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Aquaculture: To Achieve Economic Development in Bihar, India-A Review

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ABSTRACT

The contribution of aquaculture and fisheries to Gross Domestic Product (GDP) is considered as one of the most important indicators for assessing the economic performance of the country. A large section of Bihar's population relies on agriculture, animal husbandry, and fishing for their livelihood. The fisheries sector plays a critical role in ensuring nutritional security and creating employments. The culture and consumption of fish therefore has important implications for national income and food security. Bihar's entire fish output in 2019 was estimated 0.64 mt, contributing 1.5% of the State's total Gross Domestic Product (SGDP). However, the occurrence of annual saga in terms of floods and drought, rather than lack of recent advancement in aquaculture are the major challenges for the development of aquaculture in Bihar. Despite the fact that the state's momentum in aquaculture over the last decade propelled it to fourth place in inland fish production and sixth place in freshwater seed production in India. The substantial investments in fisheries sector in the State can improve the income of farmers. The State's aquaculture production can be further enhanced by harnessing the bestowed fishery resources at a sustainable level with approaches for acceleration in fish production such as promotion of aquaculture in wetlands, species and technological diversification for aquaculture, extension of improved aquaculture technology, realization the scope of integrated fish farming, establishing of fish hatchery, assembling of fish market and supply chain and propagation of ornamental fish activities.

KEYWORDS: Bihar, fish production, aquaculture, technological diversification, fishery resources

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1. INTRODUCTION

The fisheries sector contributes significantly to the Indian socio-economic, nutritional security and foreign exchange (Lokesh and Khidrapure, 2016, Sharma et al., 2019, Suguna, 2020, Ngasotter et al., 2020, Chand and Prasad, 2021) and sector shares 1.07% and 5.30% to the national and agricultural GDP, respectively (Rajani and Balasubramanian, 2021). Average size of operating land holding in Indian farmers is reducing continuously due to outcome of subdivision of property across generations and also India's policies (Kumar et al., 2012, Kumar and Sharma, 2020, Giller et al., 2021, Balkrishna et al., 2022, Paramesh et al., 2022), limits horizontal expansion of aquaculture ponds. But, aquaculture grows at an astonishing rate of 46.8% due to its technological advancement (Sarkar et al., 2019, Suguna, 2020, Chand and Prasad, 2021).

Bihar is bestowed with Gangatic fertile land and water resources (Kumar et al., 2012), where 88% of Bihar population engaged in agricultural production system including crop, fisheries and livestock (Aryal et al., 2018). However, unpredicted and extreme weather stresses are often reasons for loss in agricultural venture and downgraded the State's economy (Giller et al., 2021, Pagnani et al., 2021, Agarwal et al., 2022). But, even small and marginal farmers can improve their income dramatically with typology-based intervention for aquaculture such as land shaping for aqua-agri integration with crop, horticulture, fishery, livestock and poultry (Kumar et al., 2012, Dash et al., 2015, Srinivasan, 2017, Kumar et al., 2018, Sarkar et al., 2019, Bhargavi and Behera, 2020, Khobragade et al., 2021, Kumaran et al., 2020, Kaur et al., 2021, Balkrishna et al., 2022, Paramesh et al., 2022, Yadav et al., 2022). Kumar et al. (2016) revealed economic superiority of aquaculture over agriculture along with culture based fisheries in wetland of Bihar.

At present, Bihar is India's 12th greatest fisheries resource, with 4th place in inland fish output and 6th place in freshwater seed production (Kumar et al., 2018). However, frequent floods in North Bihar and drought in South Bihar, dominancy of traditional agriculture and aquaculture practices, underutilization and low productivity in floodplain wetlands, reservoirs and ponds and tanks, availability of limited species for freshwater aquaculture, high cost and less availability of input (fish seeds, feed, aqua-medicine, etc), imbalance use of feed, fertilizers and chemical, lack of storage facilities, marketing and transport infrastructure and uncertainty in adequate and timely availability of bank credit are the major challenges for aquaculture in Bihar (Kumar et al., 2012, Pagnani et al., 2021, Agarwal et al., 2022, Singh et al., 2022). Bihar currently needs to work on raising farmers' realised prices in order to stimulate increasing production through significant investments in fisheries and the development of farmer-oriented market infrastructure for both input and output items (Sundaray et al., 2020, Giller et al., 2021).

With an emphasis on aquaculture, Bihar's floodplain considered as wasteland at present might be transformed into revenue-generating land with appropriate technological intervention (Reddy et al., 2018, Pagnani et al., 2021). The ponds and tanks available in the State are underutilized due to lack of technical knowledge, lack of investment and support in inputs, poor marketing system and lack of interest among farmers towards aquaculture (Kumar et al., 2018, Reddy et al., 2018). Despite the importance of freshwater aquaculture for Bihar prosperity, no extensive reviews have been made on the importance of freshwater aquaculture for bringing about blue revolution in Bihar. The aim of this study intends to provide a brief overview of Bihar's water resources, trends in fish production in Bihar, the status of aquaculture input availability, and approaches towards natural water resources utilization to improve the livelihood of condition Bihar's poor fisher communities.

2. DATA ON FISH PRODUCTION AND FISHERIES RESOURCES

The statistical information on aquaculture production in Bihar was secondary source, which was collected from the Department of Fishery, Government of Bihar and published data like journals, reports, and research findings.

Bihar's natural resources were mostly land and water after the State split in 2000. In truth, Jharkhand's geography has attracted a huge number of medium and big reservoirs. Despite major natural resource losses during the State's partition, rivers, reservoirs, floodplain wetlands (oxbow lakes, meanders, seasonal floodplains), ponds, and tanks provide abundant fisheries resources. Over millennia, the rivers' lotic character has forced them to shift course, resulting in the formation of oxbow lakes (*mauns*) and depressed land masses (*chaurs*) (Sarkar et al., 2021), which offer a lifeline for the aquaculture in that regions. There are various open water fishing resources along the Gandak and Koshi basins, including floodplain wetlands, *mauns*, and *chaurs*. The total fishing resources in the State are 3,200 km of river, 9,41,000 ha of *chaurs* and floodplain wetlands, 9,000 ha of oxbow lakes or *mauns*, 26,304 hectares of reservoirs, and 93,218 ha of ponds and tanks (Table 1).

2.1. Riverine system

The Ganga, Gandak, Kosi, Bagmati, Kamala, Balan, Budhi Gandak, Bagmati, Mahananda, Son, Punpun, Phalgu, Karmanasa, and Ghaghra/Saryu are the major river systems in the State (Kumar et al., 2019). These rivers are a significant supply of natural fish and play an essential role in the capture fisheries. There is a vast scope for development of cage and pen farming in these water resources (Chand

Table 1: Fisheries resources of Bihar

Sl. No.	Resources	Availability
1.	Rivers	3,200 km
2.	Chaurs and floodplain wetlands	9,41,000 ha
3.	Oxbow lakes or mauns	9,000 ha
4.	Reservoirs	26,304 ha
5.	Ponds and tanks	93,218 ha

and Prasad, 2021). Also every year, floods in Bihar wreak havoc on these riverine systems, causing huge losses and fatalities of humans and animals. Floods in Bihar are annual saga in which large area of agricultural land are swamped and rendered uncultivable for several months. As the flood recedes, the river's water flow decreases, floodwaters are unable to return to the river, and water is trapped inside a bowl-like depression for months. Proper planning for the exploitation of these water bodies generated by a flood may be beneficial to the State's fish supply.

2.2. Wetland resources

Almost 90% of the wetlands are in north Bihar and depend for water upon six major tributaries of the Ganga, which flow between the Nepalese border and the Ganga itself. Between river Gandak (in the west) and river Mahananda (in the east), the northern part of the Gangetic plains contain numerous small freshwater lakes and *chaurs* with an estimated 200,000 ha water spread area (Sarkar et al., 2021). There are 941,000 hectares of *chaur* and floodplain wetlands in Bihar, which are low laying saucer shaped water-logged depressions and remain submerged for a considerable period of time ranging six to seven months a year. These floodplain wetland ecosystems are also considered as lifeline of riverine fisheries and aquatic biodiversity as they provide refuge, spawning and nursery grounds for a large number of freshwater fishes, which migrate from rivers and acts as repository of rich biodiversity. Protection, conservation and production enhancement of wetlands are essential for rehabilitation and sustainability of riverine fisheries. At present, mainly capture fishery is being practiced with production as less as 40–50 Kg ha^{-1} $year^{-1}$ (Sarkar and Borah, 2017), and due to low productivity, all wetlands are considered as wasteland in Bihar (Singh et al., 2014). But, wetlands of Bihar can be turned into an agricultural goldmine, if managed efficiently by adopting latest scientific and technological practices. Wetland resources in certain well managed pockets in the country have shown high fish production to the tune of more than 1000–2000 kg ha^{-1} $year^{-1}$ (Chand and Prasad, 2021). The development may create employment opportunities for many of the local youth and minimize the seasonal youth migration in other States, and may help to the farmer of Bihar in doubling their income with the pace slogan of present government of India. Bihar is a major contributor to migration and shares 15% migration in India (Kumar et al., 2020), which is the highest in the country. However, improving the economic position of marginal agricultural holdings and ancillary occupations can help to reduce rural migration (Singh et al., 2011).

2.3. Reservoirs

Total 37 reservoirs are remained in Bihar after separation of Jharkhand, which covers total area 26,304 ha, which includes only 30% of large reservoir in the residual Bihar (Kumar, 2018). These all reservoirs are present in southern bank of Ganga in four districts such as Banka, Jamui, Lakhisarai and Nawada. The maximum numbers of reservoirs in the State are present in Jamui district (18), where is the minimum number of reservoirs is existed in Lakhisarai district (2) (Anonymous, 2018). However, all 37 reservoirs are constructed for the irrigation purpose, but these water resources can be harnessed for the fish culture with regards to enhance the fish production for nutritional security and revenue generation in the State. In India, fish yields of 50 kg ha^{-1} $year^{-1}$ have been achieved from small reservoirs, 20 kg ha^{-1} $year^{-1}$ from medium-sized reservoirs, and 8 kg ha^{-1} $year^{-1}$ from big reservoirs, with scope for improvement fish production through capture fisheries and culture-based fisheries. In this context, producing fingerlings *in situ* in cages also offers an opportunity for supplying stocking materials, which are vital inputs towards a programme of enhancing fish production from Indian reservoirs (Das et al., 2009). Intervention of cage culture technology at large scale through public private partnership (PPP) mode in reservoirs can boost and bridge the gap between production and consumption of fish in Bihar (Ayyappan et al., 2007).

2.4. Ponds and tanks

The distribution of ponds and tanks in all 38 districts of Bihar is not homogenous. The highest and lowest area of ponds and tanks is found in East Champaran district (10120.42 ha) and Jehanabad district (187.05 ha), respectively. In the case of number, the highest and lowest numbers of ponds and tanks are in Madhubani (10755) and Jehanabad (130), respectively. Based on the ownership, all ponds and tanks of the State are categorized into government and private. The maximum government ponds and tanks are available in the Darbhanga (4545.21 ha) and Madhubani (4864) in the term of both area and number, respectively. Similarly, the highest area and number private ponds and tanks are existed at East Champaran (6569.39 ha) and Darbhanga (6758), respectively (Anonymous, 2018). However, the majority of fish farmers in Bihar have tiny plots of land (<1 ha), where fish farming practises are still ancient and traditional, resulting in poor yield (Chand and Prasad, 2021). According to Ahmad (2001) the ponds and tanks in Bihar have potential of producing 0.183 million

tonnes (mt) of fish per year. Besides ponds and tanks, the State has also extensive network of irrigation canals, which retains water for considerable period and offer ample opportunities for enclosure based aquaculture such as cage and pen. Furthermore, the small and marginal agri-farmers can transform their underused and fallow land into a fish pond of suitable size (0.1–0.5 ha) with a water depth of 1.25 m to 1.50 m for aquaculture, which can be could be utilized for integrated and composite farming of fish and prawn (Chand and Prasad, 2021).

3. DISCUSSION ON FISH PRODUCTION AND STRATEGIES FOR IMPROVING AQUACULTURE OPERATIONS IN BIHAR

3.1. The trend of fish production in Bihar

The maximum utilization of water resources can fetch prosperity for the State in addition to ensuring food and nutritional security. But, the lack of knowledge about scientific fish culture, illiteracy and disorganized extension linkages amongst the fishermen community are the most important obstacles of fisheries progress in Bihar. Due to these difficulties, maximum fish farmers in the State still follow the traditional method of aquaculture i.e. extensive method of aquaculture, where per capita fish production is very low. On decadal analysis of fish production, the mean fish production during 1970's decade was only 0.05 mt, which increased to 0.07 mt in 1980's decade and reached to 0.13 mt in 1990's decade. A continuously increasing trend fetches 0.22 mt fish production in the State in 2000's decade, which was four times higher than that of 1970's decade (Figure 1).

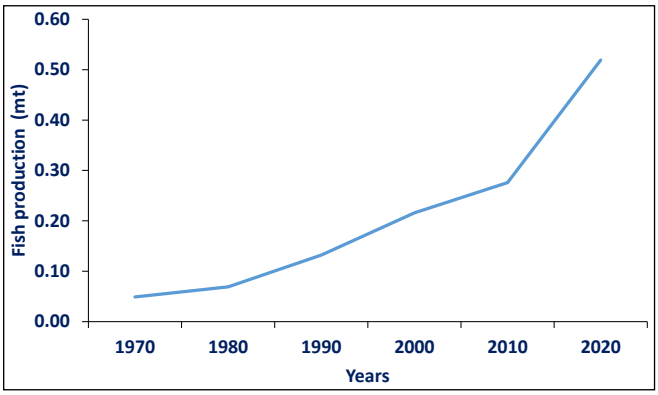

Figure 1: Decadal fish production in Bihar

Even with deprived large water resources in Bihar after its division in 2000, an increasing trend of fish production in the State is observed as the mean fish production in the State was recorded 0.28 mt during 2010-11. Since 2008, Department of Fisheries, Government of Bihar has introduced several schemes to upgrade the skill of fish farmers, where capacity building and training to the farmers on recent advances in inland fish production was introduced. A large number of fish farmers experienced the advanced technique of aquaculture, and came forward for aquaculture, which add momentum in the State's fish production over the years. The total fish production in the State during 2009-10 was 0.30 mt and crossed to 0.50 mt by the end of 2015-16. The total fish production in Bihar increased to 0.68 mt in 2020-21 (Figure 2). According to Chand and Prasad (2021), the aquaculture sector of Bihar offers a great potential for enhancing fish production for domestic market as it has increased from 0.25 mt in 2010–11 to 0.43 mt in 2013-14 and further up to 0.59 mt in 2017–18.

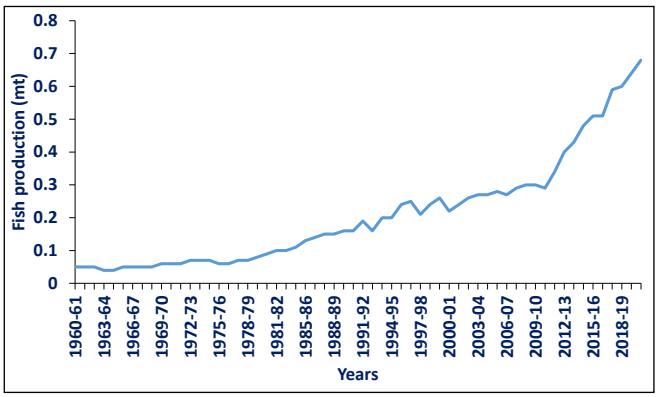

Figure 2: Trend of fish production in Bihar (Source: Anonymous, 2018 and anonymous, 2022)

3.2. Status of aquaculture seed and feed production

There are total 18 hatcheries in the State, and among them, one belongs to government sector, 03 in corporate sector and 14 in private sectors. However, these fish hatcheries contributes to the raising of culture fish production through scientific fish culture techniques among rural fish farmers, but the fish seed production in the State is inadequate to meet the demand of quality fish seeds by the farmers in Bihar (Chand and Prasad, 2021). In order to meet the demand for improved varieties of seeds for the cultivable fish, the State Government has strengthened the seed distribution system. To increase fish production in the state, about 1372.8 million fish seeds have been distributed in the state during 2019, which was higher by 47.82% compared to 2018. The distribution of fish seeds was highest in the district of Madhubani (550 million), followed by Muzaffarpur (150 million) and Darbhanga (97.3 million) during 2019 and these contributed 58.08 % of the total fish seeds distributed in the State during 2019 (Anonymous, 2020a). The Government of Bihar's assistance has helped to enhance fish output in the State, and as a consequence, fish farmers have begun to export fish (30000 t) to neighboring States and Nepal (Anonymous, 2019).

However, Bihar continues to rely on other States for fish feed, aqua-medicine, and other chemicals, despite the fact

that there are now six fish mills in operation, each with a different capacity for producing fish feed (Anonymous, 2020b). The districts of Vaishali and Muzaffarpur each have two fish feed factories, while Samastipur and Darbhanga each have one (Anonymous, 2018).

3.3. Approaches to increase fish production in Bihar using aquaculture

3.3.1. Promotion of aquaculture practices in wetlands

During monsoon season, agricultural land of many farmers are inundated with flood water and considered as waste-land for several months, where community based collective/ participatory management for aquaculture would be the best approach for transformation of waste-land into worth-land. Wetlands through community-based management may provide satisfactory employment opportunities among youths as well as increase income to land owners, landless fishers and wage earners. Stocking the seed in pen and polyculture of Indian major carp with chinese carp and giant freshwater prawn (*Macrobrachium rosenbergii*) for growing up to table size can be practiced in these water bodies. Furthermore, the integrated farming in wetlands is more suitable for farming fish with a poultry, a goat farm and a dairy. Therefore, the promotion of integrated aquaculture-agriculture-livestock systems can be explorated to enhance the productivity of low-lying wetlands and provide food and nutrition security to rural communities residing in these areas. Makhana (*Euryal ferox*) - cum - fish farming and Singhra (*Trapa biscpinosa*) -cum - fish farming are the two most economical farming practices in Mithalanchal region (Darbhanga, Sitamarhi and Muzaffarpur) have great scope for development and propagation at other regions of Bihar (Singh and Ahmad, 2003 and Kumar et al., 2018). Puste et al. (2017) shown the improvement of waste wetlands production and economic viability in several agro-climatic zones in the north-eastern region of the country, with an emphasis on food, livelihood, household labour involvement, and ultimately, rural people's economic sustainability.

In Bihar, all available open water resources (*chaur/ maun*) are owned by the village communities or self help groups or panchayat. The village communities maintain and manage these community water resources, and the advantages are shared among the community members. To attract the attention of the village communities towards scientific aquaculture in wetlands, it is necessary to change the institutional policy for the management and utilization of these open water resources with creating the awareness among local people towards the adoption of aquaculture at these wetlands region. Community participation plays a key role in common property resource management and development. The development of aquacultures in Mahisar *chaur*, Mutlupur *chaur* and Sonmar *chaur* are the result of community-based management of fish farming. Farm consolidation, mechanization and increased labour productivity in agriculture and its allied sector ensures the increasing of production and profit (Giller et al., 2021).

Mahisar *chaur* is situated in north-eastern part of Samastipur district of Bihar, is spread over 607.29 ha area with an average water depth of 2.5–3 m. Earlier the *chaur* was remained inundated with water for most part of the year and hence was not suitable for agriculture. With collective efforts of land owners, a drainage canal along with sluice gate was constructed to manage the flow of water in the *chaur* to take up both the agriculture and fishery enterprises in the *chaur*. Now the *chaur* is being successfully utilized for fishery by a cooperative society of land owners during the period of water logging (June/ July to October) and for agriculture during November to April by individual farmers (Kumar et al., 2015). Similarly, a group of farmers in Mutlupur in Muzaffarpur district of Bihar have converted 87 acres of low-lying wetland into a productive integrated farm, which is now an employment source for many youth. Also, the farmers of Sonmar *chaur* in Sarai Ranjan block of Samastipur district have showed a way for productive utilization of *chaur* area in the form of integrated aquaculture, which is spread over 44 ha of land with the ownership of about 43 farmers to monitor the activities, facilitate the resources, inputs and marketing of products. About 70% (28.34 ha) area of Sonmar *chaur* has been transformed into tiny ponds for aquaculture, which had little agricultural potential due to water logging (Kumar et al., 2016). The result of these wetlands show that fisheries at flood prone low laying area has the capacity to change in Bihar's rural condition.

3.3.2. Species diversification

In India, aquaculture is practised as polyculture of the three Indian Major Carps (Catla- *Catla catla*, Rohu- *Labeo rohita* and Mrigal- *Cirrhinus mrigala*) as well as composite carp culture of the three Indian Major Carps with the three exotic carps (Silver carp- *Hypophthalmichthys molitrix*, Grass carp- *Ctenopharyngodon idella* and Common carp- *Cyprinus carpio*) with the contribution of three Indian Major Carp's production to the extent of 70–75% of the total freshwater fish production, followed by exotic carps forming the second important group contributing remaining 25–30% (Jayasankar, 2018). However, the aquaculture activity in Bihar is also limited with very few freshwater species of fish such as Indian Major Carps, but the State has enough potential for diversification of aquaculture like introduction of freshwater prawn farming, culture of air breathing fishes such as Singhi (*Heteropneustes fossilis*), Magur (*Calarias batrachus*), Climbing perch (*Anabas testudineus)*, Murrels

(*Channa striatus* and *C. marulius*), *Pangasius pangasius, Wallago attu, Sperata seenghala, S. aor* and *Ompok pabda* and ornamental fish culture and propagation of ornamental aquatic plants and culture of medium and minor carp species which show high demand, including *L. calbasu*, *L. fimbriatus*, *L. gonius*, *L. bata*, *L. ariza*, *Puntius sarana*, *Hypselobarbus pulchellus*, *H. kolus* and *Amblypharyngodon mola* as well as other indigenous fish (Jayasankar and Giri, 2013, Jayasankar, 2018, Chand and Prasad, 2021). At 300-400 g, these medium carps have a greater market acceptance, and these species are perfect for intercropping in the major carp farming system (Jayasankar, 2018). Murrels fetch a high price in Bihar because of the flavour, meaty flesh and less intramuscular bones (Kumar et al., 2013).

Giant freshwater prawn is the largest and fastest growing species being farmed either alone or in combination with carps and possesses considerable demand both in domestic and international markets (Chand and Prasad, 2021). The polyculture of giant freshwater prawn with Catla and Rohu provides a scope for the farmers to diversify their culture. The stocking density of fish (Catla and Rohu) and prawn 500 each and 20000 (post larval size 0.005 g) numbers ha^{-1}, respectively showed the production of Catla, Rohu and prawn 1580, 1060 and 370 kg ha^{-1}, respectively (Anonymous, 2020c).

3.3.3. Technological diversification

The terrestrial agriculture sector was revolutionized by innovations including irrigation techniques, mechanization, hybridization, crop rotation, selective breeding, introduction of new species, the use of inorganic fertilizers, improved farm implements and crop protection measures and modifications in farm equipment (Kumar and Engle, 2016, John and Babu, 2021). Human manipulation of biological, economic, technical, and environmental aspects drives the blue revolution for water bodies, just as it does for agricultural sectors. The availability of sophisticated information and technology has aided the rise of aquaculture (Kumar and Engle, 2016). Technological innovation and good management are the main engine behind the rapid development and growth of aquaculture (Joffre et al., 2017, Balkrishna et al., 2022). Technological advances in aquaculture nutrition, aeration devices, genetics, and disease management have contributed to increases in aquaculture yield (Kumar and Engle, 2016).

Globally, aquaculture has expended, diversified, intensified, integrated and made several advancements during past decades. Mainly extensive method of aquaculture yet is being practiced in Bihar, where a vast scope for diversification of aquaculture is possible in the rivers, wetlands, tanks, ponds through cage and pen culture, integrated aquaculture, composite aquaculture, re-circulatory aquaculture system (RAS), Biofilm/Biofloc technology, aquaponics, hydroponic, bivalve farming, pearl culture, etc. Central Marine Fisheries Research Institute (CMFRI) developed green mussel (*Perna viridis*) farming technique in the 1970s, which is now used as a source of income for people all along the Kerala coast, as well as helping to improve the socio-economic status of the coastal community (Bharti et al., 2015). The existing ponds and tanks used in extensive fish culture need transformation by adopting semi-intensive and intensive aquaculture technique. Cage culture should be considered as a promising way in reservoirs and wetlands, where fish culture is not practical because of excessive depth, obstructions that prevent harvest, or predator problems. Therefore, adequate technical and financial support are required to the poor farmers for establishing upgraded and advance technology of aquaculture. The standardization of seed rearing technology for both Indian major and minor carps is essential, and also ensure the seed availability over the season through the production of stunted seed. Introduction of Indian minor carps with major carp in composite culture with guarantee of income source within 3–4 month of seed stocking should be popularize (Jayasanakar, 2018). The development and adoption of key technologies such as feed formulations and biotechnological advancements for reproduction, growth, and disease management that allowed farmers to overcome major production barriers and constraints have triggered the growth of farmed shrimp, Atlantic salmon, and Tilapia production worldwide, according to Kumar and Engle (2016).

3.3.4. Extension of improved aquaculture technology

The primary goal of aquaculture/fisheries extension is to encourage and assist aqua-farmers and fishing communities to improve their socio-economic conditions and quality of life by increasing fish productivity and revenue through their farming techniques (Kumaran et al., 2003). Adoption of new technologies developed through research and development has aided the evolution of aquaculture, but the decision to adopt a new technology among farmers is complicated, and the farmer must weigh a number of factors to determine whether it is in the farm's best interests to do so at any given time (Kumar et al., 2018). Lack of knowledge, lack of technological know-how, financial restrictions, and less active engagement of family members (males and females) are all limiting factors in achieving higher levels of aquaculture output (Rahman et al., 2011). There is need for spreading the knowledge about the emerging development in aquaculture technology among the fishermen communities. Various extension approaches exist, including the technology transfer model, integrated rural approach, training and visit system and farmer field schools and decentralized extension strategies have been explored in several developing nations (Sundaray et al.,

2020, Singh and Dubey, 2021). Furthermore, information and communication technology (ICT) promoted knowledge exchange at a large scale and at a low cost among farmers, extension workers, and other stakeholders. Similar to ICT driven models likes Aqua-Choupal, Village Knowledge Centres/Rural Knowledge Centres, web kiosks, help lines, Kisan Call Centres, the e-Sagu Aqua is an innovative and unique model, implemented in freshwater in Andhra Pradesh State of India. The e-Sagu Aqua aims to exchange information on freshwater aquaculture to needy farmers in a timely and personalised manner to improve freshwater aquaculture productivity and also to increase the profitability of the farmer by increasing the efficiency of aquaculture inputs and reducing the cost of production (Vimala et al., 2009), resulting development of aquaculture as one of the largest ventures in Andhra Pradesh.

Fish Farmers Development Agencies (FFDAs) were established during 1973–74 at the district level with the main objective of serving as a nucleus centre to provide need-based mechanism for promoting scientific fish farming practices so that farmers can increase their knowledge level (Das et al., 2018). In India, FFDA programme was initially sponsored by World Bank financing, provided the majority of the early funding for aquaculture in inland water bodies (Jaysankar, 2018). Fish farmers are given technical, financial, and extended assistance in order to start a culture-based fishery in village ponds and tanks (Katiha et al., 2005). Presently, Bihar has 39 FFDA, out of which 33 are in functional condition for disseminating fisheries extension services to reduce the gap between present and potential production of Bihar (Kumar, 2018, Chand and Prasad, 2021). The sensitization of short term trainings on aquaculture among rural fish farmers generates self-employment opportunities and improve the socio-economic condition of fisher folk.

3.3.5. Adoption of integrated fish farming

Integrated farming is founded on the idea that "there is no waste," and that "waste is only a misplaced resource that may become a useful material for another product" (Anonymous, 1977). The basic principles involved in integrated farming are the utilization of the synergetic effects of inter-related farm activities, and the conservation, including the full utilization of farm waste (Pillay, 1990). Integrated farming involving fish is defined broadly as the concurrent or sequential linkage between two or more human activity system, of which at least one is aquaculture (Singh et al., 2018). The integration of livestock with fisheries aquaculture has recently received considerable attention, with a focus on using animal dung as a fertilizer and nutrient to promote natural feed in fish ponds. The large amount of nutrients (NPK) present in the animal feed being recovered in the manure, with possible proportions of 72–79% nitrogen, 61–87% phosphorus, and 82–92% potassium, these act as fertilizers in fish ponds to produce plankton which comprise high-protein natural food for fish (Khan, 2011). Adoption of integrated farming in ponds, tanks and even wetlands facilitate the efficient waste utilization from different culture practice for fish production, which reduces the additional cost for supplementary feeding as well as fertilization (Jha, 2009). Integrated fish farming systems boost the income of farmer by reducing the cost on both input and waste management (Ahmed and Garnett, 2011).

The importance of integrated fish farming in Bihar is very high due to existence of larger number of small and marginal farmers in the State. Basically two types of integrated fish farming such as agri-based fish farming and livestock-based fish farming are practiced by farmers, where Bihar has ample scope for propagation of both types of integrated fish farming (Eyo et al., 2006, Khan, 2011). Mishra and Mohanty (2004) attempted to investigate the short-duration fish and prawn rearing (about 120 days) with a stocking density of 25,000 ha^{-1} along with rice crop, and produced rice 4.4 t ha^{-1} without any pesticide application with net profit of Rs. 10,781.00 ha^{-1}.

In agri-based fish farming, paddy-cum-fish farming (Mishra and Mohanty, 2004) and horticulture-cum-fish farming (Laxmi et al., 2015) can be practiced. Integrated Resources Management Approaches like Fish-cum-Duck-farming, Fish-cum-Poultry Farming, Fish-cum-Dairy Farming, Fish-cum-Horticulture, etc reduce the chemical fertilizer and input cost and help the farmers in nutrient enhancement, pest control, feed supplementation and biological control of their system (Jha, 2009). The culture of native fish in the wet rice-field boost the rural economy through community participation (Mishra and Mohanty, 2004). The horticulture-cum-fish farming system includes the culture of fruits, vegetables and flowers on the embankment of the pond (Laxmi et al., 2015). The selection of plant is the main criteria for the success of this system. The plant should be dwarf, seasonal, evergreen and less shady. In the case of fruit crops, mango, guava, banana, papaya and lime can be used. Similarly, the vegetables like eggplant, tomato, cucumber, gourds, chilli, carrot, raddish, turnip, spinach, amaranths, peas, beans, cabbage, cauliflower, ladies' finger can be grown according to their season. The flower plantation like Rose, Jasmine, Gladiolus, Marigold and Chrysanthemum on the embankment is also provides additional income to the farmer and besides aiding beauty to the farm. Farmers depending intensive agriculture on single farm enterprise in India are unable to sustain their livelihood, but the integration of crops, livestock, fishery components enable them to sustain food, and nutritional

security with regular and periodic income round the year (Paramesh et al., 2022, Yadav et al., 2022). Kumar et al. (2012) demonstrated that enhancement of the productivity of resources, economic returns, generating employment and maintaining soil health of farm can be achieved by the combination of crop, fish, duck and goat at low-laying lands of Bihar instead of cultivating crop alone on same piece of land under irrigated condition.

3.3.6. Establishment of fish hatchery

Fish seed is the basic input for inland fish farming, broodstock management is an important aspect for quality seed production (Nyonje et al., 2018). But, production of quality seed is at critical stage in the State. Easy and round the year adequate availability of good quality fish seed at farm level is not available at current situation and farmers are depend for procurement of fish on neighbor State. At present, seed production in Bihar is about 350 million, while the demand is 600 million fry. Therefore, the demand gap of 250 million (10–20% of total requirement) is met by supply from other States and natural collection. To enhance the fish seed production in Bihar, the State Government has initiated the scheme for the construction of fish seed hatchery on subsidies rate, where the unit cost of hatcheries is Rs. 1.5 million, for which 50% subsidy is provided (Anonymous, 2020a). The installation of Fibre-Reinforced Plastic (FRP) eco-hatchery at village level acts as the nucleus for quality seed supply at local region.

The creation of a fish hatchery should also focus on providing the farmer with a constant supply of high-quality fingerlings and yearlings for stocking the pond at all seasons of the year. Large water bodies can be utilized for grow out culture, while small water bodies can be used for seed rearing and brood stock management for fish hatchery creation, allowing optimal usage of all types of water bodies in Bihar. Fish culture in big water bodies such as wetlands and reservoirs, along with the investigation of small water bodies for fish seed rearing such as ponds and tanks, can be helpful for Bihar to increase both fish and seed output.

3.3.7. Assembling of fish market and supply chain

Production of cultured fish can be increased through modern and scientific method of fish culture and fishing techniques. Fish is a highly perishable commodity, and also the production and consuming locations are separated by a large distance. Improving fisheries management isn't only a matter of conservation and enhancement of production, it's also a matter of economics, as markets rely on it for long-term stability and continuity of supply of the product.

In our modern day, a well-organized fish market is essential for supplying fresh and clean meat quality, where the establishment of supply chain systems with intra- and inter-linkages between the production and consumption sectors are essential. An efficient fish marketing system is critical to the expansion of fish production and the development of the fisheries sector. Due to the poor social status of fishermen in today's society, fish sellers are having difficulty securing a suitable location for their stall in the main market, forcing them to sell fish on the side of the road or far away from the main market without maintenance of quality or hygiene and without access to drinking water, shelter and fish dressing platforms (Kumar et al., 2008). The creation of a well-organized fish market with some basic facilities is urgently required such as transportation, electricity, proper drainage system, water supply, drinking water facility, availability of ice supply, a separate toilet for male and female and waste management. Furthermore, because fish is a perishable item, the supply chain should be enhanced to assure the availability of fresh or live fish at the consumer's door through the development of mobile and web-based applications. The State Government has started a scheme to distribute moped-cum-iceboxes to help in fish marketing. For quick movement of fish from the production site to the market, two- or three-wheeled vehicles have also been deployed on subsidy rates (Anonymous, 2020a).

3.3.8. Propagation of ornamental fish and plants

The contribution of India in the worldwide ornamental fish trade is less than 1%, yet it is nevertheless regarded as a "sleeping giant" because to its vast untapped potential. More than 4000 freshwater and 1400 marine species are also traded internationally each year, making it one of the most important components of the global fish trade (Singh and Lakra, 2011). Due to the great economic potential and prospects, the ornamental fish and aquarium accessory market is gaining momentum each year. The ornamental fish sector in Bihar is expanding because of the minimum space, water, and input cost requirements compared to other pet animals, as well as strong market demand throughout the State and also in neighboring States. However, Bihar still relies on neighboring States and natural collections for all types of ornamental fish and aquarium equipment. Viewing the vast potential, the State should promote ornamental fisheries operations such as ornamental fish culture, breeding, and marketing, ornamental plant production and marketing, and aquarium accessories such as glass tank fabrication, aerators, filters, stone, and others. The lucrative schemes of Bihar Government State for training on culture and breeding are required to support the ornamental fish business enterprise at the village level. Sawant et al. (2020) remarked on the value of ornamental fish farming and trading in income-generating sources for the marginal farmers, women, and unemployed youths. Selective breeding of fish and the development of a new strain of ornamental

fish is a common practice at the global level, but in India, this technique has not yet gained attraction, and as a result, indigenous ornamental fish are not widely accepted for trade (Raghaven et al., 2013).

The criteria of low area and input budget provides to undertake the ornamental fish business as a backyard unit. Interested individuals may start an ornamental fish business with their family members and earn enough money to cover their daily home expenses at any time. In Bihar, the maximum farmers are marginal, thus adoption of ornamental fish activities among the fishermen has the favourable promise to boost their economic position. To keep the momentum in the ornamental fish enterprise, farmers must be educated on ornamental fish technologies, input costs, and cost-benefit ratios. Ornamental fish culture, like other agricultural products, is heavily reliant on frequent management, and male and female participation is critical (Rahman et al., 2011). Women's active engagement in backyard ornamental aquaculture may be a valuable source of revenue that can help them to satisfy their basic requirements.

4. CONCLUSION

Currently, the development of aquaculture in Bihar is being severely hampered by issues with water management, lack of high-quality seed and feed, and disease outbreaks. As farmers of Bihar are small and marginal and also agriculture is the main source of income, the adoption of a temporal and spatial integrated farming system is the best option to improve their livelihood. However, the farmers in Bihar need the illustration for the benefit of resource-based integrated farming rather than engaging in agriculture alone.

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