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Mola (*Amblypharyngodon mola*) aquaculture in Bangladesh:

Status and future needs

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Mola (*Amblypharyngodon mola*) aquaculture in Bangladesh: Status and future needs

Authors

Francois Rajts and Colin C Shelley

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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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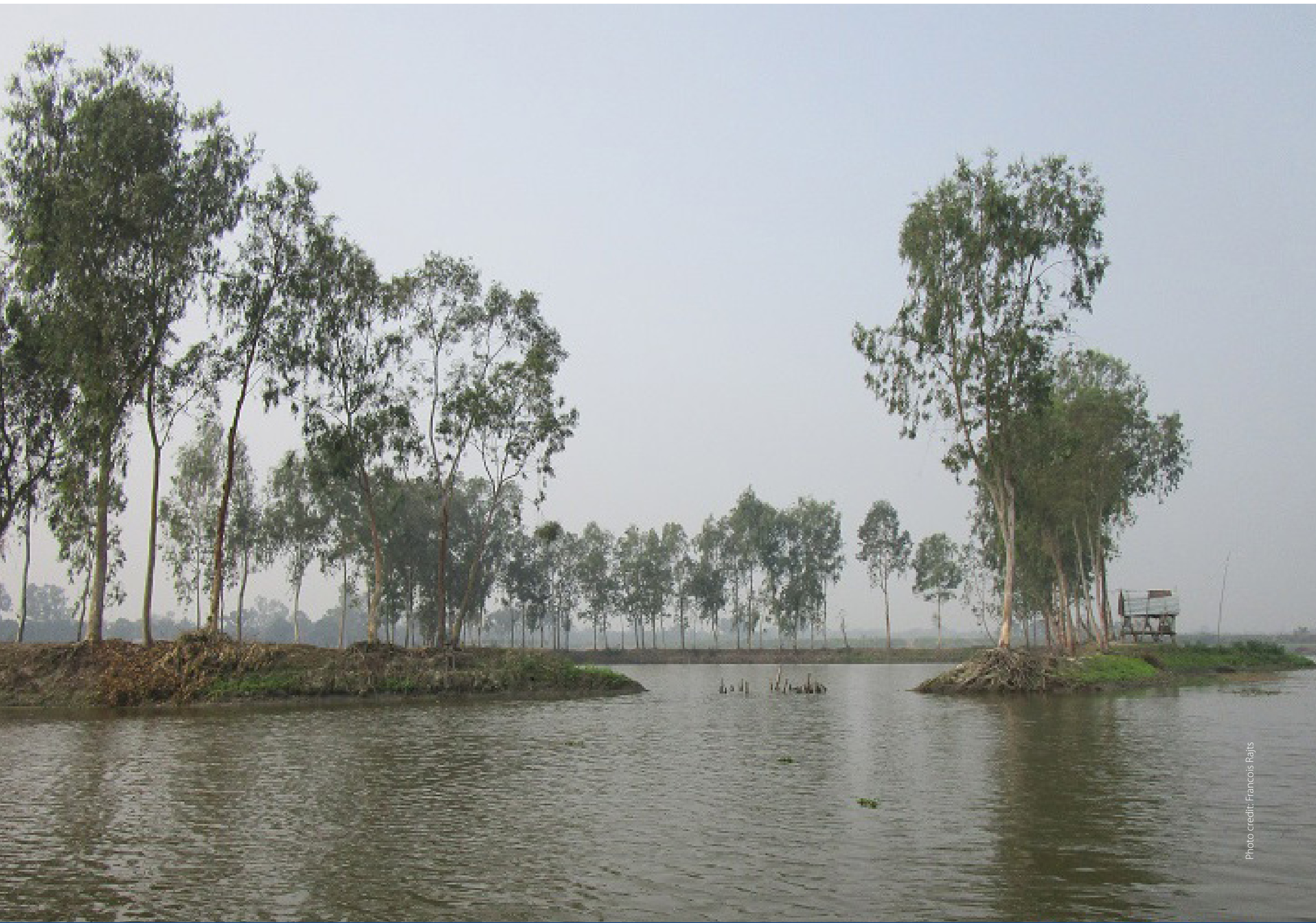
Introduction

In recent decades, there has been a spectacular increase of aquaculture production in Bangladesh. Annual per capita fish consumption has increased from 7.7 kg in 1980 (Rashid and Zang 2019) to about 23 kg (DOF 2018). However, among the 272 diverse, freshwater fish species in Bangladesh, relatively few are used for aquaculture.

Some of the smaller freshwater fish are very rich in micronutrients compared to larger farmed fish. These can be produced in ponds without hampering the growth and production of large fish, and they can greatly improve the nutritional quality of total production (Castine et al. 2017).

Mola (*Amblypharyngodon mola*) is one small indigenous fish species (SIS) that has long been identified as an excellent candidate for aquaculture because of its excellent nutritional value. Several organizations in the country have undertaken research and development into mola, including the Bangladesh Fisheries Research Institute (BFRI) and the Department of Fisheries (DOF) as well as several universities and nongovernmental organizations (NGOs). This report provides a status update on mola culture in Bangladesh and suggests recommendations for future activities. The recommendations are based on a summary of information currently available and a trip that a consultant took to Bangladesh in 2020 to review mola culture practices.



Mola and carps take shelter in deep ponds during the dry season.

1. Status of mola aquaculture

1.1. Biology and distribution of mola in Bangladesh

Mola is widely distributed in rivers, canals, beels, ponds and inundated fields throughout Bangladesh (Rahman 1989). However, it has become rare in many natural waters because of human intervention (Hussain et al. 1997). Ahamed et al. (2017) reported the longevity of mola at 13 months for males and 15 months for females in the Payra River, Southern Bangladesh. The maximum recorded size is 20 cm (Talwar and Jhingran 1991), though Rahman (1989) reported its maximum length as only 15 cm. Mola has small gill rakers, which are connected with a membrane to filter plankton. Mondol et al. (2013) found that almost the entire composition of the gut contents of mola was made up of phytoplankton (94.38%), with the rest being zooplankton (5.62%). Gupta and Banerjee (2013) found that mola is an herbivorous fish, and *chlorophyceae* has been observed as its most preferred food class. Mola has also been reported to feed on detritus, as reported in Myanmar (FAO/Fishbase 2020). In Assam, where mola contribute up to 4% of catch from capture fisheries, it was found that mola were mainly feeding on phytoplankton, representing 94.74% of food (Budhin 2017).

The reproductive biology of mola is variable, and related to climate, water quality, food availability, size and habitat. Data collected on reproductive biology is presented in Table 1.

1.2. Mola aquaculture development in Bangladesh

For more than a decade, the Bangladesh Agricultural University worked with partners from Denmark on mola aquaculture. Together, they developed production technologies for pond culture, connected pond culture (where mola is allowed to migrate in between a pond and an adjacent rice field) and stock enhancement in wetlands (Thilsted and Wahab 2014). As an understanding has become clear surrounding the nutritional importance of some SIS, several organizations in Bangladesh have taken up developing farming systems for SIS. The DOF, BFRI, universities, extension agencies and NGOs have all shown interest and participated in promoting SIS in different parts of Bangladesh. SIS have been recognized as a major animal-source food, contributing to improved food and nutrition security and livelihoods of the people.

Under the research and studies component, the Integrated Food Assisted Development Project, Sub-Project 2 (IFADEP SP 2) initiated a program to develop a viable production system for small indigenous fish species that the project beneficiaries/fish farmers would manage. The project began the bulk of trials at its field trial center with IFADEP partner NGOs for on-station trials (Rajts et al. 1997). The specific objectives of the fisheries research and studies component were as follows:

- to assess the production potential of some selected SIS in mini ponds, shallow floodplains and burrow pits under monoculture and composite culture per unit area of waterbody
- to compare the production of exotic fish species with that of SIS
- to investigate the profitability and economic viability of fish culture in Bangladesh
- to assess the capital investment and maintenance requirements of SIS culture
- to use shallow seasonal waterbodies that are not suitable for carp culture.

Trial stations were set up in various places: Karbala and Rajshahi fish seed farms of the DOF, private farms in Jhenaidah and Poba in Rajshahi, and in burrow pits of the Ganges-Kobadak Irrigation Project or G-K Project (GK).

In addition, induced breeding trials were carried out on SIS in private hatcheries in Jashore and Jhenaidah. The trials used different species of SIS, different combinations of composite culture of SIS, different cultures of SIS with fast-growing fish species, different cultures of SIS with existing carp polyculture, and different stocking rates of SIS. By manipulating the pond ecosystem, induced breeding of mola was successfully done through natural breeding in ponds.

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	FAO FishBase
Parental care	None	FAO FishBase
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 SI Khondaker
PG dose for induced breeding	25 mg/kg ♀	Saha (2019)
Latency period for ovulation (hours at 27°C)	6–7	Hatchery owner SI Khondaker
Time of egg development to hatching (hours at 27°C)	12	Saha (2019)
Larval development time (hours at 27°C)	72	Hatchery owner SI Khondaker

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

Table 1. Reproductive biology of mola in the Ganges-Brahmaputra Delta.

The results of these trials have demonstrated that SIS, particularly mola, can be profitably cultured with carps. However, regular partial harvesting of mola is necessary to prevent aging and overpopulation. Mola attains sexual maturity in a few months. Generally, mature fish will use food poorly for growth (Rajts et al. 1997). Regular partial harvesting of mola from a homestead pond is key to providing micronutrient-rich food for household consumption. The potential for improving access to micronutrients for poor rural households is great, considering the 4.27 million multifunctional homestead ponds that households own (Belton and Azad 2012). Trials on induced breeding of SIS were carried out in hatcheries, and induced breeding of *bata* (*L. bata*) and *bhagna* (*C. reba*) was successful.

Roy et al. (2015) made trials on optimizing the stocking density of mola in polyculture with rohu, catla, mrigal and grass carp. Four treatments were tried with seven replicates each. Polyculture of carps with 100 mola per decimal (40 m^2) was recommended from nutritional, socioeconomic and production perspectives. They found that mola-carp polyculture is a suitable technology for the rural poor, who can benefit from family consumption of mola through partial harvesting while using large carp as a cash crop.

Roos et al. (1999) found that mola can be cultured with carps in seasonal homestead ponds. Some partial data from past trials on polyculture of mola with carps is shown in Annex 2.

Since 2011, WorldFish has been conducting trials and successfully implementing SIS culture technologies in collaboration with national institutions and NGOs in Bangladesh. The activity was carried out in three projects, one funded by the International Fund for Agricultural Development and two by the United States Agency for International Development. The outcome of these efforts was an effective demonstration of the viability of carp polyculture supplemented with SIS, particularly with mola. In the North West region of Bangladesh, ponds connected to rice fields provided up to 7.2 t/ha of fish production and about 4 t/ha of rice production. Most of these rice fields are situated in beels and are not cultivated during the monsoon season, so they produce one crop of rice per year.

Mola is a very sensitive fish, so transportation was difficult. Saha et al. (2014) successfully worked out a method for transporting mola broodstock.

At the Dhulia beel in Nilphamari, farmers developed carp-mola polyculture techniques, including conservation of mola during the dry season for seeding the ponds in the next season. This activity was characterized by a community approach, where farmers cooperated with each activity. The Aquaculture for Income and Nutrition (AIN) project of WorldFish identified the importance of the production system there and distributed mola breeders to other areas. The project has been disseminating the technique since 2011. Other organizations and the DOF also used the Dhulia beel as a source of mola culture techniques developed by the farmers and for collecting mola breeders (Saha 2019).

Currently, more than 60 ponds have been developed on the bank of the beel, some of which are open and others closed to the beel. Many ponds have rice fields included, which make up about 50% of the land area, while the rest is excavated land with permanent water.

Mola breeding is strongly stimulated by fresh water, increasing water levels and the presence of previously (preferably the day before) dry inundated land with grasses to support their eggs. This is automatically provided in connected ponds with rice fields by adding fresh water to partially flood the rice field. After harvesting the rice, the remaining rice straw can serve as a substratum for eggs. The system is also called a connected pond, as the pond and rice field are connected.

Boreholes with diesel pumps are installed to add water if necessary, for both fish and rice.

Open ponds/connected ponds

A total of 29 ponds are open. These have a water connection with the beel during monsoons. At the side of the beel, the dikes were not fully constructed so that nets or bamboo screens can stop stocked carps from escaping. Small fish such as mola, dhela, kholisha and darkina can migrate between the pond and the beel during the monsoon and can feed on the natural food there. At the end of the monsoon season, the water level drops and the connection to the beel is severed.

Fish are concentrated in the deeply excavated pond area. This is similar to the traditional *kua*, which is a small excavated pond situated on floodplains to attract fish when water is receding from the floodplain. In some cases, a rice field is included in the fish cultivating area, which is called a "connected pond." Boro rice is cultivated there during the dry season, between December and April–June. The rice field dries up, while the mud developed during fish culture increases the land fertility. Feeding continues in the pond, but gradually the fish are sold. Finally, by April–June only about 50 kg mola remain in the excavated area, which is about 1.60 ha (Plate 1).

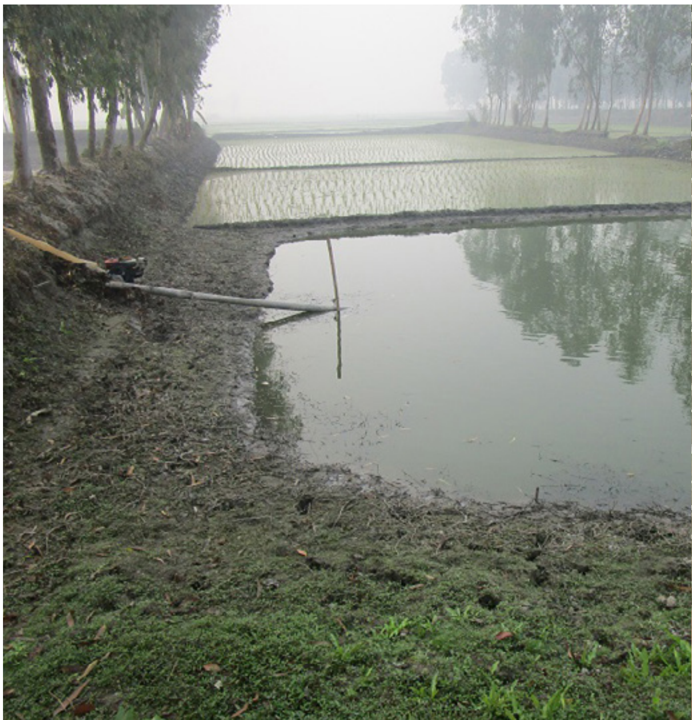
Closed ponds

Closed ponds are fully separated from the beel or rice field. In comparison with ponds or stand-alone rice cultures, the benefits of connected ponds include better land use, control of insects on rice fields and increased production of both fish and rice.

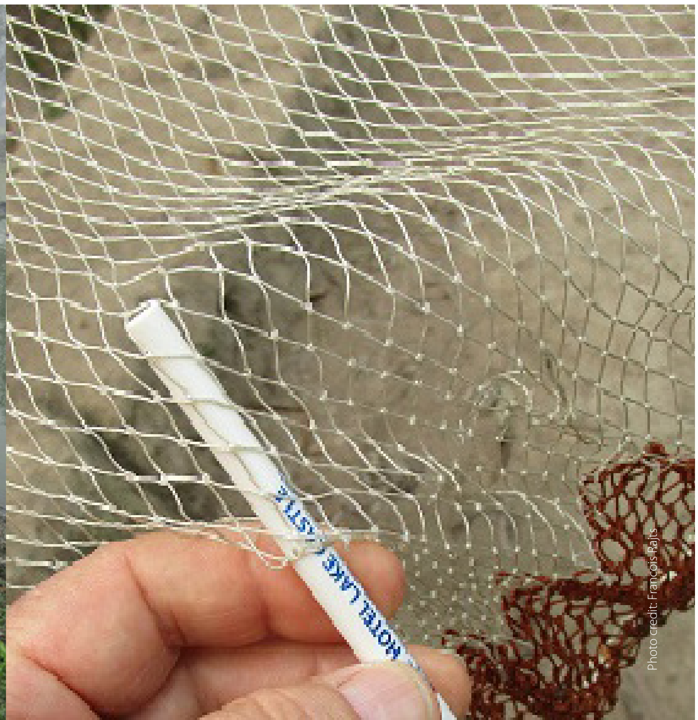
Mola can be partially harvested for household consumption (Thilsted and Wahab 2014). According to Kunda et al. (2014): "Before intervention of the project there were no mola in that floodplain, in the 1st year 5% of the total catch were mola and in the 2nd year of intervention 15% of the total catch came from mola. This has the potential to significantly contribute to household nutrition provided that those who need it most are the end consumers. Direct involvement of a community-based organization was paramount in ensuring the intervention was successful."

An additional benefit of the open pond system is that it produces a better nutrient composition of mola because more natural food is available than in closed ponds. The protein content is clearly higher in wild mola, but the fatty acid content, vitamins and minerals are of better quality (Table 2). Another benefit is the better breeding grounds for mola in flooded rice fields. These fields have a substrate that develops naturally and acts as support for eggs or rotifers, something stand-alone ponds cannot provide for the fish.

In 2008–2009, aquaculture production of Bangladesh was 1.063 million metric tons, mainly carps. It increased to more than double in 2017–2018, amounting to 2.405 million metric tons (DOF 2018). Currently, more and more farmers are trying to incorporate micronutrient-rich SIS,



Connected pond. Rice has just been planted. The remaining water is also used for irrigating rice planting. Carps were sold and 500 kg of mola were still present as of February 2020.



A mola saving net used for carp harvesting. Mola and other SIS can escape through the mesh, but larger fish are captured.

Plate 1. Farm of Abdul Sattar. Connected pond at the Dhulia beel in Nilphamari.

Species	Energy kj	Protein g	Fat g	Moisture g	Ash g
Mola natural	445	17.3	4.5	75.6	3.5
Mola culture	412	14.7	4.6	77.3	4.0

Source: extracted from Bogard et al. (2015).

Table 2. Nutrient content of mola per 100 g of edible parts.

mainly mola, in composite culture systems. This is likely the result of training, demonstration and awareness building over the past 10 years. The market demand for mola is high. In early 2020, the price per kilogram of mola was almost double that of rohu. The current price is attractive for fish farmers to introduce mola in carp polyculture. Unfortunately, poor people can hardly afford to consume mola at current prices. Increased production would help reduce the price.

1.3. Pioneering efforts to rear mola in hatcheries using induced breeding

Mola breeding has been successfully accomplished in two hatcheries in Mymensingh. One is owned by SI Khondaker and the second by AKM Nurul Haque. Both farms were visited and the farmers interviewed in February 2020.

The broodstock are maintained in broodstock ponds. The pond is fertilized to maintain a plankton bloom. Rice bran is given to breeders as supplementary feed. The size of female broodstock varies from 5 to 15 g, with males being much smaller at just 1–2 g when they reach maturity.

The breeding season lasts from February to November. Mola breeders are used repeatedly for breeding, up to four times per year. However, it is not known if the same fish can breed four times or if only part of the broodstock breeds at the time. Hormone injection was used to induce breeding. The hormone used was carp pituitary gland extract (PG). It was noted that the synthetic hormone LHRHa has a high viscosity and could not be administered using the narrow needles of syringes available to hatchery owners. The dose of PG is 2 mg/kg of bodyweight for females and 1 mg/kg for males. However, Saha (2019) indicated that a much higher dose of PG could be used (Table 1). Administering a hormone extract is a delicate and time consuming operation for small fish, because it requires four to six workers to inject 2000–3000 breeders in 1 hour. Anaesthesia is currently not used during injection. The injected breeders are kept in hapa nets in hatchery tanks under sprayed water to simulate rainfall. In February, the water temperature in the hatchery is about 25°C. Spawning occurs about 6 hours after the hormone is injected. The eggs are sticky but can be washed out from the hapas and placed in incubators. Depending on the temperature, hatching occurs after 12–24 hours of incubation. Larval development lasts for 4 days until the yolk sac has been reabsorbed and feeding starts. First feed is typically boiled egg yolk, given in the incubator.

The hatchlings were sold for BDT 12,000/kg. The hatchery owners could not give contact details of any customer who bought mola hatchlings. As a result, the survival rate and growth of produced hatchlings could not be investigated.

Saha (2019) conducted successful induced breeding trials of mola in a hatchery. PG was used to induce ovulation. The best dose of PG was found to be 25 mg/kg. Latency time was 6–8 hours, and hatching occurred 17–18 hours after fertilization, both of which are temperature dependent. The average weight of the hatchlings was 0.7 mg (1,456,000 ± 404,000 number/kg) at 4 days old.

The hatchlings were stocked in a nursery pond, and they showed good growth and homogeneity of size as they developed into fry. The fry reached 5.14 ± 0.42 cm in total length and 1.54 ± 0.33 g in weight in 34 days. This example shows that mola can grow as fast as some carps do in their early development. For example, reba carp (*Cirrhinus ariza)* achieved average length of 4.4 cm and reached 0.75 g in weight in just 5 weeks of rearing from hatchlings (Rahman et al. 2009).

2. Work required to improve the productivity of mola farming systems

2.1. Developing sustainable mola production by smallholder farmers

In the northwest of Bangladesh, there are already examples of mola production, including composite culture with carps in both connected and closed ponds, as well as in homestead ponds. However, the spread of mola culture techniques among homestead family ponds, particularly in seasonal ponds, is jeopardized by limited and timely availability of seed and a lack of knowledge on plankton management, coupled with a scarcity of organic manure. Proposed future actions to support the further development of mola aquaculture are as follows:

- Develop techniques for mass production of mola seed in hatcheries and nurseries to make them available on a large scale at affordable prices for the rural poor.
- Ensure mass production of mola seed in mola broodstock ponds through environmental manipulation. Periodically breed and harvest juveniles after 2 months.
- Establish a mola culture sector, similar to carp culture, once the mass supply of mola seeds is developed. This could include seed producers using pond breeding, seed producers by induced breeding in hatcheries, nursery operators and grow-out farmers, traders and dealers.
- Develop the reproduction and culture of other SIS, such as darkina and colisa (*Trichogaster fasciata*), to use in composite culture with mola and carps
- Jute retting is known to decrease the water quality of habitat for fish at high density in small water bodies. However, as a substitute for organic manure jute retting can be used to promote plankton development in mola ponds. Conduct trials to optimize stocking densities for this technique.
- As mola culture is negatively affected by the predation of stocks by the predator chanda, it is necessary to establish broodstock ponds free from other species.
- Market the nutritional benefits of mola (and other SIS) consumption, particularly for children and pregnant women.
- Use demonstration farms, study tours, awareness building and DOF-supported extension activities to build awareness about the benefits of mola aquaculture.
- Develop retail outlets for mola sales in ferry gats, bus/train stations, picnic corners and in towns.

2.2. Restoring mola and other SIS in floodplain enclosures

Large-scale construction of flood control structures and roads have transformed floodplains so that seasonal waters have limited connections to open waters through bridges and sluices. Landowners have taken advantage of these constructions for building further compartments inside the polders for aquaculture. Some poor rural people have lost access to those waters, and inappropriate water management practices, such as dewatering of permanent ditches, are eradicating SIS in some systems. This reduces the freshwater biodiversity of wetland ecosystems. Beels are dewatered by building a small dike to separate the waterbody into two parts, then the water is pumped from one part to the other and vice versa. The National Fisheries Policy (1998) prohibits complete dewatering of open waters, which includes floodplains, beels and ditches, but this is not being adequately enforced. It is necessary to build awareness among stakeholders on the nutritional benefits and profitability of producing SIS in these waters, as well as better enforcement of regulations. In addition, it would be useful to train stakeholders on creating and using small "overwintering" waterbodies in the enclosures to safeguard mola and other SIS breeders during the dry season. The migration of SIS through appropriate openings or screens should be allowed in large water bodies, as it is done in some oxbow lakes. In small ponds, Saha (2019) reported the use of *vorong* (small conical bamboo screens) in Dhulia beel areas to stop stocked carps from escaping while allowing SIS to migrate.

2.3. Plankton harvesting option by mola from in-pond raceway systems

The introduction of the in-pond raceway system (IPRS) is a potentially new development for intensifying aquaculture in Bangladesh. In this fish culture system, fish are concentrated in a raceway that is constructed inside a pond. Water circulates constantly between the pond and the raceway using a mechanical aeration system (Kubitza et al. 2017; Janjua 2019). A paddlewheel or air diffuser aerators are used to circulate the water and maintain appropriate DO levels. Although solid wastes are collected from the water leaving the raceway, the ammonia, carbon dioxide and suspended organic particles all go into the pond, where the water quality is regulated through plankton activity. Plankton blooms frequently develop in IPRS systems. Brown et al. (2011) produced 20,540 kg/ha of channel catfish in an experimental IPRS raceway, and an additional 2619 kg/ha of tilapia and paddlefish were harvested from the pond as co-cultured species. Mola is predominantly a plankton feeder. By stocking mola in an IPRS pond, plankton blooms could be used for additional fish production, while reducing the risk of severe plankton blooms. Such raceway systems can produce 20 t/ha of market fish (150 kg fish/m^3 of water in the raceway), while the pond could produce an estimated 1–2 t/ha of mola and mrigal without feeding. The private sector is most likely to trial such IPRS systems in Bangladesh because of the significant capital costs involved.

2.4. Controlling chanda in mola ponds

Chanda (*Chanda nama*) is a predator that feeds on mola eggs and fry. Mola breeders collected from the wild, or from ponds, are frequently mixed with undesirable species such as chanda. Mola broodstock are relatively small, generally 4–5 cm. Eliminating chanda from mola ponds requires skill, as it is problematic during stocking because they are similar in size and color (Plate 2).

Chanda can reproduce in ponds, feed on mola juveniles and prevent the establishment of thriving mola populations in ponds. In 1 year, just a few chanda can wipe out an entire mola population in a 10 decimal pond, as was experienced in an IFADEP project. Eliminating chanda from a pond is possible by harvesting and disinfecting the pond. It is not possible to eliminate them in continuous culture in homestead ponds without pumping out water. This can be too expensive for many poor households (Plate 3). Establishing mola broodstock ponds free from chanda would solve the problem.

Chanda is not such a problem in seasonal ponds, ditches and burrow pits because of the reduced time they have to impact the mola population.

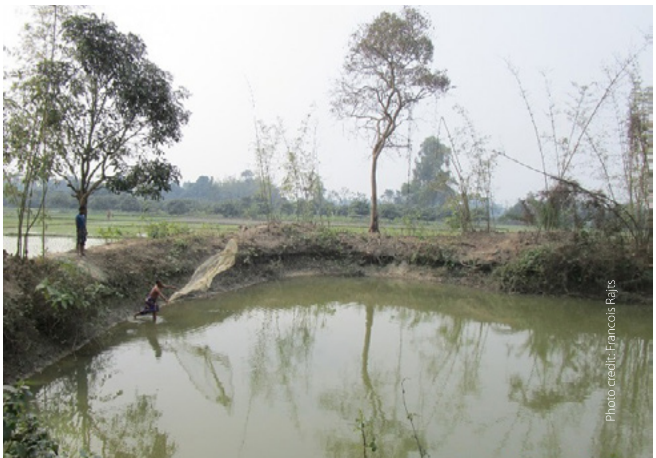
2.5. Controlled breeding of mola

Controlled breeding of mola is the best way to reduce the number of broodstock required and to improve the survival rate of fry. It can be done in ponds using environmental manipulation to inducing breeding or in hatcheries through hormone administration.

The fecundity of mola varies in relation to the size of females, but it is relatively high for such a small fish. The number of eggs recorded is 1023 for 5.5 g

Chanda (top) and mola (bottom).

Plate 2. Similarity of chanda and mola.



Mainly chanda are caught during sampling, indicating negatively affected mola population.

Plate 3. Sampling mola at a local farmer's homestead pond in Kishenbazar.

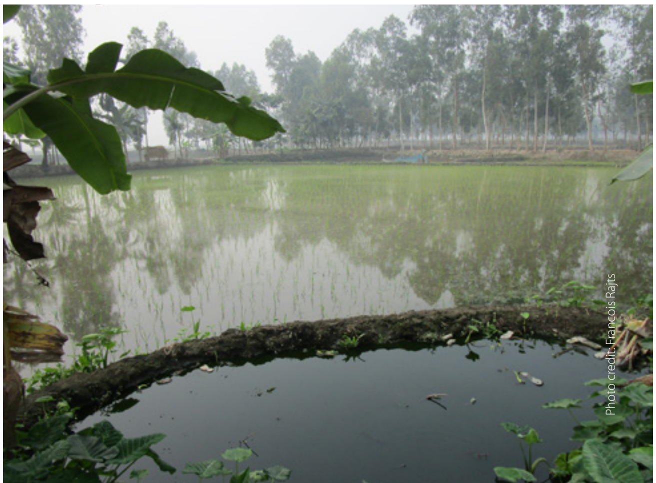
females and 6806 for 8.5 g (Hoque and Rahman 2008). The usual stocking rate in polyculture with carps is 80–100/decimal or about 3000/bigha (1 bigha = 33 decimal) (Roy et al. 2015). This represents about 2000 females of about 5 g, with a sex ratio of one male for every two females. These would release a minimum of 2 million eggs in one breeding. At harvest, however, survival is poor, mainly in closed ponds, for several reasons.

Mola eggs are adhesive and need to attach to aquatic vegetation or another hard substrate to prevent them from falling into the bottom mud, where they would die. In closed polyculture ponds, there is generally a lack of substrate for eggs, so mola either do not breed or many eggs get damaged or die. Also, carp fingerlings, if stocked previously, will pray on mola eggs. Aquatic insects such as notonectids and dragonfly larvae also feed on mola juveniles. The natural, multiple spawnings of broodstock can result in different ages and sizes of fry. The first batch of fry can eliminate the size class of plankton required for the second and subsequent batches, resulting in their starvation. It is likely that young fry are either eaten by predators or older fry damage their mucus, as happens in tilapia culture. The first food for hatchlings comes from the smallest strata of plankton, protozoans and rotifers. For good survival during the first week of life, 2–3 rotifers per ml of pondwater would be optimal. Rotifers develop in newly filled ponds during the first 5–6 days. Copepods, cladocerans and other species develop a few days later in the zooplankton community and feed on the rotifers, which decrease in number. If the pond is filled more than 1 week prior to stocking mola breeders, this will leave the hatchlings without enough food. In polyculture ponds already stocked with carps, rotifers will be few in number because other larger, dominant planktonic organisms will have already been established. In the absence of an organic fertilizer, which often is unavailable, the development of bacterioplankton (important food items for rotifers) is poor, which results in a low density of rotifers.

Providing breeding substrates and applying techniques to manage plankton, harmful insects and predators can potentially overcome many of these problems in closed ponds. Further research is needed to develop such management procedures.

2.5.1. Controlled breeding in closed ponds

Controlled breeding, also called semi-artificial breeding, can be stimulated by environmental manipulation without administering a hormone. Over the course of its evolution, mola, like many other species, has adapted to its surrounding habitat. This includes the seasonally changing environment, water quality and flooding from the monsoon season, dry season, photoperiod, substrate availability for eggs and the availability of feed for fry. In nature, mola breeds when most of these factors are present. Recently hatched mola fry require small zooplankton, which thrive in shallow inundated lands at the beginning of floods. In rivers or deep lakes, the survival of mola fry can be low, because plankton populations are poor or because the dominant zooplankton is either too large, predatory or competes with mola fry. That is why mola and carps breed best in shallow water, following water quality changes, at the beginning of the rainy season. Mola also breeds in September and October, when the water temperature drops. However, the survival rate from the second breeding is often low, because there is either a lack of food for fry or a high density of predators. Based on environmental modification, using soft rainwater, induced breeding of Indian major carps is traditionally practiced in *bundh* in West Bengal (Kumar 1992). Ghosh et al. 2018 induced natural spawning of mola five times per year using similar environmental manipulation.



A closed pond in the dry season at Dhulia beel, Nilphamari.

Plate 4. Mola breeders are preserved in a deep enclosure during land preparation for rice cultivation and released into the planted part when sufficient water is there.

Mola breeds when the environmental conditions are favourable for the survival of progeny. When breeding in ponds, the following three factors can be controlled:

1. Water quality changes can be used to simulate the heavy rains of monsoons. Flushing ponds with fresh water, or at least adding fresh water, can achieve this.
2. Shallow, freshly inundated areas with a previously dry bottom can simulate the freshly flooded wetland, which is the best breeding ground for many fish species.
3. Adding substrates to ponds provides support for released eggs.

These three factors were combined in the "Dubics" breeding pond (Woynarovich and Horwath 1980). The Dubics pond was used during the first part of last century for controlled breeding of common carp in Europe. It consists of a small pond and an adjacent breeding ground. Matured breeders are kept in the pond, while the grass-covered breeding ground is kept dry. Breeding is done by adding water to the pond until the breeding ground is flooded. Breeders migrate to the grass-covered ground and breeding occurs. Under the IFADEP project, similar ponds were built in Bangladesh, with built-in breeding grounds. These proved successful in stimulating the breeding of mature females the day after flooding, at the end of October. In controlled ponds (with no breeding grounds), breeding was unsuccessful (Rajts et al. 1997). In the Dhulia beel, a connected pond was used in a similar way with a rice field, which also proved similarly successful (Thilsted et al. 2014; Saha 2019).

In closed ponds, including homestead ponds, there are generally no aquatic plants to act as a substrate for mola eggs, particularly from March to May, when the water recedes in most ponds throughout Bangladesh. To provide a substratum for eggs, freshly cut or dried grasses, or rice straw, can be submerged all around the shoreline of the pond 1–2 days before expected breeding. Flushing the pond with fresh water can stimulate the breeding of mola. The decomposing grasses will support the development of rotifers; however, they should be removed about 2 weeks after breeding has occurred because old decomposing grass can harm the eggs.

Using hatchery-produced mola can better control the number and density of mola in grow-out ponds. Unlike natural spawning in ponds, farmers are assured of getting the required number of fry in a timely manner. Providing mola of uniform size can optimize the survival of stocked hatchery-produced hatchlings. Food competition and predation on mola eggs, larvae and young fry can occur when using mola breeders to reproduce in the pond. While stocking mola breeders, the risk of introducing the predator chanda is high. Stocking hatchery-produced fry prevents the accidental introduction of chanda into farm ponds. Mola can be grown in ditches, shallow ponds and ghers, which are cheap to construct and approximate well to the natural habitat of the species. Since the time it takes to grow mola to maturity is short, the ponds need not contain water for the whole year. In Bangladesh, there are plenty of small household ponds and roadside ditches, as almost all roads are built on embankments. These hold water for 3–6 months each year, and they can be used for mola culture. This will save time and produce a higher biomass of mola during the short grow-out period if fry from hatcheries are stocked instead of stocking brooders, whose breeding period is uncertain and difficult to manage. In addition, by stocking hatchery-produced mola, farmers can maximize how long the fish are farmed for. Hatchery production of mola provides the technology to underpin any future genetic improvement programs.

2.6. Existing and potential mola hatchery and production farms

The consultant visited several hatcheries and fish farms to select possible partners for mola breeding and grow-out trials and to see the current status of mola culture. The details are presented in Annex 1. Plate 5 shows the proposed grow-out/broodstock rearing farm.

3. Recommendations

Pond breeding of mola

- Encourage mola broodstock ponds maintained free of predators. This is one of the best options to produce quality seed supply for aquaculture.
- Harvest mola seedstock regularly from broodstock ponds prior to maturation.
- For mola breeding in ponds, provide a suitable substrate for eggs to attach to. Use rice (submerged) or dried grass or straw. A few days later, decomposing grass or straw will promote rotifer development, which is an important food for mola fry. Remove the grass after about 2 weeks.
- Develop and disseminate best management practices for breeding and farming mola in ponds.

Induced breeding in hatcheries

- For breeding mola, use clove oil or Aqui-S as anaesthesia to reduce stress.
- Aerate the water for hatcheries before use.
- Develop improved breeding technology through environmental manipulation.
- Further trials using synthetic hormones, such as LHRHa, are needed to determine the optimal use and timing of applying hormones to induce spawning.
- Examine the potential to induce mola to spawn using water of different hardness.

Research and development for hatcheries and nurseries

- Develop a broodstock feed.
- Establish the best feed regimen for mola fry.
- Confirm fecundity and number of hatchlings per gram of female broodstock.
- Investigate mola's response to anaesthetic for hatchery operations and transportation.
- Can grading fingerlings (males are smaller) improve pond production?
- Develop a nursery production technique to rear mola hatchlings to 0.5–1 g fingerlings to supply to farmers.

Research and development for production

- Establish an optimal model of mola farming in polyculture with other species.
- Investigate if aeration can improve gonadal development of mola in ponds by producing constant DO levels above 3 mg/L and through better water circulation. Investigate the effect of regional water quality on mola breeding, survival of eggs/larvae and growth. Depending on the findings, the area where mola culture is proposed to farmers by the project could be better selected.
- Determine whether mola can replace silver carp in carp polyculture?
- Optimize transportation techniques for mola fingerlings.

Dissemination

- Support community-based coordinated production activities. This includes demonstration farms, exchange of experience/study tours, awareness building and coordinated extension activities

Marketing

- Examine the potential for community-based coordinated marketing.
- Develop small-scale mola traders similar to that of shrimp traders. Collect small quantities from several homestead ponds using a bicycle or an auto rickshaw.
- Conduct trials to ensure the best quality of marketed mola by improving transportation techniques, including conditioning, starvation, live transportation and use of ice or chilled water.
- Develop the infrastructure to sell fried mola in ferry gats, bus/train stations, picnic corners and in towns.

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Annex 1. Possible sites for mola and other SIS breeding and grow-out trials

Mattri hatchery in Chachra, Jashore

The consultant visited the Mattri hatchery in Jashore to find a possible partner for mola breeding trials. This hatchery is one of the oldest of the large private hatcheries that started induced breeding in the 1980s. Water quality is good and an aeration tower ensures adequate DO. The owner lives onsite and has a lot of experience in fish breeding. He is willing to participate in future trials, using his experience and infrastructure. This hatchery is suitable to conduct mola and other SIS breeding trials.

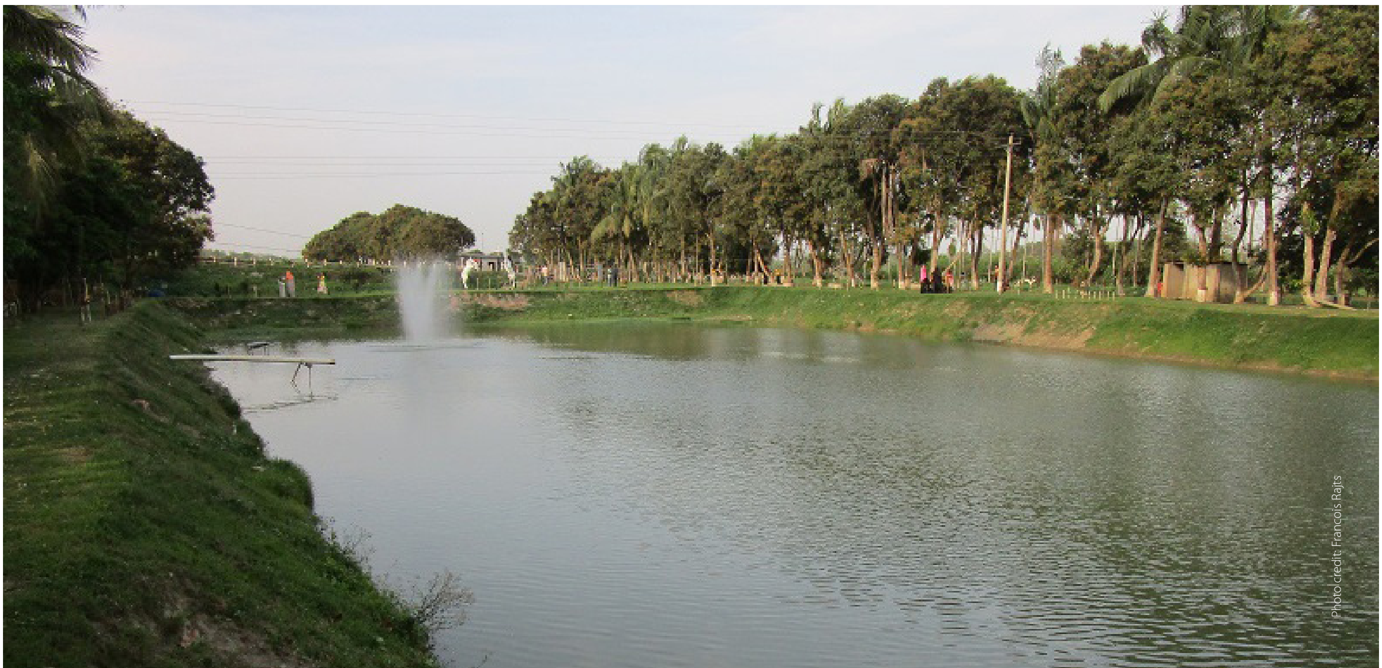
Boksipur Agro Complex

The Boksipur Agro Complex, in Hakimpur Union of Chaugacha Upazila, is located next to a large road that connects Kotchandpur and Chaugacha. It is a private farm. The owner is Md. Kalumia, who lives on the farm.

The farm has eight ponds, with a water area of about 10 bigha. It has a deep tube well with a 20 hp pump and an underground pipeline that supplies water to all the ponds. The depth of the ponds is kept at 6 feet. An aeration system is installed in some ponds. Currently, the farm cultures Indian major carps, but the owner wants to produce mola too. The farm is very well maintained and is also used as a picnic corner, mainly by people from Jashore (Plate 5). It would be ideal for stocking mola breeders and as a trial location for large-scale mola culture.

This farm offers the following advantages for mola culture:

- The farm is well secured. It has fencing, a gate with a guard and is illuminated at night.
- The owner lives on the farm.
- A deep tube well supplies water. There is a pipeline to each pond and the farm has an aeration system.
- It is possible to maintain a water depth up to 6 feet, which is ideal for mola.
- The owner has experience with using an aerator system to prevent morning low DO levels.



Water supply by a deep tube well, with a pipeline to each pond and an aeration system.

Plate 5. Water supply and aeration system in a potential mola broodstock and grow-out farm.

- Biosecurity is excellent. The ponds are cleaned of wild fish, such as chanda, and special attention is taken not to introduce any fish other than those cultured. No connection exists to open waters, and water is filled only from the tube well. Fencing prevents the entrance of disease carrying animals, such as ducks and wild fish. A guard is present at the gate to manage visitors on the picnic corner. The farm is also very clean, with no litter from the picnickers.
- The owner wants to install a small hut to sell fried mola to visitors. This would provide work for poor women in the village.

DOF hatchery at Parbotipur

This hatchery is well maintained and organized. Carrying out induced breeding trials of mola was discussed with the staff, who are highly experienced and are willing to cooperate in breeding/culture trials of mola. However, the hatchery already has a production plan, which was prepared the previous financial year. A collaboration agreement with the DOF would need to be prepared well in advance.

Mola culture in Saidpur

Muklesul Haque

Muklesul Haque is a fish farmer in Saidpur. His farm has a small familial pond that is 16 decimals in size. In 20212, the AIN project leased two larger ponds to him, totalling 50 decimals, and then stocked them with mola. He harvested 120 kg from those ponds, which is equivalent to 600 kg/ha of production. The lease agreement on the larger ponds has since expired, though he has continued to culture fish in the smaller pond, which belongs to his family. However, he is now producing carp, as mola seeds are not readily available.

Pond preparation with dewatering, liming and drying are done prior to restocking with carp. The owner harvests Indian major carps at 600 g and silver carp/common carp at about 1 kg. He occasionally feeds the fish mustard oil cake and sometimes applies chemical fertilizer, though not regularly. The fish are mainly used for household consumption.

Without access to mola seed, carps are often cultured instead.

Plate 6. A pond in Saidpur belonging to a farmer named Babu.

Nazmul Nahar

Nazmul Nahar is another fish farmer in Saidpur. She received training on fish culture from the AIN project in 2012. That same year, her 10-decimal homestead pond was first stocked with mola and carps. Generally, she harvests the pond in April and prepares the pond the way she learned from the project staff. During pond preparation, she temporarily keeps about 200 g of mola (about 1000 individual fish) in a hapa net in a nearby pond and restocks her pond when it is prepared. She can produce about 10–12 kg of mola every year, which is a production rate of about 250–300 kg/ha. The fish are used for family consumption through the year.

Mola culture allows Nazmul Nahar to harvest her pond regularly, which improves the nutrition of her family.

Plate 7. Nazmul Nahar.

Shajjadul Alom

Shajjadul Alom, known as Mukta, also has a small fish farm in Saidpur. He cultures carps with mola in three ponds about 1 bigha each. Old trees shelter the pond, restricting aeration from the wind. In 2019, Mukta sold 200 kg of mola at BDT 300–400/kg. He said that domestic ducks and wild birds are a problem, because they feed on the mola. He was using fencing to prevent ducks from entering.

Mola breeders survive in the lower water levels of the dry season and then breed at the onset of the rains.

Plate 8. Shajjadul Alom's pond.

Mola culture in Dinajpur

Tapas Roy

Tapas Roy is a fish farmer in Baul Debiganj, Ciribondor. He has a 54-decimal pond that is greenish in color. The mola population has been self-maintained since 2012, when the pond was stocked by WorldFish. Roy uses cattle dung for manure and sometimes uses oil cake. He said that every year he sells 16–20 kg of mola. He sells it for BDT 360/kg to *arotdars*. Occasionally, he stocks some carp. The pond is not dewatered yearly, and the fish are mainly used for home consumption. The mola were of good quality. This mola population was the only pond we observed where the females were full of matured eggs and ready for breeding (early in the season in the middle of February).

Mola matures early in well-managed ponds.

Plate 9. Matured mola in Tapas Roy's pond (February 18, 2020).

Ainuddin

Ainuddin is a fish farmer in Kishen Bazar, Dinajpur. The AIN project stocked his 14-decimal pond in 2012. The first harvest yielded 24 kg of mola. However, the pond was later flooded, which allowed predator fish to enter. When trying to take a sample, only the predator species chanda could be found. If chanda are in a pond, mola breeding will not be satisfactory because chanda prey on eggs and juveniles. Currently, the pond is used for home consumption only.

Mainly chanda were caught during sampling.

Plate 10. Ainuddin's pond in Kishenbazar.

Dhulia beel area, Nilphamari

In the Dhulia beel, there is a self-sustaining mola population from which farmers collect fish in open ponds during the dry season. The number of closed ponds that connect to a rice field is increasing. According to Saddiqul Islam, who guided us, there are about 60 ponds adjacent to the beel. In these ponds, the remaining mola and other fish (after harvesting) are saved in ditches during the dry season, while the higher part of the pond bottom is used for cultivating *boro* rice. After harvesting the rice, the pond is flooded or filled with water and fish are cultivated. Feed and fertilizer are used in closed ponds, and some feed is applied in open ponds too to attract fish from beels.

The water quality of the beel was as follows: the pH was 7.0, the carbon dioxide (CO_2) was 34 mg/L, the hardness ($CaCO_3$) 92 mg/L and the alkalinity 156 mg/L.

It could be possible that mola populations are more important in baors and beels that have soft water rather than hard water. For example, in Rajshahi, Jashore and Khulna, which have hard water, these areas are populated by chapila rather than mola. On the other hand, mola is abundant in North Bengal, in Mymensingh and in haors (shallow depressions with permanent water) in northeastern Bangladesh. Part of the area has soft water because of the Brahmaputra River, which over millions of years has deposited soil that is low in calcium/magnesium. Meanwhile, another area has hard water because of the higher mineral content in the soil from the Ganges River. For example, in Jashore the water hardness in hatcheries is close to 400 mg/L, which is four to five time higher than in haors. However, further investigation is needed to confirm this, because the water quality could affect mola breeding, survival of eggs/larvae and growth. If it is confirmed, then the project should propose a better area to the farmers for mola culture.

Abdus Sattar

Abdus Sattar was the only farmer who could meet us, because all the others were engaged in seasonal *boro* rice planting. Sattar, whose pond is located in the Dhulia beel, has significant experience with fish culture, having started farming fish in open ponds in 1987. He does fish culture in the traditional way. The ponds have good natural productivity, with sedimented soil from the beel. He owns two ponds, both of which are 2 acres in size. His open pond has a deeper part, where fish take shelter during the dry season. That is where harvesting is done. Small fish and mola remain for seeding in the next flooding season. Before our arrival, on the day of our visit, he sold carp using a specially made selective seine net that mola can escape through. Currently, there are about 500 kg of mola in the deepest part of the pond, while the connected part is planted with *boro* rice.

The second pond is closed. He plans to harvest this pond completely and use it for single-crop rice production followed by fish culture. He uses feed and fertilizer in the closed pond, but not on a regular basis. The pond is overstocked, so the carp cannot grow to more than half a kilogram. In the past, he has sold 1 t of mola breeders to the nongovernmental organization (NGO) Katalyst. In 2019, he sold 500 kg mola to the NGO Sharp. Those fish were distributed to Parbotipur, Rangpur, Saidpur, Domar, Jaldhaka and Kisoreganj.

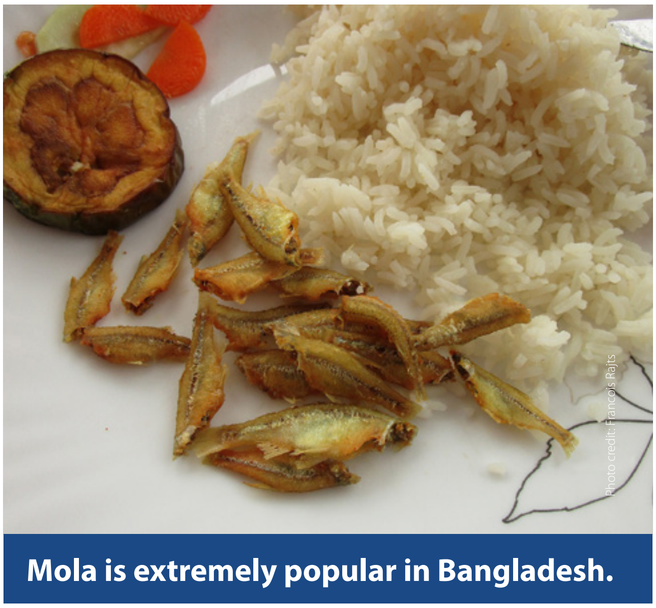


Plate 11. When eaten fully, mola are highly nutritious and easy to share equally within a family.

Annex 2. Previous trials

Stocking density (number/ha)		Calculated gross production (kg/ha/month)		Stocked carp species	Length of culture (months)	Type of waterbody	Reference
Mola	Carps	Mola	Carps				
25,000	12,500	440	3832	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 3. Partial data from past trials on polyculture of mola with carps.

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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