Malays. Appl. Biol. (2019) 48(3): 113–124

LIMNOECOLOGY AND CARP FISH SPECIES PEAK SPAWNING TIMING IN HAOR BASIN OF BANGLADESH

MD. FOYSAL AHMAD[1], MUHAMMAD ANAMUL KABIR[1,2*], ZULHISYAM ABDUL KARI[2], MD. TARIQUL ALAM[1] and LEE SEONG WEI[2]

[1]*Faculty of Fisheries, Sylhet Agriculture University, Sylhet 3100, Bangladesh*
[2]*Faculty of Agro Based Industry, Universiti Malaysia Kelantan, Jeli Campus*
[*]*E-mail: anamulka@yahoo.com*

Accepted 26 March 2019, Published online 30 June 2019

ABSTRACT

The present study was conducted to investigate the peak spawning timing based on the reproductive performance of carps species related to limnoecology variables, emphasizing to assess within fish population breeding variability and monthly effects over a period from April to July 2016 in the haors basin of Bangladesh. The reproductive performances were evaluated through artificial breeding technique by hormone injection in matured brood fish. The reproductive performance in terms of mean fecundity, egg weight, fertilization, hatchling and larval survival were significantly ($P<0.05$) highest in the month of May to June, and April compared to the months of spawning timing for the three Indian major carps, and the three exotic carp respectively. The ovulation and hatching time were significantly ($p<0.05$) highest in the month of July and April for the *Labeo rohita*, in the month of Aril for *Catla catla* and *Cirrhinus cirrhosus* and for the three exotic carp in the month of June to July compared with the others months of the breeding season. However, total length, weight and spawning response were not significantly ($P>0.05$) different among the months of the breeding time for the six carp species and a trend similar to the spawning success was also observed and numerically the mean value of the spawning response rate was between 88 to 93% and 83 to 90% for the three Indian major carps and the three exotic carp respectively among the months of the study. Furthermore, mean monthly values of limnoecological variables such as temperature, pH, and dissolved oxygen were not significantly ($P>0.05$) different among the months of the breeding season of the carp species in the three haor study sites. This study may serve as an update on carp fish species peak spawning timing related to limnoecological variables in the haor basin for carps species broodstock sustainable management to get quality seeds in the aquaculture hatchery industry.

Key words: Spawning timing, reproductive performance, limnoecology, carp species, haor

INTRODUCTION

The carps are the main dominant species for the aquaculture in Bangladesh due to high demand in the market, better growth performance, easy husbandry practices and favorable environment for farming. In 2014-15, Indian major carps and exotic carps contributed 20.50% and 9.87% of total fish production respectively in Bangladesh (FRSS, 2016). However, poor broodstock management, as well as lack of quality seed, is a serious bottleneck in the hatchery for sustainable carp fish farming in Bangladesh. Furthermore, there is a lack of information on spawning performances of wild carp brood fish in relation to peak spawning timing and limnoecological variables changes in haors basin. Information regarding limnoecological aspects of brood fish species in haor basin is necessary for reproductive performance, fish stock assessment, management control and administration of fisheries resources on a sustainable basis. The significant of reproductive variability in spawning timing to fish population resilience has been recognized, and demographic effects are increasingly reported by many researchers (Anderson *et al*., 2008; Wright & Trippel, 2009; Juntti & Fernald, 2017).

In addition, evaluating breeding timing in haor carp fishes and its effect on reproductive success at the fish population and individual levels is also necessitates both conservations of carp fish species and development of the new techniques. The artificial breeding techniques of the carp species in the aquaculture hatchery industry may have for sustainable management of wild broodstock in the haors basin of Bangladesh. Although, our current knowledge of spawning timing in carp fishes in the

* To whom correspondence should be addressed.

haor basin is limited. The lack of information of carp fish breeding timing related to limnoecological variables in haors makes it difficult to compare spawning timing over space, time or phylogeny. The limnoecology and reproductive biology of the haors basin carp brood fish have not been investigated in an exceedingly scientific manner, in spite of their contribution towards ecology of haor carp fish production and the natural carp seed quantity in the aquaculture industry of Bangladesh. In general, hatchery owners collect matured carp brood fishes from different rivers and haors during the monsoon season for seed production by the artificial breeding techniques in a hatchery due to the demand of seed from wild brood fish in aquaculture (Khatun *et al*., 2017).

Haor is a vast water body which is known as a biodiversity hot-spot. The hydrographical arrangement of the haor region is seasonal and modest compared to other parts of Bangladesh. The haor basin freshwater ecosystem of north-eastern a part of Bangladesh frequently encounters water level fluctuation and is at specific risk from climate change. This makes livelihoods extremely vulnerable and limits the potential for agriculture production and aquaculture development especially the carp fish seed production. Carp fish species shows with a relatively narrow range of birthdates in their spawning timing during the rainy season in haors and rivers of Bangladesh. Spawning timing over a fish lifetime plays a significant role in reproductive success as it defines the number of reproductive opportunities and the environment in which eggs or larvae are released (Yamahira, 2004; Lowerre-Barbieri *et al*., 2011; Nzohabonayo *et al*., 2017; Jiang *et al*., 2018). At the fish population level, spawning temporal arrangement varies in terms of its duration, the degree of synchronization among the individual spawning period. Spawning timing usually occurs at the annual scale as most carp fish exhibit seasonality in peak spawning activity and annual reproductive cycle (Rideout *et al*., 2005; Khatun *et al*., 2017). At this scale, spawning success is hypothesized to correlate with the match or mismatch between the spawning temporal arrangement and best conditions for larval survival (Lowerre-Barbieri *et al*., 2011). Additionally, a typical methodology to assess the fish population spawning season and times of peak spawning activities does not exist. This is essential because spawning timing has been shown to vary annually due to changes in limnoecology variables, primarily temperature, pH, dissolved oxygen, water depth, rainfall and demographically with the size and age of the spawning fish population (Wright & Trippel, 2009; Pankhurst & Munday, 2011; Juntti & Fernald, 2017).

Moreover, enhanced interest in aquaculture has crystal rectifier to a good range of reproductive studies on fish in captivity (Rocha *et al*., 2008), leaving direct observation and activity of individual spawning capacity over time. Similar observations are possible within the field on fish species that spawn in discrete locations over a comparatively small geographic range (Patzner, 2008). However, without a quantitative definition of peak spawning, it is difficult to compare spawning activity among species or population. This study focused to investigate of wild brood carp species spawning output variation during breeding timing in a hatchery condition instead of spawning grounds in the haors basin. Integration of all spawning output variables with information on the environment, the size structure of the spawning fishes, estimate of hatch larvae is improving our understanding of breeding timing of carp fish species in the haor basin. This research concentrated primarily on female reproduction, due to the importance of egg production to spawning potential and reproductive success in the commercial carp fish hatchery in Bangladesh.

The present study aims to investigate the peak breeding timing based on the reproductive performance and broodstock management practices related to rainfall and hydrological variables, emphasizing to assess within fish population variability and monthly effects exhibited by six commercial female carp fish species in the haors basin of Bangladesh.

MATERIALS AND METHODS

Study sites and fish species

From April to July 2016, four months prior to the breeding season the selected sexually matured both male and female brood fish samples from the three haors like Tanguar haor, Hakaluki haor and Dekar haor (Figure 1) were captured on a monthly basis, with the help of artisanal fishermen of the regions.

Fishing gear consisted of stationary nets and gillnets of different mesh sizes (5-8 cm). Then the brood fishes were immediately transferred to the hatchery in a plastic container (500-liter water capacity) in Sylhet.

The fish samples were numbered and stocked at ten individuals in rectangular cement tanks measuring 4 m × 1 m × 1 m (length × wide × depth) and maintained the brood fish in the same tank until given to hormone injection for artificial spawning. The volume of water contained in each cement tank was 4000 L. Six carp species rohu (*Labeo rohita*), catla *(Catla catla),* mrigal (*Cirrhinus cirrhosus*),

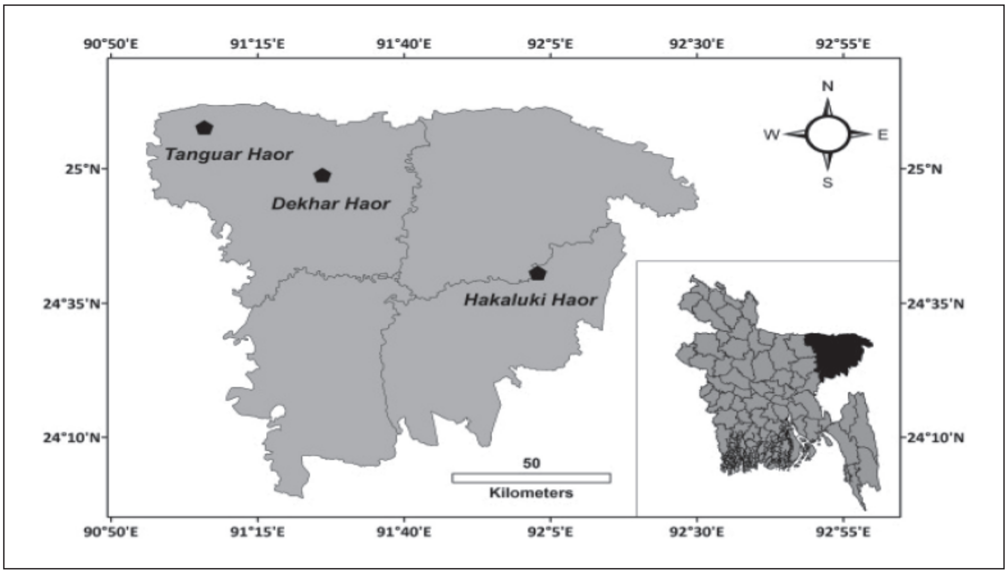

Fig. 1. Location map of sampling during the study period.

silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*), and grass carp (*Ctenopharyngodon idella*) were selected as brood fish based on the secondary sexual maturity characteristics. The brood fish sample was collected from the month of April to July due to peak breeding months of carp fish species in the natural water bodies like rivers and haors basin of Bangladesh as base information from the local fisherman.

Hydrological variables and rainfall in haors

The value of temperature, pH, and dissolved oxygen of the waters of all the three haors were monitored between 10:00 and 11:00 h on monthly basis over a period of the four months from April to July 2016, using portable equipment (Model HI98194, Hanna). The monthly rainfall data were collected during the study period from the meteorological department of Sylhet division.

Brood fish selection for spawning

The brood fish were kept in the cement tanks for 5 to 6 hours for acclimatization before hormone injection. The brood fish were caught from the cement tanks by the scoop net and measured the total length (cm) and weight (kg) of the individual for artificial spawning by the application of hormone Ovaprim-C (Syndel Laboratories, Canada). The matured males were identified by flat abdomens and long protruded genital papillae and the females were recognized by the soft and swollen abdomen and rounded and swollen urogenital ovipositor. Then the brood fish were in foam and the head region of the fish was wrapped by a wet and soft cloth. The hormone was injected at about 45° angles using a 1ml syringe in brood fish into the muscular basal region of the pectoral fin at the evening around 5:00 to 6:00 p.m and then brood fishes were transferred immediately to the spawning tanks (1000-liter water capacity). At least seven to nine fishes of each species were used in every month for the study of breeding performance. Table 1 shows the doses that were used to different carp species.

The dose and timing of injections were chosen based on the preliminary observations and practices in local carp hatcheries. During the spawning trails, dissolved oxygen remained between 4.50±1.42 mg L^{-1}, pH between 6.29 and 6.90 and the temperature was 29±2°C in the holding water of spawning tanks in the hatchery.

Table 1. The uses of hormone dose for six carp brood fish species

Fish species	Local Name	Dose of hormone mL kg^{-1}	
		Female	Male
Labeo rohita	Rohu	0.4	0.2
Catla catla	Catla	0.4	0.2
Cirrhinus cirrhosus	Mrigal	0.3	0.15
Hypophthalmichthys molitrix	Silver carp	0.7	0.35
Aristichthys nobilis	Bighead carp	0.7	0.35
Ctenopharyngodon idella	Grass carp	0.8	0.4

Evaluation of spawning and reproductive performances

After 7 to 8 hours of hormone injection, the collection of sperm and eggs, fecundity, egg weight and fertilization were determined as previously described by Kabir *et al*. (2013). In briefly, the brood fishes were carefully caught by a hand net and hold with the head pressed by using wet towels. Then the abdomen of female brood fishes pressed gently with the thumb from the anterior pectoral fin to the direction of ovipositor region. Ovulated eggs were come out in a thick jet from the ovary to the ovipositor region. The eggs were collected into a dry plastic bowl. On the other hand, the male brood was stripped in the same direction to the male genital papilla to collect the milts. Sperms from the male were collected by stripping directly into a tube containing a 9 g kg^{-1} NaCl solution (dilution rate of 1/5) and preserved at 4°C for a maximum period of 2 hours before being used for fertilization. Eggs were also collected by stripping method, weighted and immediately fertilized.

The reproductive performance was determined using the following formulae,

Spawning response (%) = 100 × (Number of brood spawned / Total number of brood hormone treated)

Ovulation time (hrs) = (Total time of ovulation – Time at hormone injection)

Relative Fecundity (eggs/kg) = (Total number of eggs in a female ovary / Total weight of female)

Fertilization rate (%) = 100 × (Number of fertilized eggs / Total number of eggs)

Hatching time and hatchling rate

The hatchling rate was counted by direct counting method. At first, the fertilized eggs were taken in white enamel bowl which had a capacity of 1.25 L. The average values of three bowls were used in the formula. The hatching time and hatchling rate was determined by the following formula,

Hatching time = (Total time of eggs hatching – Time of eggs fertilization)

Hatchling (%) = 100 × (Number of hatchling / Total number of fertilized eggs)

Survival rate of larvae

Direct counting method was used to count the survival rate of larvae. Total of 100 larvae were taken by the help of dropper in white enamel bowl which had a capacity of 1.25 L. Larvae were collected from homogenously distributed water in three bowls. Larvae were counted by naked eyes after 72 hours when the yolk sac was fully absorbed in the body. The average values of three bowls were used in the formula. The survival rate of larvae was determined by the following formula,

Larvae survival (%) = (Number of survived hatchling / Total number of hatchling)

Statistical analysis

Reproductive performance parameters were statistically treated using one-way analysis of variance (ANOVA) and descriptive statistics to determine differences among the four different months. P values <0.05 were considered significant when compared using Duncan's multiple range test. All statistical analyses were carried out using SPSS software version 20.0. The results are presented as the means ± standard deviations.

RESULTS

Hydrological variables and rainfall in haors

Mean monthly values of limnoecological variables of the three haor study sites are shown in Table 2.

Table 2. Mean monthly values of hydrological variables of the three haors during the study period

Location		Variables		
		Tem (°C)	pH	DO (mgL^{-1})
Hakaluki	April	26.56±0.37	6.8±0.35	4.46±0.15
	May	28.06±1.00	7.1±0.17	4.46±0.73
	June	32.33±2.30	7.10±0.27	4.34±0.36
	July	32.00±1.00	6.96±0.20	4.40±0.17
Tanguar	April	26.83±0.40	7.0±0.26	4.53±0.20
	May	27.80±0.52	7.00±0.26	4.80±0.76
	June	32.66±2.08	7.00±0.26	4.56±0.66
	July	32.66±1.15	6.83±0.50	4.73±0.12
Dekhar	April	26.46±0.37	6.60±0.28	5.33±0.23
	May	28.70±0.36	6.93±0.25	5.80±0.52
	June	31.33±1.15	6.95±0.25	4.86±0.55
	July	32.33±1.80	6.66±0.15	4.56±0.70

The mean values of water temperature showed slight variation ranging from 26 to 32°C in the three haors throughout the study period. The highest mean value of 32.00±1.00 was recorded during the month of June to July and the lowest mean value of 26.46±0.37 registered during the month of April in the three haors sites. However, the highest temperature was observed in June. The pH values showed minor variations and were mostly near to 7 throughout the study period in the three haors sites. The highest value of 7.10±0.27 was recorded in the month of May to June and the lowest value of 6.60±0.28 occurred in the month of April and July. The monthly values of dissolved oxygen varied from 4.34±0.12 to 5.80±0.52 mg L^{-1}. However, the values were most near to 4.5 mg L^{-1} in the three haors sites during the study period.

The total rainfall in the Sylhet region from April to July 2016 is shown in Figure 2.

Occasional intense rains during April and May, with a peak of 1030.1 mm resulted in filling up of the haors to the maximum capacity.

Evaluation of spawning and reproductive performances

Table 3, 4 and 5 provide an overview of reproductive performance of rohu (*Labeo rohita*), catla *(Catla catla),* mrigal (*Cirrhinus cirrhosus*) broodstock in April to July respectively.

The reproductive performance in terms of mean fecundity, egg weight, fertilization, hatchling and larval survival were significantly ($P<0.05$) highest for the three Indian major carps in the month of May and June compared to the month of April and July. However, the ovulation and hatching time were not followed in similar patterns for the three Indian major carps among the months of breeding time. The ovulation and hatching time were significantly ($p<0.05$) highest in the month of July and April for the *Labeo rohita*, (Table 3) in the month of April for *Catla catla* (Table 4) and *Cirrhinus cirrhosus* (Table 5) compared with the others months of the breeding season.

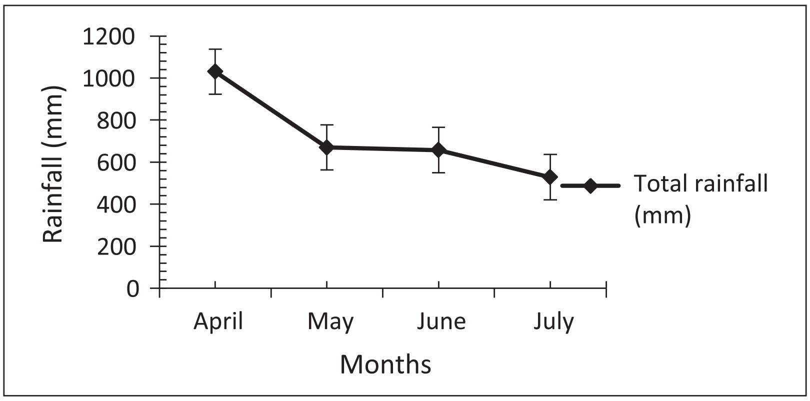

Fig. 2. Total rainfall (mm) in Sylhet from April to July 2016.

Table 3. Reproductive performance of female *Labeo rohita* (n = 32) broodstock

Parameters	Months			
	April	May	June	July
Length (cm)	48.62±3.09	49.94±2.63	50.90±1.09	49.43±0.71
Weight (kg)	2.04±0.61	2.32±0.44	2.18±0.50	2.32±0.60
Spawning (%)	89.33±9.83	90.47±14.68	91.78±12.60	90.00±13.69
Ovulation (hrs)	$7.28±0.06^{b}$	$7.23±0.03^{b}$	$7.11±0.05^{a}$	$7.37±0.04^{c}$
Fecundity (eggs/kg)×10^3	$73.52±2.06^{a}$	$82.09±3.42^{c}$	$82.53±1.25^{c}$	$78.28±2.81^{b}$
Egg weight (mg)	$3.03±0.03^{a}$	$3.16±0.05^{bc}$	$3.20±0.03^{c}$	$3.13±0.05^{b}$
Fertilization (%)	$74.60±1.14^{a}$	$80.20±1.79^{b}$	$82.40±1.95^{c}$	$76.20±1.30^{a}$
Hatching time (hrs)	$20.55±0.26^{b}$	$20.20±0.08^{a}$	$20.12±0.06^{a}$	$20.29±0.08^{a}$
Hatchling (%)	$74.60±1.14^{a}$	$79.20±1.79^{c}$	$80.60±1.14^{c}$	$77.20±1.30^{b}$
Larval survival (%)	$73.60±1.14^{a}$	$79.20±1.30^{b}$	$79.80±2.17^{b}$	$75.40±1.52^{a}$

Table 4. Reproductive performance of female *Catla catla* (n = 28) broodstock

Parameters	Months			
	April	May	June	July
Length (cm)	36.47±2.17	36.88±94	36.16±1.80	36.72±1.37
Weight (kg)	2.42±0.59	2.40±0.60	2.36±0.46	2.50±0.54
Spawning (%)	89.33±15.34	89.33±15.34	92.00±10.95	88.33±16.24
Ovulation (hrs)	7.29±0.04^{c}	7.20±0.03^{b}	7.11±0.04^{a}	7.21±0.04^{b}
Fecundity (eggs/kg)×10^{3}	72.71±2.53^{a}	80.04±1.12^{bc}	81.49±1.76^{c}	78.38±0.98^{b}
Egg weight (mg)	3.03±0.06^{a}	3.16±0.03^{b}	3.21±0.04^{b}	3.08±0.04^{b}
Fertilization (%)	73.80±2.16^{a}	81.20±1.78^{b}	82.60±2.07^{b}	76.20±2.77^{a}
Hatching time (hrs)	21.11±0.09^{b}	20.87±0.31^{ab}	20.62±0.24^{a}	21.02±0.27^{b}
Hatchling (%)	73.40±1.81^{a}	81.40±2.07^{c}	82.60±2.30^{c}	77.20±1.48^{b}
Larval survival (%)	73.00±2.12^{a}	79.60±1.67^{c}	80.80±1.64^{c}	76.80±2.48^{b}

Table 5. Reproductive performance of female *Cirrhinus cirrhosus* (n = 29) broodstock

Parameters	Months			
	April	May	June	July
Length (cm)	38.85±0.62	40.28±0.81	39.46±0.71	39.82±1.22
Weight (kg)	1.44±0.28	2.60±0.57	1.70±0.35	2.14±0.74
Spawning (%)	93.80±8.51	91.66±11.78	88.50±11.40	88.33±16.24
Ovulation (hrs)	7.33±0.07^{c}	7.19±0.04^{b}	7.09±0.04^{a}	7.25±0.05^{b}
Fecundity (eggs/kg)×10^{3}	71.19±1.40^{a}	80.40±1.96^{c}	80.38±3.17^{c}	75.12±0.95^{b}
Egg weight (mg)	2.98±0.05^{a}	3.06±0.03^{b}	3.11±0.04^{b}	3.06±0.03^{b}
Fertilization (%)	71.40±1.14^{a}	79.40±1.81^{b}	80.60±1.14^{b}	73.20±1.92^{a}
Hatching time (hrs)	21.39±0.08^{c}	21.28±0.05^{ab}	21.21±0.06^{a}	21.36±0.06^{bc}
Hatchling (%)	70.80±1.48^{a}	78.60±1.14^{b}	79.20±1.78^{b}	72.60±2.30^{a}
Larval survival (%)	73.20±1.48^{a}	81.80±1.92^{b}	81.80±2.16^{b}	75.60±2.88^{a}

Furthermore, fish total length, weight and spawning response were not significantly (P>0.05) different among the three Indian major carps in the four months of the breeding in this study. However, a trend similar to the spawning success was also observed and numerically the mean value of the spawning response rate was between 88 to 93% for the three Indian major carps among the months of the study period.

Table 6, 7 and 8 summarize the parameters of spawning performance and egg quality of the three exotic carps fish species silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*), and grass carp (*Ctenopharyngodon idella*) broodstock obtained in this study respectively. The reproductive performance in terms of mean fecundity, eggs weight, fertilization, hatchling and larval survival were significantly (P<0.05) highest in the month of April compared to the others months for the three exotic carps brood fish during the study period. However, the total length of fish, weight and spawning response were not significantly (P>0.05) different among the months of the breeding timing for the three exotic carp species.

Moreover, the ovulation and hatching time were significantly (P<0.05) highest in the month of June and July compared to the others months and a similar trend was observed for the spawning success rate between 83 to 90% for the three exotic carp among the months of the breeding time.

DISCUSSION

This is the first report on the limnoecoological variables and spawning timing of carp brood female six species phenology observation in the three major haors basin of Bangladesh. The selection of wild brood fish species from haor for artificial breeding was chosen instead of a strictly controlled experimental broodstock development in the hatchery to obtain more authentic reproductive data related to spawning grounds in the haors condition. Khatun *et al*. (2017) reported that three Indian major carps and three exotic carps are the dominant fish species in aquaculture of Bangladesh. The timing of spawning is an important issue in aquaculture and is one of the limiting factors for the reproductive success of carp fishes (Naeem *et al*., 2005b; Lone *et al*., 2012; Juntti & Fernald, 2017). On average, 2.10±0.40 kg wild brood females were chosen from the haors for this study due to the suitability of

Table 6. Reproductive performance of female *Hypophthalmus molitrix* (n = 24) broodstock

Parameters	Months			
	April	May	June	July
Length (cm)	52.42±2.84	55.01±1.70	52.80±2.43	54.40±2.20
Weight (kg)	2.20±0.68	2.60±0.62	2.30±0.65	2.62±0.57
Spawning (%)	93.33±14.90	90.00±22.36	88.33±16.24	86.66±29.81
Ovulation (hrs)	7.34±0.04^{a}	7.45±0.05^{b}	7.44±0.04^{b}	7.49±0.41^{b}
Fecundity (eggs/kg)×10^{3}	94.90±1.14^{c}	89.42±1.11^{b}	86.09±1.07^{a}	85.37±1.25^{a}
Egg weight (mg)	2.69±0.01^{d}	2.59±0.01^{c}	2.56±0.01^{b}	2.52±0.01^{a}
Fertilization (%)	81.00±2.54^{c}	76.60±1.14^{b}	73.80±1.30^{a}	71.60±2.30^{a}
Hatching time (hrs)	22.60±0.22^{a}	22.73±0.31^{a}	23.08±0.05^{b}	23.18±0.05^{b}
Hatchling (%)	78.80±1.48^{c}	76.60±3.04^{bc}	72.20±1.30^{a}	73.80±2.16^{ab}
Larval survival (%)	79.60±2.19^{c}	76.00±2.23^{b}	73.60±1.94^{ab}	71.20±1.48^{a}

Table 7. Reproductive performance of female *Aristichthys nobilis* (n = 31) broodstock

Parameters	Months			
	April	May	June	July
Length (cm)	57.14±1.44	55.87±2.49	55.67±2.15	55.52±1.55
Weight (kg)	2.66±0.48	2.26±0.70	2.30±0.66	2.18±0.57
Spawning (%)	87.66±11.64	83.33±15.59	83.33±23.57	83.33±23.57
Ovulation (hrs)	7.21±0.04^{a}	7.29±0.04^{b}	7.36±0.04^{c}	7.45±0.05^{d}
Fecundity (eggs/kg)×10^{3}	85.66±0.98^{b}	82.64±1.34^{a}	82.03±1.05^{a}	82.22±1.12^{a}
Egg weight (mg)	3.17±0.02^{c}	3.16±0.01^{c}	3.06±0.02^{b}	2.98±0.02^{a}
Fertilization (%)	82.60±1.14^{c}	79.80±1.30^{b}	75.40±1.14^{a}	74.60±1.14^{a}
Hatching time (hrs)	22.71±0.29^{a}	23.08±0.05^{b}	23.13±0.05^{b}	23.19±0.06^{b}
Hatchling (%)	80.40±1.34^{c}	77.40±1.14^{b}	73.20±1.78^{a}	73.20±0.83^{a}
Larval survival (%)	79.80±1.30^{c}	76.60±1.14^{b}	72.40±1.67^{a}	71.80±1.30^{a}

Table 8. Reproductive performance of female *Ctenopharyngodon Idella* (n=21) broodstock

Parameters	Months			
	April	May	June	July
Length (cm)	55.16±5.15	52.88±6.42	55.16±5.14	54.76±5.98
Weight (kg)	2.46±0.49	2.26±0.70	2.46±0.50	2.44±0.63
Spawning (%)	95.00±11.18	93.33±37.99	93.33±14.90	90.00±22.36
Ovulation (hrs)	7.12±0.02^{a}	7.21±0.04^{b}	7.26±0.04^{b}	7.36±0.04^{c}
Fecundity (eggs/kg)×10^{3}	81.65±0.64^{d}	80.23±1.13^{c}	77.30±0.43^{b}	74.03±0.86^{a}
Egg weight (mg)	3.30±0.02^{d}	3.22±0.02^{c}	3.11±0.02^{b}	3.02±0.02^{a}
Fertilization (%)	81.20±0.83^{d}	79.20±0.83^{c}	74.80±1.48^{b}	72.40±1.67^{a}
Hatching time (hrs)	21.28±0.05^{a}	21.40±0.06^{a}	21.43±0.07^{ab}	21.60±0.22^{b}
Hatchling (%)	79.80±1.30^{d}	76.20±1.64^{c}	73.80±1.30^{b}	71.80±1.30^{a}
Larval survival (%)	79.40±1.14^{d}	75.40±1.14^{c}	72.40±1.67^{b}	69.80±1.30^{a}

this size of fish for induced-hormone breeding as well as used this size for seed production in local carp hatchery. In this study, we observed the limnoecological variables of the three main haors and morphological and reproductive parameters to understand the spawning performance and egg quality of the six commercial carp fish species. The impact of months in the peak breeding season on growth performances and survival were also observed in this study.

There is no significant difference of temperature among the months of peak breeding season although numerically different in the mean value of temperature with the months of the breeding season in the all haors basin. Small increases in temperature might tend to favour spawning activity in carp brood fish species, especially at the haors basin. Larger temperature increases could lead to spawning failures or less, at timing or places where food supply is limited (Munday *et al*., 2008; Juntti & Fernald, 2017). All these six carp species are synchronized spawners spawned in the natural breeding ground during the rainy season of Bangladesh. In reproductively matured adult species, the temperature is usually thought of to be a monthly cue to rain in phasing reproductive timing however it has a principal role in synchronizing the final stages of reproductive maturity, and conjointly in truncating spawning episodes (Pankhust & Porter, 2003; Pankhurst & Munday, 2011).

Although monthly changes of temperature are minimal in the haors environments compared to changes in rainfall regimes do cause some seasonality in most tropical ecosystems. In tropical freshwater environments especially in the haors, the rainfall variations are high-lightened among the environmental factors since it aids in the transport of nutrients, with consequent increase of their availability in the aquatic ecosystem (Lowe-McConnel, 1987; Chellappa *et al*., 2009; Jiang *et al*., 2018). The north-eastern part of Bangladesh experiences higher rainfall than other parts of Bangladesh due to its physiographic consideration. The mean monthly rainfall data during the study period indicate that the rainy period of the haors region corresponds to a short spell of precipitation during the months of April to July, with a mean rainfall of 721.4 mm. More than 80% of the annual total rainfall occurs from May to August in this haors area. Finally, the haors area is vulnerable to flash floods resulting from rainstorms in the Indian hills include places with the world highest recorded rainfall in Cherrapunji (Mirza *et al*., 1998).

With the onset of the rainy season, there is an appreciable level of dissolved oxygen available to the organisms that stimulate the reproductive activity. The low level of dissolved oxygen in the haors waters is due to high utilization of oxygen for respiratory purposes of organisms and therefore the rotten organic material that is sometimes superabundant within the tropical reservoirs (Chellappa *et al*., 2003; Chellappa *et al*., 2009). Environmental changes predicted for riverine environments like increase temperatures, decreased flow rates and oxygen saturation may generate conditions that stimulate the activation of the hypothalamic-pituitary-interrenal (HPI) axis. A reasonable prediction is that this may contribute to reproductive suppression in these environments, severally or additively to direct thermal effects on reproductive endocrine processes (Pankhurst & Munday, 2011).

In this study, the haors aquatic ecosystems with pH near 7, values are found in areas where there is a positive hydro balance, as in the haors of the north-eastern part of Bangladesh. On potential concern is that higher CO_2 may limit the scope for aerobic performance in adult fishes (Portner & Farrell, 2008), which could affect reproductive performance.

On the basis of the haors limnoecological variables, the overall survival of the brood females after spawned in each month was 100% indicating the suitability of maintaining all six carp species brood fish during the artificial breeding in hatchery condition. Length and weight in the all six brood fish species were not significantly different at various months of the peak breeding season suggesting that size of these fish, energy from the food may be directed for reproductive development instead of somatic growth (Kabir *et al*., 2012). Data of the present study is consistent with the results of the effects of dietary protein and lipid on weight gain of broodstock has been reported in *Labeo rohita* (Khan *et al*., 2005).

The mean spawning success obtained in this study was about 80 to 90% that is much higher than the average success of six carp fish species reported by Khatun *et al*. (2017). Hormones are widely used in aquaculture to induce spawning in fish which in turn is one of the indicators used to assess the quality of brood fish. Pankhurst and Munday (2011) noted that a fish population spawning timing is typically determined by the sampling of matured females and assessing where they are within the reproductive cycle based on ovarian development and secondary reproductive characteristics (Kabir *et al*., 2012; Ghaedi *et al*., 2013).

In this study, the total ovulation time was 7 to 8 hours after a single dose of the ovaprim hormone injection, this result is better than the average total ovulation time of 10 to 15 hours upon multiple injected dosed reported previously for six carp fish species (Khatun *et al*., 2017). Legendre *et al*. (2000) noted that environmental and hormonal manipulation has been applied for spawning in brood fish to alter the spawning time and obtain continuous supplies of eggs and larvae. Timing of spawning can be advanced or delayed by factors including energy balance and the composition of the limnoecological variables in the environment. Fish sense and interpret specific limnoecological cues to breed at a time that has been selected to maximize the survival of larvae (Pankhust & King, 2010; Juntti & Fernald, 2017).

The spawning performance in terms of mean fecundity, egg weight, fertilization, hatchling and larval survival were significantly ($P<0.05$) differences for the six carps species among the months of the peak breeding season. It is generally accepted that food restriction may reduce total fecundity, delay maturation and affect egg size, while larger-sized egg, which generally have higher yolk content (Kabir *et al*., 2013; Nzohabonayo *et al.,* 2017), allow hatched larvae to survive for a longer period without food, both within species (Rombough, 1997; Green & Fisher, 2004) and among species (Houde, 1989; Benoit *et al*., 2000; Pankhurst & Munday, 2011; Nzohabonayo *et al.,* 2017).

The egg individual weight is among the parameters considered for assessing egg quality in fish. Eggs are one of the most thermally sensitive life stages in fishes and tolerance limits appear to be within ± 6°C of the spawning temperature for many species (Rombough, 1997; Pankhurst & Munday, 2011). The small increase in temperature can dramatically increase egg mortality, especially in tropical species (Gagliano *et al*., 2007.) Consequently, survivorship to hatching could decline as the ocean and river warm, unless species adjust the timing of spawning to suit the optimal temperature for embryo development (Pankhurst & Munday, 2011; Jiang *et al*., 2018).

The fertilization rate was significantly affected by the months of the peak breeding season in this study. The spawning output after fertilization, the parameters such as hatching time, hatchling and larval survival were significantly different among the months of the breeding season for all six brood fish in this study. It indicates that the suitability of the limnoecological variables for the best spawning time of all six brood fish in the haor ecology. Limnoecological variables especially the temperature has a similar important role in the modulation of post-fertilization processes both through its rate-determining effects on embryogenesis and hatching (Pauly & Pullin, 1998), and subsequent larval development (Howell *et al*., 1998), growth (Jobling 1997), and survival (Sponaugle & Cowen, 1996).

Hatching time is also dependent on egg size, with larger eggs taking longer to develop than small eggs (Pauly & Pullin, 1998; Pankhurst & Munday, 2011). Consequently, the increased temperature may advance hatching by minutes to hours in small eggs and by hours to days in large eggs (Rombough 1997; Pankhurst & Munday, 2011). Pankhurst and Munday (2011) also reported that shorter incubation periods affect individual fitness may depend on the potential for a mismatch between the timing of hatching and favorable hydroecological condition for the larvae survival. The duration of the larvae survival window may differ with limnoecological variables in the haor environment.

The peak breeding months of May to June and April to May within the three Indian major carp and the three exotic brood fish respectively may indicate that the additional quality of hydrological condition for the looking of food from the food chain ecological system in the haors basin. Indeed, the results seem to indicate that the fecundity and individual egg weight as well as the fertilization rate appear to be associated with the months within the peak breeding season of all carp fish species. Such shifts seem doubtless as a result of growing is extremely temperature and rainfall sensitive in several fish species and breeding might stop before vital thermal limits for egg survival are reached within the haors water environments. The similar results were also observed in other studies in *Labeo rohita* (Khan *et al*., 2005; Khan *et al*., 2006; Lone & Hussain, 2009; Naeem *et al*., 2013), *Catla catla* (Naeem *et al*., 2005b; Lone *et al*., 2012), *Cirrhinus cirrhosis* (Hanumantharao, 1971; Mishra *et al*., 2001), *Hypophthalmichthys molitrix* (Naeem *et al*., 2005a), *Aristichthys nobilis* (Fermin, 1990; Fermin *et al*., 1991), and *Ctenopharyngodon idella* (Naeem *et al*., 2011; Rashid *et al*., 2014), *Cyprinus carpio* (Manissery *et al*., 2001; Gamal & Abd, 2009; Ghosh *et al*., 2012) and *Oreochromic niloticus* (El-Sayed *et al*., 2008).

In this study, six female carp species have significantly variable individual spawning output during the months of the breeding season. Thus, if carp brood fish move to and from specific locations to spawning and if sampling happens solely on the spawning grounds, the carp fish population spawning output and months may overestimate the typical individual spawning period. The timing and site of egg release confirm the environment first encountered by an egg and thus determined limnoecological factors like temperature, rainfall, current, pH, dissolved oxygen and therefore the chance of fertilization. Individual spawn time within a given environment conjointly determines once eggs hatch (Asoh & Yoshikawa, 2002). From the above results and discussion, this study may indicate that limnoecological variables particularly the temperature and rain may have a great influence on the spawning timing of carp brood six species in the haor basin of Bangladesh.

CONCLUSION

Based on these findings, this study may serve as an update on haor basin carp broodstock fish species spawning timing and reproductive output as well as highlighting a standardized method of assessing reproductive variability in peak breeding timing to get quality seeds that could contribute towards developing strategies for carps broodstock sustainable management in the aquaculture industry.

ACKNOWLEDGEMENTS

The authors would like to thank Government Fish Seed Multiplication Farm, Golapganj, Sylhet to conduct this MS research and acknowledgement to NRGS project research grant scheme-R/NRGS/A07.00/00387A/006/2014/000152 at Universiti Malaysia Kelantan for the publication of this research work.

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