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REVIEW ARTICLE

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Review of the current situation, problems, and challenges in fish seed production and supply for Bangladesh's aquaculture development

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Abstract – Fish seed are important for the growth of aquaculture in Bangladesh, but there are many challenges associated with supplying quality fish seed. This review evaluated the current level of production, issues and challenges that are affecting the production of fish seed in Bangladesh. The fish hatchery was found to be the major contributor in terms of fish seed production. Out of 671 metric tons of fish seed produced in 2020–2021, above 99% were from hatcheries. Freshwater finfish hatcheries have expanded over the last 30 yr, and are distributed throughout the country, but there is no commercial hatchery for coastal and marine water finfish species in the country. Shrimp and prawn hatcheries are concentrated in Cox's Bazar and the greater Jassore regions, respectively, while crab culture is entirely dependent on wild capture. Crablets are collected from nature, which has a devastating impact on biodiversity and wild stocks. The fish seed value chain is multidirectional and interlinked, and intermediaries dominate the supply chain. Disease outbreaks and indiscriminate use of chemicals are major concerns in fish seed production. Management strategies such as the introduction of certification, training programs, technology transfer, access to credit, and implementation of the law could improve the quality and productivity of fish seed in Bangladesh.

Keywords: Fish seed / hatchery production / post-larvae / disease / chemical and drug / supply chain

1 Introduction

Bangladesh is a country in the low-lying river delta region (Alam et al., 2020). The country has active deltas fed by three large rivers: the Ganges (Padma), Meghna, and Brahmaputra (Jamuna) (Akter et al., 2016). The country's inland, coastal, and marine water resources have a high potential to boost the production of fisheries and aquaculture, which is the second largest industry in export earnings (Shamsuzzaman et al., 2020), this is because Bangladesh has an inland water area of about 45,000 square kilometres, including 700 small and large rivers, lakes, ponds, haor, baor, floodplains, canals, etc. (Biswas et al., 2021; Hossain et al., 2006). Furthermore, the country has a 710 km long coastline and a vast marine water area of more than 118,813 square kilometres (Islam et al., 2020; Roy et al., 2022). The productivity of these water bodies enabled the fisheries and aquaculture sector to significantly contribute to the country's employment, food security, and national economy (Lauria et al., 2018).

With an estimated fish production of 4.621 million metric tons (MT) in 2020–21, Bangladesh is self-sufficient in fish production. Aquaculture production, mainly from earthen ponds, is the main contributor (57%) to the total fish production (DoF, 2022), which is in line with future goals for fish production. However, for upward development and sustainable aquaculture production, timely delivery of high-quality fish seed is a prerequisite (Samad et al., 2014; Little et al., 2002). The demand for quality fish seed is growing due to the increasing participation of people in the aquaculture industry (Biswas et al., 2021). In the last two decades, a variety

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of fish culture techniques has been developed in the country, including biofloc fish culture (Saha et al., 2022), re-circulatory aquaculture system (RAS) (Arifa et al., 2022), integrated multitrophic aquaculture system (IMTA) (Kibria and Haque, 2018), cage culture and pen culture (Rahman et al., 2021), and rice-fish culture (Islam et al., 2017a, b). High-quality seed could increase yield by up to 30% of these aquaculture systems while maintaining the same management level (Hossain et al., 2022; Khan et al., 2018). Although the number of fish hatcheries and hatching facilities is increasing, this has not ensured a stable supply of quality fish seed due to low capital investment, poor management, and not adopting advanced hatchery technology (Ahmed, 2009; Das et al., 2018; Khan and Alam, 2003). Therefore, the focus on the production and supply of high-quality fish seed is substantial for the development of a sustainable aquaculture sector.

Research efforts on various aspects of fish seed production have been carried out in Bangladesh such as induced breeding (Aktar et al., 2014; Biswas et al., 2021; Debnath et al., 2020), fish seed supply chain (Hemal et al., 2017; Islam et al., 2017c), technical efficiency of fish hatchery (Islam et al., 2007), the prevalence of disease (Bappa et al., 2015), and hatchery management (Sharif and Abdulla-Al-Asif, 2015). However, most of these studies focused on a particular division, district, or selected areas of Bangladesh. Studies on the overall status of fish seed production in Bangladesh are still scarce. Therefore, the present review aims to improve the knowledge of the status of fish seed production in Bangladesh. This review also aims to provide valuable information on management strategies for sustainable fish seed production in Bangladesh.

2 Production of fish seed in Bangladesh

The two primary sources of fish seed are natural sources such as rivers, as well as government and private hatcheries (Bhuyan et al., 2011). In 2021, the total fish seed production from both sources was 670.953 metric tons (MT), which was approximately 2.5 times higher than 276.481 MT in 2001–2002. Among the two sources, more than 99% (Tab. 1) of fish seed comes from fish hatcheries, indicating that the rapid expansion of inland aquaculture in Bangladesh has been supported by greater access to hatcheries producing fish seed (Hasan and Bart, 2006). In the past, fish culture depended utterly on the seed supply from natural sources (Debnath et al., 2020; Samad et al., 2014). However, the contribution of natural sources to the total supply of fish seed was reduced due to the shrinkage and destruction of natural breeding grounds for fish (Jega et al., 2018; Khan et al., 2022), the degradation of ecological balance (Aktar et al., 2014; Rahman et al., 2020; Shamsuzzaman et al., 2017), climate change (Aziz et al., 2021), pollution, overfishing, and the use of destructive fishing gears. Despite the high production from fish hatcheries, there is a lingering challenge in the availability of high-quality fish seed and their supply (Hossain et al., 2022; Little et al., 2002).

3 Production of fish seed from natural source

Natural fish seed are collected from different rivers, mainly during the rainy season (May to August) (Haque and Dey, 2017; Rahaman et al., 2007). Jamuna, Padma, Brahmaputra, Gorai-modhumuti, Halda, and Arialkha are the main river systems from where fish seeds are collected (Tab. 2 and Fig. 1). The spawns of the major carps are mainly collected from these river systems (Hossain et al., 2022; Khan et al., 2018). The primary fishing gear used to collect fish fry are fixed purse nets and set bag nets, locally known as behundi jal, bendi jal, badha jal, and saver (Bhuiya et al., 2019). Spawn collection nets are made locally and are mostly similar in shape, size, and operation; they are set in shallow water against the water current, and collected spawns are kept in hapa until sold (Tsai et al., 1981). Among all the river systems, carp spawn from the Halda river is considered one of the best qualities because of its genetic purity and diversity (Hossain et al., 2022; Khan et al., 2018). Halda is the only river from which naturally fertilized eggs of major carp are collected, which makes it an important heritage site of the country (Islam et al., 2020; Kabir et al., 2015). The spawning of major carp occurs during the new moon and the full moon in the monsoon (April to June) when the water level rises due to rainwater runoff from the hill region from a thunderstorm. Fertilized eggs are collected using a seine net mostly made of mosquito nylon netting (9 to 12 m long and 3 to 4 m wide) operated from a boat by two fishermen (Tsai et al., 1981). Collected fertilized eggs are sold to hatchery owners (Bhuiyan et al., 2019). However, in recent years, the contribution of rohu carp fry (*Labeo rohita)* to the total production of seeds of Indian major carp has been reduced (Khan et al., 2006). The destruction of fish resources due to indiscriminate capture of brood fish, destruction of spawning ground by cutting the oxbow bend, illegal sands quarrying, and pollution of the river by industrial and agricultural wastes have been a major concern (Alam et al., 2020; Kabir et al., 2015).

Table 1. Major sources and their relative contribution to fish seed production in Bangladesh in the last 20 yr. (Adapted from DoF, 2022).

Year	Total production (MT)	Natural source (%)	Fish hatchery (%)
2001–02	276.481	0.714	99.286
2002–03	302.272	0.345	99.805
2003–04	351.606	0.449	99.551
2004–05	323.143	0.657	99.343
2005–06	414.373	0.416	99.584
2006–07	465.593	0.443	99.557
2007–08	425.885	0.440	99.555
2008–09	467.230	0.402	99.598
2009–10	499.578	0.441	99.559
2010–11	629.176	0.695	99.305
2011–12	611.473	0.669	99.331
2012–13	490.824	0.678	99.322
2013–14	492.026	0.548	99.452
2014–15	551.961	0.799	99.201
2015–16	614.433	0.784	99.216
2016–17	668.529	0.758	99.242
2017–18	696.028	1.332	98.668
2018–19	666.516	0.374	99.626
2019–20	666.503	0.391	99.609
2020–21	670.953	0.321	99.679

Table 2. Hatchling production (MT) from major rivers in 2020–21 (Adapted from DoF, 2022).

Year	Jamuna	Padma	Halda	Brahmaputra	Modhumoti/Gorai	Arialkha
2010–11	2.828	1.3	0.23	–	0.012	–
2011–12	1.514	0.587	1.569	0.013	0.36	0.05
2012–13	1.228	1.148	0.626	0.049	0.215	0.06
2013–14	0.97	0 .613	0.508	0.042	0.24	0.265
2014–15	1.541	1.919	0.107	0.1	0.515	0.23
2015–16	1.615	1.984	0.32	0.11	0.543	0.241
2016–17	1.697	2.086	0.338	0.116	0.571	0.153
2017–18	1.767	2.049	4.507	0.12	0.561	0.262
2019–20	0.952	0.97	0.191	0.05	0.158	0.175
2019–20	1.087	0.825	0.394	0.059	0.146	0.095
2020–21	0.97	0.822	0.106	0.032	0.137	0.085

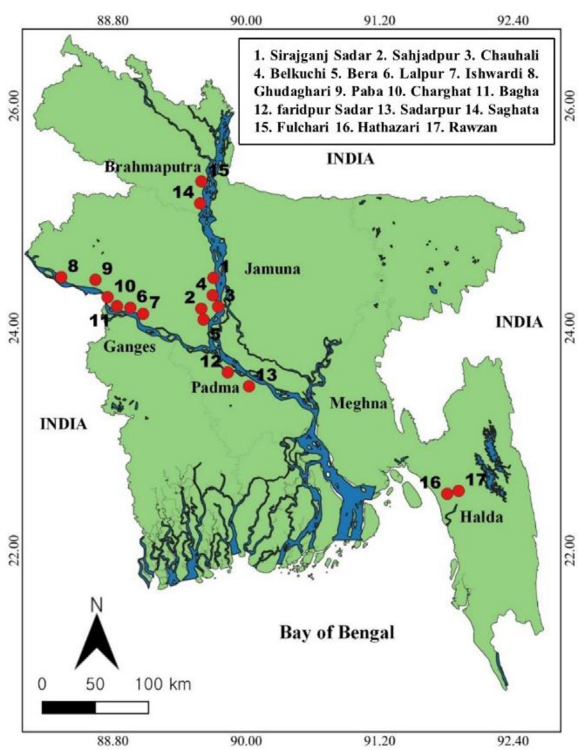

Fig. 1. Major points of fish seed collection from natural sources (Adapted from DoF, 2020).

4 Fish seed production in hatcheries

The increasing seed demand for the growing aquaculture sector and the decrease in seed supply from natural sources led to the establishment of many hatcheries in the country (Islam et al., 2017c; Rahaman et al., 2007). At present, aquaculture is mainly dependent on fish seed produced in hatcheries (Debnath et al., 2020). The quality of the seed depends on the quality of the brood fish used for spawning. In Bangladesh, some hatcheries rear and maintain their brood stock, while others acquire brood fish during the breeding season to fulfil their target (Rahman et al., 2020). Most of these brood stocks are collected from different sources, such as Halda River, Padma River, Meghna River, Jamuna River, Bangladesh Fisheries Research Institute (BFRI), and government brood banks to avoid inbreeding and to ensure seed quality (Rahman et al., 2020; Samad et al., 2014; Sharif and Abdulla-Al-Asif, 2015). The age of brood fish ranges between 1–6 yr for males and 1–3 yr for females, and hatchery owners use the same brood fish for 3–5 yr. However, with the expansion of hatcheries, the availability of large and healthy brood fishes is increasingly becoming a problem. Therefore, some hatcheries were observed to use small and unhealthy broods (Debnath et al., 2020). For induced spawning, a variety of inducing agents, including pituitary gland (PG), human chorionic gonadotropin (HCG), ovaprime, ovitide, and ovaline are used in hatcheries (Aktar et al., 2014; Bhuyan et al., 2011; Biswas et al., 2021; Islam et al., 2017c). Another hormone used in hatcheries is 17α-methyltestosterone, a sex-reversal hormone for producing monosex tilapia (Debnath et al., 2020). Hormone dose, ovulation period, and hatching time differ according to fish species (Tab. 3). Most hatchery owners perform 1–2 production cycles per year; however, some hatcheries are reported to perform 4–5 production cycles per year (Rahaman et al., 2007). An increase in the frequency of spawning and out-of-season production of fish seed could affect the quality of the seed. It may increase stress on brood fish and /or result in the production of seed from immature gametes (Little et al., 2002). Furthermore, the production rate of fish seed depends on the weather, water quality, brood fish selection, a proper dose of hormonal injection, and expertise in hatchery operations (Bhuyan et al., 2011).

5 Species-wise production in hatcheries

The most popular species produced in hatcheries are carps, including major carps such as rohu carp (*L. rohita*), catla (*Catla catla*), mrigel (*Cirrhina mrigala*), calibaush (*Labeo calbasu*) and exotic carps such as silver carp (*Hypophthalmicthys molitrix*), bighead carp (*Aristichthys nobilis*), grass carp (*Ctenopharyngodon Idella*), common carp (*Cyprinus carpio*), and black carp (*Mylopharyngodon piceus)*. Additionally, cyprinids, including bata (*Labeo bata*), gonia (*Labeo gonius),*

Table 3. Hormonal doses for induced breeding of male and female fish of different species and their ovulation period (adapted from Sarder, 2007; Aktar et al., 2014; Debnath et al., 2020; Biswas et al., 2021).

Species	Sex	1st dose of hormone (PG) mg/kg and (HCG) IU/Kg	Interval (hrs)	Final dose of hormone (PG) mg/kg and (HCG) IU/Kg	Ovulation (hrs after final dose)	Hatching time (hrs)
Rui (*Labeo rohita*)	Female	1–2	3–6	4–7	4–8	15–20
	Male	–	–	1–2		
Catla (*Catla catla*)	Female	0.5–2	3–6	4–7	5–8	15–20
	Male	–	–	1–2		
Mrigal (*Cirrhinus cirrhosis*)	Female	1–1.5	3–6	5–6	4–7	–
	Male	–		1–1.5		
Silver carp (*Hypophthalmichthys molitrix*)	Female	0.75–1 200-250IU	3–9 9–12	4–6.5 500IU+3mg	6–8	18–24
	Male	–		1–2		
Grass carp (*Ctenopharyngodon idella*)	Female	0.5–2	6–8	4–6	5–7	18–24
	Male	–		1–2		
Bighead carp (*Hypophthalmichthys nobilis*)	Female	0.75 100-150IU	6	6–8		18–24
	Male	–	–	1.5–2		
Common carp (*Cyprinus carpio*)	Female	1–0.5	3–6	4–5.5	6–8	24–36
	Male	–	–	2		
Sharpunti (*Puntius sarana*)	Female	0.25	6	4–5	6	15–20
	Male	–	6	0.75–2		
Bata (*Labeo bata*)	Female	0.25	6	4–4.5	–	15–20
	Male	–		1–1.5		
Pangas (*Pangusius hypopthalmus*)	Female	2	6–9	5–6	8–12	24–36
	Male	–		1		
Magur (*Clarias batrachus*)	Female	50	6–8	100	9–12	24–36
	Male	–		–		
Shing (*Heteropnuestes fossilis*)	Female	70	6–8	70	8–10	27–30
	Male	–	–	–	–	
Pabda (*Ompok pabda*)	Female	3	6	15–17	7–8	–
	Male	–	–	7–8		
Koi (*Anabas testudineus*)	Female	3–4	–	–	9–12	–
	Male	2	–	–		

and Thai punti (*Puntius gonionotus)* are also produced. In 2020–21, the production of major carp and exotic carp hatchlings in private hatcheries were 259.329 MT and 183.705 MT, respectively (Fig. 2). Carps are the dominant fish species for seed production in most hatcheries in Bangladesh (Bhuyan et al., 2011; Hemal et al., 2017; Sharif and Abdulla-Al-Asif, 2015). This is due to the fact that freshwater aquaculture of carp has been proven to be sustainable over the years (Islam and Hossain, 2013). The production of carp seed through induced breeding has improved the progress in the country's aquaculture. A positive impact of hatchery-produced spawn has been seen in the enhancement of aquaculture production (Rahaman et al., 2007). The contribution of the major carp to Bangladesh's overall pond fish production was about 32% (Hossain et al., 2022). Among the other native and exotic species, tilapia (*Oreochromis niloticus*), koi (*Anabas testudineus*), chital (*Chitala chitala*); catfishes such as shing (*Heteropneustes fossilis*), magur (*Clarias batrachus*), pangas (*Pangasius pangasius*), pabda (*Ompok pabda*), gulsha (*Mystus cavasius*); snakeheads such as shol (*Channa striata*), gojar (*Channa marulius*) are also produced in fish hatcheries (DoF, 2022). Due to the high market demand and success in induced breeding techniques, new species are being added to the list.

6 Distribution of fish hatcheries

Hatcheries are currently expanding exponentially, especially in the private sector. In 1982, there were only 3 private hatcheries in Bangladesh. The number was 40 in 1985, increasing to 214 by 1987 (Rahaman et al., 2007). In 2011, 922 (885 private and 77 government) hatcheries were in operation and as of 2021, there was a 14.5% increase in hatchery numbers, reaching 1056 (953 private and 103 government) (Fig. 3). The quantity of fish seed and profit of government hatcheries were less than the private hatcheries per the

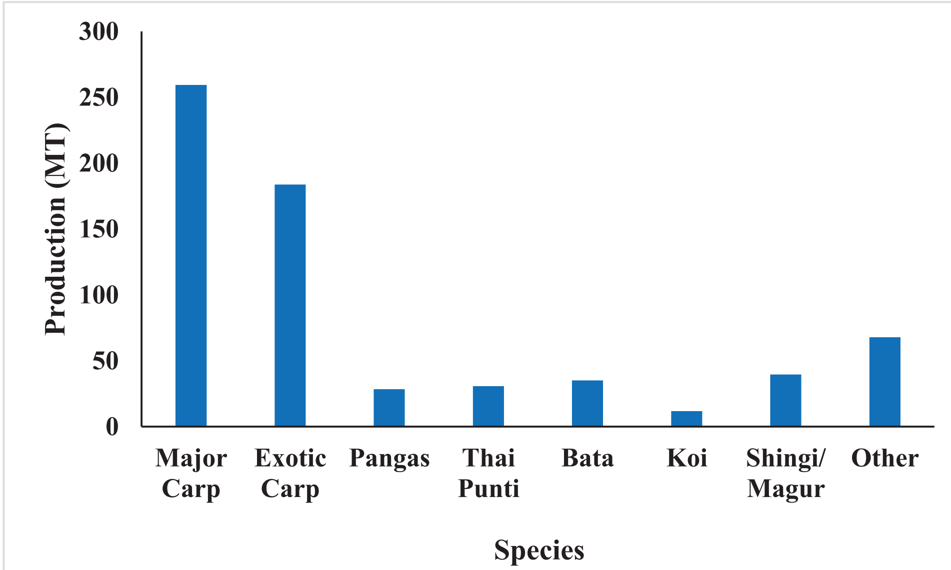

Fig. 2. Species-wise contribution of fish hatchlings produced in private hatcheries in Bangladesh in 2020–21 (DoF, 2022).

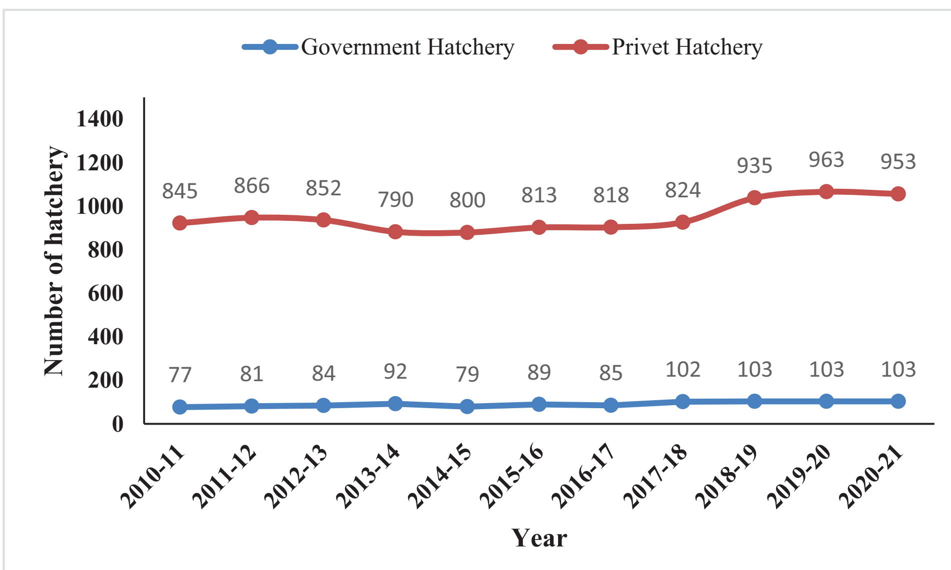

Fig. 3. Number of private and government hatcheries in production from 2010–11 to 2020–21 (Adapted from DoF, 2022).

production capacity (Aktar et al., 2014). Most government and private hatcheries are located in the Mymensingh, Rajshahi, Chittagong, Khulna, and Rangpur divisions (Fig. 4). Initially, hatcheries were built in four important clusters in Jessore, Bogra, Mymensingh, and Comilla, close to government fisheries stations or where riverine fish seed collection was a traditional practice. Fish hatcheries expanded throughout the nation by technicians from other hatcheries who were hired to start up new hatcheries or founded their own hatcheries (Khan et al., 2018; Rahman et al., 2020). Although most fish farmers collect fish seed from private hatcheries, it was reported that, in terms of growth performance, disease resistance, and survivability, fish seed from government hatcheries/brood banks, natural sources, and BFRI were superior to those from private hatcheries (Khan et al., 2018; Rahman et al., 2020).

7 Transportation of fish seed

The fry trading season starts in April and continues until the end of September in Bangladesh (Islam and Hossain, 2013). Fish seed and brood fish are transported by vehicles such as auto-rickshaws, vans, and bicycles for short distances, while buses, trucks, trains, etc., are used for long-distance travel (Sharif and Abdulla-Al-Asif, 2015). Two methods are followed to transport fish seed depending on the distance of the transportation point from the hatchery. One is an open system using an aluminium bowl/plastic container for a short distance, and another is a closed system using plastic bags filled with oxygen for long distances (Islam and Hossain, 2013; Islam et al., 2017c). In large-scale seed transportation, a fish hauling tank equipped with an agitator and oxygen supply is used.

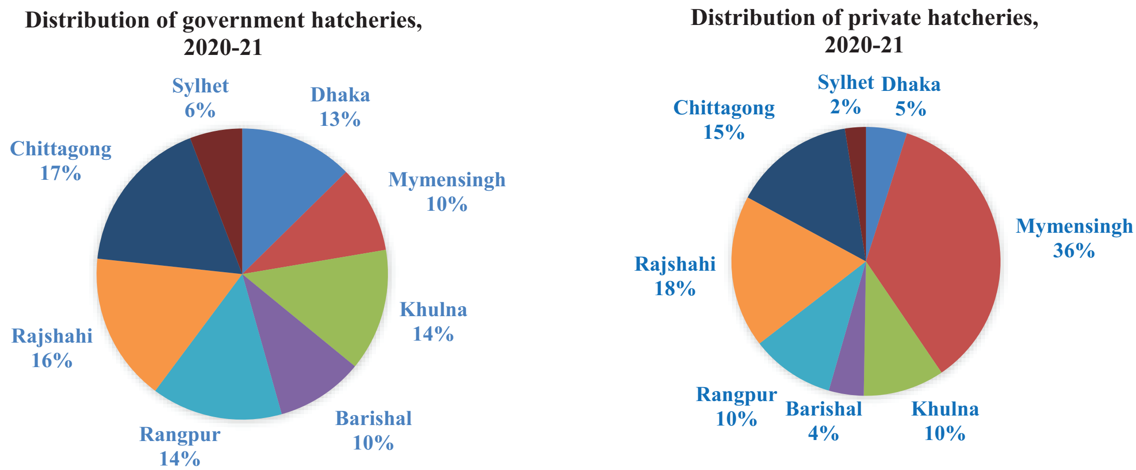

Fig. 4. Division-wise distribution of private and government hatcheries in Bangladesh in 2020–21 (Adapted from DoF, 2022).

Sometimes, the body of the truck is temporarily converted into a water pool by filling the water with a plastic mat (Sharif and Abdulla-Al-Asif, 2015). Mortality is a paramount concern during the transportation of fish seed. Seed mortality varies from 20 to 30% depending on species, size, water quality, density, transport distance, duration, and transportation method (Hasan and Bart, 2006; Hemal et al., 2017; Islam et al., 2017c; Rahaman et al., 2007). Mortality rate increases with increasing loading density, time, and duration of transportation. *H. molitrix* and *L. rohita* were found to be the most sensitive fish to transport mortality with a rate of 50% and 29%, respectively (Hasan and Bart, 2006). Islam and Hossain (2013) reported that a saltwater bath (0.9% NaCl) before transport can reduce mortality by 22% in *L. rohita* due to its therapeutic effect.

8 Marketing channel of fish seed

Marketing channels are the path of product flows from producers to consumers (Hemal et al., 2017; Sabur et al., 2010). The fish seed value chain is multidirectional and interlinked. It starts with hatchery owners collecting brood fish from different sources and ends with fish farmers, facilitated by intermediaries such as nursery owners/fry producers, wholesalers (arotdar), retailers, or middlemen or fry traders (Fig. 5). Hatchery owners produce fish spawn through induced breeding and sell to the fry producer or nursery owner, who are the main stakeholders of the marketing channel (Sabur et al., 2010). Nursery owners buy fish hatchlings from the fish hatchery on a weight basis and rear them in a nursery pond to produce fry (Islam et al., 2017c; Sharif and Abdulla-Al-Asif, 2015). Wholesalers buy fish fry from nursery owners and keep them in small hapa until they are sold to the fish farmer by a middleman/retailer (Islam et al., 2007; Sharif and Abdulla-Al-Asif, 2015). Only, a few fish farmers buy fish seed directly from the nursery, so the marketing of fingerlings generally lies with the mediators (middlemen) (Islam et al., 2007; Sharif and Abdulla-Al-Asif, 2015). There is a variation in the price of fish fry depending on size, quality, season (peak season and lean season), and species (Sabur et al., 2010).

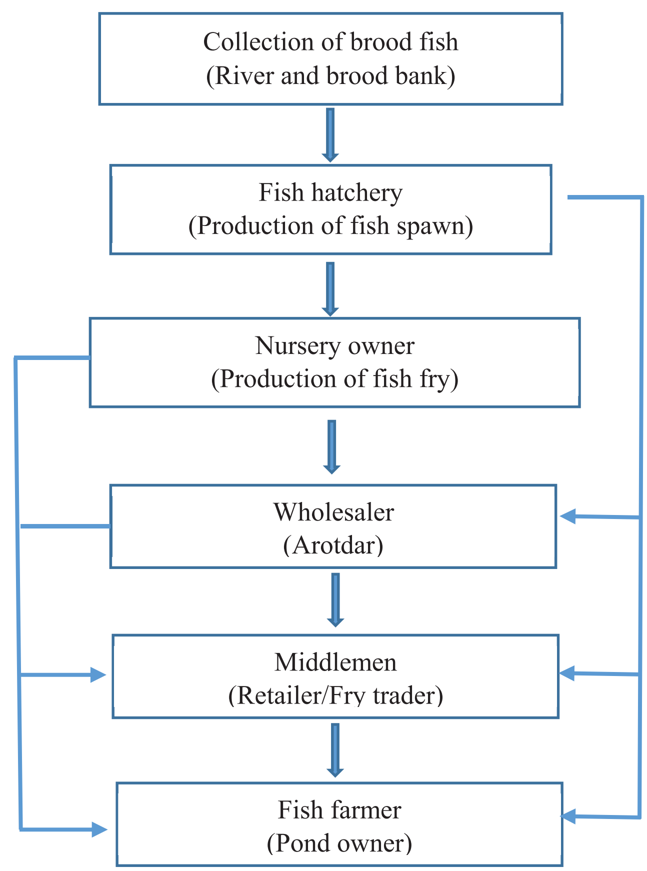

Fig. 5. Flow chart of fish seed marketing channel.

9 Disease outbreaks and use of chemicals and drugs in hatcheries

Disease outbreaks and disease-induced mortality are major constraints to the economic success and expansion of the fish seed industry. Fish fry and fingerlings become more susceptible to the pathogen due to their immature immune system (Faruk and Anka, 2017). Poor quality of water, high stocking density, and sudden fluctuation in temperature were identified as the leading causes of diseases (Shikuku et al., 2021). The hatchery fish seed could be infected, carrying the pathogens to grow systems, and causing heavy mortality. Furthermore, Bangladesh does not have a health certification system or diagnostic laboratory to check the health status of the fish and seedlings. As a result, fish farmers do not know whether their fish are carrying pathogens (Samad et al., 2014). Common fish diseases in hatcheries and early rearing stages are caused by parasites, bacteria, viruses, and fungi (Alam and Rashid, 2014; Faruk and Anka, 2017). Various chemicals and drugs are used to treat diseases in hatcheries (Tab. 4). The prevalence of disease changes with the season and winter (October to January) was identified as the period of high susceptibility to parasitic disease (Mortuza and Al-Misned, 2015; Samad et al., 2014). Proper health management strategies, maintenance of good water quality, proper nutrition, and the establishment of biosecurity measures are very important to prevent or restrict the introduction and spread of disease within or between fish production facilities (Faruk and Anka, 2017).

Various chemicals and drugs are also used as anaesthetics, disinfectants, antibacterial, antifungal agents, etc. to increase production and improve the survival of fry and fingerlings, reduce transport stress, and control possible pathogen infection (Tab. 5). Many hatchery operators are reported to use them even though any pathogens or problems were not detected. Antibiotics and disinfectant chemicals can threaten biodiversity by killing non-targeted organisms if discharged into the main water body through effluents (Uddin and Kader, 2006). Almost in all cases, hatchery operators apply chemicals and drugs at a higher dose due to a lack of knowledge of the appropriate dosage (Alam and Rashid, 2014; Hossain et al., 2013). This causes the development of drug-resistant pathogens due to the indiscriminate use of aqua drugs and chemicals, which is a significant concern nowadays (Hossain et al., 2013; Uddin and Kader, 2006; Yasmin et al., 2022).

10 Production and supply of seed in coastal aquaculture and mariculture

Despite being rich in coastal and marine water resources, mariculture in Bangladesh is still underdeveloped (Shamsuzzaman et al., 2017). Traditional culture of Asian seabass (*Lates calcarifer*) and greenback mullet (*Chelon subviridis*) is being reported on a small-scale basis depending on the supply of natural seed (AftabUddin et al., 2021). Coastal aquaculture in Bangladesh mainly refers to the culture of shrimp, prawn, and crab. Stocking post larvae (PL) in modified rice fields, locally known as *gher* is essential in shrimp (*Penaeus monodon*) and prawn (*Macrobrachium rosenbergii*) farming (Islam et al., 2017a, b). Most shrimp hatcheries are located in Cox's Bazar region, whereas prawn hatcheries are concentrated mainly in the Jessore region. Hatchery owners collect brood shrimp (mother shrimp) from the deep sea near Saint Martin Island, which is very expensive (Islam et al., 2011). Lack of technical knowledge, inadequately skilled workforce, and insufficient supply of wild broods were identified as the main reasons for limited hatchery production (Ahmed et al., 2013; Ahmed and Troell, 2010). In recent years, viral contamination in hatchery brood shrimp and horizontal and/or vertical transmission of the virus to offspring is seriously affecting production. Therefore, some traditional shrimp hatcheries adopted specified pathogen-free (SPF) production methods (Chakrobortty et al., 2020). Altogether 77 hatcheries (44 prawn and 33 shrimp hatcheries) are reported to use PL but the total number of hatcheries has been reduced in recent years (Fig. 6). Although the supply of wild collected PL is limited and the price is high, farmers prefer to stock wild PL because of high survivability, and high production performance (Hoq, 2007; Ahmed and Troell, 2010; Islam et al., 2011; Ahmed et al., 2013). The harvesting of PL from natural sources like rivers and estuaries started in the early 1970s (Abdullah et al., 2019). The collection of PL from natural sources occurs throughout the year, with the peak season in April to June following the new moon and the full moon (Ahamed et al., 2012). Fishing gears such as the dragnet, pull net, and push net are used to catch wild PL, but a set bang net is considered the most efficient considering the catch. Captured PL with a high level of by-catch are transferred in earthen/plastic/aluminium pots, targeted PL are separated using a white plate and spoon, and the rest of the non-targeted species are discarded along the shore (Azad et al., 2007; Hasan et al., 2019). Statistics estimate that the livelihoods of approximately 400,000 people, including women and children, are associated with prawn PL fishing in coastal Bangladesh, and more than 2000 million PL valued at around US$ 30 million are collected from these coastal zones every year (Ahamed et al., 2012). Although PL collection is a good source of income for coastal people, the government imposed a ban in September 2000 on wild PL collection because this practice substantially negatively impacts estuarine and marine biodiversity through the indiscriminate destruction of non-target species. However, this ban has not been strictly enforced due to the limited availability of hatchery fry and the lack of alternative employment opportunities for poor PL collectors (Ahmed et al., 2013; Hoq, 2007).

The mud crab or mangrove crab (*Scylla serrata*) is Bangladesh's second most commercially important shellfish species (Rouf et al., 2021). The high tolerance to environmental parameters, short cropping cycle, and diversified culture system plays a vital role in developing mud crab fishery in southern Bangladesh (Mahmud and Mamun, 2012; Rahman et al., 2020). Currently, Bangladesh lacks functional crab hatchery; therefore, crab culture completely depends on capturing sub-adult crabs from the wild (Lahiri et al., 2021; Rouf et al., 2021). Marine fisheries and technology station of BFRI is trying to develop a protocol for mud crab breeding, but the survival rate is very low (Hoq et al., 2014). Only one reported crab hatchery (Nowabeki Gonomukhi Hatchery in Shyamnagar in Satkhira) is in its initial stage; however, farmers believe that wild-sourced seeds are better than hatchery seeds (Ali et al., 2020). Crabbers collect crabs from the Sundarban mangrove forest channels, shrimp/prawn ghers, coastal canals, tidal rivers, and tributaries. Crabs are collected by hand picking or with the help of various gears such as bamboo trap, baited drop net, and hook using eel, tilapia, cuchia as bait (Bhuiyan et al., 2021). Mud crab is a continuous breeder with a peak breeding in March-April, and a second peak season was observed in August- September. The highest

Table 4. Disease of fry in fish hatcheries and drugs and chemicals used for treatment.

Disease	Causative agent	Chemicals and drugs with dose	References
Parasitic disease			
Ichthyopthiriasis	*Ichthyopthirius multifiliis*	• Formalin bath: 200 ppm for 1 hr • Sodium chloride bath: 2% solution • Quick lime: 200 kg/ha	(Faruk and Anka, 2017; Hossain et al., 2013)
Trichodiniasis	*Trichodina* sp.	• Formalin bath: 250 ppm for 3–5 min • Sodium chloride bath: 2–3% for 5 min • Potassium permanganate bath: 0.1% for 30 to 45 s	(Faruk and Anka, 2017; Hossain et al., 2013)
Ichthyobodosis	*Ichthyobodo necatror*	• Formalin bath: 1:4000 for 15–30 min	(Faruk and Anka, 2017)
Gill flukes	*Dactylogyrus* spp.	• Potassium permanganate bath	(Faruk and Anka, 2017; Samad et al., 2014)
Skin flukes	*Gyrodactylus* spp.	• Potassium permanganate bath	(Faruk and Anka, 2017; Samad et al., 2014)
Fish louse or Argulosis	*Argulus foliaceus*	• Dipterex: 0.2–0.3 ppm • Sumithion: 0.8 mg/L in pond • Potassium permanganate: 10 ppm for 5 h • Pillar sulfan: 3ml/decimal	(Faruk and Anka, 2017; Samad et al., 2014; Sharif and Abdulla-Al-Asif, 2015; Hossain et al., 2013)
Anchor worm or Lernaeosis	*Lernae* sp.	• Potassium permanganate: 4 mg/L in pond • Salt bath: 3% concentration	(Faruk and Anka, 2017; Samad et al., 2014)
Bacterial Disease			
Bacterial Infection	*Aeromonas*, *Pseudomonas*, *Vibrios* and *Flavobacterium*	• Aquamycine (Oxytetracycline HCL): 1–2 g/Kg feed	(Alam and Rashid, 2014; Faruk and Anka, 2017)
Motile aeromonas septecemia (MAS)	*Aeromonas hydrophila*	• Oxytetracycline: 1 g/Kg feed	(Hossain et al., 2013)
Streptococcosis	*Streptococcus iniae*	• Timsen aqua: 1g/4kg feed	(Hossain et al., 2013)
Bacterial gill disease	*Flavobacterium* sp.	• Malachite green: 3ppm	(Hossain et al., 2013)
Tail and fin rot	*Aeromonas* sp. *Pseudomonas* sp.	• Aquamycin (Oxytetracycline HCL) 1–2 g/kg feed • Pillar sulfan: 3ml/decimal	(Samad et al., 2014; Alam and Rashid, 2014; Hossain et al., 2013)
Dropsy	*Pseudomonas* sp.	• Potassium permanganate Dip bath 2 ppm • Forazine : 5g/ton feed	(Samad et al., 2014; Alam and Rashid, 2014; Hossain et al., 2013)
Fungal Disease			
Saprolegniasis	*Saprolegnia* sp.	• Malachite green: 2 ppm	(Faruk and Anka, 2017; Hossain et al., 2013)
Epizootic ulcerative syndrome (EUS)	*Aphanomyces invadans*	• Oxytetracycline: 1–2 g/kg feed • KMnO4: 2 ppm • Malachite green: 2 ppm • Lime: 1kg/decimal	(Alam and Rashid, 2014; Faruk and Anka, 2017; Hossain et al., 2013)
Viral Disease			
WSSV	White spot syndrome virus	• Zeolite: 200–250 g/decimal Bleaching powder 2–3 ppm Dolomite: 150 g/decimal • Lime: 0.5–1 kg/decimal	(Alam and Rashid, 2014; Hossain et al., 2013)
Infectious pancreatic necrosis (IPN)	Infectious pancreatic necrosis virus	• Destroy the infected stock • Rigorous cleaning followed by disinfection of all facilities and equipment	(Faruk and Anka, 2017)
Koi herpesvirus disease (KHVD)	Koi herpesvirus	• Destroy the infected stock • Rigorous cleaning followed by disinfection of all facilities and equipment	(Faruk and Anka, 2017)

Table 5. Chemicals and drugs used as antibacterial, antifungal, disinfectant, aesthetic, pesticide, and herbicide in fish hatcheries.

Chemicals and drugs	Dose	Use	References
Antibacterial agent			
Chloramphenicol	8–10 ppm or 50–200 g/100 kg feed/10 days	Stop possible infection of belonging to *Vibrio*, Aeromonas and *Pseudomonas* group	(Aftabuddin et al., 2009; Uddin and Kader, 2006)
Amoxicillin	1 g/1 kg feed		(Aftabuddin et al., 2009)
Ciprofloxacin	4–6 ppm		(Aftabuddin et al., 2009)
Erythromycin	12–20 ppm		(Aftabuddin et al., 2009)
Oxytetracycline	10–20 ppm		(Alam and Rashid, 2014; Aftabuddin et al., 2009; Uddin and Kader, 2006)
Prefuran	1–4 ppm		(Aftabuddin et al., 2009; Uddin and Kader, 2006)
Disinfectant			
Sodium hypochlorite	10–100 ppm	Disinfecting water, fish tank, filter, and equipment	(Aftabuddin et al., 2009; Yasmin et al., 2022)
Calcium hypochlorite	50–100 ppm	Foot bath	(Hossain et al., 2013)
Bleaching powder	20–50 ppm	Disinfection	(Yasmin et al., 2022)
EDTA	1–10 ppm	Cleaning tank	(Aftabuddin et al., 2009; Yasmin et al., 2022)
Formalin	25–100 ppm (15–30 min)	Washing and disinfecting	(Aftabuddin et al., 2009; Yasmin et al., 2022; Uddin and Kader, 2006, Hossain et al., 2013)
Alcohol	70%	Disinfecting hand	(Aftabuddin et al., 2009)
Iodine −PVP	20 ppm	Disinfecting equipment	(Aftabuddin et al., 2009)
Malachite green	0.0075 ppm	Antifungal agent	(Uddin and Kader, 2006)
Potassium permengate	2.5–5 ppm	Antifungal agent	(Uddin and Kader, 2006)
Methelene Blue	8–10	Antifungal agent	(Uddin and Kader, 2006)
Copper sulphate	5–25 mg/L	Water quality management	(Uddin and Kader, 2006)
Lime	1 kg/decimal	Health and water quality management	(Alam and Rashid, 2014)
Salt	1 kg/decimal	Health and water quality management	(Alam and Rashid, 2014)
Anaesthetics			
Quinaldine	5–10 ppm	Fish transportation	(Yasmin et al., 2022)
Methyl quinoline	1 ml to 13.5 L water	Fish transportation	(Hossain et al., 2013)
Pesticide			
Rotenone	20–30 g/decimal	Killing predatory fish	(Hossain et al., 2013; Yasmin et al., 2022)
Sumithion	2–3 l/decimal	Killing predatory fish and insect	(Yasmin et al., 2022)
Malathion	2–3 ml/decimal	Killing predatory fish and insect	(Yasmin et al., 2022)
Dipterex	6–12 ml/decimal	Killing predatory fish and insect	(Yasmin et al., 2022)
Herbicide/algicide			
Anhydrous ammonia	12 ppm	Controlling algae and plankton bloom	(Yasmin et al., 2022)
Copper	2 ppm	Controlling algae and plankton bloom	(Yasmin et al., 2022)

abundance of crablets (1 to 2 months of age) was recorded in May–June and the lowest in January–February during winter (Ali et al., 2020). Due to the increasing demand in the national and international market, approximately 300,000 people are directly and indirectly involved in mud crab collection and cultivation activities in the Khulna region. About 90% of exported crabs come from natural sources, and the rest are from crab-fattening farms (Bhuiyan et al., 2021). The continued pressure on the species could result in a decline in its natural stock. The crab fishery has come under heavy fishing pressure in recent years and is considered overexploited (Hoq, 2007). Therefore, it is necessary to develop artificial breeding techniques to improve the sustainability of this species. Availability of crab seed from a hatchery will reduce pressure on the natural crab sources and increase crab seed availability for the commercial culture and fattening, leading to higher production.

11 Constraints and challenges in seed production

Hatchery owners face technical, economic, social, and regulatory constraints when producing fish seed (Fig. 7). Due

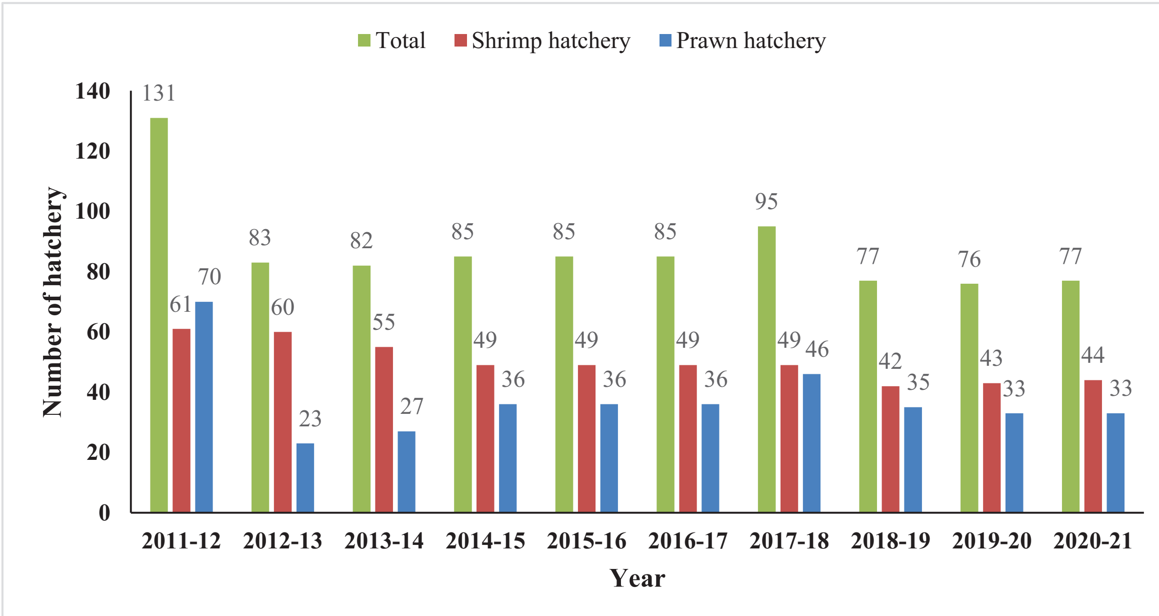

Fig. 6. Number of shrimp and prawn hatcheries in operation in Bangladesh from 2011–12 to 2020–21 (Adapted from DoF, 2022).

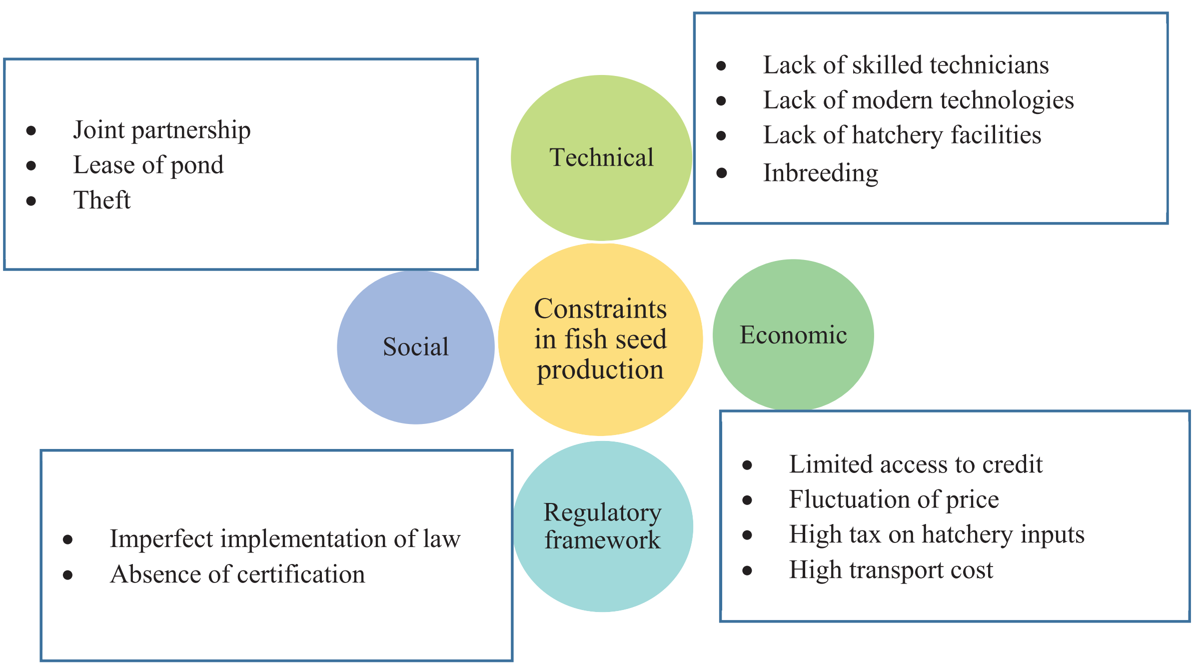

Fig. 7. Constraints and challenges in seed production.

to the lack of training, there is a shortage of skilled technicians in hatcheries. Rahman et al. (2007) reported that only 25% of the nursery operators in Jessore district received training from the Department of Fisheries (DoF) and the Department of Youth Development (DYD), and the rest had no technical knowledge. Furthermore, no modern technologies have been used in fish seed production. Hatchery operators also reported about lack of hatchery facilities such as, drainage facilities, insufficient water in the dry season, inadequate ponds to raise brood fish, inadequate sanitary facilities, and unhygienic conditions in the production and rearing area (Biswas et al., 2008; Hemal et al., 2017; Islam et al., 2017c). Lack of morality among hatchery owners is a significant obstacle in good quality seed production. The poor quality of feed inputs and hormones used for fish sex reversal affects their ability to produce quality seed (Shikuku et al., 2021). Most hatchery owners do not pay attention to genetic background and variability, breeding protocols, and practices in broodstock management and hatchery operation. Sometimes, they use the same age group probably including male and female sibs as broods for induced breeding. As a result, problems such as inbreeding, growth stagnation, and small fish production occurred, and fish culturists showed particular interest in natural fish seed (Islam et al., 2017c). The better performances of the wild seed stock can be attributed to the high genetic diversity in the free-living natural fish population, the resilience against diseases, and the high rate of survivability (Hossain et al., 2022). Lack of capital is a vital problem in developing the hatchery business, as stated by the operators. High taxation on feed, hormones, and other inputs were identified as the main reason for the exorbitant cost (Shikuku et al., 2021). They have little access to institutional credits operated by a few commercial banks in Bangladesh (Rahaman et al., 2007). Theft, joint partnership, and pond leasing are also constraints in hatchery operations (Hemal et al., 2017). Poor implementation of regulatory frameworks, including the Fish Hatchery Act 2010 and Rules 2011, absence of a certification scheme for hatcheries are the main reasons for unfair competition between unregistered hatcheries and brokers (Shikuku et al., 2021). Siddique et al. (2022a) reported that climate change such as temperature fluctuation, erratic rainfall, and solar radiation is becoming a major concern of hatchery owners for the productivity of fish hatchery. Climate change due to geographical location of Bangladesh can impact the embryonic development and impair maturation and breeding performance of broodstock (Siddique et al., 2022b).

12 Conclusion

The primary source of Bangladesh's fish seed production is the fish hatcheries. High grade fish seed is still not readily available, despite the fact that fish hatcheries produce a lot of fish. Establishment of hatcheries for commercially important marine species can boost up marine fisheries production. Economic success and hatcheries' expansion are being hampered by a production and supply chain that is dominated by middlemen, disease-induced mortality, indiscriminate use of medications and chemicals, and social, technological, economic, and legal restrictions. Complete management measures are needed to increase the quantity and quality of fish seed in Bangladesh for sustainable aquaculture production.

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Authors contribution

Md. Rabiul Islam was responsible for the experiment's conception and design, as well as for the preparatory writing and statistical analysis. The manuscript was written and edited by all contributors.

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Data availability

The data used to support the findings of this study are included within the article.

Conflict of interest

The authors declare that they have no conflict of interest.

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