While the Code of Conduct for Responsible Fisheries (CCRF) has been promoted as a global policy framework for sustainable and responsible fisheries management with the regionalized version being promoted in the Southeast Asian region through SEAFDEC efforts, international requirements emerged, particularly on the need to combat IUU fishing. Under the framework of the CCRF, the International Plan of Action to Prevent, Deter and Eliminate IUU Fishing was developed, with measures being delineated for coastal States, flag States, and port States to combat IUU fishing practices that undermine all efforts undertaken towards the sustainability of fisheries. Recently, more pressures from international and regional markets exacerbate the adoption of market-related measures by the Southeast Asian countries. These include several schemes for traceability of fish and fishery products including those issued by the private sector and groups of buyers. In 2010, the European Community started to put into force EC Regulation 1005/2008 requiring all fish and fishery products to be accompanied by a catch certificate in order to allow their entry into the Community. The U.S. also issued in 2015 the U.S. Presidential Task Force on Combating IUU Fishing and Seafood Fraud, and subsequently the new U.S. seafood traceability program to ensure that global seafood resources are sustainably managed and not fraudulently marketed.

In order to address such situation and the emerging requirements, the Southeast Asian region developed regional approaches to enhance the sustainable management of fisheries. The ASEAN Guidelines on Preventing the Entry of Fish and Fishery Products from IUU Fishing Activities into the Supply Chain was developed and adopted by the AMSs through the AMAF Meeting in 2015, as a regional framework for combating IUU fishing. The ASEAN Guidelines would be supported by several tools developed at the regional level including the Regional Fishing Vessels Record or RFVR, the ASEAN Catch Documentation Scheme or ACDS, and the RPOA for Management of Fishing Capacity or RPOA-Capacity, among others. Future challenges that lay ahead would be addressed by strengthening the momentum of the aforementioned initiatives and enhancing the capacity of the countries in the implementation of such regional collaborative frameworks.

In 2016, the AMSs adopted the Joint ASEAN-SEAFDEC Declaration on Regional Cooperation for Combating IUU Fishing and Enhancing the Competitiveness of ASEAN Fish and Fishery Products. While it is encouraged that the Joint Declaration be implemented by the AMSs with support from donors and collaborating agencies, it is also necessary that collaboration between and among the AMSs need to be strengthened, *e.g.* through bi-lateral and multi-lateral cooperation. Important issues also arose during latest regional discussions including the possible development of the ASEAN Common Fisheries Policy. However, at this moment it is still unclear to what extent such common policy would focus and cover. Further discussion on this issue is therefore another important challenge that would pave the way towards the future of fisheries in the Southeast Asian region in the years to come.

6. AQUACULTURE DEVELOPMENT

6.1 Control and Prevention of Present and Emerging Transboundary Aquatic Animal Diseases

Shrimp aquaculture is a lucrative industry responsible for generating billions of US dollars in export income annually. In Southeast Asia, *Penaeus monodon* and *P. vannamei* are the major cultivated species with the latter species currently dominating the Asian and world market. Preceding 2000s, *P. monodon* was the dominant cultivated shrimp species in Asia. However, the scenario fairly changed around that year with the widespread adoption of domesticated and specific pathogen free (SPF) *P. vannamei*, which since then has become the principal choice for shrimp growers chiefly due to its success in avoiding problems concomitant to white spot disease outbreaks.

The intensification of shrimp cultivation in Southeast Asia to increase production has been impeded by pervasive episodes of epidemic diseases, which were inflicted not only by the white spot syndrome virus (WSSV) but also by other pathogenic shrimp viruses such as the yellow head virus (YHV), Taura syndrome virus (TSV), and infectious hypodermal and hematopoetic necrosis virus (IHHNV) among others (Flegel, 2012). Unwarranted occurrences of these viral diseases in cultivated shrimps have led to serious economic losses of about US$ 15 billion over the past 15 years, with approximately 80% of the losses occurring in Asia (FAO, 2014b). Irresponsible transfer of live shrimps, particularly the farmed stocks, allegedly carrying the pathogens, is the main culprit responsible for the rapid and widespread occurrences of disease outbreaks in hatcheries and grow-out ponds.

Since 2009, the emergence of a new disease, currently termed acute hepatopancreatic necrosis disease (AHPND), has stirred financial havocs among major shrimp producing countries in Southeast Asia, especially in Viet Nam, Malaysia, Thailand, and the Philippines. Aside from AHPND, farmers have been faced with urgent pressures ascribed to the emergence of newly emerging diseases like the hepatopancreatic microsporidiosis (HPM) and the covert mortality disease (CMD), among others (Thimatadee *et al*., 2016).

In 2012, members of the Governing Council of the Network of Aquaculture Centres in Asia-Pacific (NACA) recognized the need for Regional Consultations and Contingency Planning. Moreover, during the SEAFDEC Program Committee Meetings in 2012 and 2013, representatives from SEAFDEC Member Countries conveyed their concern regarding the outbreaks of AHPND and other transboundary diseases in the region and acknowledged the need for concerted regional effort to address the issue at hand. Hence, with assistance from Japan-ASEAN Integration Fund (JAIF), SEAFDEC and the Philippine Government convened the Regional Technical Consultation on Improvement of Aquatic Animal Health Management in Aquaculture in Southeast Asia on February 2016 in Makati, Philippines (also known as the ASEAN RTC on AHPND and other transboundary diseases). The consultation was aimed at addressing the pressing concern of the AMSs on the outbreaks of AHPND and other transboundary diseases of aquatic animals, particularly in penaeid shrimps, which is the leading food commodity export of the Southeast Asian region.

6.1.1 Status of AHPND

6.1.1.1 Current host and geographical distribution of AHPND

AHPND, recently identified as the most serious disease of cultured penaeid shrimps in the tropics, has been mainly implicated in mass mortalities of the whiteleg shrimp (*P. vannamei*) but has also been reported in tiger shrimp (*P. monodon*) and fleshy prawn (*P. chinensis*). The first outbreaks of AHPND began in China in 2009 and subsequently spread to Viet Nam (2010), Malaysia (2011), Thailand (2012), Mexico (2013), and most recently in 2015 in the Philippines (Tran *et al*. 2013; Joshi *et al*., 2014; Soto-Rodriguez *et al*., 2015; dela Peña *et al*., 2015). The disease was earlier known as early mortality syndrome (EMS) because mortality occurs in the early stages of culture, *i.e*. within 30-35 days after stocking the shrimp post larvae (PL) in culture ponds. However, the term EMS led to confusions as mortality during the early phase of shrimp culture could be due to several factors.

6.1.1.2 Current tests and diagnostic methods for AHPND

The group of *Dr. Lightner* at the Arizona State University in the USA documented for the first time in mid-2000s the histopathology of *P. monodon* and *P. vannamei* obtained from culture ponds with EMS in China and Viet Nam. In their report, massive rounding and sloughing of the hepatopancreatic tubule epithelial cells occur in the absence of any detectable causal pathogen which was then subsequently coined as acute hepatopancreatic necrotic syndrome or AHPNS (Lightner *et al*., 2012). The definition of AHPNS by *Dr. Lightner*'s group served as springboard for the widespread dissemination of relevant information on AHPNS in Southeast Asia through a disease card published online by NACA as agreed upon for adoption by a meeting of specialists in Bangkok, Thailand in 2012 (NACA, 2012). The NACA disease card contains vital information including the presumptive gross signs of AHPNS. However, the gross signs only constituted the presumptive diagnosis, hence, histological examination of at least 10 specimens for confirmation was necessary (NACA, 2012; NACA, 2014).

The causal agent of AHPND as identified by the group of *Dr. Lightner* in 2013 was the specific virulent strains of *V. parahaemolyticus* (VP-AHPND). Thus, the name of the disease was changed to acute hepatopancreatic necrosis disease (AHPND) after discovering that VP-AHPND colonizes the stomach of shrimp produced toxins responsible for the sloughing of hepatopancreatic tubule epithelial cells of the hepatopancreas. Bioassay using bacteria isolated from ponds with AHPND outbreak was employed to satisfy Koch's postulates. This was successfully achieved through immersion challenge using VP-AHPND bacteria grown in broth culture, which subsequently induced 100% mortality in shrimps coupled with the expressions of typical pathognomic histology of AHPND. In addition, the cell-free broth obtained from VP-AHPND cultures was found to induce massive sloughing of the hepatopancreatic tubule cells even in the absence of bacterial cells (Tran *et al*., 2013). Fortunately, all isolates tested lacked the pathogenicity island related to human infection, hence, negative for human pathogen markers *tdh* and *trh* (Nishibuchi *et al*., 1985; Nishibuchi *et al*., 1989).

VP-AHPND isolates subjected to sequence analysis of total DNA extracts revealed that they possess a unique plasmid which contains an operon coding for homologs of *Photorhabdus* insect-related (Pir) binary toxin, Pir A and Pir B, which are key elements in the induction of AHPND (Tinwongger *et al*., 2014). Moreover, the examined VP-AHPND isolates possess a unique plasmid known as pVPA3-1 that contains insecticidal related genes PirA and PirB (Han *et al*., 2015). The detection of these two potent toxin genes in VP-AHPND isolates propelled the construction of primers for the PCR method of detecting AHPND. Preliminary PCR methods were uploaded by *Dr. Flegel*'s group at the NACA website in December 2013 and updated in 2014 (Flegel and Lo, 2014). False-positive PCR results have arisen using the AP2 primer set, perhaps due to mutation of plasmids lacking the toxin gene. However, Sirikharin *et al*. (2015) documented that the AP3 method exhibited excellent sensitivity and specificity as evidenced by nil false positive or false negative test results conducted on bacterial isolates verified as AHPND or non-AHPND by bioassays with shrimp. Such detection methods are single step PCR that require enrichment especially for samples containing VP-AHPND whose quantity is below the threshold limit of detection or at the early stage of infection. In February 2015, *Dr. Flegel*'s group published at NACA website an AP4 nested PCR method suitable for the archived DNA extracts and for tissues or environmental samples preserved in lysis buffer or alcohol. AP4 nested PCR method gave 100% positive and negative predictive values for the same V-AHPND isolates used in validating the AP3 PCR method but with notably 100 times higher detection sensitivity (Sritunyaluchsana *et al*., 2015). Recently, a loop-mediated isothermal amplification (LAMP) method that uses two sets of primers (LAMP-A2 and LAMP-A3) has been developed and validated for use to specifically identify VP-AHPND strains (Kongrueng *et al*., 2014). Aside from the fact that LAMP assay for detecting AHPND related bacteria can significantly reduce time, ease and cost of detection, LAMP method proved to be superior to the PCR method in detecting AHPND.

6.1.2 Other Emerging Transboundary Diseases of Penaeid Shrimps

The shrimp industry in the Southeast Asian region is also currently being confronted with other emerging diseases that include the hepatopancreatic microsporidiosis (HPM) and hepatopancreatic haplosporidiosis (HPH), as well as the covert mortality disease (CMD) among others. Caused by *Enterocytozoon hepatopenei* (EHP), HPM infects both *P. monodon* and *P. vannamei* (Thitamadee *et al*., 2016). EHP is transmitted directly from shrimp to shrimp by cannibalism and cohabitation and could be detected using light microscopy (100× objective lens). However, the characteristic spores are very small and sometimes present only in small numbers even in heavily infected samples. Molecular techniques such as nested PCR, *in situ* hybridization, LAMP, and real-time PCR are currently available for EHP detection in penaeid shrimps. In Thailand, most of its imported specific pathogen free (SPF) stocks of *P. vannamei* that are negative for EHP often become test-positive in recipient maturation and hatchery facilities. This observation could be attributed to poor biosecurity like use of live animals (*e.g.* polychaetes and clams) as feed for the broodstock shrimp and use of post-larvae (PL) derived from government approved, imported SPF broodstock for rearing up to broodstock size in local shrimp ponds (Thitamadee *et al*., 2016). To avoid EHP contamination in rearing facilities, the use of wild or captured live animals as feeds for the broodstock should be avoided. If not feasible, feeds should be frozen before use, pasteurized (heating at 70°C for 10 min), or gamma irradiated (Thitamadee *et al*., 2016). Just like AHPND, it is necessary that polychaetes should be tested for the presence of any shrimp pathogens, and concomitantly reared in biosecure environments.

Serious outbreak of HPH in cultivated *P. vannamei* in Indonesia occurred between 2007 and 2009 (Utari *et al*., 2012). Based on histological examination, the causative agent morphologically resembles the previously reported unnamed haplosporidian in Central America. Sequence analysis of the small sub-unit ribosomal RNA indicated that the two isolates are closely related with 96% sequence identity. Since 2010, further disease outbreaks in broodstock and post-larvae (PL) by histology and PCR methods had not been recorded so far in Indonesia. Fortunately, there have been no reports of HPH outbreak in other Southeast Asian countries. HPH, just like EHP, is not included in the OIE list of reportable diseases (Thitamadee *et al*., 2016).

The cause of CMD is a virus known as covert mortality nodavirus (CMNV). When infected with CMD, shrimps die at the bottom of the pond making fish farmers unaware of the mortality. CMD has been implicated in mass mortalities of shrimp in China since 2009, around the time when AHPND emerged, but unlike AHPND, mortality was continuous rather than abrupt and peaked later than AHPND at around 60-80 days with cumulative mortalities peaking up to 80% (Zhang *et al*., 2014). Histologically, shrimp with CMD exhibits enlarged nuclei in the hepatopancreas with coagulate muscle necrosis associated with gross signs of muscle whitening. To date, the prevalence of CMNV positive shrimp samples detected using nested RT-PCR in Thailand is apparently high (Thitamadee *et al*., 2016).

6.1.3 Issues and Concerns

Transboundary diseases, including AHPND, encompass concerns concomitant to economic, trade, and food security for a considerable number of countries. The rapid spread of pathogens to other countries may inadvertently reach epidemic proportions thereby requiring pragmatic control strategies, including exclusion, through cooperation between and among several countries. Issues covered here chiefly include the priority issues identified during the ASEAN RTC on AHPND and other transboundary diseases for improved aquatic animal health management in Southeast Asia. These priority issues shall serve as impetus for developing policy recommendations aimed at controlling and preventing the further spread of AHPND and other emerging transboundary diseases of penaeid shrimps in the region.

6.1.3.1 Strategies for disease prevention, control, and biosecurity

Considering that an important component of effective disease prevention and control is the development of appropriate diagnostic techniques, researches on AHPND chiefly focused on the pathology and etiology of the disease. Disease prevention could be achieved through implementation of good hygiene to limit the transmission pathway of the pathogens. In general, various approaches including the use of potential bacteriophages, suitable water quality, and adherence to appropriate stocking density could prevent unwarranted outbreaks of AHPND in culture ponds. In addition, aside from the quantity and quality of feed given to shrimps and quality of seeds used, an important element that may curb if not eradicate the occurrence of AHPND in culture ponds is strict adherence to biosecurity measures.

As pointed out by *Dr. Flegel* during the Fourteenth Meeting of the Advisory Group on Aquatic Animal Health (AGM 14) in November 2015 in Bangkok, Thailand, careful attention should be made on the need to test wild caught *P. monodon* breeders for presence of major pathogens prior to using these in hatcheries. Moreover, examination of post-larvae for overall health quality through microscopic detection for any abnormality and presence of pathogens, and molecular detection by PCR, of major viral pathogens should be carried out. However, these practices seemed to have stopped with the widespread use of *P. vannamei* in shrimp culture. The widespread use of live polychaetes as broodstock feed has become popular among shrimp hatchery operators because of higher nauplii yields but unfortunately it put the entire industry at risk for the spread of any transboundary pathogens. Thus, when *V. parahaemolyticus* acquired the pVA1 AHPND plasmid from China in 2009, possibly through the exportation of live polychaetes as broodstock feed, there were no preventive measures in place geared at aborting if not controlling its rapid spread in China and subsequently to other major shrimp-producing countries in Southeast Asia. Since eradication of VP-AHPND strains in culture ponds is unfeasible, measures that prevent their translocation to new geographical regions should always be looked into considering the fact that they can easily establish themselves in local environments thereby posing tremendous biosecurity threats.

Current aquaculture practices promote the proliferation of microbial communities that most often than not, include a large proportion of opportunistic pathogens not only including VP-AHPND strains but also other pathogenic *Vibrio* spp. It is therefore imperative to focus efforts on aspects that cover ecological approaches to control AHPND. It is prudent not only to look at the causal agent per se but also on the microbial community of the animal's rearing environment as a whole (Pakingking *et al*., 2015). Pond bottom management including disinfection of the pond soil and water will not warrant the eradication of VP-AHPND vectors but may reduce the epidemic spread of AHPND. *Dr. Loc Tran* from Nong Lam University in Viet Nam reported his success with the use of the tilapia "green water" system. This system involves the installation of floating net-cages stocked with tilapia in the shrimp pond or alternately with tilapia from one pond and shrimp in another pond, but with water cycling from the tilapia pond to the shrimp pond and back (Tran *et al*., 2014). In Negros Occidental, Philippines, some shrimp growers recently experienced successful shrimp production runs using the tilapia green water system. Considering that acquisition of VP-AHPND by shrimps from their rearing environment is highly feasible as supported by scientific data showing that VP-AHPND bacteria could be detected in shrimp water and pond sediments, strict adherence to proper pond preparation before stocking and pond management during culture must be conscientiously practiced.

The use of PCR methods to detect the presence of VP-AHPND in shrimps and live feeds such as polychaetes and bivalves should be an integral component of good shrimp aquaculture practices (Thitamadee *et al*., 2016). As such, shrimp growers should submit samples of shrimp post-larvae for the presence of AHPND bacteria by PCR before purchase and/or before stocking to grow-out ponds. Likewise, careful testing of live feeds given to SPF broodstock is necessary to check for VP-AHPND. Thus, AHPND-positive batches of shrimp and live feeds should not be used and must be disinfected and discarded properly. In Thailand, some farmers claimed successes in evading AHPND by culturing their post-larvae in nursery ponds for the first month or so under stringent controlled biosecure conditions. When shrimps reach the desirable size (larger PL size), the shrimps are already competent enough or less vulnerable to AHPND before their eventual release to grow-out ponds (Thitamadee *et al*., 2016). Furthermore, the installation of central drain system in culture ponds has been recently practiced by some shrimp growers to minimize the accumulation of excessive organic loads in the pond sediments arising from shrimp wastes and uneaten feeds. Hence, overfeeding should be avoided and removal of sediments as often as possible should be done as uneaten pellets could serve as substrate to the VP-AHPND bacteria.

The group of *Dr. Hirono* from Tokyo University of Marine Science and Technology is currently developing some practical prevention methods against AHPND, and generated some promising results so far, on the potential use of formalin to kill VP-AHPND as vaccine immunogen in shrimp against AHPND. However, *Dr. Hirono* pointed out that its application in small shrimps appeared to be difficult. Some encouraging data on the application of nano-bubble technology that could inactivate VP-AHPND bacteria present in shrimp rearing water and use of IgY as additive in shrimp feeds have also been recently documented by his group (Hirono, 2016). All generated data are however still under experimental stage in the laboratory and rigorous amounts of field studies are necessary to verify the practical application of these methods in the actual scenario.

In some countries that experience the impact of AHPND in their shrimp culture industry, the excessive use of antibiotics for therapeutic or prophylactic purposes has been reported. Recalling that the indiscriminate use of antibiotics to treat luminescent vibriosis in the 1980s consequently led to the collapse of the shrimp industry in Southeast Asia, this should serve as perpetual reminder for shrimp farmers to strictly adhere to the apposite use of antibiotics in aquaculture. This is to hinder similar catastrophic disease episodes inflicted by pathogenic vibrios in the 1980s to happen again. Misuse of antibiotics does not only devastate microbially mature shrimp cultivation systems but has been proven ineffective in treating diseases inflicted by vibrios such as *V. harveyi* and its closely related bacteria such as *V. parahaemolyticus* which is the causal agent of APHND. The application of phages as potential prophylactic and therapeutic methods for AHPND in shrimp culture has been recently identified as an alternative approach to prevent and control the proliferation of bacterial pathogens in shrimp farming. For example, treatment of *P. vannamei* larvae suffering from vibriosis caused by *V. parahaemolyticus* with selected phages has been reported to significantly reduce shrimp mortality (Lomeli-Ortega and Martinez-Diaz, 2014).

The use of specific pathogen free (SPF) stocks would be an effective approach to prevent viral infections and outbreaks in biosecure rearing systems. SPF shrimps for pond cultivation are the resultant populace derived from wild parents and produced by extensive quarantine procedures. However, the SPF condition of the shrimp is not heritable as what chiefly separates between the host and target pathogens is the physical environment that is free of pathogens. Thus, once shrimps are removed from the SPF production facilities, they are subject to a greater risk of infection unless they are reared in a well-established facility with history of disease surveillance and practicing biosecurity protocols. As pointed out earlier, the causal agent of AHPND is a free-living bacterium that can persevere with brackish and marine waters as well as in sediments for a long time even in the absence of carriers. Hence, emphasis on good pond management that promotes the proliferation of indigenous heterotrophic bacteria with probiotic potential that could regulate optimum water quality and population of VP-AHPND bacteria and other pathogenic vibrios in the shrimp gut and its rearing environments ought to be the first consideration in hand prior to the stocking of SPF shrimps in cultivation ponds. Additionally, concerns on inbreeding are another equally important issue confronting the shrimp industry in Southeast Asia that should be accordingly addressed (Moss *et al*., 2005). Pertaining to this concern, researches focusing on the impacts of inbreeding and consequential effects on shrimp's genetic erosion and concomitant vulnerability to diseases should be pursued. However, careful planning is necessary for selective breeding programs, which is expensive and enormous amount of investments will be required for their successful implementation and sustainable operation.

6.1.4 Challenges and Future Direction

The unprecedented outbreaks of AHPND in major shrimp-producing countries demonstrate the need for international cooperation and collaborative research among relevant institutions to curb emerging disease problems ascribed to the uncontrolled transboundary movement of live penaeid shrimp broodstock or their offspring and other living aquatic organisms from an AHPND-infected area to an unaffected aquaculture facility. Considering the intermittent occurrence of AHPND in some countries in the region, NACA, the Office International de Epizooties or World Organization for Animal Health (OIE), Food and Agriculture Organization of the United Nations (FAO), and SEAFDEC pooled their efforts to aggressively and effectively disseminate the information to these vulnerable countries in order to avoid the massive widespread of AHPND in the Southeast Asian region. For its part, NACA published an AHPND Disease Card in 2012 (updated in 2014) and routinely provides new information on AHPND on its website (*www.enaca.org*). Since NACA listed AHPND as reportable shrimp disease, focal points of the NACA member countries are obliged to report any occurrence of AHPND in its Quarterly Aquatic Animal Disease Reporting System. Another important development is the inclusion of AHPND in the listing of diseases notifiable to the OIE. Accordingly, since 1 January 2016, OIE member countries have been obliged to report to the OIE the presence or absence of this disease in their respective countries, mainly to support member countries' efforts in preventing transboundary spread and unwarranted outbreaks of this devastating disease through transparent and consistent reporting. Moreover, FAO also initiated various similar projects to disseminate information on AHPND.

In order to obtain better understanding of the etiology of the disease and identify a number of risk management measures and key areas for future research, the project TCP/VIE/3304 *Emergency Assistance to Control the Spread of an Unknown Disease Affecting Shrimps in Viet Nam* was conducted in Viet Nam in 2013 (*http://www.fao.org/docrep/018/i3422e/i3422e00.htm*). A sequel to this was the recent implementation of an inter-regional TCP project: TCP/INT/3502 *Reducing and Managing the Risk of AHPND of Cultured Shrimp* aimed at providing a platform to improve understanding of the disease through the lens of governments, scientists, and producers, and collectively generate practical management and control measures. Relative to this, are back-to-back inter-regional meetings in Panama City, *e.g.* International Technical Seminar/Workshop on *EMS/AHPND: Government, Scientists, and Farmer Responses* on 22-24 June 2015, and the First Inter-regional Workshop on EMS/AHPND Risk Management and Risk Reduction Strategies at National and Regional Levels on 25-27 June 2015 (Reantaso, 2016). By and large, despite these regional and international actions that have been undertaken so far, aggressive and continual efforts should be concerted and pursued to spur and heighten awareness among shrimp growers and pertinent stakeholders so that inadvertent transboundary movement of persistent and newly emerging shrimp pathogens in the region could be sustainably controlled and prevented.

It is recognized that the riskiest activity for geographical spread of VH-AHPND strains and other transboundary pathogens is the uncontrolled movement of live shrimp breeders or their offspring from a pathogen-contaminated area to an unaffected aquaculture area. Of unequivocally risky practice is the uncontrolled movement of live aquatic animals such as polychaetes intended for use as feeds for shrimp broodstock from pathogen-contaminated areas to unaffected areas dedicated for shrimp cultivation (Thitamadee *et al*., 2016). A plausible constraint that may hinder the effective disruption of translocation of these shrimp pathogens is the illegal importation of pathogen-carrying shrimps or their offspring and other live aquatic organisms used as broodstock feeds. Thus, development of a harmonized *Regional Guidelines on Health Management and Good Practice* applicable to all Southeast Asian countries is urgently needed to sensibly prevent and control further inadvertent outbreaks of AHPND and other emerging transboundary diseases of penaeid shrimps. Moreover, once established, a more systematic reporting system (*i.e.* early warning and subsequent monitoring) to relevant agencies or competent authorities at the countries, regional, or international level should be instituted. As such, there is a need to immediately develop emergency preparedness and contingency plans by competent authorities of concerned countries, especially in cases of the inevitable emergence of a novel and dreadful disease. More importantly, attention and guidance should be provided to farmers who are into small-scale shrimp culture as they represent a weak link in the system posing high risk for diseases.

Recognizing the importance of detecting transboundary pathogens of penaeid shrimps in broodstock and their offspring, and importantly in live aquatic organisms like polychaetes and clams which are used as feeds, detection methods should be adherent to gold standards such as those indicated in the OIE guidelines, and whenever possible should be harmonized in the region. The scarcity, availability, and capacity of some laboratories, either public or private sector, equipped with level II (parasitology, histopathology, bacteriology, and mycology) and level III (immunology and molecular techniques) facilities in some developing countries in the region is another constraint that should be tackled accordingly (Lavilla-Pitogo *et al*., 2011). In addition, rigid trainings pertinent to aquatic animal health should be strengthened among aquatic animal health personnel since an inadequate level of aquatic animal health expertise in Southeast Asia still remains. Thus, strong partnership among relevant government agencies, various international organizations, and the academia should be intensified to fill the gap. As part of capacity building program, knowledge and skills on aquatic animal health management in general could be substantiated by bringing the training module on-site in order to consequently foster greater and active participation of local staff (Lavilla-Pitogo *et al*., 2011).

It is increasingly evident that development of production systems based on cultivation of SPF stocks in a biosecure environment will be vital to ensure constant supply of SPF stocks. Thus, development of such system in major shrimp producing countries in the Southeast Asian region will be necessary in order to be assured of reliable and sustainable production with a minimal impact on the environment (Thitamadee *et al*., 2016). This goal is not impossible as the pool of knowledge on aquatic animal diseases, environmental microbiology, ecology, and biochemical engineering among others has already been generated including the ongoing researches that are optimistically sufficient to drive the establishment of a prototype SPF breeding facility (Flegel and Lo, 2014). Additionally, governmental support programs at the national and regional levels will be necessary to assist farmers in capital investments once a successful prototype SPF breeding facility for shrimps and other living aquatic organisms used as feeds is established.

More importantly, the government and private sectors at national and regional levels, should work together to generate sufficient funds and resources for the conduct of research and development programs. Hence, researches relating to the diverse aspects of fish health management including immunology and pathogenesis of infectious diseases of different etiologies and novel methods for disease prevention and therapy are respectively carried out and generated (Hong *et al*., 2015; Thitamadee *et al*., 2016). Finally, in order to prevent illegal transboundary movement of living aquatic animals including shrimp broodstock or their offspring for cultivation as well as polychaetes used as broodstock feeds, countries in the region should work in concert to harmonize national legislations and regulations related to aquatic animal health management. These could include legislations for the transboundary movement of live aquatic animals in order that unwarranted disease outbreaks and concomitant economic losses are rationally precluded during the course of shrimp cultivation.

6.2 Overcoming the Fish Meal Dependence in Aquaculture

In recent years, the inclusion level of fish meal in commercial aquafeed formulations had decreased but in terms of quantity, fish meal usage actually increased due to increased production of aquaculture feeds in the Southeast Asian region. Fish meal or fish by-catch is a major source of protein in aquaculture feeds and its widespread use puts pressure on wild fisheries, an important source of food for the human population. The aquaculture industry's dependence on fish meal has long been recognized and the use of alternative protein sources as substitute for fish meal was the theme of the consultative meeting of representatives from the AMSs in Myanmar in 2014 (Catacutan *et al*., 2015).

Protein source in aquaculture feed is expensive because of its bulk in the feed formulae. For decades, researches on suitable alternative protein sources to overcome the dependence on fish meal had been conducted by many research agencies including the SEAFDEC Aquaculture Department (SEAFDEC/AQD). Nutrient levels in materials with potential as protein sources in aquafeed were analyzed and tested for acceptability or suitability in popular species for culture. These resources mostly come from plants, some from processing by-products, and few from unconventional sources. At SEAFDEC/AQD, the materials had been processed for testing in diets of culture species such as sea bass, abalone, milkfish, catfish, grouper, snapper, and shrimps.

6.2.1 Status on Use of Aquaculture Feeds

The level of use of alternative protein sources in aquaculture feeds is not of the same intensity in every AMS. Some countries are moderate to heavy users of aquaculture feeds, reflective of the level of their respective aquaculture operations. However, other countries use very minimal volumes of aquaculture feeds or none at all because their aquaculture operation is dependent on available fish by-catch coming from either fresh or marine waters.

Countries which are low to moderate users of aquaculture feeds have shown trends towards increasing their aquaculture production. Some countries are catching up to increase production from aquaculture by engaging the private sector and their governments to build bigger capacity aquafeed mills, modify tax on importation of materials such as fish meal, and train farmers on using aquafeed. Increase in aquaculture production is also triggered by the increasing human population and consequently demand for fish protein which can be supplied through aquaculture. Importation of aquaculture feed or feed ingredients has also increased in countries with common borders. Thus, it is clear that the demand for aquaculture feeds would continue to increase in the future.

6.2.1.1 Feed utilization of aquaculture species

Some aquaculture species are common to all AMSs, and classification of these species according to feeding habits will be helpful in obtaining information on the extent of fish meal use in aquafeed. These species vary in their dietary requirements for protein and subsequently the optimum dietary level contribution from fish meal. The species could be classified as herbivores (*e.g.* milkfish, carps, and barbs), carnivores (catfish, snakehead, sea bass, grouper, and black tiger shrimp), and omnivores (*Pangasius* and tilapia).

In most AMSs, farmed freshwater species generally consume less formulated feeds as such species are mostly low-value with culture systems that usually depend on fish by-catch or on natural food available in culture facilities during rainy months. For countries with access to sea water, there is an immense use of commercial feeds where high value species, such as sea bass and grouper, are cultured for export or for local consumption. Since this system of culture is expanding in the region, fish meal usage would surely continue to increase.

6.2.2 Research Efforts to Overcome Fish Meal Dependence in Aquaculture

Research and development efforts on fish meal and fish oil substitution in aquafeed with locally available ingredients are ongoing and being done by most AMSs. Agencies or entities engaged in this activity are their respective Departments of Fisheries, universities, and the private sector. For example in Thailand, a major aquaculture producing country, its Department of Fisheries oversees the production of commercial aquafeed for eight species. Also, there is an ongoing involvement by the Government, feed millers, and fish farmers to ensure the sustainable development and use of alternative dietary ingredients in aquafeed.

In Indonesia, production of local fish meal is high but only 5% of the total production goes to aquafeed and the rest is exported. Thus, the cost of commercial feed has increased because 70% of feed components is imported, the price of which continues to increase every year. Efforts towards reduction of fish meal in commercial diets have been done particularly for freshwater species where 5-11% is fish meal compared with that in marine fish species (> 30%) and shrimp (20-30%). Soybean meal is highly utilized to replace fish meal in commercial feed production but this is