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REVIEW ARTICLE

A Brief Overview of the Integrated Fish Farming of Three Commercially Popular Fish Species (Snakehead, Tilapia and Catfish) in Malaysia

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Abstract

Aquaculture industry in Malaysia involves culture of many fish species of either fresh or brackish water origin and among the important fish species are Snakehead, Tilapia and Catfish. There is a substantial culture of these fish in Malaysia nowadays, though there are not one hundred percent native fish species but their presence in Malaysia is getting closer to over several decades and for almost a decade now, these species had been among the highest finfish produced in either fresh or brackish waters. As the global aquaculture production continue growing in order to meet up with ever increasing fish demand, especially as fish from capture has levelled off and makes an increase in aquaculture production as the only hope to meet the demand for fish, one of suggested ways in culturing them is by venturing into integrated fish farming. Integrated fish farming of different species is a practice which links together two or more normally separate farming systems, whereby the fish from different species become subsystems of a whole farming system. Although integrated fish farming may not be huge globally based on the available official statistical data but it is becoming important industry in Malaysia and neighboring countries. This review discussed briefly about the integrated fish farming of three commercially popular species (Snakehead, Tilapia and Catfish) in Malaysia and neighboring countries.

Keywords: Farming, Fish, Integrated, Three Species

Introduction

Integrated fish farming of different species is a practice which links together two or more normally separate farming systems, whereby the fish from different species become subsystems of a whole farming system. Emphasis focuses on an optimal waste or by-product utilization efficiency in which the waste of one species becomes an input to the other species. The integration of fisheries aquaculture from different species has received considerable attention lately with emphasis on the incorporation of animal manures as fertilizer and nutrient for promotion of natural feed in fish ponds (Brugere et al., 2007; Ayadi et al., 2018;). The recent surge of interest in integrated farming systems is due to the growing concern for maximizing productivity through optimum utilization of resources and to improve the diminishing per capita resources. The integration of duck and chicken with fish polyculture systems is amongst the most popular in Asian countries, followed by pig-fish and ruminants (cattle)-fish production systems (Pahri et al., 2015). A more sophisticated integrated farming system is practiced in China; Chinese livestock-fish integrated farms may have complex interactions between livestock, crops and fish. In some Chinese farms, significant off-farm inputs to feed the fish such as aquatic macrophytes, snails and a wide variety of agricultural by-products are practised even though the pig may be the major livestock integrated with fish.

Promotion of integrated farming of fish from different species is viewed as a developmental strategy in overcoming a food crisis through enhancing waste and land-space utilization efficiency. The farming system improves space utilization and land-use conflicts in which the two subsystems essentially occupy all or part of the space required for an individual subsystem. This paper provides an overview on fish production in integrated aquaculture systems, exploring the fish production levels in integrated farming systems, and ways to attain higher fish production levels.

Results and Discussion

Commercial Fish Species in Integrated Farming

In Malaysia and neighboring regions, there are many kinds of commercial fish species that had been utilized in integrated fish farming. Three species that currently popular in aquaculture industry of Malaysia are Snakehead, Tilapia and Catfish (“keli”). Snakehead, known deductively as *Channa striatus* (*C. striatus*), known in Malaysia as "Haruan," is a tropical African and Asian local freshwater fish. It has a place to the Channidae family and is in some cases alluded to as murrels or fish with serpent heads. In quintessence, it is carnivorous and eats frogs, fish, creepy crawlies, tadpoles and night crawlers. It is an air-breathing fish of low dissolved oxygen that can live in extreme situations. In Malaysia, *C. striatus* could be a well known cure for wound mending and customarily utilized among mid spouses for decades. *C. striatus* is expended to affix mending particularly for moms who experienced caesarean operations and gotten to be supplementary among ailments like diabetic gangrene and cancer (Mat Jais, 2007). *C. striatus* comprises 13% of the attractive freshwater fish in India. It is commercially vital in Philippines, Thailand, Cambodia and Vietnam (Aliyu-Paiko, 1982). The common populace of this species diminishes quickly due to living space corruption and presently this species is recognized as an imperiled angle in Bangladesh (Kumar et al., 2008).

Tilapia fish are generally originated from Cichlidae family that are native to the African continent. To date, there are at least 900 known species and estimated to be more than 1300 species worldwide (Henriksson et al., 2012). Of all the known species, none is marine except for some hybrids cultured in Bahamas and the Caribbean (Hamzah et al., 2008). The introduction of the species outside the African continent was documented in the early twentieth century to some 90 countries all over the world (Shelton and Popma, 2006). Although Cichlidae is the most species diversified fish family, only a few species are commercially important and farming significant. Species identified as commercially important are the Nile tilapia (*Oreochromis* spp.), including *O. niloticus*, *O. aureus* and various crosses of red hybrids of the former two species with *O. mossambicus* (Shelton and Popma, 2006; Henriksson et al., 2012). These tilapias have many characteristics that favour the aquaculture industry including relatively short culture period (about 6 months), high tolerance to poor water quality and high stocking density, and high productivity rates. Nile tilapia was the most cultured and produced species, followed by Mozambique tilapia and tilapia not elsewhere included (tilapia nei). The Mozambique tilapia (*O. mossambicus*) was first introduced to Malaysia during World War II. A recent study by Fitzsimmons (2006) revealed the genetic make-up of the tilapia population in Malaysia. They examined various strains of tilapia (Chitralda, Philippines, Taiwan strains and *O. mossambicus*) obtained from various regional and local commercial breeders. The cultured species in Malaysia was identified as *O. niloticus* and *O. mossambicus* or the cross-breed of both (*Oreochromis* sp.).

Catfish rank fifth in the world in terms of fresh and brackish water fish culture, annual production being around 350,000 tons (FAO, 2016). Catfish fanning is monoculture, polyculture, or integrated with rice and livestock. Although there are over 2,600 species, only three families at present are farmed in any quantity: Ictaluridae, Clariidae and Pangasidae (Anetekhai, 2013). In Asia and the Pacific, family Clariidae (Clarias spp.) dominates production, representing nearly 80% of the total 76,000 tons catfish produced in 1991 (FAO, 2017). Among the most cultured species are *Clarias batrachus*, *Clarias macrocephalus* and *Clarias gariepinus* (Csavas, 1995). *C. batrachus* is the most extensively cultivated species especially in Thailand. It grows fast and is easy to propagate but its meat is not so tender. *C. macrocephalus* on the other hand is preferred for its better taste and tender meat but its culture is not so widespread because of its slow growth and scarcity of seed. The African catfish *C. gariepinus* is the only introduced species that had a significant impact on the Asian aquaculture industry (FAO, 2016). The original introduction was made in 1975 in Vietnam, from where the species spread all over Asia. Although Asians do not prefer its meat quality and its large size, its rapid growth and hardiness made it popular among fish farmers.

Basic Techniques in Integrated Farming

Selection of suitable fish species for culture is very important aspect for integrated fish farming. A species selected for culture should have the following characters; fast growth rate, ability to withstand changing physico-chemical and biological conditions of the pond water, adaptability to crowded conditions and resistance to diseases, good food conversion efficiency, acceptability of supplementary and natural food and good market value (Bohnes, 2018). The stocking density depends on the species, culture period, desired individual size and intensity of management. In integrated fish culture, the fish seed of 10- 15 cm length (fingerling) is stocked at the rate of 7000-8000 nos. / ha (Akinrotimi et al*.,* 2011). Normally the proportion of stocking rate for this three species combination are Snakehead (30%), Tilapia (40%) and Catfish (30%) (Wing-Keong, 2009). Fish have specific dietary requirements relating to micronutrients, fats, proteins, and amino acids. The Department of Fisheries Malaysia report that diets lacking in critical micronutrients impair welfare in many species, according to a range of indicators, such as high mortality, morphological abnormalities, poor immune function, abnormal behaviour, poor feeding, impaired sensory function and slow growth (Wing-Keong, 2009).

More than half of the operating budget for intensive aquaculture is feed costs, and proteins, especially from fish meal, are the most expensive component. The production of one pound of some carnivorous species may require up to five pounds of wild fish, and, throughout the overall aquaculture industry, dietary fish inputs exceed outputs by a factor of two to three (FAO, 2016). A variety of plant sources and animal by-products have been tried as alternative feed sources to fish meal, including soybean meal, cottonseed meal, other oilseed by-products, poultry by-product meal, blood meal, hydrolyzed feather meal, meat and bone meal, and animal manures (Arokiaraj, 1999).

For Tilapia, these alternatives have been found to generally lower growth and performance compared to use of fish meal, but their inclusion into farmed fish diets has been argued from an economic standpoint (Hamzah, 2008). Some non-carnivorous fish species, such as Snakehead, may be better suited to proteins from plant-based sources. However, these alternatives may be deficient of essential amino acids, diminishing the health of some carnivorous farmed fish. Altering protein sources in feeds can cause digestion problems, irritate the intestines and cause immune depression (Fitzsimmons, 2006). Proper nutrition is vital, particularly before disease outbreaks, as it has been shown to increase resistance to disease and reduce mortalities. Conversely, improper nutrition has been shown to compromise immune function and has also been linked with skeletal deformities (Yang et al., 2004; Shelton and Popma, 2006).

Snakehead is carnivorous, while Tilapia and Catfish are both omnivorous, feeding on a wide variety of food ranging from planktonic organisms (zooplankton and phytoplankton) to plant materials. Nevertheless, food preference varies in physiology, nutrition and feeding behaviour among species and maturation stages (Pahri et al., 2015; Bohnes et al., 2018). As such, it requires a wide range of general knowledge on the targeted species to formulate the most suitable feed at the least possible cost. Most importantly, the feed should not negatively impact the health of the farmed animal or the final consumer of the fish.

The main purpose of feeding in integrated fish farming is to provide complete nutritional feedstuffs to the farmed animal to enhance growth and support life maintenances and other activities (Abol Munafi et al., 2004). Imbalanced diets or deficiency in certain substances may cause retardation in fish and make them susceptible to diseases. As such, balanced feeds should contain adequate amounts of energy, protein and amino acids, lipid, carbohydrate, vitamins and minerals in order to fulfil all the nutrient requirements of the cultured species.

The success of fish culture largely depends upon the water quality of the stocking pond (Brugere et al., 2007). Water quality is defined as suitability of water for the survival and optimum growth of cultured fish. The higher the intensity of culture the will be the water quality problem. In water quality management, we should regulate the environmental conditions so that are within the optimum range for the cultured stock. Unwanted aquatic weeds are needed to be removed from fish pond as it reduces the pond productivity. These unwanted aquatic weeds could be removed manually, mechanically, chemically and biologically. Manual removal method is better. Catfish and Tilapia are good biological agent in removing aquatic weed from fish pond (Henriksson et al., 2012). Various control chemicals can be used in the removal of aquatic weeds from fish pond. Sometimes a thick layer of algal bloom of brown or green colour is seen over the water surface of pond. This can be removed from fish pond by using a piece of split bamboo followed by liming based on water pH. Noxious gases and the effect (Pahri et al., 2015) of other substances of pond bottom mud can be reduced by repeated netting or by moving a rope through the pond bottom mud.

In integrated fish farming, the growth (weight and length) rate for these species decrease in higher stocking density. It was predicted that the moving space of the population was getting narrower when the stocking density was higher, so that the population was fighting over the feed and it caused stress. A stressful condition caused hyperglycemia which interrupted the development process, or worst it potentially caused death (Fitzsimmons et al., 2006; *Akinrotimi et al.*, 2011; Rahman et al., 2012). In a stressful condition, there was a reallocate metabolic energy (such as growth and reproduction) turned into homeostasis, such as respiration, movement, hydromineral regulation, and tissues recovery (Qin and Fast, 2003). Furthermore, high densities are known to negatively affect fish growth including general appetite reduction, increased aggression, poor water quality and increased competition for food. However, some authors, evaluating the influence of density on the welfare of juvenile fish in a growth stage of 100-1500 g, showed that the effects of stocking density are not uniform throughout the growth cycle. In most fish species, growth rate is inversely related to stocking density and a significant increase in plasma cholesterol and albumin, indicated reduced food utilization.

In average, under good growth conditions, 1-gram fish are cultured in nursery ponds to 1 to 2 ounces (20 to 40 grams) in 5 to 8 weeks and then restocked into grow-out ponds (Ayadi et al., 2018). In grow-out ponds under good temperature regimes, males generally reach a weight of 1/2 pound (200 + grams) in 3 to 4 months, 1 pound (400 + grams) in 5 to 6 months, and 1.5 pounds (700 grams) in 8 to 9 months. To produce 1-pound (400- to 500-gram) fish, common practice is to stock 6,000 to 8,000 males per acre in static water ponds with aeration or 20,000 to 28,000 males per acre where 20 percent daily water exchange is economically practical (Bohnes et al., 2018).

Grading fish into groups of similar individual sizes is a common management practice in integrated fish farming (FAO, 2016). The farmers may need to grade as follows; when harvesting juvenile fish, before stocking them in fattening ponds, when separating faster- from slower-growing stock, for example male and female tilapias, during the early life of predatory fish when the range of sizes becomes too large, when selecting predatory fish for a suitable size to use for controlling fry populations, when selecting fish of a suitable size for polyculture, when harvesting a pond where fish of various ages and sizes are present, during partial harvesting, to select the fish which have reached market size (Qin and Fast, 1997).

Grading has several advantages such as; reducing fish losses through cannibalism, improving supplementary feeding efficiency through adequate food ration; increasing the accuracy of stock estimates for monitoring; reducing the proportion of small fish at harvest of fattening ponds, increasing production, for example by increasing the proportion of faster growing males in tilapia ponds (Qin and Fast, 1998). The fish yields in integrated fish farming systems reported in the literature vary greatly. the variation in fish yield is due; the animal sub-system and its major manure input to the pond, the fish species and stocking rates, intensification of culture management inputs e.g. addition of other off-farm feed.

Farming Materials and Setup

In Malaysia, as stated by Wing-Keong (2009), the common techniques of integrated fish farming are by using earth pond, concrete pond, polyethylene (PE) lining pond and PE tank, based on the commercial scale (high or low cost) and also available space (outdoor or indoor). In general, aquaculturists who have high capital together with substantial area of land will usually opt either concrete pond or PE lining pond for these species culture as the high bio-security of the culture will ensure high yield, but, they may also choose to construct earth pond in order to save the budget. Nowadays, these species culture in PE tank are gaining popularity among aquaculture entrepreneur due to the high yield and small space needed despite high cost of construction and for culturing area (Brugere et al., 2007).

For post-harvest treatment, liming helps in maintaining the pH of fish pond water. This helps in increasing the natural productivity of the pond. Liming also helps in maintaining the cultured fish stock disease free. It is done based on the soil and water pH. Fertilization increases the natural food availability in the pond. It is believed that manuring alone can increase the production of the pond by 75% of the production cost (FAO, 2016). Organic manure like cow dung, poultry dropping, etc are used commonly in fish pond. Since animal excreta is rich in nitrogen and phosphorous, there is no need of using extra fertilizer as mentioned (Pahri et al., 2015).

In integrated fish farming, from different pathogenesis, fish diseases are simply classified into infectious diseases and invasive diseases. For Infectious disease**,** this type of disease is mainly caused by the pathogens of virus, bacteria, fungi or unicellular algae. For instance, bacterial ulcerative disease, bacterial enteritis, bacterial gill rot/ fin rot and bacterial erytherma etc. The majority of bacteria causing disease in fish are normally present in fish (surface or gut) or its culture environment and cause disease when there is stress to fish (Abol-Munafi et al., 2004). Most Gram negative bacteria belonging to Aeromonas, Vibrio, Pseudomonas, Yersinia, Edwardsiella, Pasteurella, Cytophaga cause disease in fish (Ayadi et al., 2018). There may invariably be haemorrhagic septicaemia with or without skin ulcers.

For invasive diseases, such diseases are caused mostly by fish parasites, like trichodinasis, ichthyphthiriasis, lernaesis, argulusis, etc (Bohnes *et al.*, 2018). Fish carrying parasites or corpse of diseased fish are the direct sources of invasive disease. It is called the primary source. Objects accompanied with direct source, such as contaminated feeds, gears, pond water and silt, etc. are called indirect source, or secondary source. For examples matured oocysts of Eimeria or matured myxosporidia may enter water in large numbers together with fish, and precipitate onto the pond bottom, so the pond silt is the secondary source. The occurrence and spreading of infectious and invasive diseases often appear in different seasons, because the pathogens and fish are influenced by outside factors (such as place, climate, physicochemical property of water and farming skills, etc.) and inner factors (such as growth and physiological status) (Qin and Fast, 2003).

Not unlike other industrial farm animal production systems, aquaculture facilities nowadays have increasingly stocked greater numbers of fish without making parallel increases in the size of the confinement systems (FAO, 2016). In integrated fish farming, keeping fish at high densities can have a negative impact on their health and welfare. Prior to handling, grading, the administration of bath treatments, and transport, fish are often crowded at higher than normal densities. The animals may struggle or attempt escape, suggesting acute stress from overcrowding. In addition to the deleterious effects of high stocking density discussed above, short-term crowding has also been found to increase stress and depress immune function for days after the crowding event (Henrikkson et al., 2012).

Furthermore, research has shown that the mortality of many commercial fish species in integrated fish farming increases with density, and it is believed that social stress is a contributing factor (Csavas, 1995; Wing-Keong, 2009; Anetekhai et al., 2013). Elevated densities have been linked with decreased disease resistance, perhaps because chronic stress from aggression has been implicated in impairing immune function. Aggressive interactions between fish are often based on the animals' sizes and can lead to fin, tail, and eye nipping (often referred to as cannibalism), injury from ramming, and suppressed growth (Fitzsimmons, 2006).

Differences in sizes are amplified by larger fish dominating food supplies, thus growing larger, resulting in subordinate smaller fish growing slower due to competition for food at guarded feeders and higher energy requirements caused by chronic stress. Indeed, high stocking densities that fail to meet behavioral requirements can stress fish and may lead to reduced growth and increased mortality. Lesions that develop from aggressive behaviors can further increase the risk of infection. Few alternatives exist for subordinate fish to avoid dominant individuals, as the confinement of aquaculture systems does not easily allow for conflict avoidance by escape (Yang et al., 2004; Akinrotimi et al., 2011; Rahman et al., 2012).

Conclusion

Integrated fish farming may not be huge globally based on the available official statistical data but it is becoming important industry in Malaysia and neighboring countries. While it represents the major finfish culture in Malaysia for almost several decades now, it has been responsible for the aquaculture development in Malaysia.

The future of integrated fish farming in this country tends to be great, considering available resources in terms of land and water, and the tendency of increase population with a consequent increase in demand for fish. Snakehead, Tilapia and catfish being the dominant fish culture at the moment and with a lot of favorable attributes may experience an increase in production to meet up with the increase fish demands.

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