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Artificial Propagation of Indigenous Ornamental Fish Species via Nutritional Manipulation for Stock Enhancement and Conservation as a Step towards Environmental Sustainability: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Indigenous flora and fauna of a particular habitat greatly impacts the environment in maintaining an ecological balance and equilibrium for the normal functioning of the ecosystem as a whole. Native fishes play a major role and holds a major niche in the ecosystem which needs attention at the

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moment for their conservation and protection, failure of which may prove to be detrimental to the environment. The rapid developmental activities and industrialization taking place currently are leaving a negative impact upon the natural ecosystem. These activities are a major reason for loss of habitat, deterioration, pollution, and degradation. The ornamental fish industry is a budding industry in India and the indigenous fish fauna of the country offers a good market but unfortunately, so far, the requirements and demand are fulfilled from the natural stock through manual collection. Rigorous exploitation of these species may result into loss of species diversity or reduction of stock, provided, anthropogenic causes necessitated by development and industrialization are already acting upon the ecosystem. Therefore, in this review we will discuss the implementation of captive breeding techniques through nutritional manipulation for fish species so that the wild stock is not made vulnerable and instead, the same shall be enhanced through ranching. Though this technique offers certain limitations such as genetical quality compromise, inferior breeding performance etc., nevertheless it still is a major tool in conservational biology. The review will provide insights to researchers on how to achieve captive breeding success by manipulating nutritional component in fishes and eventually with the information made available in this document certain practical implementations may be necessitated which will help us move closer to the broader aspect of biodiversity conservation and sustainability.

Keywords: Biodiversity; captive breeding; conservation; habitat; nutrition; sustainability.

1. INTRODUCTION

Fish are a vital component of our ecosystems and are key to preserving the harmony of the natural world. Particularly native fish species are essential to the general health of aquatic ecosystems and are an essential component of their own habitats. But because of human activities like overfishing, habitat destruction, and the introduction of invasive species, many native fish species are in danger of going extinct. Therefore, protecting these species is essential to ensuring the survival of our aquatic environments and the advantages they offer. For several reasons, it is essential to preserve native fish species. Fish species that are native to the area are a vital source of food for other creatures that live there. The survival of several predators, such as birds, animals, and other fish, depends on the presence of local fish species. Additionally, by consuming and excreting organic matter, native fish help to distribute nutrients throughout aquatic ecosystems, where they play a crucial role in the nutrient cycle. Furthermore, in their respective habitats, these native fish species frequently serve as keystone species. Keystone species are those that, in relation to their abundance, have an outsized influence on their ecosystem. An ecosystem can be severely disrupted by the removal of a keystone species, which may have a domino effect on other species. Because of their function in controlling the numbers of other animals and preserving the ecosystem's balance, native fish species are frequently keystone species in aquatic ecosystems. Therefore, it is crucial to preserve native fish species in order to keep these ecosystems ecologically balanced.

Native to India, ornamental fish comprise 700 marine species and 374 freshwater species. Of the marine species, 150 occurs in Andaman & Nicobar Islands and 300 in Lakshadweep Islands [1]. The demand for these fish is very high in foreign export markets. Freshwater biodiversity is abundant in NER and the Western Ghats, in contrast to marine biodiversity, which is mostly found in Lakshadweep, Andaman & Nicobar Islands, Gulf of Kutch, Gulf of Mannar, Palk Bay, Kerala coast, etc. 90% of ornamental fish marketed originates from the port of Kolkata, with the remaining 8% and 2% coming from Mumbai and Chennai, respectively [2]. In both domestic and foreign markets, demand is limited to the local fish *Sahyadria denisonii*. Even though native ornamental fish from India are highly sought-after on international markets, [3] noted that only a small amount is exported for a variety of reasons.

Maintaining biodiversity depends on protecting native fish species. Biodiversity is the term used to describe the diversity of life on Earth, including the range of species, genes, and ecosystems. Native fish species are a crucial component of this biodiversity, and their extinction could have a big effect on how resilient and healthy an ecosystem is. Additionally, protecting indigenous fish species can aid in limiting the spread of invasive species, which can harm native ecosystems and species. The most important concern is sustainability, and breeding native

species that are unpopular in the domestic market is likewise a low priority. Even though the nation has made scientific advancements in the breeding techniques for a few native ornamental fishes, their mass production has not yet begun. If government organizations can set up substantial facilities and provide breeders with specialized instruction and assistance, more indigenous ornamental fishes can be produced to increase exports from the country. According to the research done by [4], native fish species found in India, specifically the native fish fauna found in the Ganges and its tributaries, prefer shallow, clear water streams with a sandy substratum, along with the presence of gravels and substantial growths of aquatic plants like *Hygrophilia*, *Limnophila*, *Ottelia*, *Rotala*, and *Vallisneria*. And if we do a reality check, we might discover that natural water bodies are gradually losing quality as a result of ongoing industrial and development activities, endangering the abundance, existence, and biodiversity of indigenous species, and ultimately having a negative effect on the environment. Therefore, the prime need of the hour is to work on this aspect by developing captive breeding techniques for these important species and once achieved, the seeds can be ranched for stock enhancement and traders may acquire the seeds from breeders rather than collecting from the wild which will enormously reduce the pressure upon the natural ecosystem.

This review will elaboratively discuss the method of achieving captive breeding through nutritional manipulation, as we are aware that apart from other cues such as environment, health and maturity, broodstock nutrition plays a major role in enhancing the reproductive and breeding performance in terms of gonadal quality, energy build-up and other aspects of reproductive physiology of fishes which will act as a trigger for enhanced activity and response. Therefore, by supplementing fishes held in captivity with optimum nutrition as per their requirement, positive response is bound to be achieved and the entire process will eventually produce fruitful results.

2. IMPORTANCE AND LIMITATIONS OF CAPTIVE BREEDING FOR PROPAGATION OF INDIGENOUS ORNAMENTAL FISHES

In order to lessen the strain placed on nature by wild-catch and preserve the natural population of these living treasures, [1] have stressed the importance of developing captive broodstock for indigenous ornamental fish species. According to [5], both climatic and human-caused factors have contributed to the loss of fish variety. Additionally, according to their study, 63 species that were present in the Hakaluki Haor wetland in north-eastern Bangladesh were still available in 83% of cases in 2008, but a drop of 51% was noted in 2018. The wild populations of fish are at great risk due to overfishing and habitat destruction happening due to ongoing developmental activities, which is gradually reducing the species' natural supply.

Furthermore, [6] reported that only 15% of native fish species are raised in captivity, out of the total indigenous ornamental fish trade that takes place in India. If technological advancements in captive breeding are not made, this could ultimately result in over-exploitation, endangerment, and eventually lead to the extinction of native fish species, provided, climatic and anthropogenic factors are already acting upon this to create a synergistic effect.

On the other hand, every beneficial thing comes along with a few limitations and disadvantages, nevertheless, even captive breeding offers certain cons as mentioned below which may be put under consideration.

i. Captive bred individuals have poor reproductive performance and quality of juveniles is much inferior as compared to wild ones [7].
ii. Captive bred individuals may cause gene-pool replacement and alter the natural population [8].
iii. In relation with indigenous ornamental fishes, majority prefers live food, therefore, maintaining and sustaining live food production may be a cause of concern and challenge.

Limitations of captive breeding techniques mainly revolves around the quality of juveniles and genetical aspects, nevertheless [9] mentioned that in lieu of these disadvantages it still acts as a good option in conservation biology. Therefore, in order to curb with such limitations, works at the genetical and biotechnological levels may as well be necessitated.

3. HABITAT MANIPULATION FOR BREEDING OF ORNAMENTAL FISHES IN CAPTIVITY

To speed up the maturation process, it is crucial to mimic the natural environment as closely as

possible in captivity. This is accomplished by supplying a thicket of plants [10]. Males being territorial in nature require objects for hideouts to enable them to create distinct boundaries for their specific territories, which may include the use of plants, woods, or even mud pots and a substratum basically formed by laying gravel or sand. The presence of floating plants can be advantageous in the way that it blocks excess light which might negatively impact the breeding performance of the fish. A dense cushion of moss that is ideally 4 inches (10 cm) deep and without gaps is also very effective [11]. The fish feel at home in this habitat, which also serves as a shelter and an initial supply of food for the brood. Eventually, this improves the fish's ability to reproduce. For the fish to mature in captivity, Dutta *et al*., 2020, underlined the need to provide a semi-natural setting. Light maintenance from low to moderate is recommended for enhancing plant growth.

4. NUTRITIONAL REQUIREMENTS FOR REPRODUCTION OF ORNAMENTAL FISHES

Enhancing the external appearance and reproductive performance of invertebrates, including fish, and finally determining the reproductive outcome in them are all influenced by nutrition, which is one of the fundamental factors. However, nutritional information for ornamental fish is primarily based on extrapolating findings from research on food fish produced in intensive farming environments [12,13]. In their thorough investigation of the effects of dietary supplementation on fish reproduction, [12], noted that the reproduction process can only achieve success, if necessary, conditions are met; however, it may also lead to reproductive failure if devoid of optimal conditions. For example, when female fishes are malnourished, they frequently exhibit serious reproductive malfunctions which even lead to the occurrence of follicular atresia conditions and inhibition of other mechanisms in the system of the fish, which evidently will lead to the complete failure of breeding of the fish.

Due to the challenges of conducting studies concerning the optimal feeding and reproduction of broodstock, the nutrition of broodstock is currently little known [14,15]. The types of feed had a substantial impact on *Betta splendens* feed intake, growth, ovary weight, and fertility [16]. Enhancing reproductive success necessitates adequate nutrient availability as per the requirement of the fish to provide and maintain the calorific requirements for the growing cells, which are important factors in the design and final acceptance of aquatic feeds [17,12]. An otherwise nutritionally balanced meal may function poorly or ineffectively if it contains only a small amount of nutrients that cause a specific aquatic species to react positively to stimuli [17]. Fishes in the natural ecosystem frequently experience food scarcity or shortages throughout their life cycles, especially during seasonal variation and migratory phase. In response to these intrinsic and extrinsic effects, the sensory and endocrine systems, react, and the reproduction process is then carried out based on the signal produced [12].

4.1 Protein Requirement

Breeding demands huge quantity of energy for growth and reproductive performance. Carbohydrate alone cannot serve the purpose of energy supplementation as it raises questions of digestibility. Moreover, protein is made up of amino acids chains which acts as important components in growth and reproduction as its deposition into tissues supplement the required amount of energy, enhance their sexual performance and activity and are substrates for key metabolic pathways. According to [18], ornamental fishes need a crude protein content between 30 and 40% to mature. To promote reproductive activities, female freshwater ornamental swordtails, *Xiphophorus helleri*, need a diet with at least 30% protein [15]. Feeding *B. splendens* with a 35% CP diet resulted in higher growth and spawning performance [19]. Protein requirements can range from 30 to 50% for growing fishes based on the type of which wherein omnivorous goldfish, *Carassius auratus*, requires the former level and carnivorous discus, *Symphysodon aequifasciata* requires the latter [20]. According to [21], for guppy, protein requirements range from 30 to 40% for initial sizes of 0.10 g.

Furthermore, [22] revealed that most ornamental fish need diets with 25–50% protein, while [23] found that the highest fertility in female dwarf gouramis was reported from dietary supplementation of 25–45% protein. Additionally, [24] observed that *X. helleri* females fed with a very high quantity of protein (> 30%) increased their relative fecundity and produced more fry. According to [25], gourami brooders need 30–40% protein content, with the primary protein sources being fish meal, squid meal, etc. Blue

gourami, *Trichogaster trichopterus*, was fed with various protein and lipid levels, and [26] reported that treatment with 35% CP and 8% EE produced the best results. It was also noted that blue gourami, swordtail, molly, and guppy require a 30-40% dietary protein supplementation.

4.2 Fatty Acids and Lipids Requirement

The lipid and fatty acid composition of the diet of broodstock is thought to be one of the key nutritional elements, useful for effective breeding performance and the survival of spawns [12]. Dietary lipids are prime sources of energy and fatty acids, thereby playing a significant role in the regular growth and survival of fishes [20]. In addition to playing a crucial role in the flavour and texture of fish feed, lipids also play a crucial role in maintaining the structure of biological membranes, are carriers of hormones, effectively transport carotenoids and deposits in chromatophores, and also act as precursors for the synthesis of essential metabolites, including prostaglandins [27]. Fish mainly need long-chain fatty acids consisting of high levels of unsaturation as reported by [20]. A lipid content of 9–10% is added to feed for the Nile tilapia broodstock development [28].

According to [24], muscle lipid content serves as an ovarian lipid supply, making it a useful measure of reproductive function. Swordtail displayed enhanced growth performance with dietary fat increases from 8 to 16% and the same protein level. With the largest accumulation being shown with the highest dietary fat, the muscle lipid content followed the same trajectory as the protein level. According to [27], 7-8% lipid was included in the diet of milkfish broodstock. According to [26], blue gourami, swordtail, molly, and guppy need a 6–10% dietary lipid supplement. A direct incorporation of highly unsaturated fatty acids such as DHA, EPA, and ARA, to female broodstock diets, has been shown to directly benefit the reproduction of zebrafish, *Danio rerio* [29]. Fish with higher levels of some important fatty acids and vitamins, including n-3 and n-6 HUFA, vitamin E, vitamin C, and carotenoids, have better reproductive performance and better gamete and larvae quality [30]. To get the desired outcomes, it is essential to include these ingredients in tiny amounts in broodstock diets.

4.3 Carbohydrate Requirement

One of the most vital elements in all living beings is carbohydrates, commonly known as sugars or saccharides. They serve as rapidly metabolized energy source molecules that help the body transmit energy, and structural elements. There is no evidence that fish has a demand for carbs in its diet. However, because they are a cheap source of energy, carbohydrates can "spare" the catabolism of other substances like protein and lipids [20]. According to [12], lower limits of carbohydrate incorporation do not have a significant effect on maturation and breeding.

4.4 Vitamin-Mineral Supplements

While some organisms cannot synthesize vitamins, which are organic compounds needed in relatively small amounts by most forms of life and contribute to oogenesis and spermatogenesis in aquatic animals, minerals are inorganic compounds required by fish for the formation of tissue as well as aids in numerous metabolic and regulatory processes [20,12]. Vitamin E and C supplements were given to milkfish brooders, and they produced more spawns with greater percentages of viable eggs, hatching, and cumulative survival rates [31]. Additionally, [31] made a point of mentioning the requirement for vitamin C incorporation to increase the number of spawns with high-quality eggs and larvae. In rainbow trout, vitamin C has been linked to vitellogenesis and has been found to sustain sperm quality [32]. Fishes are incapable of naturally synthesizing vitamin E in their system, therefore, an external supplementation via incorporation in feedstuffs is an important step as it determines fish fertility and reproduction, as stated by [33] and [12]. Diet deficient in vitamin E inhibited ovarian growth in common carp, *Cyprinus carpio* [34], and it is also responsible for egg quality.

For their essential physiological and biochemical activities as well as to maintain their regular life processes, all aquatic species need minerals [35]. The presence of calcium in the water medium is necessary as it activates and hardens the eggs, as the eggs come into contact with water, and embryonic formation requires phosphates which are attained through vitellogenin in the yolk. Low female fecundity, hatchability, and high rates of abnormal deformity are consequences of phosphorus deficiency [12].

5. IDEAL DIET FOR GONADAL MATURATION AND REPRODUCTION

According to [16], in majority of Asian countries, broodstock development is still carried out with

the aid of live foods which are the primary sources of optimum nutrition, apart from other minor supplementation, such as feeding with a paste-based diet prepared from fish meal and skimmed milk powder. The use of formulated meals in place of live food is essential for reducing production costs and maintaining the generation of juveniles of high and consistent quality [36]. Furthermore, according to [37], freshwater fish production has been constrained due to the scarcity of live food. Formulated diets would mitigate this issue and enhance a consistently high output of high-quality seeds.

According to [16], the composition and palatability of meals had a substantial impact on *B. splendens* reproduction. The availability of proper type of feed is crucial since, according to [19], the short reproductive cycle of ornamental fish may cause continuous oogenesis in the adult female. Some species, like the voracious and indiscriminate feeder ruby barb (*Puntius nigrofasciatus*), have less preference for artificial diets, and highly accept and prefer live feed [38]. Breeders, involved in large-scale production of Discus (*S. aequifasciata*), feed the developing fry primarily with live foods including Tubifex, blood worms, and *Artemia* nauplii as reported by [39].

Furthermore, the dissociation of nitrogenous compounds from feedstuffs during protein metabolism (mostly ammonia) would immediately damage their existing habitat and cause stress in the fish, therefore this fact needs to be taken into consideration and ornamental fish kept in confinement must use their dietary protein as effectively as possible, hence the selection of an ideal diet is necessary [40]. Protein and lipid content of discussed ingredients is given in Table 1.

Table 1. Protein and lipid content of feed ingredients

Ingredient	CP (%)	CL (%)	Reference
Tubifex	59.70	17.50	[16]
Fish meal	65.42	5.58	[41]
Squid meal	72.19	10.19	[52]
Chicken liver meal	60.37	23.60	[43]

**Abbreviation – CP: crude protein, CL: Crude lipid*

5.1 Tubifex

Tubifex's crude protein and crude lipid contents are high enough, i.e., 59.7% and 17.5%, respectively [16], which will facilitate easy maturation and enhanced reproductive performance in fishes. [44] mentioned that tubifex is a nutritionally complete diet for maturation and reproduction. Tubifex is utilized as a gourami broodstock feed because it has a good amount of iron, carotenoids, and haemoglobin [25].

5.2 Fish Meal

Fish Meal is a good source of nutrients for fish maturation, with 65.42% crude protein and 5.58% lipid [41]. Fish meal is the best source for supplying the proper nutrition in terms of growth, feed conversion, and gonadal development, according to the report of [21] on guppy, *P. reticulata*.

5.3 Squid Meal

The presence of free amino acids in squid meal makes it one of the most potent attractants that pique aquatic animals' gustatory (taste) and olfactory (smell) senses. Its recommended inclusion level in broodstock diet is 20–30%. [45,46] also defined squid meal as a good source of dietary lipids and protein. Glycine and betaine, two chemo-attractant qualities of squid meal and other squid products, are crucial stimulators of the feeding behaviour [47]. Biological research has revealed that squid contains some undiscovered growth factors, which are referred to as "squid factor," and squid meal appears to have additional growth-promoting qualities [48,49].

When squid meal was added to the diet of Kuruma shrimp (*Penaeus japonicus*), growth was increased by 30 to 50%. Animals' serum cholesterol is reduced by the squid's lipid content [50]. Furthermore, 30% of the maturation diets for tiger shrimp broodstock contain both fresh and squid meal [51]. Squid meal is a feasible source of nutrients for fish growth and maturation, with a crude protein level of 72.19% and a lipid content of 10.19% [42].

5.4 Chicken Liver Meal

A very good source of nutrients for the maturity and reproductive performance of ornamental fishes is chicken liver meal, which has a crude protein content of 60.37% and a lipid content of 23.6% [43]. The best results were shown in swordtail fed a diet that included chicken liver meal in terms of weight increase, SGR, and FCR [26]. In their study, [52] found that feeding black

molly a diet including chicken liver meal produced better results than feeding fish waste meal, earthworm meal, etc. Additionally, the performance of chicken liver meal is comparable to that of squid meal and prawn meal.

6. THE IMPACT OF SELECTIVE MEAL TYPE ON GROWTH AND SURVIVAL

SGR in larval rearing of *Chitala chitala* was found to be higher in post-hatchlings fed on live tubifex worms as measured by [53] in their study to compare different diet performances, including fish eggs, dry tubifex, chironomid larvae, spirulina, daphnia, and planktons. [54] found that young South American catfish surubim (*Pseudoplatystoma fasciatum*) fed with tubifex had the best survival rate (100%) and the highest level of 20:4n-6 deposition in the fish tissue. When compared to alternative diets like formulated feed, vermicompost worms, etc., tubifex-fed angel fish showed the highest weight gain [55]. In terms of weight increase, SGR, and FCR, [56] found that goldfish fed a diet based on fish meal showed improved growth response and feed performance. However, Discus and Red Head Cichlid fed a diet based on fish meal with 40–50% protein content displayed superior SGR [57,58].

According to [42], adding 4% squid meal to de-hulled solvent extracted soybean meal as a secondary source of protein will effectively act as an attractant and boost the intake of plant-based diet for pompano. According to [26], goldfish fed squid meal had the second-highest growth performance after fish-fed tubifex, and their cost per unit of production was about 20 times lower than that of tubifex. In addition, [26] found that feeding blue gourami (*T. trichopterus*) and guppy (*P. reticulata*) squid meal and chicken liver resulted in the best growth and feed performance as measured in terms of weight gain, SGR, FCR, and PER, whereas feeding swordtail (*X. hilleri*) with chicken liver meal resulted in the best performance.

7. CONCLUSION

In conclusion, local fish species are essential for preserving the harmony and health of aquatic ecosystems. To protect these species and assure their survival for future generations, action must be taken. Enhancing the fish population's natural stock can be accomplished through captive breeding. Captive breeding can be used to supplement natural populations and boost their size in light of the decline of many fish species brought on by overfishing, habitat degradation, and other human influences. Overall, this methodology can improve the natural fish resource and aid in the conservation of these species and sustainability of the environment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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