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IDENTIFYING THE MOST PRODUCTIVE HATCHING ENVIRONMENT FOR CARP FISH FRY IN THE HALDA RIVER, BANGLADESH

Mohammad Shamsil Arafeen*, J. K. Owaresat, M. R. Islam, Ebne Foysal, M. A. Habib Siam, Abdullah Al Asek, Md. Badruzzaman Suhag[1], Mumtahena and Md. Manzoorul Kibria

Halda River Research Laboratory, University of Chittagong, Chittagong-4331 Bangladesh

ABSTRACT: Indian major carps are key species in the Halda River, both as symbols of the region and as crucial contributors to the aquatic ecosystems and fisheries industry in Bangladesh. While previous research has examined various aspects of this river, there has been a lack of studies focusing on accurately quantifying the number of eggs collected and fry produced, as well as comparing fry production at different sites (such as mud scoops and cemented cistern). This information is essential for understanding population dynamics, assessing reproductive success, and evaluating the habitat quality of fish communities. In our study, we recorded a total of 13,502 kg of eggs collected from 314 boats. The estimated total fry production was 413.163 kg, with 98.82 kg of fry hatched from 93 rectangular mud scoops, 192.377 kg from 141 cemented rectangular cisterns, and 108.59 kg from 20 circular cistern. An independent t-test comparing fry production rates at the different hatching sites showed that the average fry production rate was highest in rectangular cisterns (3.74 ± 0.13), followed by circular cisterns (3.03 ± 0.10), and lowest in mud scoops (2.26 ± 0.059). It was also noted that the heightened turbidity caused by hilly torrents plays a significant role in facilitating the natural spawning of Indian Major Carps in the river.

Key Words: Fish, Egg Collection, Fries Production, Mud Scoops, Cemented Cistern.

INTRODUCTION

The Halda River, recognized as the third most important river in Chittagong after the Karnaphuli and Sangu rivers, is a major and ecologically sensitive natural spawning bed for Indian major carp in Bangladesh (Kibria *et al.*, 2020, Owaresat *et al.,* 2022, Arafeen *et al.,* 2024). This river boasts rich biodiversity, with over 70 species of fish (Kibria, 2010; Alam *et al.*, 2013) and serves as a natural breeding ground for several carp species, including *Labeo rohita*, *Catla*

**Author for correspondence: <shamsilarafeen@cu.ac.bd>; [1]Department of Statistics, University of Chittagong, Chittagong-4331 Bangladesh.*
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catla, *Cirrhinus cirrhosus*, and *Labeo calbasu*. Additionally, the River serves as a favorable habitat for the Ganges River Dolphin (*Platanista gangetica*), with 162 individuals recorded in 2022 (Kibria *et al.,* 2023). While many rivers worldwide are known for fry collection, the Halda River is unique because it is the only river where fish eggs are collected directly (Kibria *et al.,* 2009). Throughout the year, the Halda provides numerous resources such as sand, fish, eggs, and water to the local communities (Kabir *et al.*, 2013a). Under controlled conditions, the Halda strain significantly outgrows and survives beyond that of the hatchery strain (Kibria *et al.,* 2024). Therefore, accurately determining the quantities of eggs collected and fry produced is crucial.

Previous studies on the Halda River have provided some data on egg and fry quantities; however, these data are often disputed because they were obtained from local egg collectors and pit owners without using standardized scientific methods. For instance, Patra and Azadi (1985) reported that the average amount of eggs collected per hatching pit in 1981 ranged from 35 to 105 kg, with an average fry yield of 0.26 million to 1 million. Bhuiyan *et al.*, (2019) examined egg collection, fry production, and the economic conditions of fishermen and others involved, revealing annual egg production of 61.72 kg in 2011, 302.65 kg in 2012, 81.9 kg in 2013, 178.38 kg in 2014, and 38.42 kg in 2015. Tsai *et al.* (1981) recorded 3540 kg of eggs in May and 563 kg in June, along with 118 kg and 8.1 kg of fry in those respective months.

Egg and fry data have also been recorded by institutions like the Department of Fisheries (DoF) and the Halda River Research Laboratory (HRRL). However, these records often differ significantly due to irregularities among egg collectors and variations in data collection times. Some fishermen exaggerate their yields, while others underreport quantities to manipulate the market based on annual production. In this study, we identified methods to prevent misinformation and accurately determine the amounts of eggs and fry collected, which will help authorities assess the river's health and develop appropriate policies. Additionally, this study compared fry production at two different hatching sites, which will aid future efforts to develop infrastructure to enhance fry production near the Halda River.

MATERIAL AND METHODS

Study Area: The Halda River (Figure 1) is located in the South-East region of Bangladesh, a major tributary of the river Karnaphuli in the Chittagong district originated from the hilly Haldachora fountain at the Patachara hill ranges of Ramgarh in the Khagrachari hill (Akter and Ali, 2012; Kabir *et al.* 2013b; Islam, 2017). During the egg collection data were collected from the whole river on continuous movement with the help of speed boat. But, for recording fries data,

35 mud scoops from river adjacent areas and 05 hatcheries with 161 cemented cisterns were covered.

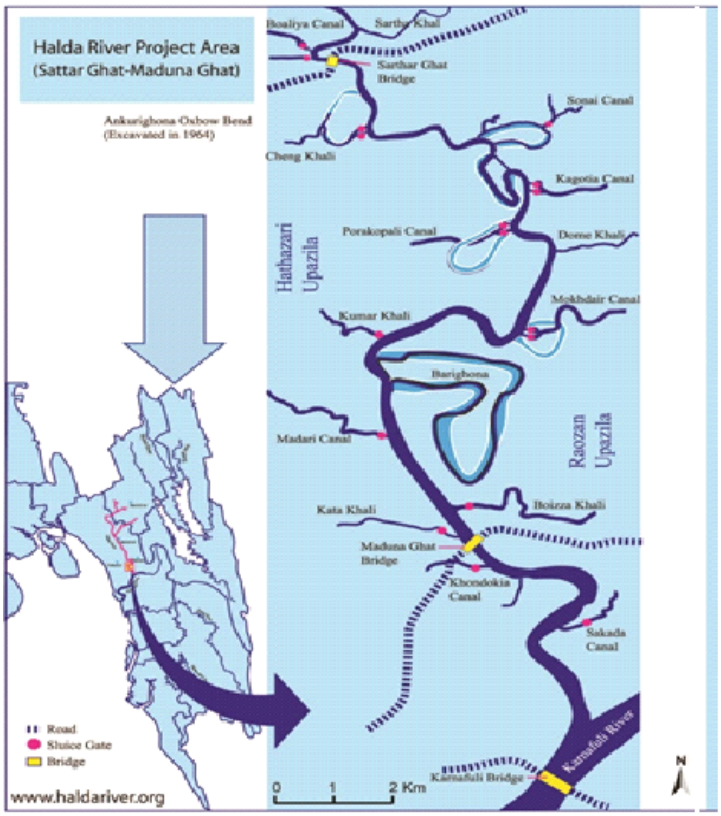

Figure 1: Map of the Halda River

Duration: Data of egg amounts were noted on 10th April, 2023. The data on fry production in hatching sites (mud scoops and cemented cisterns) were collected on 14th April 2023. Water samples from the Halda River were collected during the breeding season over a periods of three months (April to June) and sent to the Halda River Research Laboratory to measure water quality. Determination of the amount of eggs. To determine the amount of eggs, timing is the most important thing to stop manipulation. As eggs follow the water current, the distribution of egg collection boats varies with high tides and low tides. To identify the total population of egg-collecting boats, we used a speed boat to count the total number of those boats on the breeding ground of the river, from Gorduara to Ramdas Munsir Hat. To measure the amounts of eggs, we used PRA (Participatory Rural Appraisal) where selective local egg collectors were first trained to use 10 L buckets when carrying eggs to the hatching cisterns. We

selected the egg collectors based on their distribution at breeding sites during egg collection. During high tide, we chose 30 boats from Gorduara to Machuaghona, and during low tide, we selected another 30 boats from Napiter Ghona to Ramdas Munsir hat area by analyzing their distribution this year. We collected all the data (such as, total bucket number) directly from the egg collectors during that time to avoid misinformation. Later after that, the total amounts of eggs were calculated from the samples.

Determination of the amount of fries: There are two types of places for egg hatching, one is rectangular mud scoops made by local egg collectors and the other is cemented cisterns (with 2 types of shapes- rectangular and circular) found in local hatcheries. The egg collectors built the traditional mud scoops from their own experiences and use traditional techniques to rear eggs. On the other hand, rectangular and circular- two types of cemented cisterns are found in four government hatcheries- Mubarakkhil, Modunaghat, Shamadahri, and Machughuna hatchery, and one private institution Integrated Development Foundation (IDF) hatchery facilitated with motors for continuous water supply, permanent water tanks, springs for aeration, and a well-developed drainage system. On 4^{th} day of egg hatching in mud scoops or cemented cisterns when fries became marketable, we started to count the fries.

For determining the number of fry from rectangular shaped hatching cisterns, the length, width, and height of the used water level were listed first. To estimate the volume of the water (m^3) in these types of cisterns, the formula for volume = lbh (m^3) [l= length, b= width, h= height] was used where the m^3 unit of water volume was converted into litre (L) unit. Then, we collected a 1 L water sample with fries of a 4-day-old using a 1 L beaker to count the individual's number. The procedure was repeated five times to avoid miscalculation and average number of fries were counted later. Using this, the total number of fries in respective rectangular shaped cisterns were calculated by multiplying with the total volume (L) of the pit.

For determining the number of fry from circular shaped hatching cisterns, radius and height of the water were listed first. To estimate the volume of the water (m^3) in these types of cisterns, the formula for volume = $\pi r^2 h$ (m^3) [here, r= radius, h= height, π= 3.1416] was used where the m^3 unit of water volume was converted into litre (L) unit as well. Later the number of fries in those types of cisterns were calculated using the previous procedure. To convert the number of fries into the weight (kg) of fry, we collected 01 g of fry and counted the number of individuals. Later, from the total number of individuals in a particular hatching pit, we determined the amount.

RESULTS AND DISCUSSION

Data were collected from a sample of 60 boats (30 during high tide and 30

during low tide) out of a total of 314 boats involved in egg collection in 2023. The number of buckets transported to the hatching pits from these samples was recorded at 258 for both high and low tide conditions. Since each bucket contains 10 kg of eggs, the total amount of eggs from the sampled boats was calculated to be 2,580 kg, or an average of 43 ± 3.06 kg per boat, with a 95% confidence interval. Based on this sample, the total amount of eggs collected from all 314 boats was estimated at 13,502 kg. An independent t-test comparing egg collection during high tide and low tide showed no statistically significant difference, indicating that egg collection in the Halda River is not affected by tidal conditions.

Fry production can differ significantly from one person or hatching pit to another due to various factors, such as the knowledge and skills in rearing, and access to aeration facilities. To minimize errors and ensure accuracy, we collected data from the entire population, covering all hatching pits. Data were gathered from 93 rectangular mud scoops managed by 35 fisherman groups and 161 cemented cisterns (141 rectangular cisterns and 20 circular cistern) across five hatcheries. The total fry production was estimated at 98.82 kg from the 93 rectangular mud scoops, 192.377 kg from the cemented rectangular cisterns, and 108.59 kg from the circular cistern. Therefore, the total amount of fry recorded this year was 413.163 kg. The average egg-to-fry production rate was 2.26 ± 0.059 in mud scoops, 3.74 ± 0.13 in rectangular cisterns, and 3.03 ± 0.10 in circular cistern. Based on this data, it is evident that the fry production rate is comparatively higher in rectangular cisterns (as shown in Table 1 and Figure 2). Although there has been no previous work to estimate the quantity of eggs and fries using scientific methods, several studies have explored various aspects of the Halda River, such as spawning biology, fry mortality rates, egg collection and hatching management, and the livelihoods of egg collectors. These studies have often included data on the amount of eggs and fries during the years they were conducted. However, there is uncertainty about the accuracy of the data was primarily collected from local egg farmers, who may not have provided accurate information.

Additionally, significant discrepancies have been noted between the data from the Halda River Research Laboratory (HRRL) and the Department of Fisheries (DoF) from 2003 to 2015, raising questions about the true annual productivity of the Halda River. To address this issue, this study aimed to accurately estimate the quantity of eggs and fries using a scientific method, under the collaboration of HRRL and DoF. This approach has been tested for its accuracy and reliability from 2016 to 2022, and in 2023, it provided precise data on egg and fry quantities.

Table 1: Egg to Fry Production percentage in mud scoop, cemented rectangular cistern and cemented circular cistern

Statistics	Egg to Fry Production rate in mud scoop (%)	Egg to Fry Production rate in cemented rectangular cistern (%)	Egg to Fry Production rate in cemented circular cistern (%)
Mean	2.2609319	3.748864066	3.031986928
Standard Error	0.029998022	0.068221108	0.04963542
Median	2.176	3.705	2.959722222
Mode	2.146	4.333333333	N/A
Standard Deviation	0.289290444	0.810080773	0.221976346
Sample Variance	0.083688961	0.656230858	0.049273498
Kurtosis	-0.653689559	-1.571680911	-0.295052554
Skewness	0.48165293	-0.239175724	1.07226334
Range	1.1	2.4	0.688558824
Minimum	1.775	2.6	2.7885
Maximum	2.875	5	3.477058824
Sum	210.2666667	528.5898333	60.63973856
Count	93	141	20
Confidence Level (95.0%)	0.05957866	0.134876795	0.103888128

According to this study, a total of 13,502 kg of eggs were collected from 314 boats. The estimated total fry production was 413.163 kg, with 98.82 kg of fries hatched from 93 rectangular mud scoops, 192.377 kg from 141 cemented rectangular cisterns, and 108.59 kg from 20 circular cistern. Statistical data comparison of fry production rates across different hatching sites shows that the average fry production rate is highest in rectangular cisterns (3.74 ± 0.13) compared to mud scoops (2.26 ± 0.059) and circular cisterns (3.03 ± 0.10). Fry from the Halda River are naturally bred in the wild, which contributes to their stronger genetics and higher survival rates. The current study thus identifies that about 4-5 days after hatching, the fry are sold off by egg collectors to different fish farmers throughout Bangladesh, which would charge between BDT 100,000 to 150,000 per kilogram, whereas hatchery fry are available at a much lower price of BDT 8,000 per kilogram. Every year, from April to June, most of most of the inhabitants of Indian Major Carps, such as 'Katla', 'Rui,' 'Mrigal', and 'Kalbaoush,' spawn in the Halda River's spawning grounds. Additionally, a

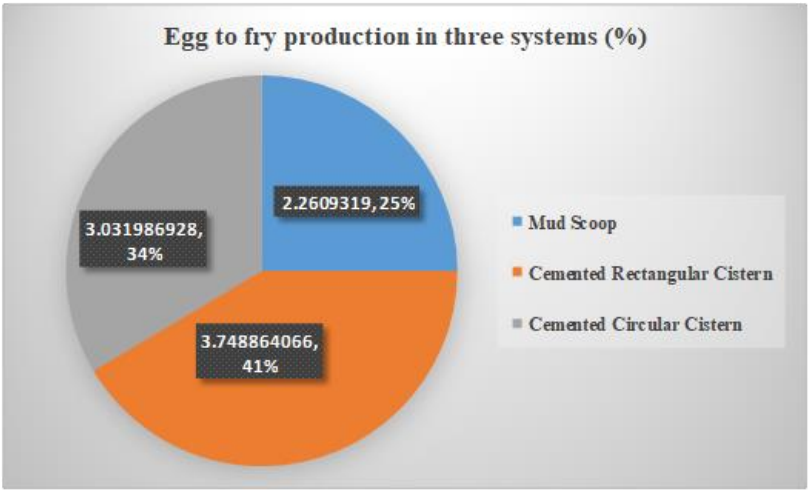

Figure 2: Egg to Fry Production Percentage

smaller number migrate from the Karnaphuli upstream to the Halda River's spawning grounds to spawn. Successful spawning in the Halda River requires specific environmental conditions, but these have been adversely affected by climate change and human activities. As a result, there have been significant fluctuations in the collection of eggs and fries from the Halda River between 2005 and 2023 due to various anthropogenic and natural factors shown in Table 2.

Table 2: Yearly eggs and fries collection from Halda river from 2005-2023 (Source: Halda River Research Laboratory, University of Chittagong)

Year	Egg in kg	Fry in kg	Year	Egg in kg	Fry in kg
2005	14922	248.7	2015	2820	47
2006	32724	545.4	2016	735	12
2007	22314	371.9	2017	1680	28
2008	2400	40	2018	22680	378
2009	13200	220	2019	6986.7	191.2
2010	9000	150	2020	25536	393.74
2011	12600	210	2021	8580	105.73
2012	21240	354	2022	7235	128.7
2013	4200	70	2023	14664	437
2014	16500	275			

Carp fish spawning in the Halda River depends on various contributing and regulating factors. Contributing factors like turbidity, precipitation, tide, and fish age significantly influence reproduction and egg production, with changes in these factors directly affecting the egg production rate. Regulating factors include Dissolved Oxygen (DO), pH, CO_2, salinity, conductivity, resistivity, and temperature, all of which must be within specific ranges for spawning to occur. In 2018 and 2020, hilly torrents caused turbidity levels to range from 600-700 NTU (Nephelometric Turbidity Unit), which played a key role in increasing egg production due to lower salinity. However, in 2019, 2021, and 2022, reduced precipitation led to lower turbidity (50-120 NTU) and higher salinity, resulting in decreased egg production. Persistent high temperatures, influenced by climate change, have increased salinity levels, while insufficient rainfall has created unfavorable conditions for successful egg hatching in the Halda River. Additionally, the construction of unplanned sluice gates and dams has reduced water flow, leading to a decline in essential food sources like benthos, contributing to the decline in fish species.

There are two types of factors affecting the reproduction of Indian major carp in the Halda River (Table 3). Firstly, there are factors referred to as contributing factors, which play a significant role in fish reproduction. The amount of eggs spawned fluctuates based on variations in these contributing factors. These factors include turbidity, precipitation, tidal currents, Jow, and the presence of brood fish, among others. Secondly, there are other factors referred to as regulating factors. If these factors fall outside a specific range, the fish will not spawn. These factors include temperature, pH, dissolved oxygen, carbon dioxide, conductivity, resistivity, and salinity.

Table 3: Contributing and Regulating Factors during breeding season (April-June, 2023) in Halda River

Months / Parameter	April		May		June	
	High Tide	**Low Tide**	**High Tide**	**Low Tide**	**High Tide**	**Low Tide**
Water Temperature (°C)	29.75	31	30.75	31	29	30.75
pH	7.43	7.45	7.43	7.4	7.25	7.3
DO (Dissolved Oxygen) (mg/L)	8.22	8.01	6.015	5.93	16.95	16.25
Salinity (ppt)	1.55	1.075	1.16	0.573	0.138	0.193
Conductivity (µS/cm)						
TDS mg/L	439.6	414.75	831.25	625.25	79.9	80.6
Turbidity (NTU)	650	648	727	720	710	685

An analysis of the contributing and regulating factors over the last six years (2018 to 2023) revealed that the higher quantities of eggs (Table 4) were recorded in 2020 (25,536 kg), 2018 (22,680), and 2023 (14,664 kg), respectively. In contrast, lower quantities of eggs were recorded in 2019 (6,986.70 kg), 2021 (8,580 kg), and 2022 (7,235 kg). The lower amount of eggs spawned in 2021 was due to Cyclone Yaas, less rainfall, and increased salinity in the river, which created less favorable conditions for spawning. Similarly, fewer eggs were spawned in 2019 and 2022 due to the absence of water torrent, as rainfall was insufficient. During those years, the average turbidity of the Halda River ranged between 52 and 120 (NTU) due to absence of the influx of water torrents.

Table 4: Relations between Turbidity during breeding seasons and Eggs production of Halda River (Source: Halda River Research Laboratory, University of Chittagong)

Year	Turbidity (NTU)	Production of eggs
2018	680	22680
2019	65	6986.7
2020	735	25536
2021	72	8580
2022	60	7235
2023	690	14664

However, during 2020 and 2023, the turbidity levels increased significantly (ranging from 600 to 700 NTU) due to the influx of water torrents, while other environmental factors remained normal. In addition to increasing turbidity, hill water torrents also helped to reduce the river's salinity. This suggests that the increased turbidity from the water torrents is a key contributing factor to the natural spawning of Indian Major Carp in the river.

Another interesting observation regarding the river is that it does have periodic fluctuations in turbidity, since the Halda is a tidal river. This phenomenon acts as a catalyst for the regular physiological behavior of the fish of the river. As there were fewer of eggs in the years when fish spawned without the torrents of water, measures should be taken to maintain higher turbidity levels in the river to make the natural spawning grounds more productive. Steps should be taken to ensure continuous inflow of hilly torrents, with consideration given to obstacles or management issues upstream in the Halda River.

CONCLUSION

The Halda River is renowned not only in Bangladesh but globally as a significant breeding ground, earning the recognition of 'Bangabandhu Fisheries

Heritage' by the Government of Bangladesh. While fry or fingerling collection from rivers is a common practice worldwide, the process of egg collection is uniquely practiced in the Halda River, setting it apart. Locals collect these eggs, rear the fries, and distribute them across the country. Hence, obtaining precise data on egg collection and fry production is vital for the effective management and analysis of the Halda River. This study provides valuable insights into the reproductive success and habitat quality of Indian major carps in the Halda River. By identifying the most productive hatching environments, the research supports the development of improved management strategies for enhancing carp populations and sustaining the economic viability of the fisheries industry in Bangladesh. Further research is recommended to explore other environmental and ecological factors influencing fry production and to validate these findings over multiple spawning seasons.

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