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Production and Culture Scenario of Striped Catfish (*Pangasianodon hypophthalmus*, Sauvage, 1878) in India

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Abstract

India's *Pangasianodon hypophthalmus* catfish farming is on a steady rise, harnessing its abundant potential and extensive resources, which include vast land areas, specialized expertise and rich indigenous cultural knowledge. In the fiscal year 2020-2021, the nation achieved an impressive total fish production of 162.48 lakh tonnes, with the aquaculture sector playing a pivotal role by contributing 121.21 lakh tonnes to this remarkable figure. Noteworthy is the significant individual contribution of catfish (*Pangasianodon hypophthalmus*), accounting for 4.32 lakh tonnes. These statistics underscore the crucial and prominent role that catfish farming plays in driving India's thriving aquaculture industry. This article covers an overview of the current condition and features of striped catfish in India, as well as the breeding status and seed production methods and larvae rearing.

Keywords: Breeding, Exotic species, Seed rearing, Striped catfish

Introduction

In the fiscal year 2021-2022, India achieved a noteworthy fish production of 16.24 million tonnes. This impressive output reflects the significance of the fisheries sector, contributing approximately 1.1% to the overall Indian GDP and comprising 6.27% of the agricultural GDP of the country (Anonymous, 2022). The Asian striped catfish (*Pangasianodon hypophthalmus*) has gained recognition as a prominent tropical fish species in the realm of aquaculture exports. The Mekong River basin is the natural habitat of this freshwater fish species, encompassing countries such as Cambodia, Vietnam and Thailand. However, in 1997, *P. hypophthalmus* was introduced to West Bengal, India, by crossing over from Bangladesh (Mukai, 2011). The projected aquaculture production of *Pangasianodon hypophthalmus* ranges from 8,20,000 to 15,00,000 tons (Singh and Lakra, 2012). Additionally, the estimated annual seed production of Pangasius from West Bengal ranges from 1000 to 1500 million; further highlights the region's importance in this sector (KUFOS, 2022).

The species is widely distributed, with over 100 countries participating in the trade of its fillets, predominantly across Asia, Russia, Southeast Asia, the United States and the European Union (Nguyen, 2009; Phan *et al.*, 2009; Phuong and Onah, 2010). *Pangassius* sp., also referred to as the river catfish, silver-striped catfish, siamese shark, swai catfish and sutchi catfish, belongs to the Pangassidae family. This riverine catfish demonstrates rapid growth when raised in a healthy environment, making it a sought-after species for aquaculture. Its cultivation is driven by several factors, including its high market demand, fast growth rate and its dominant position in aquaculture production, where it ranks as the third most significant freshwater catfish in the industry. Pangassius culture has gained popularity in various countries worldwide, with nations such as Nepal, Pakistan, Bangladesh, Thailand, Indonesia, Laos, Myanmar, India, Cambodia and Vietnam actively practicing and participating in its cultivation. The air-breathing striped catfish, known for its ability to survive in low levels of dissolved oxygen (DO) in water, can be successfully raised in concrete tanks, fish cages, ponds and pens. Its aquaculture is rapidly expanding

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in countries like India, Vietnam, Bangladesh and Indonesia, as evidenced by the increasing interest and development in this species (Kumar *et al.*, 2013; Griffith *et al.*, 2010; Phan *et al.*, 2009; Bui *et al.*, 2010; Ahmed *et al.*, 2013). Initially, the cultivation of this species in India was primarily in the private sector, with operations in West Bengal and Andhra Pradesh. However, starting from 2010-2011, the Indian government granted official approval for *P. hypophthalmus* aquaculture, signaling a more formal and widespread adoption of this practice. The introduction of striped catfish (*Pangasianodon hypophthalmus*) to Andhra Pradesh dates back to 1995 when seed sellers from West Bengal, India, brought the species to the region (Singh and Lakra, 2012). Primarily, it was incorporated into the Indian main polyculture system with carps. Still, its superior growth and production rates have led to a shift towards monoculture, where it is now cultivated exclusively due to its faster growth and higher productivity.

Objective of the Study

The objective of the study is to comprehensively analyze and present the production and cultural scenario of Striped Catfish (*Pangasianodon hypophthalmus*, Sauvage, 1878) in India.

This research aims to investigate the current status of Striped Catfish aquaculture in India, including its production practices, cultural techniques and associated challenges. By examining the existing trends and constraints, the study seeks to provide valuable insights and recommendations to enhance the sustainable growth of the Striped Catfish industry in the country. The research will contribute to the scientific knowledge base and offer valuable information for policymakers, aquaculture practitioners and stakeholders, aiding in the development of effective strategies for improving productivity, profitability and environmental sustainability within the Striped Catfish production sector in India.

Why Striped Catfish (*Pangasianodon hypophthalmus*)?

A rare species of freshwater catfish called striped catfish (*Pangasianodon hypophthalmus*) (Family: Pangasiidae, Class: Actinopterygii, Order: Siluriformes) was brought into Indian water and is now cultivated in all over India for a number of purposes, including:

(i) Less cost of production,

(ii) Fast growth rate (attains 1.5 kg in 6 months),

(iii) Sustain DO stress and other factors.

Less intermuscular bones in the meat of Pangasius (*P. hypopthalmus*) were thought to be a factor in consumer choice. The Indian government created criteria in 2009 to formally admit the pangasius culture to Indian waters (Seshagiri *et al.*, 2021).

Reproductive Biology of *Pangasianodon hypophthalmus*

Sexual Dimorphism

When selecting males and females for breeding purposes, it is crucial to ensure that they are generally in good health and devoid of any evident injuries or abnormal symptoms. The females, in particular, should exhibit large bellies, delicate abdominal skin, swelling, reddish genitalia and fully developed ovarian follicles. Determining the maturity state can sometimes be challenging based solely on external characteristics, so an intraovarian biopsy using a flexible catheter is often employed to monitor oocyte growth. This biopsy method allows for a more accurate assessment of the maturation process.

In well-matured broodstock males, applying slight pressure on the abdomen should prompt the release of milt. Moreover, the oocytes in such males should have a diameter ranging from 1.0 to 1.1 mm. These indicators help ensure the selection of appropriate candidates for successful breeding and reproduction.

Age at First Sexual Maturity

This fish species, which is benthopelagic, has a maximum standard total weight of 44 kg and could reach 130 cm. In its natural habitat, it thrives within pH (6.5 to 7.5) and temperature range from 22 to 26 °C (Griffith *et al.*, 2010).

Males of this species usually attain sexual maturity in their second year, a timeframe consistent with their counterparts living in the wild. However, females typically require three years to reach sexual maturity when raised, in captivity, it need to attain a minimum weight of over 3 kg before they become ready for reproduction.

Spawning Season

As per nature's cycle, the peak breeding period for this species occurs between May and July, coinciding with the beginning of monsoon season (Bui *et al.*, 2010). During this time, environmental conditions are favorable for the fish to engage in reproductive activities, contributing to their natural breeding patterns.

Fecundity

P. hypophthalmus is known for its high fertility and follows an annual spawning pattern, typically occurring during the period when the river experiences flooding. According to Datta and Ansal (2020), the species exhibits a relative fecundity ranging from 0.80 to 0.95 lakh eggs kg^{-1} of body weight. Additionally, its average stripping fecundity is recorded to be around 0.50 to 0.65 lakh eggs kg^{-1} of body weight. This prolific reproductive capacity contributes to the species' ability to sustain its population in its natural habitat.

Eggs and Incubation Period

The eggs of *P. hypophthalmus* display distinct characteristics. Unfertilized eggs have an opaque white appearance, while fertilized eggs appear transparent. Initially, before fertilization, the egg's diameter ranges from 1.0 to 1.20 mm and following fertilization and water hardening, it increases to 1.10 to 1.30 mm.

The incubation period for these striped catfish eggs is influenced by the temperature of the environment. At a temperature of approximately 27.33 °C, the eggs typically take around 30 to 36 hours to complete the incubation process (Datta and Ansal, 2020). During this time, proper temperature management is essential to ensure successful hatching and the development of healthy fry.

Artificial Propagation

Brood Stock Development

P. hypophthalmus juveniles, measuring approximately 2.93 cm in length and weighing around 0.25 g, can be successfully reared in a 700 m^2 earthen pond during the summer months (April to November). The recommended stocking density is 3 juveniles m^{-2}. Over the four-year overwintering period, the fish can be cultivated to develop a healthy brood stock, with a remarkable 100% survival rate during the overwintering phase. To ensure the successful overwintering of the brood stock, the water temperature within the poly house should be maintained at a range of 22.5 °C throughout this period. The appropriate fish diet comprises floating feed containing 28.0% crude protein based on its dry weight. This feed can be supplemented with rice bran (30%), deoiled groundnuts (30%), fish meal (13%), deoiled soybeans (25%) and vitamin-mineral mixture (2%). During the overwintering period, the fish should be fed twice daily, in two divided doses, amounting to 2% of their body weight (BW) between the hours of 9:00 AM and 5:00 PM. To ensure the optimal rearing conditions for the brood stock, it is vital to maintain the recommended range of physico-chemical properties for the water in the rearing pond. Table 1, as stated by Bhatnagar and Devi (2013), provides the appropriate guidelines for these parameters.

Table 1: Water quality parameters for brood stock rearing pond

Water parameters	Range
Temperature	22 to 30 °C
pH	7.01-7.14
Dissolved Oxygen	2.5-7.5 ppm
Alkalinity	50-150 ppm
Hardness	75-200 ppm
Ammonia - Nitrogen (NH_3-N)	0.039-0.127 ppm
Phosphate - Phosphorus (PO_4-P)	0.018-0.944 ppm
Nitrate - Nitrogen (NO_3-N)	0.198-0.75 ppm

(Source: Bhatnagar and Devi, 2013)

Induced Breeding

In the process of induced breeding practices for *P. hypophthalmus*, skilled technicians delicately extract mature female and male brood fishes from the rearing pond, employing a seine net for the task. These carefully selected individuals are then transferred to a designated breeding tank. The selection of ripe fishes for breeding is based on a thorough physical and visual assessment of certain features, including the belly, pectoral fin and genital aperture, as described by Hossain *et al.* (2021). Males that release milt with mild pressure on the abdomen and females with a visibly swollen abdomen, displaying a pinkish coloration due to the presence of eggs, are considered suitable for breeding. To induce spawning, an injection is administered below the dorsal fin. Pituitary glands from Indian big carps, preserved in 100% alcohol and refrigerated, can be used to produce pituitary extract (PE), which is utilized in the breeding process. For female brood fishes, a priming dosage of 2.5-3.0 mg PE kg^{-1} of body weight (BW) is given before breeding. After six hours, a second resolving dose of 10-12 mg PE kg^{-1} BW is administered. Male brood fishes, on the other hand, receive a single dosage of 2.5-3.0 mg PE kg^{-1} BW at the same time as the females receive their resolving dose. This carefully managed induction process is essential for successful breeding and reproductive success in *P. hypophthalmus*. For induced breeding in *P. hypophthalmus*, synthetic hormones like ovaprim are commonly used. To initiate the breeding process, female brooders should be supplied with 0.5 ml of ovaprim kg^{-1} of their body weight (kg^{-1}), while male brooders receive 0.3 ml of ovaprim kg^{-1}.

Following the hormone injection, it is crucial to house the male and female fish separately in individual tanks. These tanks should have a continuous showering system in place to simulate a rainy environment, which encourages spawning behavior in the fish. To prevent the fish from jumping out, the tanks must be securely covered. Additionally, an outlet should be provided for excess water drainage to maintain optimal water conditions. Females will typically be ready for stripping, a process of gently squeezing the eggs from the female's belly, approximately 12 to 17 hours after the hormone injection (Chakraborty, 2021). This carefully managed breeding process helps ensure successful fertilization and the production of healthy offspring.

To collect eggs, the ready-to-spawn female fish should be stripped and the eggs should be accumulated in a plastic bowl or enamel tray (Figure 1b). Milt from male fish can be obtained by gently pressing on the male's abdomen (Figure 1a). When stripping, it is necessary to dilute the sperm in a 0.9% NaCl solution at a five-fold ratio. To reduce the stickiness of the eggs, 1% tannin can be used. Using a soft and clean feather, thoroughly mix the eggs and milt in the plastic dish (Figure 1c). Add a few drops of water to the bowl and keep swirling it continuously for 5-6 minutes. Following this step, these eggs should be cleansed multiple times with freshwater. Subsequently, the cleaned eggs are transferred to separate hatching jars equipped with a constant water circulation system to promote proper incubation and hatching of the fry. This carefully managed process ensures the successful development of healthy fry from the fertilized eggs.

During the incubation period, it is essential to carefully control the water flow in the hatching jar, maintaining a flow rate of 600-800 ml $minute^{-1}$. Under optimal temperature conditions ranging from 26 to 31 °C, the eggs will hatch within 22 to 25 hours after fertilization. The hatching process itself takes approximately 2.0 to 4.0 hours. To ensuring the well-being of the hatchlings requires the timely removal of unfertilized eggs and eggshells from the hatchling jar within the first hour after hatching. This precautionary measure helps protect the larvae from fungal infections

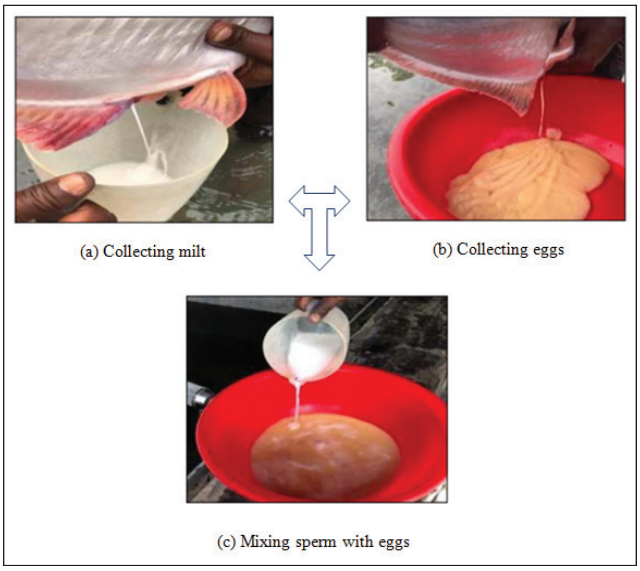

Figure 1: Stripping procedure for the induced breeding: (a) collecting milt, (b) collecting eggs, (c) mixing sperm with eggs (Source: Chakraborty, 2021)

(Chaturvedi *et al.*, 2015). Starting from the egg fertilization stage, the early developmental stages of the striped catfish (*P. hypophthalmus*) should be closely monitored for up to 72.0 to 74.0 hours. To feed the newly hatched larvae, a thin egg yolk emulsion should be added to the water. For better genetic diversity, it is advisable to collect and release larvae from various parent couples into nursery ponds (Chaturvedi *et al.*, 2015). This approach helps enhance the overall health and robustness of the fish population during the early stages of development.

Larval Rearing

During the larval rearing process of *P. hypophthalmus*, hatcheries are a common practice. However, to ensure successful development, the larvae are often transferred to a separate nursery pond after hatching, distinct from the main hatchery facilities. This separation is mainly due to the fish's cannibalistic tendencies, particularly in the first week after hatching. To prevent significant mortality resulting from cannibalism, commercial nursing of the larvae-to-fry and fry-to-fingerling stages takes place in earthen ponds. These earthen ponds provide a more natural and spacious environment, allowing for better management and control of potential cannibalism among the fish. This method helps increase the survival rate and overall success of the larval-rearing process, contributing to the production of healthy fry and fingerlings for subsequent stages of fish farming.

Nursery Pond Construction

On-stream and on-canal nursery ponds are preferred for larval rearing and nurturing of fry and fingerlings because they offer several advantages. These types of ponds facilitate better water exchange and allow for more efficient transfer of fry and fingerlings, enhancing the overall health and growth of the fish. The preferred shape for ponds in such cases is generally one with a width-to-length ratio of 4:3. It is advisable to have a pond area ranging from 1000 to 5000 m^2, accompanied by a water depth of 1.5 to 2 m. For efficient water flow and exchange, the pond's inlet and outlet are designed with a diameter of 20 to 40 cm. These inlets and outlets are strategically located on opposite sides of the pond, depending on the pond's size and layout. Such design considerations contribute to maintaining optimal water quality, ensuring a suitable environment for the successful rearing of fry and fingerlings.

Pond Preparation

To facilitate stocking, nursery fishponds exclusively designed for nurturing larvae to fry undergo a series of vital steps aimed at enhancing the growth of live food organisms. The pond preparation entails essential measures like eliminating bottom muck, applying lime to the pond at a rate of 10-15 kg per 100 m^2 and allowing the pond bottom to dry for a period of 3-5 days. Furthermore, all unwanted species are carefully eliminated from the pond to create a favorable environment for the fry. In situations where complete drainage of the pond is not possible, alternative methods can be employed. For example, the use of 0.5-1 kg per 100 m^2 of derris root (*Derris elliptica*) saponin derivatives or rotenone (1 kg for 300-500 m^3) can effectively eliminate harmful species from the pond. The water supplied to the fishpond is of utmost importance and must be of high quality.

Key parameters, such as dissolved oxygen (3 ppm), pH (6.4-8.5) and the absence of toxicants, must be closely monitored. To prevent the entry of unwanted organisms' eggs and larvae, a fine mesh is used to screen the incoming water. Water level management is essential and the pond's water is often maintained at a height of one meter. To ensure water quality, treatment with chlorine (1 kg per 1000 m^3) or formalin (25 ppm) is conducted. However, chlorine is more commonly used due to its cost-effectiveness. These measures collectively contribute to creating a healthy and conducive environment for the successful nurturing of fry in the nursery fishponds.

Larvae to Fry Nursing

Indeed, striped catfish larvae are known for their cannibalistic behavior, which can lead to a low survival rate during the early stages of larval rearing. To improve the chances of survival and minimize mortality, certain practices are essential.

Firstly, maintaining a low stocking density is crucial. Overcrowding can exacerbate the cannibalism behavior and lead to higher stress levels among the larvae, which negatively affect their health and growth.

Secondly, the development of natural feed in the rearing water is essential. Providing suitable live food sources for the larvae can help divert their cannibalistic tendencies. By ensuring an abundance of natural prey, the larvae are less likely to turn to each other as a food source.

These measures play a vital role in promoting a healthier and more successful rearing environment for striped catfish larvae, ultimately contributing to a higher rate of survival during the critical early days of breastfeeding.

Stocking

Feeding live food to striped catfish larvae is crucial within the first 24 hours after hatching. The larvae should be promptly transported to rearing tanks or ponds during this critical period. High-quality larvae exhibit uniform size, active swimming behavior and a lack of abnormalities. They also display quick responses to external stimuli, indicating their health and vitality.

In pond rearing, larvae are usually stocked at a density ranging from 500 to 800 larvae m^{-2}. Nevertheless, Bui *et al.* (2010) reported that farmers commonly employ a broader range of stocking densities, spanning from 250 to 2000 larvae m^{-2} and the average density used is 863 larvae m^{-2}.

In order to safeguard the larvae's well-being during transit, specially designed bags with oxygen are employed, holding 5000-8000 larvae $litre^{-1}$ of water. The transportation takes place either in the early morning hours (7:00-10:00 AM) or late afternoon, as this timing prevents direct sunlight exposure, which could prove detrimental to the larvae. Upon reaching the rearing pond, the larvae undergo a gentle acclimation process by leaving the bags in the pond for 15-30 minutes before being released into their new environment. This acclimation process allows the larvae to adjust gradually to the new environment and improves their chances of successful adaptation and survival in the rearing pond.

First Feeding

Approximately two days after hatching (or 48 hours), striped catfish larvae display exogenic feeding behavior. Interestingly, even though their yolk is not completely absorbed and their digestive tracts are not fully functional at this stage, they still engage in feeding activities. For optimal development and growth during this critical period, live food organisms are essential. In tank rearing conditions, larvae are commonly fed with high amounts of *Artemia nauplii*, Tubifex and Moina, while gentle aeration is provided to ensure a suitable feeding environment. In pond rearing conditions, promoting the growth of natural food sources through pond fertilization is crucial. Additionally, supplementary stocking of zoobenthos species such as Tubifex, Artemia and Moina, along with zooplankton, plays a vital role in increasing larvae survival rates.

Among the live food options, Artemia stands out as an excellent initial meal for striped catfish larvae, providing the best growth performance, as reported by studies conducted by Hung *et al.* (2002). Proper feeding practices are fundamental during this stage of development to support the healthy growth and successful rearing of the striped catfish larvae.

Pond Management

The water quality and larval behavior in the nursery ponds must be regularly examined, ideally every morning, to ensure a healthy and suitable environment for the striped catfish larvae. Maintaining the water color similar to that of a banana leaf (green hue) is important for the well-being of the larvae. Predators such as frogs, snakes, insects and carnivorous fish pose a threat to the larvae and should be monitored regularly. Measures should be taken to prevent or minimize their access to the ponds. Achieving this can be done by employing a light source on the surface of the pond during the evening. This will effectively lure and gather hazardous insects such as dragonfly larvae and Notonecta. A net barrier should be installed to prevent frog invasion and tadpoles should be removed from the water surface on a regular basis during the nursing stage.

To prevent water quality degradation, overfeeding should be avoided. Proper feeding practices and control are essential to maintain good water quality.

After heavy rain, lime, such as dolomite or $CaMg(CO_3)_2$, $CaCO_3$, should be applied at a rate of 3-5 kg per 100 m^2 pond to counteract any potential water quality issues. Around 20-45 days after stocking, the larvae will have developed into fry, with a density of 3000-4000 fry kg^{-1}. At this stage, the fry might be categorized and moved to different fishponds for further nurturing until they reach the fingerling size.

It is important to note that the larval-to-fry survival rate ranges between 30 to 50% and diligent management practices are crucial to enhance the overall success and productivity of the nursery rearing process.

Fry to Fingerling Nursing

In the nursery farms, the fry of striped catfish are nurtured to fingerlings in clay ponds. It is common to have ponds that serve the purpose of nursing both fingerlings and fry, as these ponds have similar features suitable for the growth and development of the fish. After spending approximately 20 to 45 days in the nursing ponds, the fry are collected. At this stage, they have developed into fingerlings. Depending on the farm's requirements, these fingerlings may be sold to other nursery farms or shifted to separate fingerling nursing ponds.

This practice of nurturing fry to fingerlings in clay ponds allows for efficient management and development of the fish at different steps of their life, contributing to the successful production and supply of healthy fingerlings for further aquaculture purposes.

Stocking

In the process of nurturing fry to fingerlings, it is crucial to ensure that the fry are in good health and exhibits certain characteristics. Healthy fry should exhibit vigorous swimming behavior, exhibit no indications of illness or physical harm and maintain a consistent size. The stocking density of fry in the fingerling nursing ponds typically ranges between 200 and 300 individuals m^{-2}. This stocking density is carefully managed to provide sufficient space and resources for the fry to grow and thrive. However, despite proper care and management, it's important to note that between 40 and 50% of the fry may survive to become fingerlings. The survival rate is subject to fluctuations influenced by several factors, such as environmental conditions, feeding practices and overall health management.

Maintaining the health and well-being of the fry and providing them with an appropriate environment are key factors in increasing the survival rate and ensuring successful development into fingerlings for further aquaculture purposes.

Feed and Feeding

During the fingerling nursing stage, the fry are provided with pelleted feeds tailored to their specific size and nutritional requirements. These feeds typically contain 30-45% crude protein, ensuring that the fingerlings receive the necessary nutrients for optimal growth and development. Feeding rates are carefully managed and range from 6 to 8% of the fingerlings' body weight day^{-1}. These feeds are administered through two or three feedings day^{-1}, providing a consistent and balanced diet to support their healthy growth. To optimize the nutritional content of the feeds, standard practice involves incorporating nutrient supplements like Bio-Mos (at a rate of 2 kg ton^{-1} of feed) and vitamin C (at a rate of 1-2 kg ton^{-1} of feed) during the nursing period. These enhancements help fortify the feeds with additional beneficial nutrients, promoting the overall health and immune system of the fingerlings. By carefully monitoring their feeding regimen and incorporating nutrient enhancements, farmers can ensure that the fingerlings receive a well-balanced diet, leading to better growth rates and improved survival during the nursing period.

Larvae to Fingerling Nursing

Raising larvae into fingerlings in earthen ponds employs comparable methods to those employed in nurturing larvae to fry and fry to fingerling stages. The typical stocking density during this stage is 724 individuals m^{-2}, ensuring ample space and resources for the healthy development of the growing fingerlings. The nursing period typically lasts around 2.72 months, which falls within the range of 2.5 to 3 months. During this time, the fingerlings continue to receive appropriate feeding and care to support their growth and development. However, the survival rate of the fingerlings can vary depending on the season. In the peak season, which usually occurs between March and May, the survival rate is relatively higher, ranging from 15-20%. In contrast, during the remaining months, the survival rate tends to be lower, ranging from 5-7%. This variation in survival rates is likely affected by reasons for instance water temperature, natural food availability and other environmental conditions, which can impact the overall health and growth of the fingerlings during the nursing period. Proper management and care during this stage are essential to maximize the survival and successful development of the fingerlings into healthy and robust fish for future aquaculture activities.

Harvesting and Transportation

Seining is a common method used to gather fry and fingerlings from the ponds. Prior to harvest, the ponds are interrupted three to four days in advance to train the fish and familiarize them with transportation conditions. Once gathered, the seined fish are sorted within a pond before being transported to the designated transportation facilities, such as bags or boats. Fish transportation involves utilizing hapas to house groups of fish of consistent size. Smaller fry are transported in oxygenated polyethylene bags, while larger fish are carried in aerated composite tanks using open transport methods. To ensure the well-being of the fish during transit, regular salt treatment may be applied before or during transportation. The transit duration can vary from 6 to 25 hours, depending on the destination. For fingerlings weighing 30-33 grams, the recommended stocking density is 3 fish litre^{-1} of water and for fingerlings weighing 14-16 g, the stocking density is 6.0-6.5 fish litre^{-1} of water. To maintain water quality during shipment, it is advised to change the water every six hours, with approximately 20-30% water renewal in the transportation containers.

By implementing these transportation practices, the fish can be safely and efficiently transported to their intended destinations, ensuring minimal stress and maintaining their health for further aquaculture activities.

Seed Production of *P. hypophthalmus* in India

West Bengal has emerged as the primary centre for Pangasianodon hypothalamus seed production in India. While Andhra Pradesh takes the lead in exporting *P. hypophthalmus* seeds among the states, other states like Bihar, Chhattisgarh, Kerala, Rajasthan, Uttar Pradesh and Karnataka also contribute to this trade. The production of *P. hypophthalmus* seeds serves both aquaculture purposes and the aquarium trade. In pond-cultured Pangasius, the yearly production ha^{-1} can vary from 7 to 50 tonnes. The significant fish seed production in West Bengal has played a pivotal role in facilitating the expansion of Pangasius aquaculture in Andhra Pradesh. West Bengal's fish seed traders have been instrumental in meeting the demand for 2 billion Pangasius seeds required by Andhra Pradesh, which were sourced from hatcheries across borders. This collaboration has been crucial in supporting the aquaculture industry and promoting the growth of Pangasius farming in the region.

In terms of expenses, seed acquisition constitutes a significant portion, accounting for about 12 to 14% of the overall crop costs. To address this challenge, a *Pangasianodon hypothalamus* hatchery and seed production facility was established in Andhra Pradesh, resulting in a successful demonstration of commercial-scale Pangasius seed production. This development has significantly reduced the dependence on West Bengal for seeds, with a notable 30% decrease. The establishment of a prominent commercial hatchery facility in the private sector in Andhra Pradesh in 2018 played a pivotal role in achieving this outcome. This shift has played a vital role in enhancing the self-sufficiency and sustainability of Pangasius aquaculture in Andhra Pradesh, allowing for increased domestic seed production and reduced dependency on external sources.

Conclusion

The culture of *Pangasianodon hypophthalmus* in India has experienced significant success over the years with advancements in culture techniques, brood fish rearing, seed production technologies and improved feed and transportation facilities. In addition, it appears that greater integrated nutrient reuse, whether in pond soil or discharged water, could further improve the sustainability of current culture systems. This study identifies and highlights various aspects of cultural practices, breeding status, seed and larval rearing techniques for this species. This article also presents the emerging picture of increasing pangasius production through intensive unmanaged intensive cultural practices and helps in drawing the attention of scientists and decision-makers to the need to develop pangasius culture practices that are environmentally sustainable and to improve culture technology in order to have quality fish production while keeping in mind international standards and consumer preferences. Overall, this effort will contribute to building a solid knowledge base for the country's other forms of aquaculture as well, helping to promote and control technologically sound cultural practices for striped catfish.

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