Maximizing the Potential of Stunted Fish Fingerlings through Innovative and Sustainable Aquaculture Practices for Enhanced Growth and Production.

ABSTRACT

Aquaculture is an important industry for national economies, but it needs to improve its survival rates through increased technology awareness. Stunted fingerlings, obtained from aged fish, are a practical alternative for stocking in aquaculture due to their higher survival rates and disease resistance. Farmers can produce stunted fish fingerlings by rearing fish at a higher stocking density and feeding them with natural food for a prolonged period.

Farmers use a supplementary feed mixture of Soya Bean Cake, Ground Nut Oil Cake, Rice Bran, and Fish Meal to promote optimal growth. Using feed bags to reduce waste can also help ensure proper growth and reduce costs. Stunting of fish fingerlings has been shown to improve growth and survivability in grow-out ponds, resulting in higher yields. Access to quality fingerlings, market demand, and best management practices are critical for success. Stunted fingerlings could be a practical solution to address the problems of limited fingerling availability and high production costs in aquaculture. Multiple stockings and multiple harvesting are cost-effective methods to increase fish production and enhance pond productivity. Farmers need to follow best management practices and implement sustainable practices to minimize environmental and community impacts.

Keywords: [Aquaculture, Stunted fingerlings, Sustainable practices, Best management practices, multiple stockings.]

1. INTRODUCTION

Fisheries and aquaculture are important for food, nutrition, and employment worldwide. However, they face many challenges, such as managing fish stocks sustainably and responsibly, adapting to climate change impacts, ensuring fair benefits for fishers and fish farmers, reducing environmental impact, and improving access to markets, finance, and technology. We need a collaborative and integrated approach that involves all stakeholders to address these challenges. This approach should include better governance and regulation, responsible and sustainable practices, research and innovation, and support for small-scale fishers and fish farmers. This way, fisheries and aquaculture can provide vital resources and opportunities for communities worldwide [1,2].

Stunting is a phenotypic change that can occur in various fish species, including tilapia, catfish, and carp. The development of individuals in stunted populations may be influenced by various ecological factors, such as increased survival from reduced predation and decreased food availability [3,4]. Stunted yearlings have slow growth rates, early maturation, small size, and density-dependent mechanisms that restrict their growth. However, their diminished maximum size has yet to be genetically determined. They are suitable for stocking in ponds or tanks, as they have higher survival rates, are disease-resistant, and can withstand environmental fluctuations, leading to higher yields and income [5].

Adopting the method of multiple stocking and multiple harvesting (MSMH) in composite fish farming can significantly increase fish production by up to 6-10 tons per hectare per year. This method is cost-effective and suitable for small and marginal farmers who can manage the pond for a maximum period of 4 months and start earning within this period, reinvesting the profits for further fish rearing. MSMH also enhances the primary productivity of the pond by releasing noxious gases and mixing bottom nutrients with surface water [6].

Aquaculture can make a significant contribution to the national economy and create livelihoods for a large number of people in the country. By adopting new technologies, such as MSMH, fish production can be increased significantly, making the practice more sustainable and cost-effective.

2. WHAT IS A STUNTED FISH FINGERLING?

The Stunted fish seeds are aged and arrested from attaining their proper growth and development due to high density and minimum food available. Stunted fingerlings refer to juvenile fish raised in conditions that lack adequate nutrition or space to grow to their full potential. As a result, they remain small in size and need to reach their intended market weight. Fish require various factors, including adequate pond size, a balanced and appropriate diet, proper water conditions, and compatible fish species, to thrive and grow properly. However, when these factors are not met, it can affect their growth and overall health, leading to stunted growth. Several stressors can impact fish growth and lead to stunting. Crowding and inadequate nutrition are significant stressors in aquaculture practices

[7,8]. These stressors can cause physiological changes in fish, including their defence system [9]. Due to its intensification, diseases have become a significant problem in aquaculture [10, 11].

Recent studies suggest stunted carp fingerlings improve growth and survival when stocked in rearing ponds with optimal conditions [12,13]. These highlights the importance of providing suitable living conditions for fish to prevent stunting and ensure optimal growth and survival rates.

The available information suggests the improved performance of stunted carp fingerling in terms of growth and survival when stocked in rearing ponds with optimal conditions.

3. WHY STUNTED FISH FINGERLING

Stunted fingerlings have become a topic of increasing interest among researchers and fish farmers in recent years due to their potential benefits in aquaculture practices such as,

i. High survival rate: The stunted fish survived better than the normal fish, indicating their better adaptation to the pond environment [14, 15].

ii. **Feed conversion ratio (FCR):** Feed conversion ratio (FCR) increased with increasing stocking density [16,17].

iii. **High feed utilization efficiency:** Stunted fish have a lower metabolic rate and growth rate than non-stunted fish, resulting in lower feed requirements. This means they require less feed to maintain their body weight, which can lead to cost savings for the farmer [18].

iv. **Compensatory growth (CG):** When the stunted yearlings are stocked in production ponds under standard rearing conditions, they show compensatory growth, resulting in faster growth than normal fingerlings [13, 14]. The growth rate of the fish is higher in its second year of life.

v. **Higher stocking densities:** Stunted fish can be stocked at higher densities than non-stunted fish due to their smaller size and lower oxygen demand [4]. This allows more fish to be produced in a smaller area, improving production efficiency and profitability.

vi. **Disease Resistance:** Stunted fish may be less susceptible to certain diseases as their slower growth rate can give their immune system more time to develop. Larger fingerlings have higher survival as they are less vulnerable to predation and disease and more tolerant of environmental fluctuations [4,13].

vii. **Alternative markets:** These have good market demand as they utilize seasonal grow-out ponds efficiently and can sell the fish at a higher price [17]. The commercial market for stunted fish can include alternative markets such as pet food or bait. These can generate additional income for the farmer while reducing waste.

Fish farmers in Andhra Pradesh, India; have developed the technology of producing stunted carp fingerlings for stocking in culture ponds [19]. Stunted fish fingerlings are obtained from aged fish, arrested from attaining their proper growth and development due to high density and minimum food available.

4. SUITABLE FISH SPECIES USED FOR STUNTED

Stunted fingerlings are fish intentionally kept at a small size for extended periods due to limited resources or space. The selection of fish species for stunted fingerlings can depend on water quality, food availability, and market demand. Recent research has suggested that other fish species can also be considered for stunted fingerling production.

i. **Tilapia:** Tilapia (*Oreochromis* spp.) can be a suitable species for stunted fingerlings as they have a high survival rate, are resistant to disease, and can tolerate poor water quality [20].

ii. **Largemouth Bass:** The Largemouth Bass (*Micropterus salmoides*) can also be a good candidate for stunted fingerlings as they are resilient, adaptable to different water temperatures and have a high feeding rate [21].

iii. **Yellow Perch:** A Yellow Perch (*Perca flavescens*) is a promising candidate for producing stunted fingerlings due to their efficient feed conversion, excellent taste, and high demand in the market [22].

iv. **Channel Catfish:** Channel Catfish (*Ictalurus punctatus*) is another species that can be considered for stunted fingerlings. Stunted channel catfish could be a viable option for farmers looking to maximize production efficiency and can grow well in low-nutrient environments and tolerate high-density culture conditions [23].

v. Milk fish: Stunted milkfish fingerlings grew and survived better than non-stunted ones. Lijauco et al. (1978) [24] recommend using stunted fingerlings for brackishwater milkfish culture. These could enhance the productivity and profitability of milkfish farming in seasonal water bodies[24].

vi. **Freshwater Fish Species:** According to a study published in 2017 in the Indian Journal of Fisheries, the selection of fish species for stunted fingerlings production in India should prioritize Indian major carps such as Catla (*Catla catla*), Rohu (*Labeo rohita*) and Mrigal (*Cirrihnus mrigala*), as well as commercially important exotic carps like Silver carp (*Ctenopherengodon idella*), Grass carp (*Hypophthalmicthys molitrix*), and Common carp (*Cyrpinus carpio*). These species are widely used in aquaculture and have a high market demand [25, 26, 27]. The stunted Indian major carp are being cultured in some regions of India because they are believed to have a rapid growth rate after stunting [28].

Choosing the appropriate fish species for stunted fingerlings involves considering crucial factors such as water quality, food availability, and market demand. Seeking advice from local fisheries authorities and experts to identify the most suitable species for a specific location is highly recommended. By doing so, the selected fish species will be better adapted to the environmental and market conditions, leading to a more successful cultivation process.

5. PRODUCING STUNTED FISH FINGERLINGS

Stunting fish fingerlings is still a common practice in aquaculture. It can help eliminate weak and unhealthy seeds and increase the survival rate of healthy seeds for culture purposes. However, producing stunted fingerlings can negatively impact fish welfare and overall production. Therefore, it is important to maintain proper stocking density and provide adequate nutrition to avoid stunting.

Stunted fingerlings are produced by stocking fingerlings at a high density of 250,000 individuals per hectare during July-August. They typically reach a weight of 12-15 g within 10-12 months, achieving a survival rate of 50-70%. Stunted fingerlings have reduced nutrient requirements and can be grown with lower nutrient input compared to conventional fingerlings[5]. While producing stunted fingerlings can have its benefits in eliminating weak and unhealthy seeds, it is important to ensure proper stocking density and adequate nutrition to avoid stunting and negative impacts on fish welfare and overall production. Recent studies have shown that stunted fingerlings can be produced by rearing fish fry/fingerlings at a higher stocking density and feeding them with natural food for a prolonged period. However, maintaining an optimum stocking density and providing regular management practices can lead to higher growth rates in fingerlings.

Experimental evidence in marine finfish indicated that the stunted fishes attained compensatory growth with adequate feeding when shifted to favourable conditions. Preliminary results reveal that marine finfishes such milkfish (*Chanos Chanos*) and) Snubnose pompano (*Trachinotus blochii*) exhibits compensatory growth pattern during post- stunting rearing period in both marine and low saline conditions [29,30].

6. SEASONALITY AND AVAILABILITY

Seasonality and availability are significant challenges in aquaculture production. Various innovative approaches have been developed in different regions to overcome these issues.
In Andhra Pradesh, India, carp farmers have developed a system of producing "stunted yearlings" to overcome seasonality and availability problems. In this approach, farmers would purchase seeds during the carp breeding season and stock them at high densities (50,000-100,000/ha), feeding them at 1-2% body weight and rearing them for 6-12 months. After the specified period of confinement, the fish that survive would experience stunted growth and reach a size of around 100-200 grams. This approach has become very popular in the region [19].

A recent study by Seshagiri et al. (2020)[31] revealed that premonsoon fish breeding in Andhra Pradesh yields 10 to 20% of carp seed, amounting to 100 crore fry, which is stocked for rearing up to September for the raising of stunted seed. The feasibility of producing stunted yearlings of Indian major carp (IMC) using this approach with the stocking densities and feeding regimes significantly influenced the growth and survival of IMC.

7. TRANSPORTATION AND CARE

Transportation of stunted fish fingerlings is a critical process that requires careful consideration of their unique characteristics and needs. The following steps can be taken to ensure the safe and effective transportation of stunted fish fingerlings:

i. **Water quality:** Stunted fish fingerlings are more sensitive to changes in water quality than non-stunted fish. Therefore, it is essential to maintain good water quality during transportation. The water should be clean, contaminant-free, and well-oxygenated. It is important to keep the water's temperature and pH levels within appropriate limits suitable for the species to ensure the safe transportation of aquatic species [32].

ii. **Container selection:** The container for transporting stunted fish fingerlings should be appropriate for size and number. The container should have adequate ventilation, be leak-proof, and be made of non-toxic materials. Providing adequate space for fish to move freely during transportation is essential to prevent any harm or damage to aquatic animals. Double-layered plastic bags filled with pure oxygen and devoid of water can be utilized for the short-distance conveyance of stunted fingerlings [33].
iii. **Handling:** Stunted fish fingerlings are delicate and can quickly become stressed or injured during handling. Therefore, it is crucial to handle them with care. Fish should be caught gently and placed into the container without being squeezed or dropped. During transportation, the container should be secured to prevent it from moving around and causing injury to the fish [34].
iv. **Duration of transport:** The duration of transport should be minimized as much as possible. The longer the transport, the more likely the fish will experience stress and adverse effects on their health. If the transport is expected to take longer, providing additional oxygen to the water or adding aeration devices to the container may be necessary[32].
v. **Inspection:** Before and after transport, it is important to inspect the fish for any signs of stress, injury, or disease. This can help identify and address any issues before they become more serious.

Transporting stunted fish fingerlings requires careful consideration of their specific needs to ensure safe and practical transport. Farmers have started adopting new methods to reduce stress and mortality rates during transport. One such approach is a conditioning process at least 12 hours before embarkment, which helps prepare the fish for transportation.

Moreover, spacious PVC containers ranging from 2,000 to 3,000 litres in capacity have become increasingly popular. These containers are placed on trucks for easy transportation, and after filling them with water, the conditioned fish seed is stocked within them. Oxygen is supplied through cylinders attached to the truck, ensuring the fish have adequate oxygen during transport. This method has proven effective in mitigating mortality rates during long-distance transport.

8. GROWING STUNTED FISH IN PONDS

The minimum grow-out pond size is 0.05 to 0.25 hectares with a depth of 1 to 2 meters. When stocked in the culture pond, stunted seeds can compensate for the growth lost during the stunting period and attain a one kg weight, with almost a 100% survival rate except for mortalities due to other environmental conditions. This technology of stunting fish seed developed by farmers is considered one of the most practical solutions to address the problems related to fish growth and yield.

Recent studies have highlighted the effectiveness of stunting fish for aquaculture production. For example, Sankar Raja, (2022)[35] studied the production performance of stunted and non-stunted Indian major carp in ponds. They found that stunted fish exhibited significantly higher growth and survival rates than non-stunted labeo fish. According to Nandeesha et al. (1994) [36], stunted carp exhibit increased weight gain due to their rapid growth during the second year of their life. Ramesh et al. (2000) [37] demonstrated the potential use of the finest stunted rohu fingerlings in fish farming. A study by Hossain et al. (2003) [38] comparing the growth of stunted and non-stunted fingerlings of Indian major carps (*Labeo rohita* and *Cirrhinus mrigala*) cultured with monosex male Nile tilapia (*Oreochromis niloticus*), it was observed that stunted rohu performed better in terms of growth when the density of tilapia was high.

Fish farmers believe stunted fingerlings of Indian major carp species, *Catla catla, Labeo rohita,* and *Cirrhinus mrigala*, exhibit faster growth than their regular counterparts. The potential of stunting tilapia fingerlings in ponds that stunted fingerlings (stocked at 150,000/ha) showed higher survival rates, growth rates, and biomass production than normal fingerlings. Stunting could be a practical solution to address the problems of limited fingerling availability and high production costs.

Stunted fish fingerlings, which have failed to grow normally and have a reduced body size, may experience hormonal changes to compensate for the lack of growth.

a. ***Growth hormone(GH):*** GH is a peptide hormone that stimulates growth and development in fish. In stunted fish fingerlings, the growth hormone levels may be elevated to promote growth. Zhang et al. (2020)[39] found that the growth hormone levels were significantly higher in stunted yellow catfish fingerlings than in normal-sized fingerlings.

b. **Insulin-like growth factor 1 (IGF-1):** This hormone mediates the effects of growth hormone in promoting growth and development. In stunted fish fingerlings, the levels of IGF-1 may be altered to try to compensate for the lack of growth. The levels of IGF-1 were significantly higher in stunted trout fingerlings compared to normal-sized fingerlings[40].

c. ***Cortisol:*** It is a steroid hormone released in response to stress. In stunted fish fingerlings, cortisol levels may be elevated due to the chronic stress of living in crowded conditions with limited food resources. In a favourable pond, the stunted fish compensate for the growth and optimization of the cortisol level. [41].

9. FEEDING METHODOLOGY

Supplementary feeding is essential for optimal growth of fish in ponds. Using locally available feed ingredients such as soybean cake, groundnut oil cake, rice bran, and fish meal in appropriate ratios can provide a balanced and cost-effective feed for fish. A feed formulation comprising soybean meal, rice bran, and fish meal resulted in significantly higher growth rates and feed conversion efficiency in Indian major carp [42].

The size of ponds used by farmers is generally large in Andhra Pradesh. Because of this, the broadcast feeding method resulted in massive wastage of feed and poor growth of fish. Farmers have developed a simple and effective technique of feeding fish through “feed bags” to overcome this problem. Chemical fertilizer bags made of polyethene with a 20-30 kg capacity are commonly used for making feed bags. Small holes at the bottom of feed bags arranged in 2-3 rows are made. Feeding bags are filled with rice-bran and oil cake mixture, tied to bamboo poles, and fixed in the ponds. Fish feed through the holes, which are generally exhausted in less than two hours after suspension [43]. This simple, practical and economical feeding method developed by farmers has helped in many ways:

i. The technique has reduced feed wastage drastically, and almost all the feeds kept in the bag are consumed directly by fish.
ii. Feed bags are an excellent indicator to assess the health and growth of the fish. If the feeds provided in the bag are not exhausted within the given period, farmers immediately suspect problems with health and/or water quality.
iii. The bag-feeding method has given a very effective pathway for treating fish in such large culture ponds.

Farmers use various drugs to feed fish through feed and for external treatment; containers filled with chemicals and perforations are tied close to feeding bags. Dissolutions of chemicals into the water provide an opportunity for treating fish infected with the disease. Various recent studies have investigated the use of feed bags in fish farming. The feed bags significantly reduced feed waste, enhanced fish development and improved water quality in the system [44]. Using feed bags in fish farming effectively reduces feed waste and improves fish growth and health.

Following feeding methodology can also play a crucial role in the production of stunted fish fingerlings.

a. ***Restrictive feeding:*** Restricted feeding regimes may be promising tools for increasing the efficiency of fish production. Dar, et al.,(2021) [45] suggested restriction feeding could improve rohu fingerlings' growth performance and feed utilization efficiency. Farmers can save money by not feeding or limiting feed during the winter by reducing feed and labour costs and decreasing disease losses [45,46].
b. ***High-energy diets:*** High-energy diets, typically rich in carbohydrates and fats, can promote rapid fish growth. However, feeding fish high-energy diets beyond their growth capacity can lead to stunted growth. It suggests that optimal feeding strategies and high-energy dietary formulations are needed to improve the performance and welfare of Yellowtail Kingfish in aquaculture [47].
c. ***Alternate-day feeding:*** It is possible to decrease feeding expenses significantly while maintaining the growth of Atlantic cod during the on-growing phase by implementing an alternate-day feeding regime. [48].

10. POST-STOCKING MANAGEMENT

Post-stocking management is a crucial aspect of fish farming, and maintaining water quality is one of the essential factors in ensuring the healthy growth and survival of fish. The following table shows the recommended ranges of various physical and chemical parameters for maintaining water quality in the fish pond.

Maintain water quality as given below in the table

Table 1.

Sr. No.	Parameter	Range
Physical parameters		
1	Temperature	20-35oC
2	Colour	Greenish
3	Turbidity in cm	8-20
Chemical parameters		
4	Dissolved oxygen	3-8 ppm
5	pH	7.2-7.5
6	Dissolved CO2	4.0- 12.0 ppm

7	Total alkalinity	80 – 150ppm
8	Ammoniacal Nitrogen NH4N	0.2-0.5 (mg/1)
9	Nitrate Nitrogen N3 Or N	0.2-0.2 (mg/l)
10	Nitrite Nitrogen NO2 - N	<0.014 (mg/1)
11	Phosphorus P2O5	0.01-0.5 (mg/1)
12	Iron (Admissible range)	0.05 - 0.02 (mg/1)
12	Manganese (Admissible range)	0.01 - 0.04 (mg/1)

Apart from maintaining water quality, farmers can use ash as a substitute for lime to promote the healthy growth of fish. The use of ash produced from the banana stem as a substitute for lime has become popular among farmers due to the cost and non-availability of lime in remote areas. A banana stem with an alkaline condition can improve water quality, similar to lime [49].

11. GENERAL PRECAUTIONS

i. Algal bloom control: Manual algal bloom control is better than chemical application [50].

ii. If required, Diuron @0.1 - 0.5 ppm (1- 3 gm/ ha /meter depth of water) may be sprayed over the water surface uniformly. Never apply in nursery ponds.

iii. Maintenance of water quality: Lime is an effective method for maintaining water quality in fish ponds [51].

iv. Transportation of fish seed: Proper acclimatization and oxygenation during transportation can improve the survival rate of fish seed While packing for transportation, oxygen should be provided sufficiently depending on the size and number of fish seeds to be carried [52].

v. Acclimatization is a critical process that needs to be done before releasing fry and fingerlings into culture ponds. It involves gradually introducing the fish to the water and environmental conditions of the culture pond to minimize stress and increase their chances of survival. The following steps can be taken to acclimate fry and fingerlings:

   a. Prepare the culture pond: Ensure that the culture pond is properly prepared before introducing the fish. The pond should be clean and free from any harmful chemicals or pathogens.

   b. Gradual temperature adjustment: The water temperature in the culture pond may differ from where the fish were previously kept. Gradually adjust the fish tank's temperature to match that of the culture pond over several hours or days, depending on the temperature difference.

c. Gradual salinity adjustment: If the culture pond has a different salinity level than the water where the fish were previously kept, gradually adjust the salinity level of the fish tank to match that of the culture pond over several hours or days.
d. Gradual water quality adjustment: Gradually introduce the fish to the water quality of the culture pond. Start by adding small pond water to the fish tank over several hours. Increase the pond water gradually until the fish is fully acclimated to the pond water.
e. Monitor the fish: Monitor the fish closely during acclimatization for signs of stress or illness. If any problems are detected, take appropriate measures to address them before releasing the fish into the culture pond.
f. According to recent studies, proper acclimatization can significantly improve fish survival and growth rates in culture ponds [28,53,54]. It is essential to ensure that the fish are gradually introduced to the new environment to minimize stress and prevent mortalities.

vi. Water bath treatment: A bath treatment with $KMnO_4$ can reduce the risk of disease transmission during fish seed transfer [55]. A water bath treatment with $KMnO_4$ @ 1-2 ppm for a minute is essential before releasing the fish seed into the culture ponds.
vii. Feed management: Optimal management of feed and manuring is essential for stunted fingerlings [49].
viii. Agrimin Forte is a commercial feed additive often used in aquaculture to improve the health and growth of fish. It is a multivitamin and mineral supplement added to the feed at a rate of 0.1 to 1% [56].
ix. Hardening fingerlings is an important process in aquaculture, as it helps prepare the fish for the conditions they will experience in the grow-out phase. Netting a big mesh-sized net at fortnight intervals is one method used to harden fingerlings
x. Stress Management: In order to mitigate stress in fish seeds, the following measures can be implemented:

a. Maintain optimal water quality: It is important to ensure that the water quality parameters, including temperature, dissolved oxygen, pH, and ammonia levels, are maintained within the recommended range for the specific species being cultured.
b. Avoid overcrowding: Overcrowding can increase competition for food, space, and oxygen, resulting in stress and stunted growth.

c. Provide adequate nutrition: To provide adequate nutrition, it is important to ensure that the fish seed is provided with a nutritionally balanced diet that meets their specific dietary requirements.
d. Minimize handling and transport: Handling and transport can be stressful for fish seeds, so minimize these activities as much as possible.
e. Manage disease: Implement disease prevention and control measures to minimize the incidence and impact of diseases, which can also contribute to stress and stunted growth.

By implementing these measures, the stress levels in the fish seed can be minimized, which in turn can promote optimal growth and development.

12. FISH PRODUCTION

The stunted fingerlings of rohu show better growth and survivability in grow-out ponds than commonly raised rohu fingerlings under everyday pond management practices. In the North-Eastern region, stunting of earlier year carp seed can be an effective tool to better utilize the potential growth season in polyculture. However, the genetic quality of the seed must be ensured before adopting this technique [57].

When stocked into grow-out ponds at a density of 3,000/ha, stunted fish fingerlings weighing 50-100 g can achieve marketable size (1.0-1.5 kg) within a 5-6 month period with a high survival rate of 85-95% [35]. Progressive farmers can achieve more than 15 tonnes/ha/year, while the average yield is around 8 tonnes/ha. The stunted rohu fingerlings performed better in growth and survivability when raised in grow-out ponds than commonly raised rohu fingerlings [57]. The study also found that stunted fingerlings stocked at a density of 3,000/ha achieved marketable size within 5-6 months with a high survival rate of 85-95%.

13. MULTIPLE STOCKING AND HARVEST

Multiple stockings and harvesting are common in aquaculture to maximize fish production and increase profitability. Several studies have evaluated the effectiveness of this technique. One study in India found that multiple stockings and harvesting in carp polyculture ponds increased fish production and profitability. The study showed that a stocking density of

5000/ha/yr had no adverse effects on the pond's carrying capacity, and regular harvesting and restocking fingerlings could lead to high yields [3,58,43].

Multiple stockings and harvests are used in polyculture ponds to maximize fish production. Recent studies have shown that this technique can significantly increase the productivity of aquaculture systems [2].

Here are some additional points to improve the production:

a. Multiple stockings and harvesting can increase production rates but should be done cautiously. Studies have shown that higher stocking densities can lead to decreased water quality and increased stress on fish, which can negatively impact growth and survival [11].

b. Regular harvesting and restocking with fingerlings of the same species can help maintain high stocking densities and continuous production in the pond [11].

c. Proper pond management practices, such as regularly monitoring water quality parameters, maintaining appropriate feeding rates, and controlling the use of inputs, are critical to prevent disease outbreaks and maintain optimal conditions for fish growth [59,60].

d. Proper pond maintenance, including periodic draining and debris removal, is essential for preventing problems with high biological oxygen demand (BOD) in the water, which can lead to decreased water quality and negative impacts on fish health [61].

CONCLUSION

The aquaculture of stunted fingerlings can offer several benefits for fish farmers. It can help overcome the challenges of limited fingerling availability and high production costs, ultimately leading to higher yields and profitability. However, the success of this approach requires adherence to best management practices, including proper pond management, regular monitoring of water quality, and restocking with fingerlings of the same species. Access to quality fingerlings, market demand, and genetic quality is crucial for success. Using stunted fingerlings in aquaculture can improve fish production's efficiency and sustainability while providing economic opportunities for communities.

REFERENCES

1. Naylor, R.L., Hardy, R.W., Buschmann, A.H. et al. A 20-year retrospective review of global aquaculture. Nature. 2021; 591: 551–563 https://doi.org/10.1038/s41586-021-03308-6.
2. FAO. (2020). The state of world fisheries and aquaculture, 2020. Sustainability in action. Rome. https://doi.org/10.4060/ca9231en

3. Ylikarjula, J., Heino, M., and Dieckmann, U. Ecology and adaptation of stunted growth in fish. Evolutionary Ecology. 1999; 13: 433-453.
4. Arranz, I., Mehner, T., Benejam, L., Argillier, C., Holmgren, K., Jeppesen, E., Lauridsen, T. L., Volta, P., Winfield, I. J., & Brucet, S. Density-dependent effects as key drivers of intraspecific size structure of six abundant fish species in lakes across Europe. Canadian Journal of Fisheries and Aquatic Sciences. 2015; 72(7): 1065-1077. https://doi.org/10.1139/cjfas-2014-0508
5. Radheyshyam, De, H.K., and Saha, G.S. Role of community in production and supply of larger, quality fingerlings. Aquaculture Asia Magazine. 2009;14(1): 16-17.
6. Pradhan, A. "Studies on the Status and Future Management Strategies of Fish Farming in the Rainfed Districts of Purulia and Bankura" Ph.D. Thesis, 2019.
7. Oliva-Teles A. Nutrition and health of aquaculture fish. J Fish Dis. 2012; 35(2):83-108. doi: 10.1111/j.1365-2761.2011.01333.x. PMID: 22233511.
8. Iwama, G.K., Pickering, A.D., Sumpter, J.P., & Schreck, C.B. Fish stress and health in aquaculture. *Estuaries.* 1998; *2:*, 501.
9. Mateus, A.P., Power, D.M., & Canário, A. Stress and Disease in Fish, 2017.
10. Behringer, D.C., Wood, C.L., Krkošek, M., and Bushek, D., *Disease in fisheries and aquaculture* In: *Marine Disease Ecology*. Edited by: Donald C. Behringer, Kevin D. Lafferty, and Brian. R. Silliman, Oxford University Press, 2020. © Oxford University Press. DOI: 10.1093/oso/9780198821632.003.0010
11. Mishra S.S., Das R, Dhiman M, Choudhary P, Debbarma J, et al. Present Status of Fish Disease Management in Freshwater Aquaculture in India: State-of-the-Art-Review. J Aquac Fisheries. 2017; 1: 003.
12. Ramaswamy, B., Naveen Kumar, B. T., Doddamani, P. L., Panda, K., & Ramesh, K. S. Dietary protein requirement of stunted fingerlings of the Indian major carp, *Catla catla* (Hamilton) during grow-out phase. Indian Journal of Fish. 2013; 60(4): 87-91.
13. Das, P. C., Mishra, S. S., Mishra, B. and Jayasankar, P. Influence of juvenile stunting on grow-out performance of rohu *Labeo rohita* (Hamilton, 1822). J. Appl. Ichthyol. 2016; 32: 848-858. https://DOI: 10.1111/jai.13131.
14. Murnyak, D.F., M.O. Murnyak and L.J. Wolgast Growth of stunted and nonstunted bluegill sunfish in ponds. Prog.fish cult., 1984;46(2): 133-138. https://doi.org/10.1577/1548-8640(1984)46%3C133:GOSANB%3E2.0.CO;2
15. Nandeesha, M.C., K. Dathathri, D. Krishnamurthy, T.J. Varghese, B. Gangadhar and N.R. Umesh Effect of varied level of protein on the growth and tissue biochemistry of stunted yearlings of rohu *Labeo rohita* in the absence and present of natural food. Fish nutrition research in Asia. Proceedings of the fifth Asian Fish Nutrition Workshop, Silva, De. S.S.(ed.), 1994; 9: 93-100.
16. Chattopadhyay, D.N., B.C. Mohapatra, S. Adhikari, K.C. Pani, J.K. Jena and A.E. Eknath: Effects of stocking density of Labeo rohita on survival, growth and production in cages. Aquacul. Int. 2013; 21:19-29.
17. Muralitharan, A.V. Studies on the growth of stunted and normal fingerlings of major carps catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*) in aquaculture ponds. Thesis: Bharathidhasan University, Thiruchirappali, Tamil Nadu, India, 2006.
18. Amin, A.K., M.R. Bapary, M.A. J. Islam, M. Shajahan and M.A.R.Hossain: The impacts of compensatory growth on food intake,growth rate and efficiency of feed utilization in Thai pangas(*Pangasius hypophthalmus*). Pak. J. Biol. Sci., 2005; 8: 766–770
19. Abraham, T. J., S. K. Sil, & P. Vineetha. A comparative study of the aquaculture practices adopted by fish farmers in Andhra Pradesh and West Bengal. Indian Journal of Fish, 2010; 57(3): 41-48.
20. Bhujel, R. C., Little, D. C., & Hossain, A. Reproductive performance and the growth of pre-stunted and normal Nile tilapia (*Oreochromis niloticus*) broodfish at varying feeding rates. Aquaculture, 2007; 273(1): 71-79.

https://doi.org/10.1016/j.aquaculture.2007.09.022

21. Swingle, H. S., & Smith, E. V. The management of ponds with stunted fish populations. Transactions of the American Fisheries Society, 1942; 71(1): 102-105.
22. Heath, D., & Roff, D. A. Test of Genetic Differentiation in Growth of Stunted and Nonstunted Populations of Yellow Perch and Pumpkinseed. Transactions of the American Fisheries Society, 1987; 116(1): 98-102. https://doi.org/10.1577/1548-8659(1987)116<98:TOGDIG>2.0.CO;2
23. Otto W. Tiemeier & James B. Elder Growth of Stunted Channel Catfish, The Progressive Fish-Culturist. 1960; 22(4): 172-176. DOI: 10.1577/1548-8659(1960)22[172:GOSCC]2.0.CO;2
24. Lijauco, M.N., Grino, E.G., Gerochi, D.D., & Rodriguez, E.M. A preliminary study on the growth and survival of stunted and non-stunted milkfish fingerlings. Quarterly Research Report of the Aquaculture Department of the Southeast Asian Fisheries Development Center, 1978; 2(3):35-36.
25. Sahoo, S. K. Kumar, R., Tiwari, P. K., Pillai, B. R. , & S. S. Giri. (Eds.), Training Manual on Mass Breeding and Culture Technique of Catfishes. SAARC Agriculture Centre, Dhaka, Bangladesh, 2018;180.
26. Pradeep K. Katiha, J. K. Jena, N. G. K. Pillai, Chinmoy Chakraborty & M. M. Dey. Inland aquaculture in India: past trend, present status and future prospects, Aquaculture Economics & Management, 2005; 9(1-2): 237-264, DOI: 10.1080/13657300590961573
27. Das, P., Bhattacharjya, B. K., Yadav, A.K., Debnath, D., Yengkokpam, S., Sarma, K. K., Gogoi, P., Sharma, N., Borah, S., Kakati, A., Ray, B. C. and Das, B. K., 2017. Impact of fish stock enhancement through in-situ raising of stunted carp fingerlings in pens on fish production. In: Fostering Innovations in Fisheries and Aquaculture: Focus on sustainability and safety- Book of Abstracts (eds., Thomas, S. N., Rao, M. B., Madhu, V. R., Asha, K.K., Bisni, P.K., Viji, P., Sajesh, V.K. and Jha, P.N.). 11th Indian Fisheries and Aquaculture Forum, 21-24 November, 2017, Kochi, India. Organized by AFSIB, Indian Branch and ICAR-CIFT, Kochi. Published by Convener, 11th IFAF. p.228.
28. Paswan, V.K., K.D. Rawat, P.P. Srivastava, C. Prakash, M.D. Aklakur, S. Saseendran and R.S.S. Lingam: Optimization of stocking density and feeding ration for rearing of stunted Labeo rohita fingerlings in cages. J. Environ. Biol. 2021; 42: 229-234
29. Lijauco, M.N., Grino, E.G., Gerochi, D.D., & Rodriguez, E.M. A preliminary study on the growth and survival of stunted and non-stunted milkfish fingerlings. Quarterly Research Report of the Aquaculture Department of the Southeast Asian Fisheries Development Center, 1978; 2(3): 35-36.
30. Anikuttan, K. K., Jayakumar, R., Suresh Babu, P. P., Nazar, A. A., Tamilmani, G., Sakthivel, M., ... & Imelda, J. Assessment of compensatory growth in stunted fingerlings of Snubnose pompano, *Trachinotus blochii* (Lacepede, 1801), in marine conditions. Aquaculture Research. 2021; 52(1): 403-409.
31. Seshagiri, B., Nagireddy, M. V. S., Raju, V. R., Nagireddy, S., Rangacharyulu, P. V., Rathod, R., & Ratnaprakash, V. Impact of nationwide lockdown on freshwater aquaculture in Andhra Pradesh, India. Int. J. Fish. Aquat. Stud. 2020; 8: 377-384.
32. Yatsenko, Y., Hritonenko, N. Aquaculture: an Emerging Research Area. Academia Letters, Article, 2021; 680. https://doi.org/10.20935/AL680.
33. Helfrich, L. A., Bark, R., Liston, C. R., Weigmann, D. L., & Mefford, B. Live transport of striped bass and rainbow trout using a Hidrostal pump. *Journal of the World Aquaculture Society*, 2004; *35*(2): 268-273.
34. Iwama, G. K., Afonso, L. O., & Vijayan, M. M. Stress in fish. *Annals-New York Academy of Sciences*. 1998; *851*: 304-310.
35. Sankar Raja, P., Arunachalam Veluchamy, M., & Ramakrishana, B. A Comparative Study on the Growth and Production of Stunted and Normal Fingerlings of Major Carps Catla (*Catla catla*), Rohu (*Labeo rohita*) and Mrigal (*Cirrhinus mrigala*) Cultured in Composite Fish Culture under Second Level Management. *Muralitharan and*

Ramakrishana, Bakthavathsalam, A Comparative Study on the Growth and Production of Stunted and Normal Fingerlings of Major Carps Catla (Catla catla), Rohu (Labeo rohita) and Mrigal (Cirrhinus mrigala) Cultured in Composite Fish Culture under Second Level Management (June 30, 2022).

36. Nandeesha, M.C., K. Dathathri, D. Krishnamurthy, T.J. Varghese, B. Gangadhar and N.R. Umesh., Effect of varied level of protein on the growth and tissue biochemistry of stunted yearlings of rohu *Labeo rohita* in the absence and present of natural food. Fish nutrition research in Asia. Proceedings of the fifth Asian Fish Nutrition Workshop, Silva, De. S.S.(ed.), 1994;(9): 93-100.
37. Ramesh, K.S., G.P. Puttswamy, K. Chandramohan, I. Ahmed and H. Hanumanthappa Stunted carp fingerlings are a boon to seasonal water bodies. Fish. Chimes. 2000; 20(4): 25-26
38. Hossain, M.A., D.C. Little and R.C. Bhujel. Nursing duration and pond fertilization level affect polycultures of Indian major carp (rohu *Labeo rohita* and mrigal *Cirrhinus mrigala*) with monosex Nile tilapia (*Oreochromis niloticus*). Aquacult. Res.2003; 34(9): 765-775.DOI:10.1046/j.1365-2109.2003.00883.x
39. Pérez-Sánchez, J., & Le Bail, P. Growth hormone axis as marker of nutritional status and growth performance in fish. *Aquaculture*.1999; *177*(1-4): 117-128. https://doi.org/10.1016/S0044-8486(99)00073-3
40. Montserrat, N., Gabillard, J. C., Capilla, E., Navarro, M. I., & Gutiérrez, J. Role of insulin, insulin-like growth factors, and muscle regulatory factors in the compensatory growth of the trout (*Oncorhynchus mykiss*). General and comparative endocrinology. 2007; 150(3): 462-472.
41. Fatima, S., Izhar, S., Usman, Z., Rashid, F., Kanwal, Z., Jabeen, G., Latif, A.A. Effects of High Stocking Density on Condition Factor and Profile of Free Thyroxine and Cortisol in *Catla catla* (Hamilton, 1822) and *Labeo rohita* (Hamilton, 1822). Turkish Journal of Fisheries and Aquatic Science. 2018; 18: 217-221.
42. Jose, S., Mohan, M. V., Shyama, S., Ramachandran Nair, K. G., & Mathew, P. T. Effect of soybean-meal-based diets on the growth and survival rate of the Indian major carp, Cirrhinus mrigala (Ham.). Aquaculture Nutrition. 2006; 12(4): 275-279.
43. Mandal, S. C., Barman, D., & Das, P. Modern approach of composite fish culture—the examples of Andhra Pradesh (India) to emulate. World Aquaculture. 2011; 42(4): 44.
44. Ramakrishna, R.; Shipton, T.A.; Hasan, M.R. Feeding and feed management of Indian major carps in Andhra Pradesh, India. FAO Fisheries and Aquaculture Technical Paper No. 578. Rome, FAO, 2013;90.
45. Dar, S. A., Srivastava, P. P., Nazir, M. I., Jahan, I., Varghese, T., Hajam, I. A., & Gupta, S. Modulations of Digestive and Metabolic Enzymes Profiles during Restriction Feeding in Rohu Labeo rohita Fingerlings. *North American Journal of Aquaculture*. 2021; *83*(2): 58-66. https://doi.org/10.1002/naaq.10164
46. Kumar, P., Arun Sudhagar S, V. Harikrishna, and Jayant,.M. "Practical significance of restricted feeding regime in aquaculture." *Aquaculture Asia Magazine.* 2017; *21(1): 18*.
47. Crowe, B. H., Harris, J. O., Bansemer, M. S., & J. Stone, D. A. Restricted feeding and dietary energy levels affect liver structure in cultured Yellowtail Kingfish (*Seriola lalandi, Valenciennes*) at summer water temperatures. Aquaculture Research. 2021; 52(12): 6074-6086. https://doi.org/10.1111/are.15469
48. Bjørnevik, M., D. Imsland, A. K., Hanssen, H., Roth, B., Vikingstad, E., & Foss, A. The effect of alternate-day feeding on growth and feed conversion in Atlantic cod Gadus morhua. *Aquaculture Nutrition*, *27*(4), 1206-1211. https://doi.org/10.1111/anu.13260Eyo, A. A. (2013). The use of banana peel (*Musa sapientum*) ash as a substitute for lime in aquaculture. African Journal of Agricultural Research. 2021; 8(27): 3564-3569.

49. Hoque, F., Hussan,A., Das, A., and Chakrabort, P. Managing water quality and fish health in aquaculture: Farmer's traditional practices in west Bengal. International Journal of Fisheries and Aquatic Studies. 2018; 6(4): 31-35.
50. Anderson D,M., Approaches to monitoring, control, and management of harmful algal blooms (HABs). Ocean Coast Manag. 2009; 52(7): 342.
51. Boyd, C. E. Use of agricultural limestone and lime in aquaculture. CABI Reviews. 2017; 1-10.
52. Rimmer, M. A., & Franklin, B. Development of live fish transport techniques. Brisbane, Australia:: QDPI. 1997.
53. Jonssonn, S., Brønnøs, E., & Lundqvist, H. Stocking of brown trout, *Salmo trutta* L.: Effects of acclimatization. *Fisheries Management and Ecology*. 1999; *6*(6): 459-473. https://doi.org/10.1046/j.1365-2400.1999.00176.x
54. Das, T., Pal, A. K., Chakraborty, S. K., Manush, S. M., Dalvi, R. S., Apte, S. K., Sahu, N. P., & Baruah, K. Biochemical and stress responses of rohu *Labeo rohita* and mrigal *Cirrhinus mrigala* in relation to acclimation temperatures. *Journal of Fish Biology*. 2009; *74*(7): 1487-1498. https://doi.org/10.1111/j.1095-8649.2009.02216.x
55. *Lazur, A. M. The use of potassium permanganate in fish ponds. University of Florida Cooperative Extension Service, Institute of Food and Agriculture Sciences, EDIS.* 1996.
56. Vishwakarma, B. K., Sharma, A. P., Kala, P., Mohan, D., & Pandey, N. N. Effect of mineral mixture-based diet on the growth performance of common carp (*Cyprinus carpio*) fingerlings. Journal of Krishi Vigyan. 2020; 9(si): 81-84.
57. Mishra, R. P., Mishra, C. K., Kumar, N., & Das, S. K. A Study on Growth & Economic Parameters of Stunted Yearling (Indian Major Carp) Culture Technique in Nine Village Ponds of Angul District, Odisha, India. International Journal of Current Microbiology and Applied Sciences. 2020; 9(4): 1414-1420. doi: https://doi.org/10.20546/ijcmas.2020.904.168
58. Jayasankar, P. and Das, P. C., Vertical expansion strategy for increased freshwater aquaculture production. Fishing Chimes. 2015; 35: 44-51.
59. Lazur, A. Growout pond and water quality management. JIFSAN (Joint Institute for Safety and applied Nutrition) Good Aquacultural Practices Program, University of Maryland, 2007; 17.
60. Crochet, D. W. Fish pond management guide. South Carolina State Documents Depository, 2000.
61. Mukherjee S, Dutta M Biological Oxygen Demand in Controlling Fish Production and Cost of Supplementary Feed towards better Sustainability of a Sewage-Fed Aquaculture System: A Case Study of East Kolkata Wetlands, West Bengal, India. Int J Waste Resour. 2016; 6: 209. doi:10.4172/2252-5211.1000209