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A Study on Biology, Brood-stock Management and Induced Breeding of Amur Common Carp, *Cyprinus carpio haematopterus* (Linnaeus, 1758)

PRATISHRUTI GOUDA[1], MANAS KUMAR SINHA[2]* and SIBA PRASAD PARIDA[1]

[1]Department of Zoology, School of Applied Sciences, Centurion University of Technology and Management, Bhubaneswar Campus - 751 009, Odisha, India
[2]National Freshwater Fish Brood Bank, Kausalyaganga, Bhubaneswar - 751 002, Odisha, India

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Amur carp (*Cyprinus carpio haematopterus*) is a Hungarian breed of common carp (*Cyprinus carpio*) which grows to a larger size in a minimum rearing period compared to other common carp. It is a species delivered by selective breeding of different common carps available in the world. The species can also be cultured in controlled condition and also in open water bodies. Proper selection of breeders and their management is the key to success in induced breeding. A detailed study was conducted to undertake brood-stock management and induced breeding (Happa and Chinese circular hatchery) of Amur common carp at National Freshwater Fish Brood Bank, Kausalyaganga, Bhubaneswar, Odisha, India. The fork length (FL) at first maturity for male and female was 155 and 170 mm, respectively. The average rate of spawn production per kilogram of female varied between 28,145 to 31,250 numbers in happa breeding and between 53,333 to 64,103 numbers from Chinese circular hatchery. The results of happa breeding impedes the way to small scale seed producing entrepreneur and the technology can cater the need of small-scale farmers locally, whereas circular tank paves the way for better output and commercial production of Amur seed at any given point of time.

(***Key words:*** *Brood-stock management, Chinese circular hatchery, Happa breeding, Induced breeding*)

In India 85% of the total aquaculture production is contributed by the carps. Carps are major contributors in land fish production either from fisheries or aquaculture. Carp fish production in the country is harvested from both capture and aquaculture systems. During the last five decades, freshwater carp culture in India has grown both in geographical coverage in terms with diverse systems and farming intensification. Carp culture is the backbone of Indian freshwater aquaculture practice. The share has gone up from 46% in the 1980s to over 85% in the recent years. The three Indian major carps, *viz*. catla (*Labeo catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*) has been contributing the maximum in the inland production of India (Basavaraju and Reddy, 2013). The three domesticated exotic carp *viz*., silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*) and common carp (*Cyprinus carpio*) are regarded as second important group in the Indian fish farming (Laxmappa, 2014).

During 2017-18, out of total production of 125.90 lakh metric tonnes, 89.02 lakh metric tonnes (71%) is the inland sector and 36.88 lakh metric tonnes (29%) is from marine sector. The Indian major carp constitutes 58.63 lakh metric tonnes, more than 65% from the total inland fish production (Hand Book of Fisheries Statistics, 2018). Common carp, the most common cyprinid species, creates an important part of inland fish production (Basavaraju and Reddy, 2013). Polyculture carp system is an old practice in South Asia, especially in India, Bangladesh and Pakistan, and it is the main aquaculture system in this region (FAO, 1997; Miah *et al*., 1997; Reddy *et al*., 2002). It is an omnivorous bottom dweller which managed to survive mainly on benthic fauna and decaying matter. It often warrens the pond bottom in search of food. This habit of burrowing the pond bottom helps in maintaining the productivity of un-drainable ponds, hence culture of common carp with other carp species is of great advantage. Furthermore, it also feeds directly on the defecated material of grass carp. Its growth mainly depends upon the underneath fauna, stocking density and the rate of supplementary feed. In poly culture fish ponds, it grows to about 1 kg within a year (Jena *et al*., 2001, 2002). In a tropical climate, common carp spawns throughout the year while in the pond environment there are two peak periods: one

**Corresponding author:* E-mail: manasnfdb@gmail.com

between January and March, and the other during July and August. The eggs are minute and adhesive in nature, while in tropical conditions it achieves maturity within 12 months (Alikunhi, 1966). In a temperate climate, carp spawn once a year between May and June (Kottelat and Freyhof, 2007). Common carp is the most commonly transplanted fish species in the world. The fish species is very much favored for cultivation in ponds in Asia, near and far east, alone or in combination with other fishes, because of its faster growth rate, omnivorous habit, breeding in confined waters (unlike the Indian and Chinese major carps), hardy nature and easy adaptation to artificial feeds. Studies have shown that this bottom feeder has a much higher growth rate than *Cirrhinus mrigala*, the Indian major carp with similar feeding habits (Parameswaran *et al*., 1971).

Amur carp (*Cyprinus carpio haematopterus*) is a Hungarian breed of common carp (*Cyprinus carpio*), which grows to a larger size in a minimum rearing period compared to other common carps. The improved strain of wild common carp of Hungarian origin is known as Amur common carp (Rahman *et al*., 2007). Amur common carp is an ancient form that originated from the Asian carp centre and spread to the water bodies of western Asia. It is a species delivered by selective breeding of different common carps available in the world. The species can also be cultured in controlled condition and also in open water bodies. The Amur carp lives in both cold and warm environment and survives at very low temperature (0-4°C) too.

The technique of induced breeding was first evolved in Argentina through administration of pituitary extract by Houssay (1930), where a viviparous fish was injected with the hormone to make premature birth. In the year of 1934, Brazilians succeeded in induced breeding by using pituitary extract (Chaudhuri and Alikhunhi, 1957; Panda, 2016). In India the first attempt of induced breeding was made by Khan in 1937 on the species *Cirrhinus mrigala* (Panda, 2016). The first successful induced breeding on major carps was carried out by Dr. Hiralal Chaudhuri during 1957 in *Cirrhinus mrigala, Cirrhinus reba* and *Labeo rohita*. Parameswaran and Alikuni in 1963 successfully bred, the exotic Chinese carps - *Hypophthalmichthys molitrix* and *Ctenopharyngodon idella*.

Proper selection of breeders and their management is the key to success in induced breeding. The brood fish should be healthy, fully ripe and of medium size. These are collected from their natural habitat quite in advance of their breeding season and raised in fertilization pond of the fish farm. They are stocked at a rate of 1000-2000 per hectare area (*e.g*. carps). The breeders should preferably be in the age group ranging from two to four years and have a weight averaging 1-5 kg. Large size breeders are avoided for difficulty in handling. A fish farm may have its own stocking ponds from which the breeders of suitable age are selected and transferred to a well-prepared brood-stock pond. Fully ripe male and female carps are easily distinguishable (Basavaraju and Reddy, 2013).

In order to promote Amur carp in farming, development of commercially viable hatcheries for the species, roping in of production enhancement technologies, use of inputs, adoption of farm level management, effective and targeted research & development and extension to steer the next wave of adoption need attention of institutions, planners and policy makers. Promotion of scientific knowledge, technical services and facilitation for access to quality seed of Amur common carp at the grass root level are most warranted (Sennappa, 2015). Keeping in view the advantages and the compatibility of the Amur carp species for composite fish culture, a detailed study was conducted to undertake brood-stock management and induced breeding through Happa and Chinese circular hatchery to produce seed commercially.

MATERIALS AND METHODS

The study was conducted at National Freshwater Fish Brood Bank (NFFBB) farm (20° 11′ 5.6″ N and 85° 50′ 59.9″ E) situated at Kausalyaganga, Bhubaneswar, Odisha, India. For conducting the experiment, two ponds of size 400 m^2 each were selected. Initially the marginal grasses and weedy grasses were cleared and the nursery pond bottom was ploughed in order to tilt the soil for better aeration. Water was filled into the pond and the mahua oil cake @ 2,500 kg ha^{-1} was applied to the water for eradication of the weed and predatory fishes. Water was filled up to 1.0 m. Then the mixture of 750 kg groundnut oil cake, 200 kg urea and single super phosphate 50 kg ha^{-1} was added in order to get desired primary productivity in the pond water. After three days of fertilization, kerosene oil @ 100 L ha^{-1} was used to kill the aquatic insects.

The Amur common carp brooders (size between 1.5 to 2.5 kg) were collected from NFFBB farm rearing ponds. The brooders were netted out from the rearing ponds and then they were segregated sex wise and kept in two well prepared ponds. Altogether 200 females and 200 males were stocked and they were fed @ 2% of body weight with the prepared farm made feeds (feed composition is given in Table1). The bag feeding was carried out during morning hours by placing bags in corner location of ponds. On weekly basis the water quality parameters were checked and also on weekly basis the sampling was carried out to find out the development of gonads. The females were observed physically for bulging belly and the males were observed to find out if the oozing milt was coming out freely by slight pressing of the abdomen. After 4 weeks it was found that brooders were ready for induced breeding.

Four numbers of nylon breeding happas (size: 2 m × 1m × 1m) (Fig. 1) were tied in pond and fixed by the support of GI pipes. The best females and males were selected from the brood ponds to undertake the breeding. The selected fishes were induced with the GONOPRO-FH (Amrit Pharmaceuticals, Aurangabad). The females were injected with 0.3 mL kg^{-1} body weight and the males were injected with 0.2 mL kg^{-1} body weight. After injection the male and females were kept in 1:1 ratio in the happa. In every happa two pairs of brooders (two male and two female) were released. After the injected brooders were released in the happa, the plastic strips/water hyacinth floating weeds were spread on the water surfaces for attachment of eggs. The happas were covered there after so that the fish does not jump out from the happa. The happas were kept undisturbed till morning as the fishes spawn after 4-6 hrs of the hormonal injection.

Next day morning the outer happa was fixed in the pond with the help of GI pipes. The floating plastic strips/water hyacinth floating weeds attached with fertilized eggs were collected from the breeding happa and kept in the outer happa. After 80-85 hours the spawns get hatched out of the fertilized eggs. The spawns were collected and counted for ascertaining the seed output rate. One set per week was taken and the induced breeding and happa breeding was continued for 5 more weeks. The collected spawns were stocked in the well-prepared nursery ponds for further rearing to obtain fry and fingerlings. Some parts of the produced spawn were also sold to the local seed growers.

Similarly, the induced breeding was also taken in the Chinese circular hatchery (Fig. 2) available at NFFBB site. The best suited females and males were selected from the rearing pond and induced breeding was taken with the GONOPRO-FH. Both the male and female were injected at the same dose which was used in happa breeding. After injection the male and females were kept in 1:1 ratio in the breeding pool. In one batch 20 pairs of male and females were taken for breeding in the breeding pool. After that injected brooders were released in the breeding pool. Plastic strips and floating weeds (water hyacinth) were spread into the water

Fig.1. *Happa breeding of Amur carp at NFFBB*

Fig.2. *Chinese circular hatchery at NFFBB*

surfaces as in case of happa breeding for attachment of adhesive eggs. The breeding pool was covered so that the fish don't jump out from the pool. The pool was kept undisturbed till morning as the fishes they spawn after 4-6 hours the hypophysation or induced breeding. Next day morning the floating plastic strips and the water hyacinth attached with fertilized eggs were collected from the pool and distributed in the spawning pools. After 80-85 hours the spawns hatched out of the fertilized eggs. The spawns were collected and counted for the fecundity study. Three breeding sets altogether were taken in the Chinese circular hatchery available at NFFBB. Water quality parameters in brood stock ponds and breeding pool, hatching pools were also checked and recorded throughout the study period following standard methods of APHA (2005).

RESULTS AND DISCUSSION

In the present study the brood-stocks were maintained for 30 days in the brood-stock pond. During the period of brood management, the female and the male fishes have gained weight and also the gonads got matured up to the stage- IV (fully matured). The females were found to have bulged belly and males had the oozing milt. It is evident that the management of brood stock is the key to success of any hatchery. During the present study, the females were of 580 mm to 650 mm in total length (TL) at first maturity. It was found to be variable, ranging from 90 to 430 mm TL for both males and females in wild *C. carpio* population (Fernández-Delgado, 1990; Prochelle and Campos, 1985). In the present study, the fork length (FL) at first maturity for male and female were found to be 155 mm and 170 mm, respectively, which did not vary from other studies. However, the length at first maturity is lower than that reported in Lake Naivasha where it is 340 mm for male and 420 mm for females (Oyugi *et al*., 2011). In Amerti reservoir, males matured at smaller sizes (272 mm FL) than females (283 mm FL). This may be related to the preparation of females to sustain large number of eggs. Males attaining maturity at a smaller size than females are also reported in both temperate and tropical aquatic ecosystems (Britton *et al*., 2010; Tempero *et al*., 2006). The present study is in conformity with the findings of the latter.

Table 1. *Feed composition of brood-stock feed of Amur carp*

Ingredient	% composition
Rice bran	25%
Ground nut oil cake	25%
Horse gram	10%
Rice broken	10%
Maize	10%
Fish meal	10%
Total	100 %

Amur carp breeding in happa was taken up at NFFBB during 15th January, 2020 to 10th March 2020 and total 21 lakhs of spawn were produced from five breeding sets. The details are depicted in Table 2. From the table it can be seen that the seed production per set varied between 4.0 to 4.5 lakhs. The seed produced per kg was calculated from the retrieved spawn from each breeding sets. The average rate of spawn production per kg of female varied between 28,145 to 31,250 numbers.

Besides the above, Amur carp breeding was also taken up in Chinese circular tanks during 15th January, 2020 to 5th February, 2020 at NFFBB multiplication centre and a total 67 lakhs of spawn were produced from three breeding sets. The details are depicted in Table 3. From the table it can be seen that the seed production per set varied between 20 to 25 lakhs. The seed produced per kg was calculated from the retrieved spawn from each breeding sets. The average rate of spawn production per kg of female varied between 53,333 to 64,103 numbers.

The spawn produced from each set indicated that there is no significant difference between the sets. The seed output from each female depends upon the size of the female and its environmental factors. However it is imperative to state that the spawn per female is directly proportional to the brood fish management. As it is highly relevant that brood fishes fed with high protein and fat diet will always give higher seed output than only protein rich diet. Secondly the spawn output is also directly proportional to the rate of fertilization which is evident from several studies (Das, 2017; Sinha and Ananth, 2019).

While comparing the happa breeding and circular tank breeding, it was observed that the seed output rate is

Table 2. *Details of Amur seed production in Happa at NFFBB, Kausalyagnaga*

Particulars	1st Breeding	2nd Breeding	3rd Breeding	4th Breeding	5th Breeding
Date of breeding	15-1-2020	22-1-2020	5-2-2020	12-2-2020	19-2-2020
Number of females taken for breeding	8	8	8	8	8
Total weight of female fish in kg	13.6	12.8	15.7	15.1	14.5
Number of males taken for breeding	8	8	8	8	8
Total weight of male fish in kg	15.2	14.5	16.9	15.4	12
Spawn produced (in lakh)	4.0	4.0	4.5	4.25	4.25
No. of spawn recovered per kg of female	29,411	31,250	28,662	28,145	29,310

Table 3. *Details of Amur seed production in Chinese circular tanks at NFFBB, Kausalyagnaga*

Particulars	1st Breeding	2nd Breeding	3rd Breeding
Date of breeding	15-1-2020	22-1-2020	5-2-2020
Number of females taken for breeding	20	20	20
Total weight of female fish in kg	38	37.5	39
Number of males taken for breeding	20	20	20
Total weight of male fish in kg	42	40.5	43.5
Spawn produced (in lakh)	22	20	25
No of spawn recovered per kg of female	57,895	53,333	64,103

higher in circular tanks compared to happa, which may be due to water circulation in the spawning pool. Due to the circulation of water the oxygen level of water might be at higher concentration. In general, the fecundity rate of Amur carp is 60,000 to 80,000 numbers per kg female. In the present study, the breeding undertaken in circular tanks showed better seed output which is an indication for commercial and economical production of Amur spawn. As there is no study of Amur carp seed production in Chinese circular tanks except few studies in carp hatchery for IMC and Chinese carps (Chowdhury *et al*., 1996; Halim *et al*., 2018), therefore the result could not be compared with other studies. However, the methods pave the way for commercial production of Amur seed at any given time.

Determination of fecundity and spawning season are indispensable in understanding the population dynamics of fish species (Sivakumaran *et al*., 2003). Fecundity also explains the degree of invasiveness and the ecosystem impact (Bajer and Sorensen, 2010). The mean relative fecundity in Amerti reservoir was 177,786 kg^{-1} is larger than 97,200 oocytes kg^{-1} reported in New Zealand (Tempero *et al*., 2006); but comparable with 163,000 eggs kg^{-1} total body weight (Sivakumaran *et al*., 2003). Female *C. carpio* can carry >1000000 oocytes for length groups >60 cm (Bajer and Sorensen, 2010). But in the present study the fecundity is found to vary from 28,145 to 64,103 numbers which differs from the study by Sivakumaran *et al*. (2003). This may be due to the different strain of common carp and may also be due to different breeding season. Moreover, when it is reared in larger water body like reservoir, it may have better output than the confined pond environment and it needs further investigation.

From different studies (Basavaraju and Reddy, 2013; Basavaraju *et al*., 2003) it is clear that Amur is an improved strain compared to local common carp and the growth of Amur is faster than Mrigal. Therefore, the farmers will be much interested for undertaking culture of Amur along with Rohu and Catla. Sinha and Ananth (2019) stated that Amur if stocked in the ratio of 15% with other carps is more profitable and economically feasible in carp poly-culture system. The present study agrees with the observations made by Sinha and Ananth (2019).

The physico-chemical parameters of water in the experimental units were recorded weekly throughout the experiment and are presented in Table 4. All the water quality parameters were found optimal for carp culture during the experimental period. Although, some fluctuations in water quality parameters were recorded during the experiment, the ranges were suitable for fish culture. The water temperature in the treatments, during the culture period varied between 14.0-24.7°C and found suitable for rearing of Amur carp and breeding of common carp. During the experiment, water pH varied between 7.23-8.49 in all treatments and was suitable for Amur carp. The dissolved oxygen (DO) content in all treatments ranged from 5.01 to 6.61 ppm, which was favorable for Amur carp. In the present study, alkalinity was recorded in the range of 86.7-114.7 ppm which is in the acceptable range for fish culture. Variation in alkalinity was not very high and these few changes might be due to the continuous flow of water along with biological changes in the tank. Hardness was in the range of 110-144 ppm which was within the range suitable for Amur carp. The inorganic nutrients such as nitrite (0.23-0.42 ppm), nitrate (0.42-1.93 ppm) and phosphorus (0.16-0.28 ppm) were also within the acceptable ranges for brood-stock development and breeding. The results of the present study are similar to those recorded by Fernández Delgado (1990). He stated that the spawning in *C. carpio* occurs at a water temperature of around 18°C. The mean monthly water temperature that ranged from 18.9 to 23.1°C during the study period appears to favor the year round spawning of common carp in the reservoir (Fernández Delgado, 1990). Year-round breeding pattern for *C. carpio* has been reported in other tropical lake (Oyugi *et al*., 2011). It is observed that lower the temperature, the better is the development of gonads. In the present study breeding of Amur carp is well documented for the first time in the state of Odisha and in particular during winter season.

Introduction of fast growing strains and production of Amur common carp may restore producers' confidence in growing this species under various culture systems (monoculture and polyculture) and help to develop sustainable aquaculture in the country. The present study indicated that the overall performance in terms of brood-stock management and seed production of Amur carp is equally important and at par with the Indian major carps. In general, the fecundity rate of Amur carp is 60,000 to 80,000 numbers per kg female. The present study of breeding in circular tanks showed better seed output (average 55,000 numbers) than that of happa breeding (average 30,000 numbers) which might be due the fact that there is better water circulation and exchange of water in the circular tanks than happa. The same water that of the pond moves with the wind flow where the happa is fixed. But in circular tank always freshly aerated water is flowing through gravity flow which provides favourable water quality that the egg or spawn requires. The comparative study during the present study of happa breeding and the seed production in Chinese circular hatchery are quite encouraging. The results of happa breeding impedes the way to small scale seed producing entrepreneur and the technology can cater the need of small-scale farmers locally whereas circular tank paves the way for better output and commercial production of Amur seed at any given point of time.

Table 4. *Physico-chemical parameters in different experimental units at NFFBB*

Parameters	Brood stock pond	Happa	Breeding tank
pH	7.23-8.49	7.31-8.18	7.47-8.00
Transparency (cm)	16.0-72.3	16.0-57.7	14.3-57.3
Temperature (°C)	14.0-24.4	14.0-24.6	13.9-24.7
Dissolved Oxygen (ppm)	5.0-6.2	5.3-6.2	5.4-6.6
Alkalinity (ppm)	90.7-114.7	86.7-109.3	87.3-114.0
Hardness (ppm)	110.0-136.7	113.3-144.0	110.0-134.0
Ammonia (ppm)	0.55-0.64	0.55-0.64	0.59-0.68
Nitrate (ppm)	0.42-1.84	0.85-1.93	0.67-1.70
Nitrite (ppm)	0.24-0.34	0.23-0.42	0.27-0.35
Phosphate (ppm)	0.17-0.27	0.16-0.28	0.19-0.27

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