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Selection of small indigenous fish for induced breeding trials in the states of Assam and Odisha in India

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Selection of small indigenous fish for induced breeding trials in the states of Assam and Odisha in India

Authors

Francois Rajts, Ben Belton and Shakuntala Haraksingh Thilsted.

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Contact

WorldFish Communications and Marketing Department, Jalan Batu Maung, Batu Maung, 11960 Bayan Lepas, Penang, Malaysia. Email: worldfishcenter@cgiar.org

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1. Executive summary

In the recent past, wetlands, lakes and rivers in South Asia supported a diverse and abundant fish fauna. Small indigenous fish species (SIS) represented an important component of capture fisheries landings and crucial part of the diets and livelihoods of rural households, offering a readily available and accessible source micronutrient-rich food and income.

In the present, multiple anthropogenic threats to the environment place ever-greater pressure on aquatic biodiversity, negatively affecting the abundance of SIS. These stressors include flood control structures, conversion of wetlands to agriculture and aquaculture, overexploitation of fish populations, invasive exotic species, and climate change.

SIS were once considered a "food of the poor", but their price now commonly exceeds that of large, farmed fish. Although common species of farmed fish are now relatively affordable, many SIS possess micronutrient profiles that are superior to those of larger species. These nutrients include calcium, phosphorus, zinc, selenium, and vitamins A and B12 that generally are consumed in inadequate quantities by poorer households, and are particularly important for pregnant women and children under 1000 days of age.

Farming SIS has great potential to increase their availability in the market and make them more accessible to consumers but scaling up production of cultured SIS will require the development of new captive breeding techniques. The following criteria were applied to select candidate species of SIS for initial artificial reproduction trials:

a. The micronutrient profile of the fish, with preference given to those with high levels of important vitamins and minerals.

b. Trophic level, with species with at lower trophic levels (i.e., lower in the food web), preferred over higher trophic level species.

c. Suitability for culture.

d. Market demand and consumer preferences.

Six species were selected for induced breeding trials, as listed below.

- Mola carplet (*Amblypharyngodon mola*) is predominantly a phytoplankton feeder, and has high Vitamin A and B 12, Iron and Calcium content.
- Pool barb (*Puntius sophore*) is mainly herbivorous. Its polyunsaturated fatty acid (PUFA) content is almost three times higher than that of mola, and it also contains high levels of Calcium.
- Flying barb (*Esomus danrica*) has a high Iron, Iodine, Selenium and Vitamin B12 content.
- Dhela (*Rohtee cotio)* is dominantly phytoplankton feeder, with high levels of Calcium, Selenium, and Vitamin A.
- Banded gourami (*Cholisa fasciata*) is an omnivore that can survive in hypoxic water where most fish cannot and is thus very effective for eliminating mosquito larvae. It contains high levels of Iron, Calcium, Zinc and Vitamin B12.
- Koi (*Anabas testudineus*) is an omnivore, with high levels of PUFA, and a moderate selenium and high vitamin A content.

2. Introduction

WorldFish is implementing a GIZ-supported project called *"Taking Nutrition-Sensitive Carp-SIS Polyculture Technology to Scale"*, in Odisha and Assam states in India. The project aims to develop induced breeding techniques for small indigenous fish species (SIS), with the ultimate goal of improving the nutritional status and health of children, pregnant women and the poor. All are susceptible to micronutrient deficiencies, which can lead to impaired physical and mental development, reduced resistance to diseases, and stunted growth.

SIS can be an important source of essential micronutrients for combatting micronutrient deficiencies. Prior research has demonstrated that polyculture of carps with SIS species is possible and profitable, but to date there has been little investment the development of induced breeding technologies to produce SIS seed on a commercial scale. Closing the lifecycle on promising SIS candidate species to support mass breeding thus represents the single most critical supply-side bottle neck to scaling up SIS aquaculture to meet nutritional needs.

In India, out of 765 native freshwater fish species documented by the National Bureau of Fish Genetic Resources (NBFGR), about 450 may be categorized as small indigenous freshwater fish species (Sarkar et al. 2010).

This document presents a rationale of proposed selection of SIS species for experimental induced breeding, considering the following factors:

1. Micronutrient composition, with particular attention paid to vitamin and mineral composition.
2. Trophic level, with herbivorous species lower in the food web preferred over predatory species.
3. Suitability for culture, including polyculture with commonly cultured larger fish species.
4. Growth rate and time take to reach market size in small seasonal water bodies.
5. High level of consumer preference and market demand as indicated by a higher price than common farmed species, to incentives farmers adopt production, but with the ultimate of objective to reducing prices by increasing availability.

Developing induced breeding techniques for SIS could help to mitigate destruction of wild spawn.

3. Malnutrition in low-income populations

Until recently, SIS were highly abundant in Assam and Odisha. These small low-cost fish contributed a major share of fishers' income and nutrition and were readily accessible to the poorest strata of the rural population.

However, habitat destruction and overexploitation of natural waters have reduced SIS populations in recent decades. SIS consumption among the rural population has dropped significantly as a result, contributing to poor nutrition outcomes. For good health, a diet should contain a high diversity of foods, including those rich in micronutrients, in adequate quantities. Inadequate nutrient intakes are associated with negative health outcomes including reduced resistance to diseases, stunted growth, and impaired cognitive development.

Pregnant woman and children in particular require a balanced diet, including adequate proportions and quantities of amino acids, essential fatty acids (EFAs), vitamins, calcium, iron, zinc and other micronutrients. Deficiencies in any of these nutrients can lead to serious health problems. For example, vitamin A deficiency, which affects many developing countries, (Figure 1) can result in night blindness, total blindness, delayed growth, improper healing and predisposition to throat and chest infections.

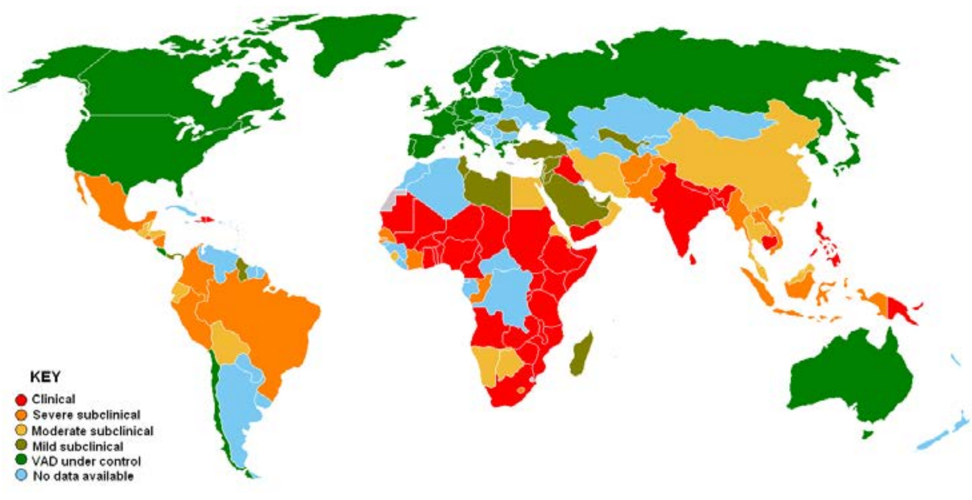
In Bangladesh, although the country's vitamin A supplementation program has reduced vitamin A deficiency, 20.5% of pre-school children are still deficient (Chanda et al., 2019) found that. Moreover, 43% of children in Bangladesh under 5 years of age suffer from zinc deficiency Ahmed (2012).

In parts of India, the situation is worse still. According to Kapil (2011), Odisha State has the highest level of zinc deficiency among children from low socioeconomic groups, which is the highest level of five Indian states: Odisha (51.3%), followed by Uttar Pradesh (48.1%), Gujarat (44.2%), Madhya Pradesh (38.9%) and Karnataka (36.2%)

Mahanta et al. (2012) examined the prevalence of undernutrition among pregnant women in a rural area of India's Assam State. Their results showed that 62% of the women were anaemic, and copper and zinc intakes were 29% and 12% below normal levels, respectively.

Because levels of consumption of animal source foods in these two states are low, the poor often make extensive use of spices and monosodium glutamate (MSG) to improve the variety and taste of their diet. However, excessive use of MSG can have neurotoxic effects and detrimental consequences for the reproductive organs (Niaz et al. 2018).

Moreover, grains and vegetables, which make up the major portion of the diet, quantitatively for poor consumers in these states, contain antinutritive elements, especially phytates. Dietary phytates reduce the bioavailability of calcium, magnesium, iron, and zinc in the diet as phytic acid binds with these elements (Sandstead et al. 2014). However, micronutrients in fish and other animal-source foods are generally more bioavailable than those from plant-source foods, and consumption of fish can enhance the bioavailability of micronutrients from plant-source food in the diet (Ahern et al., 2021).



Source: Wikimedia Commons.

Figure 1. Countries with vitamin A deficiency.

4. Nutritional value and health benefits of SIS

Small fish are a rich source of most macro- and micronutrients, and are often cooked and eaten whole, meaning that micronutrients such as the vitamins and minerals that are present in the head, bones and liver are consumed (Thilsted 1997). Cooking and eating small fish whole is thus superior, in nutritional terms, to eating a fish fillet. Moreover, small freshwater fish are generally free from mercury, which can bioaccumulate in larger marine fish and is particularly harmful for children and pregnant women.

Historically, freshwater fish culture has focussed mainly on producing large fish species. However, the edible portions of large fish such as carps, tilapia and catfish generally have a lower nutritional value than most small fish when eaten whole.

For example, mola (*Amblypharyngodon mola*), pool barb (*Puntius sophore*) and dhela (*Osteobrama cotio*) contain more available vitamin A than any cultivated large freshwater fish in Bangladesh (Thilsted et al. 1997). In 100 g of raw edible SIS, most have a retinol equivalent content of vitamin A between 100 and 2500 µg (Roos et al. 2003). In comparison, the total vitamin A content in raw rohu is less than 2% of that in mola (Roos et al. 2002).

Table 1 lists the levels of important nutrients of some SIS and large fish species, while Annex 1 shows the vitamin A content, in order, of SIS and large fish in Bangladesh.

When eaten whole, SIS provide calcium, which is important for healthy development and the

		Energy	Protein	Fat	Iron	Zinc	Calcium	Iodine	Selenium	Vit A	Vit B_{12}
		kJ	g	g	mg	mg	mg	mg	mg	mg	µg
Mola	*A. mola*	455	**17.3**	4.5	5.7	3.2	853	17	5	**2503**	7.98
Dhela	*Rohtee cotio*	387	14.7	3.8	1.8	3.7	1200	9.5	**29**	918	4.7
Jat puti	*P. sophore*	541	15.7	7.2	2.2	2.9	1042	20	9.5	54	4.01
Darkina	*E. danrica*	384	14.7	3.8	**12**	**4.0**	891	**81**	12	660	**12.5**
Tengra	*M. tengara*	428	15.1	4.6	4	3.1	1093	28	24	12	3.5
Koi	*A. testudineus*	**737**	15.5	**12.8**	0.87	0.6	85	nd	19	295	2.38
Kholisa	*C. fasciata*	345	15.2	2.5	4.1	2.3	**1700**	20	26	46	5.55
Catla	*G. catla*	267	14.9	0.7	0.83	1.1	210	18	27	22	1.3
Rohu	*L. rohita*	422	18.2	3.0	0.98	1.0	51	20	29	13	5.05

Source: Extracted from Bogard et al. 2015.

Table 1. Nutrient composition of SIS and cultured large fish species per 100 g of edible portion of fish.

maintenance of bones. SIS also provide iron, a vital mineral in the production of hemoglobin in blood cells, which carry oxygen. Anaemia can cause shortness of breath and fatigue and can reduce resistance to diseases and cause thyroid affection. Zinc is another essential nutrient, important for preventing stunted growth and maintaining a healthy immune system.

In some developing countries, fat intakes in the human diet, including n-3 polyunsaturated fatty acids (PUFAs), are below minimum recommended levels. Michaelsen et al. (2011) recommend continuing breastfeeding for children up to at least 2 years of age and promoting increased intake of fish, such as farmed SIS.

EFAs are particularly important for the human diet because they cannot be synthesized by the human body. The fat content in fish is generally highly valued as a food because of the presence of EFAs. For example, mola fat has a relatively high level of EFAs (Mustafa et al. 2015) and, as shown in Table 1, is higher in lipids than most cultured carps. In Assam, Chakraborty (2015) found that the proximate composition of mola to include 18.3% protein and 3.5% fat, while Mustafa et al. (2015) found a slightly higher percentage of fat (4.5%). Bogard et al. (2015) found similar percentages of protein and fat in wild mola (17.3% and 4.5%) and cultured mola (14.7% and 4.6%).

Mustafa et al. (2015) and Bogard et al. (2015) mention that variations in nutrient content may be due to differences in location, food, season, sex, habitat, and other environmental factors. This indicates the need for further research in pond management and appropriate feed formulation for culturing SIS, including mola.

The micronutrient content of most SIS exceeds that of larger fish.

5. The status of SIS

Production of SIS in natural waters in South Asia has been declining over time despite the ability of many species to reproduce quickly and withstand poor environmental conditions. As such, fewer SIS are available in markets than in the recent past. The following factors have contributed to declining SIS populations:

- Loss of natural habitat, including breeding grounds:
    - Wetlands have been converted into agricultural land by draining natural depressions called beels.
    - Flood control and hydroelectric dams have prevented migration to breeding grounds. Hydroelectric dams also reduce fish habitat and breeding grounds below the dam by discharging water more or less constantly, which prevents seasonal inundations of low-lying areas downstream near rivers.
    - Construction of flood control structures such as polders, which are used to protect land from flooding to facilitate agriculture, reduce water area and depth during periods of flooding. Flood control infrastructure has interrupted fish migrations to breeding grounds and reduced the length of the production period for SIS.
    - Construction of roads in floodplains, which requires building high dikes, has cut off the connection between floodplains and permanent water bodies, except for some openings via culverts or small bridges. Broodfish of most SIS survive in permanent beels and rivers during the dry season and migrate to floodplains for breeding. However, various fishing gear is being placed over dike openings to catch migrating fish, which limits SIS reproduction.
    - Road dikes and screened culverts have created large floodplain enclosures, which prevent SIS from migrating to breeding grounds. In Bangladesh, these compartments are used for seasonal carp culture alternating with rice cultivation.
- Uncontrolled high fishing pressure in natural waters, including the use of gill nets with small mesh sizes as well as large seine nets made from mosquito nets, have reduced the abundance of SIS.
- Widespread use of exotic fish species in aquaculture and escapes of non-native fish into natural waters have also reduced SIS populations. For example, SIS face increased competition for food from bighead carp, increased predation from feral African catfish and increased habitat destruction from grass carp and feral tilapia because of prolific breeding and competition for food and space. Another example is the excessive nest building of tilapia males in shallow waters. In defending their territory, tilapia males destroy benthic flora and fauna at the expense of the breeding, nursing and feeding grounds of SIS.
- Permanent small natural water bodies are often drained completely during the dry season to harvest fish—a practice that, although prohibited, is not being controlled sufficiently. This practice prevents the recruitment of SIS during the following monsoon season. In addition, the genetic variation of the next generation of SIS is reduced when a small number specimens of the smallest size among the population survive during dry season in crab holes. This can potentially lead to negative selection for growth, inbreeding depression and other genetic damage to the concerned species, particularly when this practice is repeated every year.
- Fish strains are being imported from tropical waters to subtropical regions on a large scale. Natural or artificial hybridization between exotic tropical strains and endemic strains of the of the same species is modifying the genetic pool of endemic strains, resulting in the loss of genetic resources and reduced resistance to diseases during the cold season. For instance, climbing perch (*Anabas testudineus*) imported to Bangladesh and India from the Mekong Delta grows larger than the endemic strain and frequently contracts epizootic ulcerative syndrome (EUS) in winter, which increases the risk of spreading the disease to local SIS populations.

- New diseases are also being accidentally imported. For example, for years the hills of Myanmar prevented the spread of EUS from Myanmar to Bangladesh. In 1988, however, the disease finally got into Bangladesh through imports of silver barb.
- In countries where intensive culture of pangas, tilapia and climbing perch is practiced with frequent preventive and curative use of antibiotics, multiple resistant strains of pathogens have emerged. For example, *Streptococcus* spp. and *Edwardsiella* spp. (Wendover et al. 2011; Niu et al. 2019). Frequent imports of fry of those infected species for aquaculture is threatening indigenous fish populations, including SIS. Streptococcus in freshwater fish has caused disease in humans in Singapore (FAO 2021), while *Edwardsiella* spp., which is a Gram-negative pathogen, has become antibiotic resistant and is now frequently present in intensive pangasius and tilapia farms. *E. tarda*, another pathogen, can trigger zoonotic disease (Dung 2010).
- During the breeding season, deep nets are being used to collect wild spawn from the Ganges and Brahmaputra watershed, a practice that is destructive to targeted carp species and detrimental to recruitment of SIS (See photograph of wild spawn collection on page 2.)

Additional causes of SIS declines include: poisoning fish before a new cycle of carp culture, use of pesticides on paddy fields, open-water pollution from untreated industrial effluents, and climate change.

Although aquaculture has made spectacular progress through the development of hatchery and nursery techniques, polyculture, and introducing new species for better use of vacant niches, the development of cultivation techniques of small fish as food began much later. The likely reasons for the late start are assumed food competition with cultured species, as well as the abundance of SIS in the past in open-water catches and resultant low market prices.

Woman fisher with a haul of SIS in Odisha, India.

6. Market demand and prices of SIS

Before the widespread loss of floodplains, the main animal source food for the rural poor in Bangladesh and other parts of South Asia were SIS purchased from local markets or caught themselves in open waters. At that time, the price of SIS was the lowest among all fish available in markets and ensured better nutritional balance among rural poor.

Demand for SIS is growing thanks to awareness building about their nutritional value by development projects, universities, research institutions and governments. However, because of their increasing scarcity and growing demand, market prices of SIS are now frequently higher than for large fish. This has made it progressively more difficult for the poor to buy SIS, resulting in higher consumption of less nutritious, intensively farmed large fish.

Gogoi et al. (2015) report that the demand and price of SIS are high in markets in Assam, specifically mola (*Amblypharyngodon mola*), puti (*Puntius* spp.), bata (*Labeo gonius*), singara (*Mystus* spp.), singi (*Heteropneustes fossilis*) and kawai (*Anabas testudineus*).

In Bangladesh, the price of SIS is approximately two to three times higher than for common farmed fish, such as rohu. The Plate 1. Shows mola, having double price than the traditionally preferred Rohu. Prices found at the Shaheb bazar in Rajshahi, Bangladesh in February 2020 are presented in Annex 3.

Today, however, the market prices of most SIS are higher than for large-sized farmed fish because of the scarcity of SIS coupled with the increased demand resulting from recent efforts of awareness building about the advantages of consuming SIS. By buying the most inexpensive large fish from markets, the poor are being prevented from having a balanced diet.

For example, the calcium in large fish is mainly found in their bones, which are not edible, while SIS are entirely edible and have high bioavailability of vitamins and minerals, including calcium, iron, zinc, selenium, vitamin A and B12, so eating them would help prevent vitamin and mineral deficiencies among the rural poor. This is why adapting technologies for large-scale production of SIS is so important.

Plate 1. A handful of mola for the price of large carp.

7. Developing induced breeding techniques

There are a huge number of unused seasonal small water bodies, roadside ditches, *kuas* and household ditches throughout the region that are not well suited to culture of large fish, but are suitable for SIS production. Several studies have investigated developing SIS culture techniques. Most are based on stocking fish seed collected from the wild or of uncertain origin in production ponds.

To evaluate the production potential of SIS, Kohinoor et al. (2005) conducted a polyculture trial of Indian major carps with three SIS: mola, puti and chela (*Chela cachius*). The result showed that partial harvesting of SIS is necessary for best production. This requires stocking SIS seed of the same age, at the right time, and in sufficiently large numbers during polyculture with carps.

As SIS culture spreads, the demand for SIS seed is increasing. Stocking wild breeders is one method that is already being practiced. However, starting SIS culture using hatchery-produced fry of a known number and of the same age would have many advantages:

- It would reduce the number of mortalities associated with transporting mature, sensitive SIS breeders for stocking grow-out ponds.
- It would eliminate the presence of predators. Currently, thousands of small breeders weighing just a few grams are stocked for breeding in grow-out ponds, making it difficult to sort out predators because of the difficulties in handling the breeders. For example, if chanda *(Chanda nama)* get into the pond they will prey on mola fry.
- The growing period is reduced when breeders are stocked. This mostly affects production in seasonal water bodies, where water is only available for a few months. Stocked breeders need an acclimatization period in the new environment and time for gonads to fully develop. As a result, the water body dries out before the new generation has time to reach to market size.
- Scattered breeders frequently prey on eggs and larvae or even small fry. Stocking hatchery-produced fry instead of breeders would eliminate this.
- When breeders are stocked for seeding of pond, the recruitment capacity of late breeders is mainly lost. Natural spawning does not occur in a single day. As a result, younger fry become victims of food competition and cannibalism from older fry. Young fry are extremely sensitive to a lack of plankton of the right size to eat. During the initial weeks, they eat zooplankton, starting with protozoans and rotifers and gradually working up to larger zooplankton according to fry growth. If older fry have already consumed the available food, then the youngest strata of the population will not be able to find enough food. Any survivors would remain undersized or die off because of competition for food from older fry.
- The growth rate of young fish is high until they reach maturation. Mature fish consume the natural food and supplemental feed, using it as energy for gonad production, survival into the next breeding season, defending territory, and so on. Consequently, ponds stocked with SIS breeders will have a mixed population of different ages during the production period. This makes it impossible to calculate the survival rate, feed conversion rate and specific growth rate, all of which are important for improving pond management and profit. The solution is to stock hatchery-produced fry of the same age.
- For the above reasons, in the case of stocking hatchery-produced fry, a smaller number of breeders are required to have the same number of fry in the pond.
- Stocking hatchery raised SIS seed reduces the risk of infections from pathogens, as SIS breeders collected from the wild or other ponds can introduce parasites or diseases into a well-prepared pond.
- Hatcheries can induce spawn production earlier than as happens in the wild. This facilitates timely stocking of water bodies, which would be highly beneficial in seasonal waters.
- Stocking hatchery-produced fry will result in a uniform size at harvest, which is more attractive in the market and fetches better prices.

Most SIS are too small and sensitive for applying usual hatchery techniques to produce industrial quantity of spawn. That is why developing induced breeding methods, adapted to each SIS, is required.

8. Proposed SIS for induced breeding trials

It is not easy to select the most suitable SIS for mass seed production, because there are more than 200 candidates, many of which are not well known. The overall objective of selection is to improve the nutritional status of children and pregnant women in developing countries by improving the availability of micronutrient-rich SIS. The specific objective is to find out the best SIS candidates for induced breeding trials, which could lead to improved technologies for mass production of high-quality SIS seed. Based on these objectives, we identify six potential candidate species for breeding trials in Assam and Odisha, as follows.

8.1. Mola carplet

Amblypharyngodon mola (Hamilton, 1822)
Other names: moa, mourala, mowka, moya (Froese and Pauly 2021).

Plate 2. Mola carplet.

Mola is the first choice for induced breeding trials, because its high nutritional value, good taste and small size mean it can be equitably distributed among family members and eaten whole. Mola is rich in micronutrients, has high fecundity, can be cultivated in polyculture with other fish and currently fetches good market prices, although, one of the ultimate aims of the induced breeding trials is to reduce the market price by increasing the supply to make it more readily available to low-income consumers.

8.1.1. Characteristics of mola

Mola is distributed through Pakistan, India, Bangladesh and Myanmar, and it has been reported in Afghanistan. It inhabits rivers, streams, lakes, ponds, ditches and other stagnant waters (Froese et al. 2021). Its maximum recorded size is 20 cm (Talwar and Jhingran 1991), though Rahman (1989) reported its maximum length as only 15 cm. Its lifespan is usually 13 months for males and 15 months for females, as reported in the Payra River of Southern Bangladesh by Ahamed et al. (2017).

Mola has small gill rakers, which are connected with a membrane to filter plankton. In Assam State, where mola make up to 4% of catch from capture fisheries, they mainly feed on phytoplankton, which consists of 94.74% of its food (Gogoi 2017). Mondol et al. (2013) found that almost the entire composition of the gut contents of mola is made up of phytoplankton (94.38%), with the rest being zooplankton (5.62%). Gupta and Banerjee (2013) found that mola is a herbivorous fish, and chlorophyceae has been observed as its most preferred food. Mola has also been reported to feed on detritus, as reported in Myanmar by Froese et al. (2016).

First maturity occurs at 3 months of age (Rajts et al. 1997), and mola is a fractional spawner (Gupta and Banerjee 2013). Its eggs are slightly adhesive, so the presence of an appropriate substrate stimulates spawning and improves the hatching rate. Data collected on reproductive biology of mola is presented in Table 2.

8.1.2. Nutrient content of mola

Mola is particularly rich in vitamin A, amounting to 2503 µg per 100 g of edible fish (Bogard et al. 2015). It is also rich in EFAs and in minerals and is well suited to alleviate vitamin A deficiencies that cause eye and skin diseases, among others. Mola has the potential to meet the nutritional requirements for vitamin A, iron, zinc, EFAs and protein among children and pregnant women. Mola is also high in essential amino acids. Mustafa et al. (2015) found that the lipid content of mola is 4.5%, while the percentage of omega-3 PUFAs in total fatty acids is 6.31±1.4 % in the head and 5.93±0.75 % in the body.

The nutrient content of cultured mola, as shown in Table 3, is different in fish culture than in the wild. The calcium content of natural mola is only

Particulars	Value	Reference
Age of maturity (month)	3	Rajts et al. (1997)
Spawning frequency/year	5	Ghosh et al. (2018)
Weight at maturity, female (g)	0.25–11.82	Rahman et al. (2018)
Weight at maturity, male (g)	0.39–6.86	Rahman et al. (2018)
Length at first maturity, female (cm)	3.57–9.94	Rahman et al. (2018)
Length at first maturity, male (cm)	3.69–8.88	Rahman et al. (2018)
Breeding habit	Batch spawner	Froese et al.2021
Parental care	none	Froese et al. 2021
Breeding ground (preferable)	Freshly flooded dry land with plant substrate	Rajts et al. (1997)
Natural breeding per year	2	Kohinoor et al. (2005)
Semi-natural breeding per year (induced by environmental manipulation)	5	Ghosh et al. (2018)
Gonado Somatic Index (GSI) female (January and June)	1.78 and 17.06	Kohinoor et al. (2005)
Eggs per female 5–5.5 cm and 8.1–8.5 cm ♀	1023 and 6806	Hoque and Rahman (2008)
Eggs per gram of female 5–5.5 cm and 8.1–8.5 cm ♀	200 and 850	Hoque and Rahman (2008)*
Diameter of vitellogenic oocyte µm	27–30	Hoque and Rahman (2008)
Pituitary gland (PG) dose for induced breeding	2 mg/kg ♀ and 1 mg/kg ♂	Hatchery owner S.I. Khondaker
PG dose for induced breeding	25 mg/kg ♀	Saha (2019)
Latency period for ovulation (hours at 27°C)	6–7	Hatchery owner S.I. Khondaker
Time of egg development to hatching (hours at 27°C)	12	Saha (2019)
Larval development time (hours at 27°C)	72	Hatchery owner S.I. Khondaker

** Calculated from data in Hoque et al. 2008. Relative number increases with size.*

Table 2. Reproductive biology of mola in the Ganges-Brahmaputra Delta.

	Energy	Prot.	Fat	Fe	Zn	Ca	I	Se	Vit. A	Vit B_{12}
	kJ	g	g	mg	mg	mg	µg	µg	µg	µg
Natural	455	17.3	4.5	5.7	3.2	853	17	5	2503	7.98
Cultured	412	14.7	4.6	19	4.2	1400	33	19	2226	5.9
C/N (%)	91	85	102	333	131	164	194	380	89	74

Source: Extracted and modified from Bogard et al. 2015.

Table 3. Nutrient composition per 100 g of edible mola.

61% of cultured mola. Freshwater fish can absorb calcium (and other minerals) from the water through the gills (Flik et al. 1986), though mola may not be able to absorb enough from soft water alone. A lack of minerals negatively affects growth in fish and reduces its nutritive value for human consumption. However, the amounts of vitamin A and B12 are significantly lower in cultured mola. Water from the Ganges has higher mineral content than in the Brahmaputra, including in the alluvial soil there. In water bodies in the Brahmaputra watershed, particularly rainfed ponds, mola culture could be improved by applying feed and using feed formulated to their requirements in relation to environmental water quality. More research is needed in this area. Mola have a higher lipid content than most carps, and similar protein content (Table 4)

8.1.3. Culture potential of mola

Among SIS, mola is known as an excellent candidate for aquaculture. For more than a decade, Bangladesh Agricultural University has been working with partners from Denmark on mola culture. Together, they have developed production technologies for pond culture, connected pond culture (where mola is allowed to migrate between a pond and an adjacent rice field) and stock enhancement in wetlands (Thilsted and Wahab 2014). The Bangladesh Fisheries Research Institute and the Department of Fisheries (DOF), as well as several universities and nongovernmental organizations, have also been promoting SIS culture. Polyculture of mola with carps has been successfully demonstrated by several trials (Annex 2).

Species	Protein	Lipid
Mola	17.3	4.5
Mrigal	18.9	1.1.
Rohu	18.2	3.0
Silver carp	17.2	4.1
Common carp	16.4	2.9
Grass carp	15.2	1.1
Catla	14.9	0.7

Source: Extracted from Mustafa et al. 2015.

Table 4. Comparison of protein and lipid content of mola and carps as a percentage of edible parts.

Based on results in Bangladesh, WorldFish initiated mola culture in India during 2019 and 2020. In Odisha State, together with the Fisheries and Animal Resources Development Department (FARD), Government of Odisha, WorldFish initiated mola culture in small homestead ponds, community tanks and minor irrigation reservoirs and found that the production potential was huge. In Assam State, in collaboration with the College of Fisheries under the Assam Agricultural University and the DOF, successful mola production was demonstrated in 67 ponds, which triggered farmers outside the project to start mola culture as well (Saha and Barman 2020).

Although the International Union for Conservation of Nature's Red List lists mola as a species of "least concern," its population, along with most SIS, is becoming scarcer in wetlands day by day. Suresh et al. (2007) stated that the availability of mola has been drastically reduced in the estimated 42,000 ha of wetlands in West Bengal, where mola represented a major component of the fishery of indigenous fish in the past. They also mentioned that mola from these wetlands play an important part in the nutritional requirements of population.

8.1.4. Market availability and price of mola

Mola availability in the market is highest during the dry season, when natural waters like beels and haors are harvested. Large-scale development of mola aquaculture would ensure better availability of mola year-round.

A market price as high as BDT 600/kg is not easily affordable for pregnant women and young children in the low-income population. Although high prices are attractive for fish farmers to introduce mola into carp polyculture, establishing the hatchery and nursery industry of mola would be the first step toward increasing mola production and reducing the price of mola in the market.

8.2. Pool barb

Puntius sophore (Hamilton, 1822)
Other names: katcha-karawa, phabounga, bhadi punti, jat punti, jatputi, puti, sar puti (Froese and Pauly 2021)

Plate 3. Pool barb.

The pool barb, which is mainly herbivorous, is another popular tasty and nutrient-rich SIS. Its traditional popularity is due to its tastiness, and abundance in rivers, floodplains, beels, ditches and ponds. Pool barb populations have decreased because the size of the flooded areas where it breeds and the duration of flooding have declined. Despite this, it is still the most frequently available SIS in the market. A huge amount of pool barb is harvested during the dry season and conserved by drying or by fermentation. Fermentation is done using salt, packing fish in earthen jars, and storing for at least 2 months.

8.2.1. Characteristics of pool barb

Pool barb is found in Afghanistan, Bangladesh, Bhutan, China, Pakistan, India, Myanmar and Nepal. Das et al. (2013) estimated feeding habits in relation to its morphometric characteristics. They found that pool barb is a surface and column feeder. It is herbivorous up to a total length of 5–7 cm, with a relative gut length (RGL) of 4.6. Above 5.59 cm total length, it starts to feed on zooplankton as well, and becomes carnivorous at 8.5 cm total length, with an RGL of 3.9, when the percentage of zooplankton in the diet reaches 60%.

Dashgupta et al. (2017) found that pool barb has a salinity tolerance of 0–5 ppt. Hossain et al. 2012 determined that its length at first maturity is 5 cm. During the breeding season, males develop a reddish coloration. Kant et al. (2016) found that the estimated fecundity ranged from 1560 to 2314 eggs, with a mean total length of 5.5 cm and a weight of 5.47 g. The relative fecundity ranged from 390.85 to 480.18 per fish while the absolute fecundity ranged from 6106.73 to 6942.35 eggs.

Hasan et al. (2018) stated that pool barb is a pre-monsoon and monsoon spawner that spawns from March to July in Bangladesh. They also compared the breeding season of pool barb in two regions of the country, where they observed its GSI, fecundity and the diameter of oocytes. The diameter of mature eggs is 0.7 mm, though this varies slightly according to size and nutritional status. The highest GSI found was 15.43 for the month of April at Gazipur and 15.60 in June for Jessore (Jahsore). The highest fecundity (5053) in Gazipur was recorded in April and for Jessore in June (5433). Fecundity was lowest in September in all cases.

Hasan et al. (2018) concluded that only one breeding season exists for pool barb in Bangladesh. However, Ghosh et al. (2018) induced natural spawning five times per year for mola and three times for pool barb by making changes to water quality. Induced breeding of Indian major carps based on environmental modifications using soft rainwater is traditionally practiced in *bundh* in West Bengal (Kumar 1992). The delay in breeding by 2 months in Jahsore can be explained by the delayed onset of monsoon rains there. Hasan et al. (2018) also concluded that environmental factors strongly determine the breeding season and so may vary from region to region. These findings indicate the possibility of inducing spawning for pool barb several times a year.

8.2.2. Nutrient content of pool barb

Pool barb is high in both fat and calcium, as shown in Table 5.

	Energy	Prot	Fat	Fe	Zn	Ca	I	Se	Vit. A	Vit B_{12}
	kJ	g	g	mg	mg	mg	mg	mg	mg	µg
Pool barb	541	15.7	7.2	2.2	2.9	1042	20	9.5	54	4.01

Source: Extracted from Bogard et al. 2015.

Table 5. Nutrient composition per 100 g of edible of pool barb.

The fat content of pool barb is of good quality for human consumption. Mustafa et al. (2015) found a higher percentage of fat and a higher proportion of PUFAs in the fat content of pool barb than in mola (Table 6).

8.2.3. Culture potential of pool barb

In field trials of polyculture with carps, Kohinoor et al. (1999) obtained the highest production (2103 kg) when Indian major carps were cultured with pool barb. Kohinoor et al. (2001) obtained 509 kg/ha for a 6-month production cycle of pool barb in a monoculture trial, using only organic pond fertilizer and low-cost agricultural by-products, such as rice bran at 3% of biomass per day.

Wahab et al. (2003) conducted a polyculture trial of pool barb and mola with catla, rohu and mirror carp in 25 ponds. The stocking rate of carps was 1000/ha, with SIS added at a rate of 25000/ha, either puti, mola, or both. The results show that adding puti and mola did not reduce the original cash crop production. As a result, the authors suggested that these SIS might be a good source of food for household consumption.

8.2.4. Market availability and price of pool barb

Pool barb is available in the market, though mainly during dry season, when beels and other seasonal waters dry up. Developing and disseminating controlled breeding and culture techniques of this species could help improve market availability throughout the year. The price observed in the Rajshahi retail market is shown in Annex 3.

8.3. Flying barb

Esomus danricus (Hamilton, 1822)
Other names: darkina and darka in Bangladesh, darikana and doricana in Assam, jhai in Odisha

Plate 4. Flying barb.

8.3.1. Characteristics of flying barb

Flying barb is found in Pakistan, India, Nepal, Bangladesh, Afghanistan and Sri Lanka. It has a maximum length of 13 cm, a fecundity of 392–2412 and primarily feeds on detritus and zoobenthos (Froese and Pauly 2021).

Mondal et al. (2019) studied the reproduction biology of flying barb and found that the diameter of mature ova was 0.31–0.45 mm and that of the ripe ova 0.41–0.6 mm. The GSI was high in both June and July and again in September. Breeding was observed in June and September. Mature ova were found in every month except January, with proportions fluctuating. This indicates the likely possibility of induced breeding of this species by environmental manipulation outside the natural breeding season.

Species	Fat in edible portions %	Omega-3 PUFA in fat	
		In head %	In body %
Mola	4.5	6.31±1.4	5.93±0.75
Pool barb	7.2	4.28±1.01	17.86±3.98

Source: Mustafa et al. 2015.

Table 6. Comparison fat and omega-3 PUFA content of mola and pool barb.

8.3.2. Nutrient content of flying barb

Flying barb is exceptionally high in iron, zinc, iodine and vitamin B12, and vitamin A, as shown in Table 7.

8.3.3. Culture potential of flying barb

Debnath and Sahoo (2020) stocked Indian major carps in polyculture with darkina, and with darkina and mola in Tripura. The highest yield during 8 months of culture was 3711 kg/ha, obtained with Indian major carp-darkina polyculture, with a feed conversion rate (FCR) of 2.7, followed by Indian major carp-darkina-mola polyculture (3559 kg/ha, FCR 2.8).

The productivity of both treatments was higher than culture of Indian major carps without SIS (3515 kg/ha, FCR 2.8). Since mola and darkina are mainly phytoplankton feeders, the authors concluded that mola competed with both Indian major carps and darkina, likely due to overlapping feeding habits. They stated that darkina in polyculture with Indian major carps improved fish productivity of the pond by more than 5.5% and complements the growth of Indian major carps. Darkina cultured with Indian major carps had the highest production and financial benefit. Partial harvesting of mola and darkina was started at three months from stocking, when sexual maturity starts. The authors also recommended to not culture mola and darkina together.

Rajts et al. (1997) recommended that the harvesting time of SIS should be adapted to sexual maturity, because the growth rate of mature fish drops while the FCR increases. However, different species may need different lengths of time to reach sexual maturity. Moreover, the time required can vary due to environmental influences. Mature stock should be harvested regularly to avoid loss of profit.

8.3.4. Market availability and price of flying barb

Because culture of flying barb has not yet been developed, its availability is more or less restricted to the dry season. The market price is generally same as for mola.

8.4. Dhela

Osteobrama cotio (Hamilton, 1822)
Other names: hafo (Assamese), gila khani, keti (Froese and Pauly 2021).

Plate 5. Dhela.

8.4.1. Characteristics of dhela

Dhela is distributed throughout Pakistan, India, Nepal and Bangladesh (Froese and Pauly 2021). Adults mainly occur in rivers, lakes, ponds and ditches (Rahman 1989). It has a max length of 15 cm (Menon 1999) and is an omnivorous column feeder that prefers phytoplankton over both zooplankton and benthos (Rafin et al. 2019).

Energy	Prot	Fat	Fe	Zn	Ca	I	Se	Vit. A	Vit B_{12}
kJ	g	g	mg	mg	mg	mg	mg	mg	µg
387	15.5	3.8	12	4.0	891	81	12	660	12.5

Source: Extracted from Bogard et al. 2015.

Table 7. Nutrient composition per 100 g of edible flying barb.

Hussain et al. (2003) observed that the fecundity of dhela varies from 512 (total length 2.2 cm and bodyweight 1.12 g) to 6849 (total length 5.7 cm and bodyweight 7.1 g). The breeding season starts at the onset of the monsoon rains in May, peaks in June–July and ends before September. The maximum GSI value was found to be 15.31 in June and the minimum 3.79 in September, indicating the end of breeding season.

8.4.2. Nutrient content of dhela

Dhela is high in calcium, selenium and vitamin A , as shown in Table 8.

8.4.3. Culture potential of dhela

Kunda et al. (2014) conducted trials of dhela, rohu, catla and mrigal polyculture over 4 months and found that dhela could not reproduce in the ponds, likely because of late stocking in July. Moreover, the depth of the trial ponds was 2–3 m, with the usual steep slopes that characterize ponds in Bangladesh, and this type of pond does not have appropriate shallow and weed-covered areas that dhela need to breed.

The survival of stocked dhela was 83.56% and the growth was almost three times the stocked weight, while the specific growth rate was 0.75. For 4 months, this can be considered satisfactory growth. Total production in ponds stocked with dhela was lower than that of the ponds stocked with only carps. However, this is unlikely to be due to the presence of dhela, because they were not able to breed. As a result, the biomass of dhela at harvest was only 4.87% of total biomass, which is not significant enough to compete with carps.

The main benefit of this trial was the possibility to calculate the survival and growth rate, which cannot be found in other SIS trials because the SIS are reproducing in these trials.

8.4.4. Market availability and price of dhela

Dhela is a favored species in Bangladesh, but it is not abundant in the market and rarely sold separately. Generally, it is mixed with mola, and the prices are similar. Nurullah et al. (2005) investigated the availability of SIS in the markets of Mymensingh, Kishoregonj and Netrokona. Among 143 indigenous species found in the markets, dhela represented only 0.3%, 0.4% and 0.2% respectively. As such, the authors stated that dhela is an endangered species due to the destruction of its natural habitat.

8.5. Banded gourami

Trichogaster (Colisa) fasciata
Other names: kholiana, boro kholisha, khailsha, khalisa, kholiana (Froese and Pauly 2021).

Plate 6. A male banded gourami male (top) and the bubble nest of a male (bottom).

Energy	Prot	Fat	Fe	Zn	Ca	I	Se	Vit. A	Vit B_{12}
kJ	g	g	mg	mg	mg	mg	mg	mg	µg
387	14.7	3.8	1.8	3.7	1200	9.5	29	918	4.7

Source: Extracted from Bogard et al. 2015.

Table 8. Nutrient composition per 100 g of edible dhela.

Banded gourami is found in Pakistan, India, Nepal, Bangladesh and upper Myanmar (Talwar and Jhingran 1991). It inhabits freshwater pools, ditches, ponds and marshes (Rahman 1989) and prefers shallow waters with plenty of submerged weeds, which are necessary for reproduction. It's maximum length is 12.5 cm (Froese and Pauly 2021).

8.5.1. Characteristics of banded gourami

Felts et al. (1996) report that banded gourami is an air-breathing species thanks to its suprabranchial chambers that allow it to live in shallow, weed-infested waters with extremely high fluctuations of DO and toxic gases. They also found that banded gourami is omnivorous feeder, similar to results from Moitra et al. (1977), who stated that banded gourami is an omnivorous mid-feeder. Its RGL varies from 4 to 5.

According to investigations made by Mitra et al. (2007) in an ox-bow lake of the Ganga River basin in India, banded gourami prefers to eat plant matter, but it also feds on *Brachionus* sp., *Chironomus* sp. larvae, *Cyclops* sp., *Cypris* sp. and *Notholca* sp. among animal matter. Its fecundity ranged from 1095 (6.1 cm and 5.3 g) to 19,291 (8.6 cm and 13.9 g). Its relative fecundity was 206–1392 and the length at first maturity was 6 cm. The authors also noticed that banded gourami breeds during from March to September, when the diameter of ripe ova is 0.66–0.78 mm.

Breeding is stimulated by sudden changes in water quality. In the 1980s, the author observed tens of thousands mature banded gourami migrating from the deep ox-bow lake (Baluhar baor in Bangladesh, having water hardneess 250 as CaCO3) into shallow breeding grounds against the inflowing rainwater from the catchment area. Today, banded gourami have nearly disappeared from the area because of habitat destruction (clearance of vegetation) and food competition from intensified carp polyculture, with high stocking densities of both Indian major carps and Chinese carps.

Males have parental care characteristics. They prepare a bubble nest by secreting saliva in shallow water covered with high density vegetation. Breeding takes place under the nest and the fertilized eggs float up into the nest due to their oil content, which makes them less dense than the water. Males guard the eggs and larvae in the nest until they reach the free-swimming stage.

8.5.2. Nutrient content of banded gurami

Banded gourami plays an important role in meeting the nutritional requirements of poor fishers in India and neighboring countries, such as Bangladesh, Myanmar and Sri Lanka (Mitra et al. 2007). Among its nutritional benefits, as shown in Table 9, it is high in both calcium and selenium.

8.5.3. Culture potential of banded gourami

Banded gourami has an additional respiratory organ that makes it able to breathe air. This allows it to live in waters where cultured fish usually cannot survive. Banded gourami would therefore be particularly well suited among potential candidate SIS for bringing unused water resources under food production.

These include very shallow seasonal waters and water bodies polluted with organic waste, especially ditches near rural markets and homesteads, and shallow ponds used for duckweed production. The latter have DO levels that are too low for the survival and growth of most fish species, and are breeding grounds for mosquitos, which are vectors of several human diseases. As a small, air breathing fish, banded gourami could be cultured in these waters, serving a dual role as a biological control agent against mosquitos and a source of high-value nutritional human food.

Energy	Prot	Fat	Fe	Zn	Ca	I	Se	Vit. A	Vit B_{12}
kJ	g	g	mg	mg	mg	mg	mg	mg	µg
354	15.2	2.5	4.1	2.3	1700	20	26	46	5.55

Source: Extracted from Bogard et al. 2015.

Table 9. Nutrient composition per 100 g of edible banded gourami.

8.5.4. Market availability and price of banded gourami

After many natural waters were cleared of floating aquatic weeds, either manually or by using herbivorous fish, banded gourami became rare in the markets of Bangladesh. Forty years ago, the markets contained large baskets of them. Now, however, they are much less common, and generally sold mixed with other small fish in the market. The price of mixed SIS is similar to cultured carps.

8.6. Climbing perch

(*Anabas testudineus*)
Other names: koi, Thai koi, kai, kawai.

Plate 7. Climbing perch.

8.6.1. Characteristics of climbing perch

Climbing perch are found in Bangladesh, Cambodia, China, India, Indonesia, Laos, Malaysia, Myanmar, Nepal, Pakistan, Singapore, Sri Lanka, Taiwan, Thailand, Timor-Leste and Vietnam (Froese and Pauly 2021). They mostly inhabit haors, ponds, ditches, swamps and lakes. They use their tail and spiny gill covers to migrate over land into other water bodies. They have modified gills that allow them to breathe air, and will die if they cannot do so. Migration is mainly triggered by rain during the breeding season. During the dry season, they remain buried under the mud (Rahman 1989). Just like frogs, they have a remarkable ability to migrate to and breed in freshly filled nursery ponds of commercial fish farms, where they compete with or even prey on the cultured fish. Because they are widely distributed, the existence of different species, subspecies and geographical strains is likely.

There is confusion about the morphological differences of specimens from diverse regions. Several authors have revealed differences. Investigations made by Dutt and Ramaseshaiah (1980), as found in Thakur et al. (1985), revealed 48 diploid chromosomes in *A. testudineus* and only 46 in *A. oligolepsis*. During the past decade, fry imports into Bangladesh of a fast-growing variety of *Anabas* sp. from Taiwan, Vietnam and Thailand was started by the aquarium trade for aquaculture use, where the species is referred to as *"Thai koi"*.

Juveniles feed on zooplankton, while adults eat insects as well as some plant material. Fishers have observed that they can even jump to catch hanging maturing rice in paddy fields. Rahman (1989) indicated that climbing perch breed from April to July during the monsoon rains. Their eggs float on the surface of the water, and hatching occurs in 18 hours at a temperature of 28.5°C. Rahman found that absolute fecundity ranged between 39,687 and 86,108, with an egg diameter of 0.7 mm.

8.6.2. Nutrient content of climbing perch

Climbing perch is highly preferred by consumers in India and Bangladesh. As shown in Table 10, it is high in energy and vitamin A and has moderate amounts of selenium. According to Chanda et al. (2017), climbing perch has high PUFA content: 23.67% and 13.62% of the total fat content in small and large size fish, respectively.

Energy	Prot	Fat	Fe	Zn	Ca	I	Se	Vit. A	Vit B_{12}
kJ	g	g	mg	mg	mg	mg	mg	mg	µg
737	15.5	12.8	0.87	0.6	85	nd	19	295	2.38

Source: Extracted from Bogard et al. 2015.

Table 10. Nutrient composition per 100 g of edible climbing perch.

8.6.3. Culture potential of climbing perch

Because of its pleasant taste, climbing perch has traditionally been in high demand and commanded elevated market prices. It can be cultured at high stocking densities in seasonal waters because of its fast growth. It requires feed that is high in protein, and the waste it produces from eating this feed generates plankton and benthos, which can be used by other species in polyculture.

Ahamed et al. (2018) conducted a satisfactory trial in a semi-arid zone of Bangladesh, where ponds dry up after the monsoon rains. An imported fast-growing Thai koi variety climbing perch was stocked with silver barb and Nile tilapia fingerlings in seasonal ponds at an average weight of 1.3 g, 3 g and 2 g respectively. During 4 months of polyculture, the Thai koi reached an average weight of 198.67±3.28 g in T1, 179.67±9.06 g in T2 and 174.33±4.25 g in T3. The cost-benefit ratio was 1.64±0.03 in T1, 1.52±0.0 in T2 and 1.40±0.02 in T3. Although it was not observed during the trial, it is likely that the climbing perch controlled the usual unwanted reproduction of tilapia in the trial ponds.

8.6.4. Market availability and price of climbing perch

Since the late 1980s, the population of climbing perch has declined drastically from open waters due to various ecological changes in inland water bodies. It is now sold at exorbitant prices in the market (Kohinoor et al. 2007). The price of climbing perch is two to three times higher than for Indian major carps. However, the price of cultured climbing perch is inferior that of climbing perch from the wild.


Photo credit: Francois Rajts/WorldFish

Farming climbing perch will improve availability in the market.

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Annex 1. Vitamin A

Category	Vitamin A content (RE/100 graw edible parts)	Common name[a]	Scientific name
Very high	>1500	Mola Chanda	*Amblypharyngodon mola* *Parambassis baculis*
High	500–1500	Dhela Darkina	*Osteobrama cotio cotio*[b] *Esomus danricus*
Medium	100–500	Chanda Koi Tengra Taki Chella	*Parambassis ranga, Chanda nama* *Anabas testudineus* *Mystus bieekeri* *Channa punctatus* *Chela cachius*
Low	<100	Kaski Chikra/baim Puti Gutum Chapila Kolisha Shing Magur Chata Tilapia Mrigal Rui Silver carp Hilsha	*Corica soboma* *Macrognathus aculeatus, Mastacembelus pancalus* *Mastacembelus amatus* *Puntius sophore, Puntius chola, Puntius ticto* *Lepidocephalus guntea* *Gudusia chapra* *Colisa fasciatus* *Heteropneustes fossilis* *Clarias batrachus* *Colisalalia* *Oreochromis niloticus* *Cirrhinus mrigala* *Labeo rohita* *Hypophthalmichthys molitrix* *Tenualosa ilisha*[c]

[a] *The fish species are listed in order of decreasing vitamin A content.*
[b] *One sample of dhela was analysed in a minor study conducted at the Research Department of Human Nutrition, The Royal Veterinary and Agricultural University, Denmark, in 1993. Dhela was not available for sampling at the time when this study was conducted.*
[c] *An alternative scientific name is Hilsa ilisha.*

Source: Roos et al. 2002.

Table 11. Vitamin A content of select fish consumed in Bangladesh.

Annex 2. Previous polyculture trials

Stocking densities number per hectare		Calculated gross production kg/ha/month		Stocked carp species	Length of culture month	Type of polyculture	References
Mola	Carps	Mola	Carps				
25,000	12,500	35	357	Silver carp, grass carp, mrigal	7	Seasonal homestead ponds	Roos et al. 1999
12,000	9000	64	1757	Calta, rohu, mrigal, grass carp, silver barb, common carp, silver carp	4	Undrainable ponds	Kunda et al. 2009
25,000	8000	184	1326	Calta, rohu, mrigal, grass carp, silver barb, common carp	4	Undrainable ponds	Kunda et al. 2009
25,000	10,750	69.4	1813.3	Calta, rohu, mrigal, grass carp	6	Undrainable ponds	Roy et al. 2015
37,500	10,750	61.3	1803.3	Calta, rohu, mrigal, grass carp	6	Undrainable ponds	Roy et al. 2015
50,000	10,750	58.7	1214.6	Calta, rohu, mrigal, grass carp	6	Undrainable ponds	Roy et al. 2015

Table 12. Partial data from past trials on polyculture of mola with carps.

Annex 3. Fish prices in Bangladesh

Bangladeshi name	Scientific name	Common name	BDT/kg
Ayre	*Sperata (Mystus) aor*	Long-whiskered catfish	700
Bagna	*Cirrhinus reba*	Reba carp	300
Baim; Guchi	*Macrognathus pancalus*	Barred spiny eel	950
Bata	*Labeo bata*	Bata	160
Boal	*Wallago attu*	Wallago	700
Catla	*Gibelion catla*	Catla	400
Chital	*Chitala (Notopterus) chitala*	Clown knifefish	700
Gonia	*Labeo gonius*	Kuria labeo	250
Grass carp	*Ctenopharyngodon idella*	Grass carp	250
Common carp	*Cyprinus carpio*	Common carp	230
Kachki	*Corcia soborna*	Ganges river sprat	480
Kajuli	*Ailia coila*	Gangetic ailia	800
Kakila	*Xenentodon concila*	Asian garfish	720
Magur	*Clarias batrachus*	Philippine catfish	600
Mola	*Amblypharyngodon mola*	Mola carplet	600
Mrigal	*Cirrhinus cirrhosus*	Mrigal carp	160
Pabda	*Ompok pabda*	Pabdah catfish	620
Pool barb	*Puntius sophore*	Pool barb	320
Rita	*Rita rita*	Rita	1000
Rohu	*Labeo rohita*	Roho labeo	300
Sharputi	*Olive barb*	Systomus (Puntius) sharana	450
Shing	*Heteropneustes fossilis*	Stinging catfish	600
Shol	*Channa stirata*	Stripped snakehead	600
Silver barb	*Barbonymus gonionotus*	Silver barb	420
Silver carp	*Hypophthalmichthys molitrix*	Silver carp	150
Taki	*Channa punctatus*	Spotted snakehead	150
Tara baim	*Macrognathus aculeatus*	Lesser spiny eel	950
Tengra	*Mystus tengara*	Tengra catfish	600

Table 13. Prices at a retail market in Shaheb Bazar, Rajshahi (February 14, 2020).

About WorldFish

WorldFish is a nonprofit research and innovation institution that creates, advances and translates scientific research on aquatic food systems into scalable solutions with transformational impact on human well-being and the environment. Our research data, evidence and insights shape better practices, policies and investment decisions for sustainable development in low- and middle-income countries.

We have a global presence across 20 countries in Asia, Africa and the Pacific with 460 staff of 30 nationalities deployed where the greatest sustainable development challenges can be addressed through holistic aquatic food systems solutions.

Our research and innovation work spans climate change, food security and nutrition, sustainable fisheries and aquaculture, the blue economy and ocean governance, One Health, genetics and AgriTech, and it integrates evidence and perspectives on gender, youth and social inclusion. Our approach empowers people for change over the long term: research excellence and engagement with national and international partners are at the heart of our efforts to set new agendas, build capacities and support better decision-making on the critical issues of our times.

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