on primers designated as AP1 and AP2 were introduced at the NACA Website in December 2013 and later updated. Of these, AP2 turned out to be the better primer, with about 3 percent false-positive results. Despite this weakness, the method was used successfully to reveal a high prevalence of VP_{AHPND} in live broodstock feeds (i.e. polychaetes and bivalves), in pond-reared and hatchery broodstock and in PL used to stock shrimp farms. Testing in Thailand also provided evidence that specific pathogen free (SPF) stocks of shrimp that had tested free of VP_{AHPND} became positive after use for PL production in some local shrimp hatcheries, providing clear evidence of biosecurity failures.

To address the problem of false-positive PCR test results, an improved PCR detection method (AP3) was developed based on discovery of the two AHPND toxins and on use of the gene sequence of the smaller 12.7 kDa toxin. The AP3 method, which was released at the NACA Website in June 2014, gave no false-positive or false-negative results with 104 bacterial isolates tested. Since the AP1 to AP3 methods for VP_{AHPND} detection were one-step PCR detection methods and could not be successfully modified into nested-PCR methods, samples with low pathogen loads had to be subjected to an enrichment step by culture in broth medium for 4 hr before separation of bacterial cells to prepare DNA template for the PCR assays. To address the problems with samples that could not be subjected to the enrichment step (e.g. samples preserved in alcohol or archived DNA samples), a nested-PCR method (AP4) was then developed (introduced on the NACA Website on 20 February 2015).

It targeted the whole sequence of the 12.7 kDa toxin gene and 70 percent of the large toxin gene, and it gave 100 percent positive and negative predictive values for the same 104 isolates used to validate the AP3 method. However, it had 100 times higher detection sensitivity (down to 100 fg template DNA). By cooperation between Centex Shrimp and Sakarindrwirote University in Bangkok, antibodies have been produced against heterologously expressed AHPND toxins and used for detection by enzyme-linked immunosorbent assay (ELISA). This will allow for quantification of the toxins in feeds and the environment and for more convenient laboratory testing for therapeutic measures and resistant shrimp stocks.

***Risk factors*.** The most important risk factors for the international spread of AHPND are:

- the movement of live shrimp from a geographic region where AHPND is prevalent to an unaffected region for aquaculture (AHPND is thought to have been transmitted to Mexico from Asia by this route), and
- the importation of live animals (e.g. polychaetes, clams) as feeds for shrimp broodstock (polychaetes imported from P.R. China may have been the major route for introduction of AHPND to Thailand).

Other potential but as yet unconfirmed routes of disease transfer are by:

- crabs, crayfish and other crustaceans;
- predatory birds and mammals;
- attachment of flocs to zooplankton that are carried long distances by ocean currents;
- attachment on crustaceans and in ships' ballast waters;
- via untreated wastes from infected shrimp in processing plants; and
- via use of infected shrimp.

Environmental factors that are believed to promote infection by VP_{AHPND} in shrimp ponds include:

- high concentration of nutrients in pond water by addition of fertilizers, molasses, etc.;
- high water temperature, salinity >5 ppt and pH >7;
- low water turnover coupled with low planktonic biodiversity; and
- the presence of soluble nutrients (feed), unconsumed pelleted feed, and shrimp carcasses, leading to accumulation of organic-rich sediment.

Most cases of VP_{AHPND} have shown co-infection with other shrimp pathogens, for example, monodon baculovirus (MBV), whitespot disease (WSD), hepatopancreatic virus (HPV), *Enterocytozoon hepatopenaei* (EHP) and unidentified gregarine-like entities.

Farm-level disease management: AHPND cannot be excluded from the farm, but it can be managed. Effective farm-level management measures include:

- ensuring good farm biosecurity and best management practices (BMPs) by:
    - beginning with PL derived from broodstock verified to be free of AHPND (i.e. PL derived from SPF or high health (HH) broodstock);
    - avoiding overfeeding, as uneaten pellets are substrate for AHPND bacteria to grow;
    - removing sediment as often as possible, as it also serves as substrate;
    - ensuring that all facilities and equipment are properly desinfected before stocking of PL (e.g. implementing cyclical dry-out and clean-up routines after every production cycle, involving careful cleaning and disinfection of all facilities, including the insides of air lines, pipes, water pumps and air pumps);
    - ensuring that live and treated feeds are free of infection (e.g. by sterilization of frozen material via gamma irradiation or pasteurization or by the development of SPF lines of polychaetes and clams for use in shrimp culture);
    - modifying farm and pond designs to allow better biosecurity (e.g. use of smaller-sized ponds with plastic liners that can be fully drained, dried and disinfected between culture cycles);
    - increasing the number of reservoirs and water filtration to eliminate fish and other disease carriers;
    - using water of a salinity of 5 ppt for growing shrimp;
    - using water drawn from a deep well for growing shrimp;
    - avoiding heavy chlorination pre-treatment of water;
    - avoiding traditional fertilization schedules with commonly used products, especially if these strategies have been used previously and were found not to reduce AHPND losses;
    - avoiding stocking ponds during the high-temperature season;
    - applying “designer” pre- or probiotic preparations (if available); and
    - applying “designer” phages that specifically target the VP_{AHPND} (if available).

- where AHPND is present in the culture environment, managing culture systems to delay infections by, e.g.:
    - stocking larger-size PL;
    - co-culturing of shrimp with finfish (e.g. tilapia) or using water from tilapia ponds;
    - using appropriately designed grow-out systems which mitigate the environmental conditions that support high densities of VP_{AHPND} (i.e. central drainage);
    - stocking at appropriate density according to farm capacity;
    - monitoring of shrimp health and removal of infected animals; and
    - if diseased shrimp are found, conducting laboratory analyses to aid decision making.

Reducing the risk of international spread of AHPND: The international spread of AHPND can be prevented or at least, reduced, by moving only live penaeid shrimp broodstock or PL that have tested free from AHPND by use of the AP4 test.

Conclusions of the Panama AHPND 2015: Outbreaks of AHPND caught the entire industry by surprise and took a long time to unravel because the disease broke through all existing biosecurity measures. While the industry had been dealing with vibriosis in all phases of culture for decades, nobody thought that a *Vibrio* would become an industry game-changer. Because the pathogen is ubiquitous in the environment, the disease thus calls for new strategies in biosecurity and control. A series of important questions that may require future research include:

- Is AHPND caused solely by a strain of *V. parahaemolyticus* that has a plasmid containing some toxins; or are other strains of *V. parahaemolyticus* or even other *Vibrio* spp. involved?
- Is the disease continuing to spread to new countries and geographical regions?
- What recent improvements are there in terms of detection methods?
- What is the current thinking on what are the persistent risk factors and how these risks be can reduced, prevented or managed?
- What technologies may assist the aquaculture sector in dealing successfully with AHPND?(For example, does the solution lie in the use of relatively closed culture systems? What technological and management innovations may be required?)

Highlights of Bangkok AHPND June 2016

The highlights of the Bangkok EMS/AHPND June 2016 event are summarized below based on the conclusions of the plenary panel discussion (industry, academe and government) that followed the expert presentations that were given during the seminar/workshop:

Industry update on AHPND: Some general conclusions drawn from the Industry Panel Discussions are summarized as follows:

- There is no "silver bullet" or "quick fix" to AHPND available or on the horizon.
- The continued spread of AHPND indicates that national biosecurity measures have for the most part failed. AHPND will probably soon be enzootic in all major shrimp producing countries.
- The industry must thus adapt to the new reality.
- Highly intensive and extensive systems appear to offer the best chance of success; semi-intensive and traditional large pond systems are likely to face more difficulties.
- Several systems are being successfully used in various parts of the world. In general, to be successful, the "clear water" system requires an improved ecology-based farm and pond management to assure: (i) clean PL, (ii) clean water and (iii) clean pond bottom.

- Some actions that can contribute to success include:
    - use of smaller ponds;
    - good pond preparation;
    - use of pond liners;
    - good feed management;
    - use of clean broodstock and PLs;
    - use of water treatment systems (shift to closed, semiclosed and recirculation systems);
    - use of "shrimp toilets" or other systems allowing rapid and frequent removal of pond wastes;
    - higher stocking densities to compensate for loss of area used for shrimp toilets and settling ponds;
    - on-site nurseries can help by conditioning PLs before stocking;
    - partial harvest (when risky conditions require);
    - avoiding the use of unapproved drugs and chemicals
    - higher rates of water exchange; and
    - improved surveillance and routine monitoring for early detection.
- Conversion to the "Asian system" will be expensive for owners of traditional ponds; however, it may now be "convert or perish".
- Biofloc ("brown water") and polyculture ("green water") systems may also be successful, but come with their own issues.
- Systems allowing higher biosecurity will be better able to deal the next transboundary aquatic animal disease (TAAD) coming down the road.
- Novel bacterial strains may help to reduce organic wastes in ponds and balance microbial populations.
- Use of some oral probiotics, bacterophages, herbal extracts and toxin absorbents mixed in feed may show promise; however, researchers need to know exactly what it is they are testing and have rigorous experimental design backed by strong statistical analysis.
- Genetic improvements offer some hope.
- Countries need to "step up" and comply with the spirit of their membership in the OIE, as without timely and accurate disease reporting, the OIE system cannot function properly.

Academic update on AHPND**:** This session discussed the most recent advances in research on AHPND. A general theme throughout this session was the opportunistic nature of vibrios, their great diversity in both species and strains, and their great adaptability to environments and hosts. Some general conclusions are summarized below:

- *The pathogen(s): one or several?*
    - Two bacteria (belonging to the genera *Shewanella* and *Delftia* were identified as having synergistic effect with VP_{AHPND} on shrimp mortality.

  - Genomic analysis has been done to AHPND *V. parahaemolyticus* strains from P.R. China, Thailand, Viet Nam and Mexico together with non. *V. parahaemolyticus* strains. The conclusion is that AHPND is caused by more than one strain of *V. parahaemolyticus* or even by other *Vibrio* species.
  - The plasmids have mutations that suggest a fast evolutionary process.

- *Pathogenicity:*
  - There is variation of the virulence of AHPND isolates that may act to potentiate the binary toxins killing shrimp without the pathognomonic histopathology characteristics of AHPND.
  - There are bacteria of different genera that are synergistic with *V. parahaemolyticus*, resulting in infections leading to higher mortalities.
  - *Vibrio* does not colonize shrimp tissues (without chitin lining), but liberates toxin into the hepatopancreas. In broth culture, after centrifugation the toxin remains in the supernatant and not in the cells.
- *Host and geographical distribution:*
  - No new shrimp species have been reported to be naturally infected, but it is likely that there could be.
  - There are OIE reports of two outbreaks in northern Australia with Pir^{vp} toxin genes in the chromosome.
  - There may be unreported outbreaks in India and Central America other than Mexico.
  - *V. parahaemolyticus* adheres to and degrades chitin, especially in low salinities. This characteristic relates to the number of zooplankton in the environment.

  - Possible carriers include zooplankton, birds, ballast water and marine currents.
- *Risk factors observed in Viet Nam*
  - Infected PL were the major source of infection.
  - Other associated factors include contaminated water, live feeds and broodstock, high stocking density and nearby contaminated farms sharing the same water supply.
- *Diagnostic considerations*
  - Diagnosis should be done at the pond-side by equipping farm staff with the skills to recognize early signs of disease.
  - This can be enhanced by incorporating new formats for molecular diagnosis to verify and confirm pond-side observations.
- *Genetic improvement*
  - Genetic improvements could offer options for resistant or tolerant stocks.
- *Other issues: specific pathogen free, (SPF), specific pathogen tolerant (SPT) and specific pathogen resistant (SPR)*
  - Detailed definitions of SPF, SPT and SPR were offered to avoid confusion.
  - The use of SPF stocks has achieved levels of productivity never seen before, which proves that the health status of PL is a key factor for the development of the industry.

  - Selective breeding is necessary to search for resistance to the toxin in those animals that do not die.
- *Other issues*: *Enterocytozoon hepatopenaei* (EHP)
  - The other disease of high concern is hepatopancreatic microsporidiosis caused by EHP, which is enzootic in Asia.
  - This parasite causes severe growth retardation, morbidity and mortality in the infected countries. For example, losses in Thailand due to EHP could be in the order of US $32 000 per ha per culture cycle.
  - There is the danger that this parasite could be exported to different areas and regions, so it should be added to the OIE list of pathogens.
  - Polychaetes have potential risk for pathogen transmission, especially via feeding to broodstock. Epidemiological studies on EHP in polychaetes are necessary.
  - EHP and AHPND cause significant losses in P.R. China. Sensitive and more effective diagnostic tools have been developed to detect both pathogens.
  - EHP infection may cause more than two times percentage of size variation, two to three times percentage of unexpected weight fluctuation, and about 30 percent of weight losses for same-size individuals.

National and international framework update: This session informed the participants about the global and national impacts of AHPND and other emerging shrimp diseases, the progress made by several countries (i.e. Brazil, Islamic Republic of Iran, Thailand, Viet Nam) in combating these diseases, and the relevant activities undertaken by several international and regional organizations (e.g. OIE, NACA, OIRSA, the Association of Southeast Asian Nations (ASEAN) and the Andean Community of Nations (CAN)). The following summarizes the major points made during this session:

- It is important to protect the affected and unaffected small-scale shrimp sector from AHPND. Efforts in research and biosecurity should also consider opportunities for this important sector. If not, the contribution of shrimp aquaculture to alleviating poverty and increasing food security will be reduced.
- There is a hidden role that ballast waters may be playing in spreading some shrimp pathogens, including those involved in AHPND. Some consideration appears necessary.
- Establishing and implementing the comprehensive National Action Plan towards either preventing the occurrence or reducing the occurrence of AHPND in the participating countries is paramount.
- Collaboration and communication among the relevant agencies should be improved.

Conclusions of the Bangkok AHPND 2016: The following recommendations were made by the experts and participants attending the seminar/workshop:

- Countries should establish a National Taskforce on AHPND.
- Countries should conduct a national epidemiological survey for AHPND.
- Countries should establish active surveillance programmes for AHPND.
- A collaborative research programme on AHPND should be developed.
- Counties should take steps (e.g. via good aquaculture practices (GAPs) or hatchery standard operating procedures (SOPs)) to ensure better national PL quality (SPF/ SPR/SPT, PCR-tested PL, etc.).
- If possible, establish broodstock and multiplication facilities for better PL.
- Establish a national programme and develop a national better management programme (BMP) or GAP guidelines towards improving shrimp pond biosecurity.
- Improve diagnostic capacity.
- Empower farmers to detect the disease and take remedial action based on the national programme/action plan.
- Develop national guidelines and standards, including quarantine procedures, risk analysis, etc. for importation of live shrimp and shrimp products.
- Initiate an awareness campaign on AHPND.
- Improve national fisheries-veterinary dialogue.
- Improve private-public partnership.
- Link up with relevant regional and international agencies.
- The reported survival of EHP at -20 ^{o}C for 1 month contradicts previous understanding and if confirmed, has major implications for international trade in frozen product; this needs to be sorted out quickly.

Conclusion

Globally, the trend in aquaculture is that every 3 to 5 years or so a serious emerging disease (a transboundary aquatic animal disease, TAAD) appears that spreads rapidly and causes major production losses. As can be seen in the disease scenario for AHPND, there is often a long time lapse (usually years) from the time that a serious mortality event caused by an unknown and emerging pathogen is observed in the field, to its subsequent identification and confirmation, acheiving global awarenss among aquaculturists and aquatic animal health experts, establishment of surveillance systems, and disease listing and reporting/notification, up to the time when cost-effective risk management measures are identified and implemented. The aquaculture sector and all its stakeholders need to rethink critically the drivers and pathways to aquatic animal disease emergence. In cooperation with partners together with member countries, FAO is leading the process of developing a new paradigm for dealing with aquatic animal diseases, the Progressive Management Pathway for Improving Aquaculture Biosecurity (PMP/AB).

This is a framework, originally called Progressive Control Pathway (PCP), that has been used by the terrestrial animal disease sector for dealing more effectively with specific livestock diseases such as foot and mouth disease, pestes des petits ruminants (PPR), rabies and African animal trypanosomosis (AAT). The PCPs provide systematic frameworks for planning and evaluating field interventions and enable realistic control objectives to be defined and achieved. In a similar manner, the PMP/AB is a step-wise risk management framework that focusses on building management capacity through both bottom-up and top-down approaches, with strong stakeholder involvement to promote the application of risk assessment and management at the producer level, as part of a national approach. Thus, it is risk-based, collaborative and progressive.

AHPND is a disease of significant concern to the shrimp aquaculture sector that will continue to hamper the continuity of food supply, impact livelihoods and reduce national export earnings. This special issue of Asian Fisheries Science on AHPND contains some of the technical papers that were delivered during the Viet Nam, Panama and Bangkok EMS/AHPND events between June 2013 and June 2016. This volume contains 23 contributions on a range of topics aimed at continuously updating the knowledge and experiences in dealing with AHPND and related topics from the perspectives of the government, academe and producer sectors.

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