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Review Article

Emerging Sustainability Issues and Management Needs of Booming Aquaculture Production of Introduced *Pangasianodon Hypophthalmus* (Sauvage 1878)

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Abstract

Pangasius production has greatly expanded in India covering over 42,500 ha of ponds and tanks and also 2500 cages. It is mostly produced in small ponds (0.4 ha)by small farmers commonly producing 40-45 tons/ha but larger ponds above 4 ha having 1.5 to 2 m deep are many producing 80-85 tons/ha. West Bengal is the main hub of seed production, supplying over 700 million fry, while few commercial nurseries and hatcheries have recently come up in the states of Andhra Pradesh, Chhattisgarh, Odisha and of late Uttar Pradesh. Aquaculturists are facing several risks and challenges owing to growing eutrophication in culture ponds and tanks, effluent discharge from pangasius farms into the receiving waters, overexploitation of the aquatic resources for intensive aquaculture of pangasius especially by using large number of cages and pens in reservoirs, lakes and rivers. Further, farmers are producing African catfish as well as Pangasius seed in the same farm while in natural drainages both the species are availableraising possibility of genetic pollution and biodiversity concern due to inadvertent releases and escapes. The emerging production practices warrant formulating refined and improved method of farming and developing stringent standards and regulations to make pangasius farming sustainable.

Keywords: Biodiversity issues; Culture standards; Environmental issues; Pangasius aquaculture; Production system

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Introduction

Striped catfish *Pangasianodon hypophthalmus* (Sauvage) being fast-growing and popular food fish isthird most cultured species of freshwater aquaculture in south-east Asia [1-4]. The natural distribution of the fish is although restricted to small geographical area of Mekong River basin [1], it is now introduced to several Asian countries such as Bangladesh, Indonesia, China, Laos, Myanmar, Nepal, Malaysia and Pakistan including India for aquaculture. Striped catfish culture is booming aquaculture in India, Bangladesh and China [2,4] in recent couple of decades. Looking at the demand and enthusiasm of fish farmers to culture and propagate it, the Ministry of Agriculture and Farmers Welfare, Government of India approved the introduction of the species for aquaculture after a risk and benefit assessment study conducted during 2008-2009 by the author himself. Today, this introduced fish species is flourishing under aquaculture on large scale [5,6]. Fast growth and easy farm operations of the culture production attracted large number of farmers to adopt the fish species on large-scale culture production.

Aquaculture of *Pangasianodon hypophthalmus* in India has succeeded considerably over the years as the culture practices, broodfish raising, seed production technology, improved feed and transportation have been accomplished to make pangasius industry viable [4,6]. Nevertheless, several risks and challenges have been cropping up from growing eutrophication in culture ponds and tanks, effluent discharge from pangasius farms into the receiving waters, overexploitation of the aquatic resources for intensive aquaculture of pangasius especially by using large number of cages and pens in reservoirs, lakes and rivers. All these triggered sustainability concern, which are reported from other countries [7-10] drawing attention. Further, diseases [1,11,12], climate change impacts including salt-water intrusion [13-14] and market requirements for higher quality product [15] have also emerged as important concerns to meet societal and consumer demands for ensuring sustainable and acceptable production practices. Since aquaculture production of pangasius in India has been continuously intensifying over the years, this paper identifies and discusses various emerging issues of deteriorating aquatic environment, biodiversity concern, food safety and health management aspects. The emerging scenario of booming pangasius production through unmanaged intensive farming practices have been presented in this paper so as to draw attention of the scientists and policy makers to develop pangasius culture practices environmentally sustainable and to improve culture technology so as to have quality fish production keeping in view of the international standards and consumers preferences.

Production Systems in India

Ponds, cages and net pens are three major production systems available in pangasius farming covering the states of Andhra Pradesh, Telangana, West Bengal, Jharkhand, Chhattisgarh, Maharashtra, Gujarat, Kerala, Tamil Nadu, Madhya Pradesh, Bihar and Uttar Pradeshin India. The fish is also cultivated in the Islands of Andman

& Nicobaralong the sea coast besides foot hills of Himalayas which happens to be entirely a different agro-climatic condition. Striped catfish is mostly produced in small ponds (0.4 ha to 4 ha) preferably in 1.5 to 2 m deep water using the culture technology being practiced in Bangladesh and Vietnam [1,2,16]. Nevertheless, large ponds up to 56 ha are also under pangasius culture especially in the states like Andhra Pradesh and Telangana. It is assessed that over 42,500 ha of ponds and tanks are under pangasius culture in India where Andhra Pradesh has the major cultivated area of 24000 ha (56.47%) followed by approximately 8000 ha (18.82%) in Jharkhand and Bihar together and 6400 ha (15.05%) in West Bengal (Figure 1). There are over 2500 cages fixed to culture pangasius in an area spread over 1800 ha in the states of Andhra Pradesh, Telangana, Chhattisgarh and Maharashtra. The total area of ponds and tanks under pangasius culture gives an idea of the importance of the culture, though not its relative importance compared to other species farmed in India.

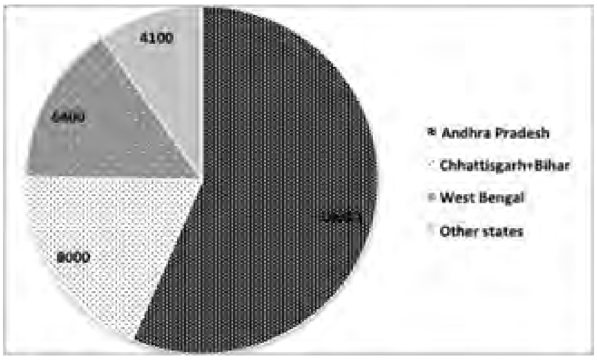

Figure 1: Pangasius culture areas (ha) in different states.

Monoculture of pangasiusis practiced predominantly in over 82% of ponds while pangasius polyculture with Indian major carps *Labeorohita, Catlacatla*, *Cirrhinus mrigala* as well as Amazon red bellied pacu *Piaractus brachypomus* in different combinations are also available in culture practice. In Bangladesh, pangasius polyculture with carps, tilapia and prawn has been reported profitable [16,17] while in India farmers experienced monoculture a better option. In pangasius grow-out systems of polyculture with Indian and Chinese carps as well as tilapia, the other fish species utilize nutrients from waste and uneaten feed by pangasius which would otherwise be lost and would cause eutrophication deteriorating water quality [16-18]. The five most popular species used in pangasius polyculture production in the Mekong River Delta are *Cyprinuscarpio, Helostoma temminckii, Barbuscholoensis, Oreochromis niloticus, Osphronemus goramy* [2].

West Bengal is the main hub of seed production, which produces over 700 millionfry, which is supplied to all other states producing pangasius. However, few commercial nurseries and hatcheries have recently been established in the states of Andhra Pradesh, Chhattisgarh, Odisha and of late Uttar Pradesh where pangasius breeding and seed production activities are going on (Figure 2). For grow-out systems, the stocking density depended on water depth where 8000 to9000 fingerlings/m deep water are stocked while 25000 to 42000 fingerlings/ha when water depth is 1.5 to 2.5 m. In culture practice, fingerling of >5g are stocked in majority (72%) of the ponds, which costs Rs. 5 to 7 each fingerling. However, the reported maximum fish density at any time for ponds is 35kg/m^2 and for cages 78kg/m^3 which is in conformity with reports from other countries [1-2,16]. In comparison with ponds, cages allow higher fish densities and have been reported higher productivity [2,17]. The density of fingerlings in cages has been reported usually high in deeper areas where the flow of water is considerably good [2,17].

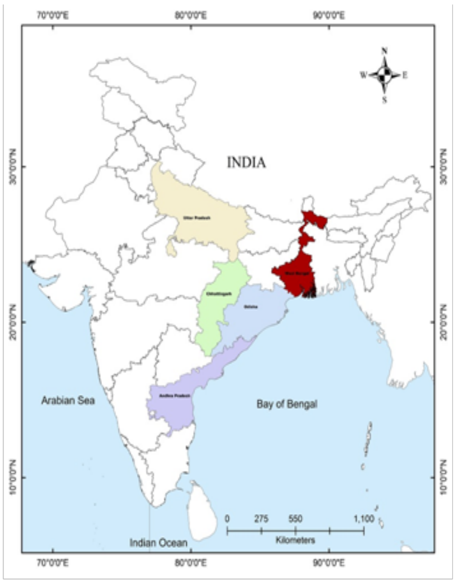

Figure 2: Map showing pangasius seed producing states in India. The dark coloured state of West Bengal is the hub of seed production.

Present pangasius production in the country is assessed to be 850,000 metric tons out of which maximum contribution of about 500,000 metric tons (58.45%) comes from Andhra Pradesh alone (Figure 3). In India, when official sanction of pangasius culture was deliberated and approved, the production level was merely 0.2 million tons which shot up to 0.7 million tons during 2012 [6] which was nearly 350% up within five years. At present, the aquaculture production of pangasius in India has gone up from 0.7 million tons to 0.855 million tons bringing up 25.89% growth in the pangasius industry during the last seven years (Figure 4).

Figure 3: Contribution (%) of total pangasius in different states.

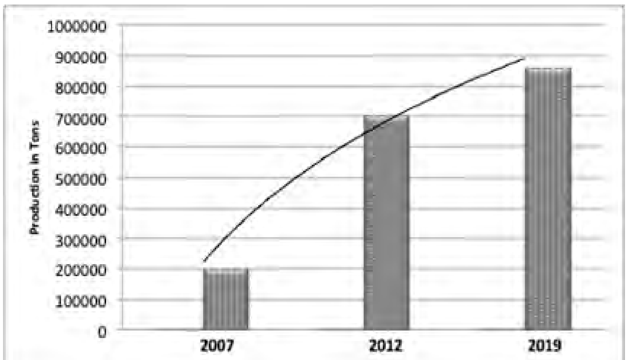

Figure 4: Pangasius production in India over last twelve years.

The production costs and returns in case of striped catfish *Pangasianodon hypophthalmus* aquaculture depended on the production technology which included better feeding and management. It is to mention that farmers are producing pangasius in extensive, semi-intensive or intensive type of culture [4,6]. The current farm gate price fluctuated between INR 55.0 to 75/kg (UD $ 0.77 to 1.06/kg) depending on the intensive farming, stocking densities and harvesting patterns practiced by the farmers. However, the frequently available sale price is INR 57-60/kg. Production variability between farm to farm and location-to-location depended mainly on differences in biophysical factors, input use and socio-economic conditions that differed among the farm sizes [4,6]. The production and farm yields of pangasius catfish have been reported to range from 70.0 to 850 tons/ha/crop in Vietnam and Bangladesh [1,16]. In India, the general production although ranged from 20-25tons/ha yet higher productions of 50 to 80 tons/ha are not uncommon. The fish are harvested at size range of 0.6-1.0 kg, after a grow-out period of 6-7 months; whereas water consumption per ton of fish produced is understood to range from 0.7-59.7 million litres/tonne.

At present pangasius is marketed in over 218 domestic markets from Kerala to Arunachal Pradesh as whole fish in chilled condition with improved packaging and extended shelf life. The pangasius farming has stabilized farmers' culture skills to adjust local market demand and to produce fillets. It is assessed that over 1 million tons/annum pangasius catfish production may be produced within a few years. The upward trend of pangasius production in India is assessed to be associated with several concerns such as deteriorated environment, change in culture of local fish diversity, food safety and culture related resource competition demanding culture standards and the product certification [19] as per international needs. Developments of measures of modern culture standards, food safety, green certification and safe processing may counteract the emerging issues. Government of India permitted pangasius farming based on the developed regulatory guidelines requiring proper implementation. The sector should stick to regulatory guidelines; some kind of checking on the adoption of these guidelines need to be put in place. Nevertheless, it is now realized that's tringent regulatory measures and upscaling of technological knowledge and its implementation are urgently needed for sound management of the expanded pangasius industry so as to meet with the international demand and quality. The revised improved guidelines should encompass a sustainable culture practice and enforcements on regulations and good management practices following technical standards laid down and documented internationally [19,20].

Environmental Issues

For raising quality aquaculture productions, suitable environments such as water temperatures between 26 and 30°C; dissolved O_2 between5 and 6 mg/l; optimum pH values between 7.6 and 8.6; turbidity around 10-15cm; total alkalinity between 75 and 125 mg/l, total ammonia nitrogen between 0.7 and 1 mg/l; salinity at <2 ppt; total hardness between 45.3 and 65.5mg/l; and chloride at <550mg/l [21] are optimally required.However, these optimal water quality conditions are drastically missing at pangasius farms in India showing significantly poor conditions where water quality problems ensued from high stocking density indiscriminately increased feeding rates and intake of polluted water for culture systems. The farmers repeatedly stocked ponds and tanks without any prior treatment rather they were using probiotics. It was a common practice to discharge the polluted pond effluent into the receiving natural aquatic bodies utterly degrading the receiving environment. Farming practice in polluted water ultimately affects the produce quality and has been associated with disease outbreaks very often. For environmentally sustainable striped catfish production and processing, the farmers and processors must be made aware of the needs to apply technical standards laid down and documented internationally [19-22].

The government through regulatory guidelines supported the pangasius production in India yet limited success could be realized in mitigating the environmental and social impacts emerging from unmanaged and *ad hoc* expansion of pangasius farming. Therefore, it is important to develop a better culture and management practice on the lines of ASC through stringent regulatory framework and enforcement in steering sustainable production [19]. Further, responding to environmental concerns, striped catfish production in flow-through tanks and in Recirculating Aquaculture Systems (RAS) may also be considered [23,24] to overcome problems of deteriorated water quality and to enable collecting highly polluted compost from solid wastes from ponds. Adopting RAS besides better management practices could be further an important step to achieving compliance with sustainability certification [18] and disease containment and the same may be taken up in the country for culture intensification. With the implementation of the existing RAS technology besides cage culture, pangasius farmers not only could increase fish production significantly but can also use local resources efficiently [4,25], feeding judiciously [4,26] and improving oxygen content.

Biodiversity Issues

The culture of pangasius is now beyond pond and tanks and it is also largely cultured in cages [27], so as to get better returns and production. These cages are fixed in river streams, reservoirs and lakes where thenatural aquatic bodies which are harbouring rich local fish diversity. At the same time, the locations of pangasius culture farms and hatcheries are in close proximity to open waters hence there exists every possibility of its escape into river streams or reservoirs. The escapee fish is now available in natural aquatic bodies in several states particularly Andhra Pradesh, Kerala and Maharashtra in India. The fish has potential to mature and breed in wild as the environmental conditions in these water bodies are similar to that native to the fish. So far, any naturally breeding population of pangasius is although not recorded which may be due to the fact that hatchery stock of this highly domesticated fish might not have fully adapted to the riverine conditions and so poor performance exists of hatchery bred stock available in wild [28-29]. It is pertinent to mention here that Common carp *Cyprinus carpio* a very common and highly domesticated species of aquaculture was introduced during 1939 to India. However, its inadvertent releases caused heavy invasion into the biggest river system, the Ganges after 65 years [5,30,31]. Genetic diversity is another important conservation issue as escapee farmed pangasius have the potential to negatively impact the genetic diversity of local *Pangasius pangasius* by interbreeding. Genetic changes in captive bred or hatchery populations are likely to happen in any stock of fish that is bred in captivity over several generations. Pangasius, in its natural habitat, has a complex population structure and there is evidence that different genetically distinct populations of pangasius species exists [32-33]. Introduced *P.hypophthalmus* which is a different species of the locally available *Pangasius pangasius* may therefore, pose risk of impacting the ecosystem when escapee *P.hypophthalmus* happens to mix [32-33]. Further, it is also important to mention here that culture of another introduced catfish *Clarias gariepinus* is also very popular fish in India in all those states where Pangasius culture is ongoing. Besides aquaculture activities of the two introduced catfish, they are also available as escapee in natural drainages in the rivers and reservoirs [31,34]. Since introduced pangasius and African catfish both are under large scale culture, it is quite likely that introduced *Clarias gariepinu s*and *Pangasianodon hypophthalmus* may interact with each other not only in culture but also in wild also since the native habitats of both the fish is similar in conditions. It has been established under experimental conditions that pangasius hybridizes with African catfish and a successful breeding and larval production of hybrids from reciprocal crosses of Asian catfish *Pangasianodon hypophthalmus* (Sauvage, 1878) and African catfish *Clarias gariepinus* (Burchell, 1822) have been produced and documentedby many workers [35-36].

Food Safety Issues

Pangasius is one of the highly consumed fish because of its low cost, mild taste and less bones. Nevertheless, the food safety is emerging as a big concern since the fish is produced even in highly polluted and contaminated water. Rapid expansion and intensification of striped catfish farming are often accompanied by excessive feeding and indiscriminate use of fish health chemicals and fertilizers that cause environmental problems such as eutrophication and aquatic pollution. Cultured fishes have potential to absorb dissolved trace metals from its feeding diets and/or habitat leading to its accumulation in various tissues [37]. Irrespective of the source, the potential bioaccumulation of heavy metals in fish to a degree that may constitute a potential threat to human health. Copper, lead, nickel, cadmium, chromium, and zinc have been found in the muscles of fish [37]. Health Index (HI) when calculated based on the bioaccumulation of heavy metals has been reported to have a value of 1.2531, which is more than 1 suggesting possible human health risk [37-38]. A wide range of mercury concentrations between 0.10 and 0.69 mg/kg fish, with an average value of 0.22 mg/kg has also been reported from Vietnam [39]. Despite having developed a modern production chain in which many producers have achieved international certification for such demanding markets of pangasius as the EU and USA, the Vietnam industry still faces smear campaigns by foreign environmentalists and media for more than a decade on food safety aspects [40-42]. Recently, food safety issue was studied in details and based on the latest toxicological findings; all claims wererefuted [43].

Health Issues

Pangasius are generally resistant to diseases during grow-out period but deteriorating water quality, sub-standard management practices and highly varied water temperatures (low and high) have been invariably causing heavy parasitic and bacterial diseases. The deteriorated farm water quality provoked physiological changes in fish thereby increasing the susceptibility of fish to various diseases of bacteria, fungus, virus and other parasites [44]. Furthermore, high stocking density and unhygienic culture conditions also enabled the spread of pathogens and eventually led to high mortality due to diseases. The most common diseases identified are the parasitic diseases, followed by hemorrhage or red spot, anal protrusion, pop eye, tail and fin rot, ulceration and white spot [6]. Parasitic diseases in nurseries were one of the most important limiting factors affecting the growth and survival of pangasius fry and fingerlings. Owing to the economic losses related to sanitary inadequacies, several chemotherapeutics and antibiotics have been used in pangasius farming to contain the mortality due to diseases [45].

Irrational use on antibiotics and chemicals in pangasius farms has been another environmental concern [46-48]. Frequent outbreaks of bacterial diseases put considerable pressure on farms and hatcheries to use a variety of antibiotics and chemicals. It was estimated that 106 tons of antimicrobials were used to produce 1.14 million tons of Pangasius catfish in 2011 [45] of which approximately 29 tons of active compounds were discharged into rivers and canals of the Mekong Delta representing risks to the aquatic environment [11]. Disease management efforts in pangasius farming should be focused on the establishment of environment friendly and sustainable culture methods through refinements and adopting better management practices.

Conclusion

The production data on pangasius over the years indicated that the production sharply shot-up after its approved aquaculture in India and there was 350% increase in the production during the year 2012. However, such scenario of heightened production has been languishing associated with the over-all returns realized by the farmers intrigued with low management, mortalities with diseases, use of improved feed, probiotics and medicines infringing upon returns. Production variability and cost benefit returns has been associated from farm to farm and location to location due to differences in input use and socio-economic conditions between different farm sizes and other physical conditions. The economics and determinants of Pangasius culture in India has been worked out and reported various factors affecting productions [49].

It was considered that the main production constraints could have been consequentially affected returns over cost of production, unavailability of quality seed, water quality, improved feed and above all sub-standard culture practices as well aspoor disease management. There were many potential sources for contamination of farmed pangasius with different pollutants alongthe production chain due to unethical culture practices, low level of hygiene, inadequate technological adaptations and modest regulations.

For culture promotion of pangasius, initially the country had developed a set of guidelines that is now old and requires modifications and rectifications to support the farmers' knowledge base and improve culture practices to come-up to the international level of culture standards. Unregulated culture ethics and inadequate technical monitoring of *P. hypophthalmus* aquaculture has caused concern to the environmental safety, biodiversity, health issues and warrants a much more cautious approach to formulate a much refined and improved sustainable method of pangasius culture along with stringent regulatory framework. There is urgent need to create awareness amongst stakeholders and aquaculturists towards sustainable production methods utilizing Best Management Practices (BMP) for managing the culture environment, reducing pollution, containing pathogenic bacterial loads, reducing fish diseases, prevention from escapes from farms and other culture operations and accelerating removal of waste compounds. Aquaculture Stewardship Council has developed a set of standards on pangasius aquaculture covering hygiene, modern culture practice, biodiversity concern and product safety along the value chain with an increased inclination of farmers to compete international markets and export in recent years.

Today the pangasius farms need to be registered with the help of the state fisheries departments and to regulate the quality and quantity of farmed pangasius. In this direction the following studies are proposed: (1) Monitoring of the water quality of culture farms and regulating the use of chemicals, probiotics and antibiotics (2) Assessing the quality of feed and feeding methodsto identify the most efficient and cost effective way of feeding so as to avoid eutrophication (3) Assessing the impact of polluted water on both quantity and quality of pangasius production (4) Assessing the impact of current culture practices on the nutritional quality and food safety and (5) Assessing the impacts of pangasius on local fish diversity and ecosystem. Future endeavor should also be made to ensure modernization of culture practice using international standards to improve water quality, biodiversity safety and stock improvement besides looking at the profitability, nutrition and safety of the final products.

To meet international market requirements, an increasing number of striped catfish producers are being forced to follow at least one of the aquaculture certification schemes recognized by international markets to incorporate environmental and social sustainability practices in aquaculture. The ASC certification scheme is considered to be useful approach for determining adequate environmental sustainability, especially concerning emissions in intensive pangasius production. International retailers are an important driving force behind the demand for certified fish. Since India is chasing fast the production target of highest pangasius producing country, the Vietnam it has to improve the culture technologies at par with international standards so as to comply the standard requirements and compete with the international market.

Credible pangasius health schemes should be developed and monitored in small or medium scale farms for scientific use of chemicals and implementing measures to ensure food safety [46-48]. There is an urgent need to improve knowledge base on cutting edge technologyincluding capacity and access to disease diagnosis, particularly for small-scale grow-out farmers and nurseries. It would be advantageous to establish a 'National Centre' for monitoring the linked issues of sub-standard culture practice, environmental hazards, antimicrobials use, and antimicrobial residues. Recently Indian Council of Agricultural Research, New Delhi has developed a policy guidelinesinitiatives/directions in the form of recommendations in order to protect, maintain and improve the fish health to achieve the goal of higher productivity and sustainability [50]. This action will help creating a strong knowledge base to regulate and promote technologically sound and sustainable culture practices not just in pangasius catfish but also for other types of aquaculture in the country.

Data Availability Statement and Conflict of Interest

There is no data appended with this manuscript rather the information and data are appended with references. Further, it is also declared that there is no conflict of interest

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