fish meal in the diet of aquaculture species classified under omnivores, carnivores, and herbivores species (refer to ***Appendix 2***), the vital one is information on suitable alternative sources for specific species and their availability. For alternative sources of plant origin, information on anti-nutrient factors, nutrient information and quality are crucial to their utilization. Soybean is the most common plant protein used to replace fish meal in aquafeed formulations, but due to its increasing cost as dictated by the market, local sources have been identified but production volume is limited. Furthermore, information is scant with regards to the digestibility, amino acid profile, and dietary inclusion level (suggested level) of plant protein sources with potential for use in aquafeed. Research results on alternative protein sources in aquafeed are not available to interested stakeholders.

6.2.5 Future Directions and Policy Recommendations

Strong collaboration is encouraged among AMSs in exchanging research information or joint research work between institutions with appropriate facilities and expertise. This is also true between local agencies especially with the agriculture sector for the mass production of identified plant protein sources suitable for aquafeed production and also among R&D institutions, the private sector, the academe, and donor agencies.

The policies recommended for AMSs on overcoming the dependence on fish meal by development and use of alternative dietary ingredients in aquaculture feed are shown in **Box 17**.

Box 17. Recommended policies on the use of alternative dietary ingredients in aquaculture feed

- Establish a national aquafeed quality control to ensure high compliance of feed milling companies to fisheries regulations and acts.
- Establish a focal agency of ASEAN Programs for this purpose. SEAFDEC/AQD could be given the role of focal agency and as such should work closely with ASEAN Member States, research institutions, academe, industry, and international organizations.
- Create an ASEAN Forum or network and include all stakeholders.
- Formulate the National Action Plan.
- Enhance awareness on the importance of reducing dependence of aquaculture on feed and ingredients of marine origin.

6.3 Production and Dissemination of Good Quality Seedstock

The world's total farmed food fish production in 2012 was approximately 66.6 million metric tons, of which 88.4% came from Asia (FAO, 2014a). China contributed 61.7% to the 88.4%, followed by Southeast Asia with 26.2% and the rest from Central and Western Asia. Farmed aquatic commodities include high volume of low value aquaculture species like tilapia, carps, as well as Clariid and Pangasiid catfishes that are easily traded. Freshwater fish species are easily produced for they have been successfully bred in captivity and farmed historically long enough in that their husbandry protocols are already well established and optimized. On the other hand, marine fishes especially those requiring years to mature and are often hormonally induced to breed, need extensive hatchery and nursery facilities and technical skills for seedstock production before these could be farmed in ponds or cages. Brackishwater and/or marine invertebrates like mud crabs, shrimps, and shellfishes are among the commercially valuable species from marine aquaculture. Mariculture necessitates higher investment inputs from feeds to technical farm operations and maintenance, hence marine fish products are inevitably sold at higher market prices.

With regards to farmed aquatic plants, Indonesia, Philippines and Malaysia are recognized as among the major producers with an estimated combined production of 8.6 million metric tons or 36.0% of the total world production of aquatic plants mainly comprising seaweeds (FAO, 2014a).

For both inland and mariculture systems, farming methods have progressively evolved and many have resorted to intensification to achieve higher outputs. This has led to problems such as poor quality broodstock and seedstock, deterioration of culture environments as well as the proliferation of aquatic fish disease-causing agents that pose challenges in sustainable aquaculture production in the Southeast Asian region. Such issues continue to occur despite the initiatives to: a) find solutions to nutrition, water quality, and health management concerns; b) develop sustainable intensive husbandry methods; and c) adopt genetic programs to produce genetically enhanced, quality seedstock that are on-grown to maximize farm yields for a short rearing period. Nonetheless, such concerns are gradually being addressed through policies as well as practical techniques and/or scientific interventions to enable the production of food fish that will not only support food security but also promote economic growth. Motivation to improve economic growth through fish production and trade is seen as an offshoot of the ASEAN integration where each Southeast Asian country must be ready to compete foremost against other regional market forces and ultimately contribute to global fish production.

6.3.1 Why Good Quality Seedstock?

Although aquaculture yields from the Southeast Asian countries are still high, a slight decline in the annual production was noted in recent years. This has clearly been due to the adverse impacts of climate change and natural calamities on farmed fish stocks with the assumption that farmed stocks are well managed. If farms are poorly managed more so for intensively farmed species, problems such as disease outbreaks would inevitably affect operations adversely. Examples of such aquaculture species are the penaeid shrimps that have been highly susceptible to pathogens, *e.g.* white spot syndrome virus (WSSV) and the bacteria that cause acute hepato-pancreatic necrosis syndrome or early mortality syndrome (EMS). These pathogens have caused massive shrimp die-offs thus affecting shrimp production. In this instance as an immediate solution, the tiger shrimp industry has shifted to the culture of the whiteleg shrimp *Litopenaeus vannamei*, a more resilient species although genomics applications have now found a way of understanding the mechanism behind WSSV and EMS in tiger shrimps and are starting to provide solutions to the same. Given the option to produce and/or procure better seedstock of the desired species that are genetically fit or ideally superior, fast-growing, pathogen-free, stress resilient, and well-nourished, their survival and yield in the grow-out farms can at least be sustained and at best, be improved. Apart from the use of good quality seedstock, fish farm operators can invest on a breeding, hatchery, nursery and/or grow-out facility that is provided with optimal rearing conditions from quality rearing water to nutritionally complete and cost-effective diets to ensure a profitable and sustainable yield. These genetic and environmental factors influence growth and survival in farmed aquatic species. Knowledge of how each factor affects their economically important traits can definitely help one define, develop, and adopt technical measures especially starting from broodstock management to production of quality seedstock. With the fact that environmental manipulation can be done with more ease, on the whole, quality seedstock production (either through traditional methods or advance genetic improvement schemes) must be given due attention and the benefits of using genetically enhanced seeds should be highlighted.

6.3.2 Status of Seed Production in Southeast Asia

For many farmed species, particularly those with life cycles that have been successfully closed or completed in captivity, seedstock can be obtained from hatcheries aside from wild sources. ***Appendix 3*** summarizes the sources of seedstock for commercially farmed aquatic species in each AMS. While most of the species in Southeast Asia that are commercially produced in large volumes are introduced, *e.g.* Nile or red tilapias and the African catfish to name a few, some indigenous species such as carps and Pangasiid catfishes have been successfully domesticated and artificially propagated after years of research. For some, larval rearing in the hatchery remains to be a limiting factor due to various reasons that may range from diseases, low survival, occurrence of abnormalities due to inbreeding depression or nutritional deficiencies, poor water quality, or simply unsustainable larval food production. In a complete hatchery (or a hatchery that is engaged in all phases of seedstock production from selecting and maintaining broodstock to larval rearing), when the cause of poor growth and survival of seedstock can be addressed by genetic intervention, it means that the hatchery has successfully adopted a scheme that considers the use of genetically variable, fit and preferably known unrelated spawners for producing quality seedstock. For species produced from medium-scale and/or large-scale aquaculture operations, quality seed production is assured as well if genetic improvement schemes apart from biosecurity measures are incorporated in the program. ***Appendix 4*** summarizes conventional, advance and/or marker-aided genetic methods that have been developed in Southeast Asia or otherwise, for the production of quality seedstock of major Southeast Asian aquaculture species. Since many countries in Southeast Asia are developing countries, most genetic improvement programs are focused on low-value species that have short generation intervals such as the tilapias. Carps have likewise been the subject of full-blown genetic improvement programs. The development of improved tilapia and carp strains has employed mostly combined selection methods based on genetic programs supported by either government funds or international grants (*e.g.* for the development of GIFT and GIFT-derived strains). Local public initiatives on other species (abalone, mangrove crab, and milkfish) are currently being undertaken and the approaches start with genetic profiling of aquaculture stocks using DNA markers, with the ultimate aim of using genetic diversity information as basis for marker-aided broodstock management and selection. Other studies use genomics to investigate genes that are linked to growth and other economically important traits such as disease resistance (especially in penaeid shrimps). With the development and use of advance equipment and molecular biology methods (*e.g.* next generation sequencing) for genomic studies, the outcome of aquaculture genetic improvement programs may soon be achieved in a shorter period as compared to when conventional or traditional selection is used.

6.3.3 Issues and Concerns

Increase in fish production from aquaculture would be difficult to attain if the industry continues to use slow growing, poorly adapted, and inadequately surviving seedstock that comes mostly from multiple and pooled sources as is the case with species that are produced by small-scale hatcheries. The challenge is not only with the fact that enough seedstock are pooled and on-grown but on how to maintain the genetic integrity and quality of such stocks. For some species, *e.g.* milkfish and groupers disseminated in Indonesia, seedstock production remains sustainable in view of government-initiated efforts to organize the industry into a network composed of complete hatcheries (breeding centers), meaning hatcheries that maintain broodstock for seedstock production and basic hatcheries that simply obtain eggs from the breeding centers (Sugama *et al*., 2016). This system has been adopted in milkfish seedstock production, which enables Indonesia to export seedstock to other milkfish producing countries like the Philippines and Taiwan. The same approach is being used for grouper seed production. If the Southeast Asian countries can adopt a similar scheme in the production of other economically valuable aquaculture species then the problem of inadequate seedstock can be partly addressed. Aside from inadequate seedstock, another issue that has plagued the aquaculture industry is the production of healthy or disease resistant stocks and prevention of the spread of infected seedstock through importation and/or local stock transfers. This has been a major concern particularly in species that are susceptible to viruses that can be spread by way of seedstock movement. Examples of disease-prone stocks include penaied shrimps and some high-value marine fishes that suffer mortalities brought about by deadly viruses. Solutions to such problems sometimes start in the production of specific pathogen-free seedstock and/or the prevention of stock infection and vertical transmission of the disease by injecting potential broodstock with species-specific vaccines. Early detection using molecular tools likewise help screen infected seedstock. Guidelines and/or criteria for evaluating good quality seedstock prior to being sold locally and exported or post-procurement and importation, as the case may be, often include the need for pathogen screening as part of quarantine procedures.

Other issues that have to be continually looked into with regard to seedstock production would be on how to maintain the genetic quality of the stocks being produced apart from other technical concerns which can be addressed through research and development. ***Appendix 5*** contains a summary of the constraints in the seed production industry in the Southeast Asian region.

6.3.4 Challenges and Future Direction

Challenges in the production and dissemination of quality aquaculture seedstock remain to be both technical and non-technical in nature. As previously emphasized, most of the issues that may be complicated to address is on how to technically produce healthy seedstock as the Southeast Asian aquaculture is constantly being challenged by having to intensively produce commodities in the grow-out phase. The approaches being pursued are being addressed by advanced techniques in PCR-assisted disease diagnosis apart from the development of schemes to produce disease and/or stress resistant stocks using genomic information. With molecular tools that can be employed to survey and collect highly genetically variable broodstock from the wild, continuously monitor the genetic integrity of hatchery broodstock (including changes in successive generations of the same), address aquatic health management problems, and enhance genetic enhancement schemes in the production of quality aquaculture seedstock, the industry as a whole can look forward to benefitting from quicker R&D solutions to problems on aquatic seed production. As for the non-technical challenges, perhaps additional enabling laws and or current policies particularly on the adoption and implementation of good aquaculture practices should be promoted and strictly observed especially in many developing countries where the seedstock industry is composed mostly of small-scale hatcheries. Collective efforts, not only from the hatchery industry sector but from all the stakeholders, should be pooled to help the aquaculture industry achieve its production targets.

6.4. Producing Safe and Quality Aquaculture Products

The use of antibiotics and other chemicals in aquaculture is widely practiced to help meet the increasing demand for fish food from aquaculture. These antibiotics and chemicals appear to be part of material inputs during rearing, mostly from feed ingredients and as therapeutants for prevention or treatment of diseases. Thus, cultured shrimps and fish in various stages from hatcheries to grow-out ponds are exposed to chemicals. Consequently, with the ever-growing demand for food safety, fish farmers are faced with the challenge of producing safe food from farm to fork. Government regulations are becoming stricter on the uncontrolled use of chemicals due to their adverse effects on human health and the environment, and the development of pathogen resistant bacteria. Many chemicals have already been banned and the use of some is being regulated. The spectrum of allowable chemicals for aquaculture is becoming narrower, with the trend towards the use of environment-friendly mitigating agents geared to a more responsible approach to aquaculture.

6.4.1 Current Status

Concerns for safe, effective, and minimal use of chemicals in aquaculture in order to protect human health and the environment are reflected in the FAO Code of Conduct for Responsible Fisheries (FAO, 1995). In 2000, a comprehensive report on use of chemicals in Asia with emphasis on various aquaculture systems, species, and country regulations regarding distribution and use was made available after the Experts Meeting on the Use of Chemicals in Aquaculture in Asia at SEAFDEC/AQD in 1996 (Arthur *et al*., 2000). Since then sustained efforts were made to update the general information based on chemical usage in aquaculture in Asia and understand the