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Research Article

Glochidia larval occurrence does not affect condition index of freshwater unionid mussel, *Lamellidens jenkinsianus* (Benson, 1962): A study from a wetland of Bangladesh

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ABSTRACT

Freshwater unionid mussels have a unique life cycle with glochidia larval occurrence for certain period in the suprabranchial chamber of females may have effect on condition index of the brood. Current study reports temporal changes in glochidia larval occurrence and its effect on condition index (CI) of freshwater mussel, *Lamellidensjenkinsianus* collected monthly over a year from a lentic habitat Darikathal Beel, Trishal, Mymensingh of Bangladesh during January to December 2023. Microscopic observation of the gonadal smears revealed an overall male-female sex ratio of 1:0.90, which did not deviate significantly from the expected 1:1 ratio. Glochidia larvae were present in the gills of females during February to July, September, and December. Majorityof the females (>75%) contained larvae in their gills during February, May and December. No glochidia larva was observed during August, October, and November indicated that larval shedding could have been completed before those months. Condition index (CI) of the mussels was the highest in February; indicating ideal time of harvesting from the habitat. In the current study, no noticeable difference in CIs of males, females without glochidia, and females with glochidia was reported over the study period. Therefore, it can be concluded that glochidia larval occurrence have no impact on condition index of *L. jenkinsianus*.

Introduction

Lamellidens, belongs to the Unionidae family,is a frequently harvested freshwater bivalve genus, widely utilized for human consumption in Nepal and Bangladesh (Budha, 2016).Because they function as natural water filters, freshwater mussels are crucial to the health of streams and rivers because they remove contaminants like bacteria, heavy metals, algae, and tiny particulate organic matter (POM) particles (Islam et al., 2020; Shah et al., 2022). Similar to how earthworms enhance soil, their function as filter feeder's aids in maintaining the quality of the water (Dan et al., 2001). In addition to being a food source for many animals, mussel's shells serve as habitats for other aquatic life. Native Americans and Europeans have historically valued mussel's cultural significance, using them for tools, buttons, food, and decoration. These days, their gorgeous shells and pearls are prized for their ornamental and commercial value (Ghiselin, 2009).In Bangladesh, these mussels are widely distributed in both standing water bodies (lentic habitats) and flowing water environments (lotic habitats) (Dan et al., 2001). *Lamellidens jenkinsianus* is a species of freshwater commonly found in rivers, streams, and freshwater bodies in South Asia, particularly in countries like India and Bangladesh.The species primarily inhabit river bottoms and typically rely on clean, flowing water to ensure their survival and successful reproduction.

The complicated life cycle of freshwater mussels (Unionida) includes parasitic larvae known as glochidia that, in most cases, do not harm their fish hosts. The sexes of most species are separate (Cek and Sereflisan, 2006). In the gills of the female mussel, glochidia begin to grow at the start of the life cycle (Salam et al., 2023; 2024). After being released as free-drifting larvae, they

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eventually become parasites and cling to the fins or gills of their fish host. They separate after this parasitic stage to create young mussels that can live on their own. If glochidia do not find a suitable fish host within a few days of drifting in the water column, they die (Helfrich et al., 2019).

Condition Index (CI), which quantifies the proportion of flesh to shell, is a crucial statistic in ecological and physiological research, particularly on bivalves. The CI in mussels is greatly influenced by variables such shell size, season, weather, food availability, and reproductive stage (Gosling, 1992; Siddique et al., 2020). Seasonal changes in food availability, temperature, and salinity have a complex impact on somatic growth and reproduction (Soniat and Ray, 1985; Brown and Hartwick, 1988; Uddin et al., 2012; 2013). These variations have an indirect effect on the CI, which affects the mussels' quality and market value.

Condition index of freshwater mussels is closely tied to their reproductive success, particularly in terms of glochidia larval occurrence (Siddique et al., 2020; Salam et al., 2023; 2024). Healthy mussels are more likely to produce and release larger numbers of viable glochidia larvae, contributing to the overall population dynamics of these important aquatic organisms. Freshwater mussels initiate their reproductive process by depositing eggs into the interlamellar gaps of the female's gills, where they encounter and fertilize sperm filtered from the water column (Haag, 2012). Subsequently, the fertilized eggs develop into glochidia, and the parent mussel releases them, which can occur within a range of 2 to 6 weeks for short-term brooders and extend up to eight months for long-term brooders (Haag, 2013).

Freshwater mussel species exhibit a wide range of annual fecundities, with the number of glochidia (larval stage) produced varying from 2,000 to more than 10,000,000 per individual (Bauer, 1987; Haag, 2013). The glochidia larvae undergo an extended residence period inside the marsupial pouch of the female mussel before eventually traveling to the supra-branchial canal, from where they are expelled through the excurrent siphon. To continue their development, glochidia need to find and attach themselves to an appropriate host fish (Dillon, 2000). The relationship between glochidia and fish is primarily described as phoretic, which means that the symbiotic organism (glochidia) is mechanically conveyed or transported by its host (fish) without being nutritive or protective. Several studies (Barnhart et al., 2008; Schwalb et al.,2011; Horký et al., 2014; Terui et al., 2014) suggest that the primary advantage of using fish as hosts lies in dispersal mechanisms, including upstream colonization and enhancing connectivity among populations (Leibold et al., 2004; Newton et al.,2008). In the context of farming and commercial harvesting, understanding the occurrence and behavior of glochidia larvae is crucial for implementing effective cultivation strategies. Ensuring the attachment of glochidia to suitable fish hosts, mimicking their natural habitat conditions, and providing appropriate nutrition are key factors that contribute to the successful rearing of juveniles. By focusing on these aspects, practitioners can enhance the success rate of cultivating and harvesting these aquatic organisms, contributing to both ecological conservation and economic benefit.

Until now, there have been no studies conducted to determine the presence and abundance of glochidia larval occurrence of freshwater mussels, *L. jenkinsianus* found in Bangladesh. Freshwater mussel culture in Bangladesh has not been pursued thus far, mainly because of limited understanding regarding the timing of glochidial release in natural population or the absence of a dedicated mussel hatchery. Consequently, to gain a comprehensive understanding of glochidial occurrence and habitat discharge, it is crucial to examine a year's worth of data. With this in mind, the present research was undertaken to investigate the presence of glochidia in the gill chambers and assess the condition index of *L. jenkinsianus* specimens obtained from Darikathal Beel in Trishal, Mymensingh.

Materials and Methods

Ethical Statement

The research was approved by the Ethical Standard of Research Committee (ESRC), Bangladesh Agricultural University Research System (BAURES) under Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh; Ref: BAURES/ESRC/47/FISH/2024.

Sampling Location

Specimens of the freshwater mussel *L. jenkinsianus* were collected from DarikathalBeel in Trishal, Mymensingh, located at coordinates 24.39°N and 90.27°E, as depicted in Fig. 1. A beel refers to a wetland that captures surface runoff water via internal drainage systems. This waterbody is perennial and has a marsh-like appearance, resembling a saucer.Such depressions are primarily formed by erosion and are commonly found across Bangladesh. The region experiences a tropical humid climate, characterized by significant seasonal rainfall (Shahid, 2010). Temperature fluctuations are notable, with January being the coldest month, averaging 18.4°C, while July records an average high of 28.5°C.

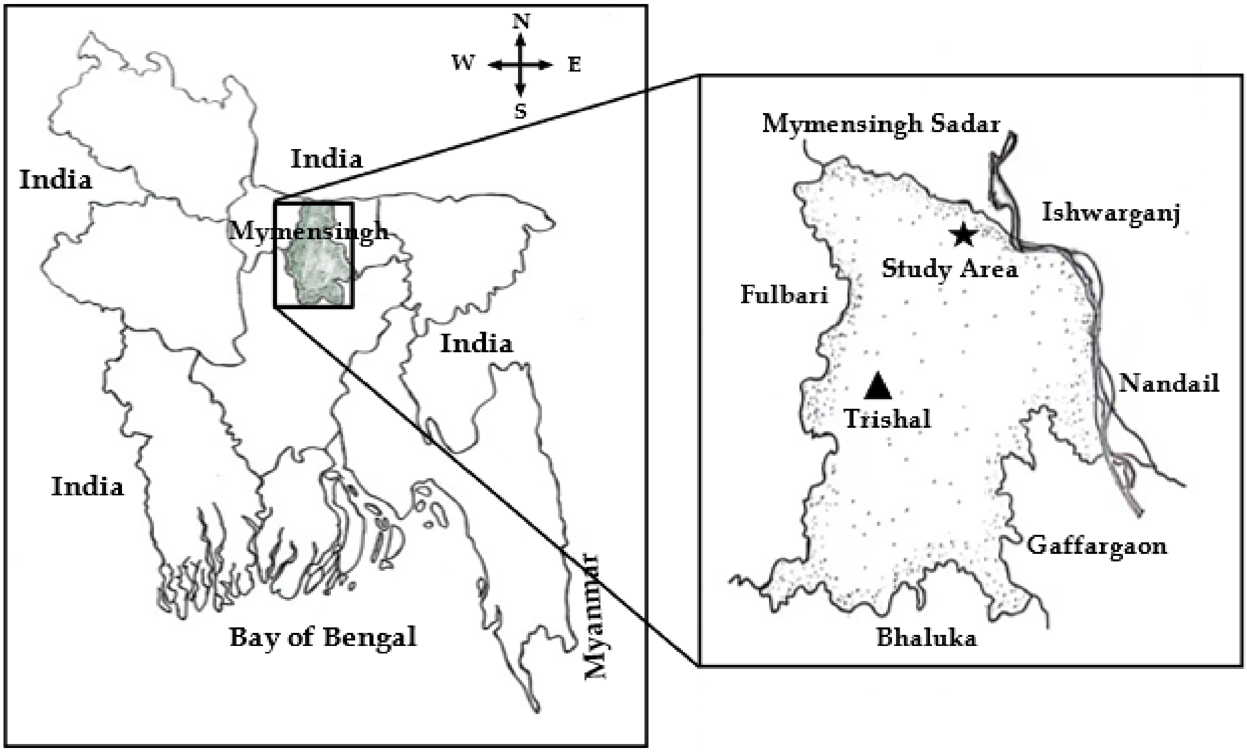

Figure 1. Map showing sampling location (*) at DarikathalBeel of Trishal Upazila, Mymensingh

Sample Collection

L. jenkinsianus samples were collected monthly through hand-picking. Following collection, the samples were promptly transported to the Aquatic Ecology Laboratory at Bangladesh Agricultural University. From the monthly collections, twenty mature specimens were randomly selected for morphometric analysis, sex determination, and assessment of glochidial presence in females. Specimens were collected on a monthly basis throughout the year, from January to December 2023. Biometric measurements, including shell length, shell height, and shell thickness, were recorded for each specimen using digital calipers (Model: Heng Liang, China). The specimens were carefully dissected to separate the soft tissue from the shell. The wet tissue weight (unit?) was measuredusing an electronic balance (model: EKI 600-2N). The labeled shells were then dried in sunlight for 48 hours before being weighed. Gonadal smears and gill samples from each specimen were placed on microscopic slides to confirm sex and the presence of glochidia larvae, examined under a compound microscope (Novel Biological Binocular Microscope XSZ-107T, China).

Occurrence of Glochidia Larave in the Suprabranchial Chamber of Females

The freshwater mussel, *L. jenkinsianus*, utilizes internal fertilization for reproduction. In this process, the male releases sperm directly into the surrounding water, which the female then collects through her incurrent siphon. Following fertilization, the eggs progress into a larval form known as glochidia (singular: glochidium) in the suprabranchial chamber of gills of females. The fully developed larvae are expelled by the female into the water to seek out host fish.These glochidia temporarily attach to the fins or gills of fish, acting as parasites. Prior to their release, the glochidia develop within the gills of the female mussel, where they are continuously supplied with oxygen-rich water. A microscopic examination of the female mussel's gills was conducted to assess the timing of glochidial presence and brooding.

Condition Index (CI)

The condition index (CI) serves as a metric for evaluating the reproductive and nutritional health of bivalves, which is essential for identifying the best times for harvesting. This index reflects the general condition of the bivalve species and typically aligns with their gametogenic cycle. The CI is calculated using the formula outlined by Uddin et al. (2010).

Condition Index (CI) = Tissue wet weight (g) /Shell length (cm)

Statistical Analysis

The collected data was subjected to statistical analysis, with the findings displayed as the mean (± standard deviation) utilizing MS Excel. To determine if there were significant deviations from a 1:1 sex ratio between males and females, a chi-square (χ^2-test) was employed to test the null hypothesis. Additionally, a one-way ANOVA was performed followed by Tukey's post-hoc test to compare CIs of males, females having glochidia larvae and females lacking glochidium larva using SPSS version 25.0.

Results

Biometric Measurements

The biometric measurements of *L. jenkinsianus* show notable monthly variationsas shown in Table 1. The mean shell length (SL) was 73.24 ± 6.00 mm, ranging from 66.81 mm to 89.67 mm, with the highest SL in February and the lowest in October. Shell height (SH) ranged from 19.60 mm to 46.41 mm, peaking in February and dropping in October. Shell thickness (ST) varied from 21.00 mm to 35.55 mm, with July showing the highest ST and March the lowest. Total weight (TW) averaged 32.20 ± 10.37 g, and tissue wet weight (TWW) was 8.24 ± 4.62 g, with the highest values in February and the lowest in October. Dry shell weight (DSW) ranged from 7.85 g to 16.01 g, the highest in April and the lowest in October.

Table 1. Biometric measurements of *L. jenkinsianus* (Mean ± SD) collected from Darikathal Beel, Trishal, Mymensingh

Months	Sample no	Shell Length (mm)	Shell Height (mm)	Shell Thickness (mm)	Total weight (g)	Tissue wet weight (g)	Dry Shell weight (g)
Jan 23	20	75.23 ± 4.53	37.60 ± 2.89	23.00 ± 2.71	34.48 ± 8.09	8.50 ± 2.11	13.85 ± 3.90
Feb 23	20	89.67 ± 5.33	46.41 ± 3.18	28.05 ± 1.66	62.36 ± 8.78	22.62 ± 4.52	10.52 ± 2.51
Mar 23	20	70.66 ± 5.39	33.50 ± 4.90	21.00 ± 2.33	26.77 ± 5.45	7.85 ± 1.76	9.32 ± 1.68
Apr 23	20	71.12 ± 4.99	35.11 ± 2.14	22.04 ± 3.54	27.72 ± 5.48	7.14 ± 1.19	16.01 ± 3.82
May 23	20	76.84 ± 2.49	37.54 ± 1.85	22.71 ± 1.25	36.58 ± 4.56	7.93 ± 1.02	15.67 ± 2.85
Jun 23	20	69.81 ± 4.94	34.77 ± 2.86	21.21 ± 1.32	28.96 ± 5.96	6.91 ± 1.52	11.57 ± 2.99
Jul 23	20	70.11 ± 6.32	35.06 ± 3.03	35.55 ± 2.91	28.94 ± 7.07	6.52 ± 1.80	11.00 ± 3.15
Aug 23	20	74.20 ± 5.46	36.10 ± 2.36	21.61 ± 2.17	30.73 ± 5.86	6.72 ± 1.88	11.27 ± 2.17
Sep 23	20	74.52 ± 4.78	36.98 ± 3.35	22.03 ± 1.97	32.68 ± 8.91	6.31 ± 1.41	12.25 ± 3.28
Oct 23	20	66.81 ± 6.60	19.60 ± 2.12	32.38 ± 4.28	22.50 ± 7.70	5.34 ± 1.49	7.85 ± 3.51
Nov 23	20	67.58 ± 8.21	20.25 ± 3.54	32.70 ± 4.48	23.25 ± 9.31	5.83 ± 2.27	7.88 ± 3.75
Dec 23	20	72.30 ± 4.51	36.37 ± 2.63	21.20 ± 1.37	31.38 ± 6.22	7.21 ± 1.03	13.60 ± 3.82

Sex Ratio

The examination of gonadal smears indicated that *L. jenkinsianus* exhibits clear male and female sexes, with no signs of hermaphroditism or undifferentiated individuals (Fig. 2). The female follicles contained large, spherical ova characterized by prominent nuclei, whereas the male follicles contained oval or elongated spermatozoa. Both follicle types were surrounded by connective tissue and lined with germinal epithelium. In a study involving 240 mussels, 52.50% were identified as male and 47.50% as female, with no individuals showing sexual indifference. The overall male-to-female ratio was 1:0.90, indicating a slight predominance of males. A χ^2-test demonstrated that the observed sex ratio did not significantly deviate from the expected 1:1 ratio ($P > 0.05$), as the calculated χ^2 value (0.6) was below the critical threshold (3.841) at 1 degree of freedom (Table 2). Consequently, the sex distribution was statistically balanced.

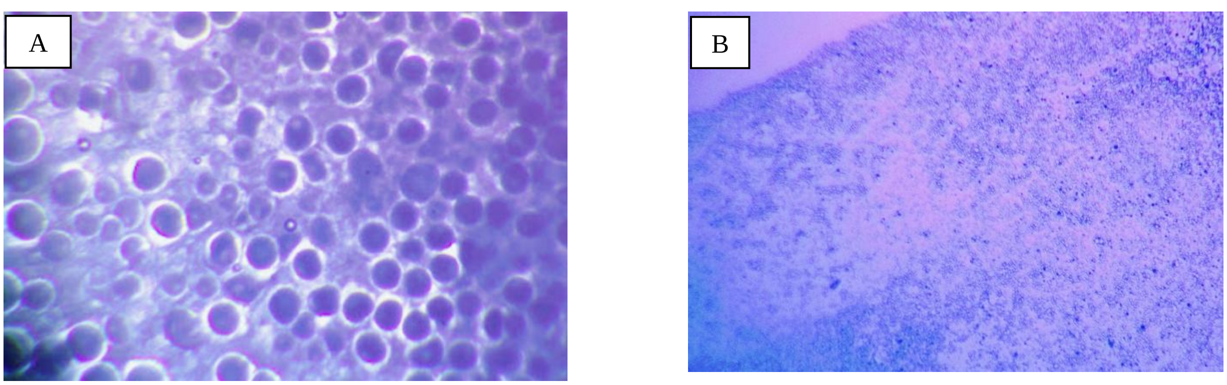

Figure 2. Identification of male and female *L. jenkinsianus*byinvestigating gonadal smears under microscope. A,ovarian follicles; B, testicular follicles

Occurrence of Glochidia in Female L. jenkinsianus

Glochidia were discovered in the gills of female *L. jenkinsianus* in the current investigation. Glochidia (larvae) were affixed to the female mussel's gill. In January, August,October, and November no females had glochidia (larvae) (Table 2). But in February, March, April, May, June, July, September, and December the proportions offemales having glochidia larvae were 75%, 60%, 66.67%, 80%, 33.33%, 20%, 28.57%, and 83.33%, respectively. The percentage of females with glochidia first reported in February and the proportion decreased by March. The percentage of females having larvae in their gill chamber dropped consistently after May implied that glochidial shedding from the females initiated after May.Further, a little increase was noticed in September and it became high in December. Glochidia larvae were not reported in January, August, October, and December indicated that larval discharge was completed by these months. The glochidia larvae observed in females during February to May and December were morphologically developed, as shown by their robust activity under the microscope. All females collected from February to July, September, and December had a puncture at the distal end of each marsupium, which showed that glochidia larvae were being released into the environment from the gill chamber throughout this time (Fig. 3).

Table 2. Observation of glochidia in monthly samples of *L. jenkinsianus* females

Months	Number of females	Number of females containing glochidia	Number of females lacking glochidia	Percentage of females containing glochidia (%)
Jan 23	7	0	7	0
Feb 23	8	6	2	75.00
Mar 23	10	6	4	60.00
Apr 23	6	4	2	66.67
May 23	10	8	2	80.00
Jun 23	12	4	8	33.33
Jul 23	10	2	8	20.00
Aug 23	7	0	7	0
Sep 23	14	4	10	28.57
Oct 23	8	0	8	0
Nov 23	8	0	8	0
Dec 23	12	10	2	83.33

Glochidia were identified within the gills of female *L. jenkinsianus* during this study. The larvae were attached to the gills of the female mussels. Observations indicated that no females contained glochidia in January, August, October, and November (refer to Table 2). However, in the months of February to July, September, and December, the percentages of females with glochidia were recorded at 75%, 60%, 66.67%, 80%, 33.33%, 20%, 28.57%, and 83.33%, respectively. The presence of glochidia was first noted in February, but the proportion decreased by March. Following May, there was a consistent decline in the percentage of females with larvae in their gill chambers, suggesting that the shedding of glochidia from the females began after this month. A slight increase was observed in September, which peaked in December. The absence of glochidia in January, August, October, and December indicates that larval discharge had completed by these months. The glochidia larvae found in females from February to May and in December exhibited significant morphological development, as evidenced by their vigorous activity under microscopic examination. All females collected between February and July, as well as in September and December, displayed a puncture at the distal end of each marsupium, indicating that glochidia larvae were being released into the environment from the gill chamber during this period (Fig. 3).

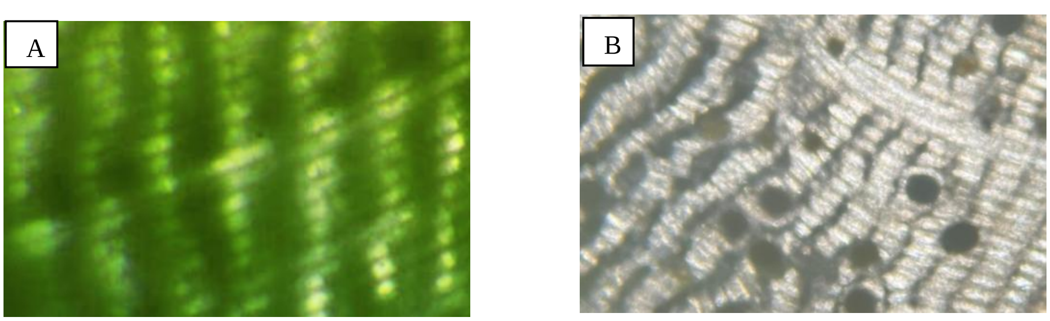

Figure 3. Occurrence of glochidia larvae in the branchial chamber of female *L. jenkinsianus*. A, without glochidium; B, with glochidia

Condition Index (CI)

In the current investigation, CIs that displayed one peak for combined sexes over the course of the 12-month study period revealed notable temporal changes that were easily discernible (Fig. 4). The CIs were the highest in February and lowest in October. The CIs dropped suddenly from February to March. The CIs remained more or less consistent during the remaining study period from March to December.

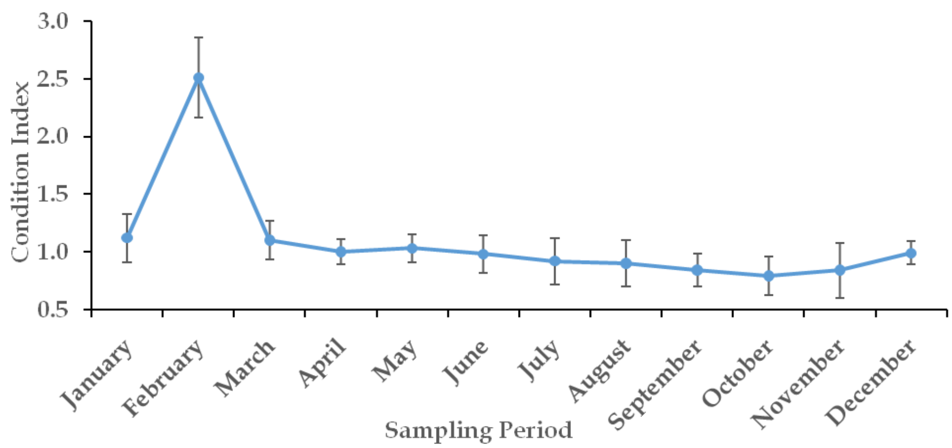

Figure 4. Monthly changes in condition index of *L. jenkinsianus*combined population

CIs of males exhibited only one major peak value during February over the twelve-months study period with considerable temporal changes as shown in Fig. 5. It was revealed that the condition index was highest in February and lowest in October. After February, there was an abrupt fall in the trend of CI, and after March, there was a steady decline. A little increase was noted that reached a minor peak in June. Following that, a downward trend in CI was seen through October. After October, there was a sudden ascent in the trend of CIs by November and December.

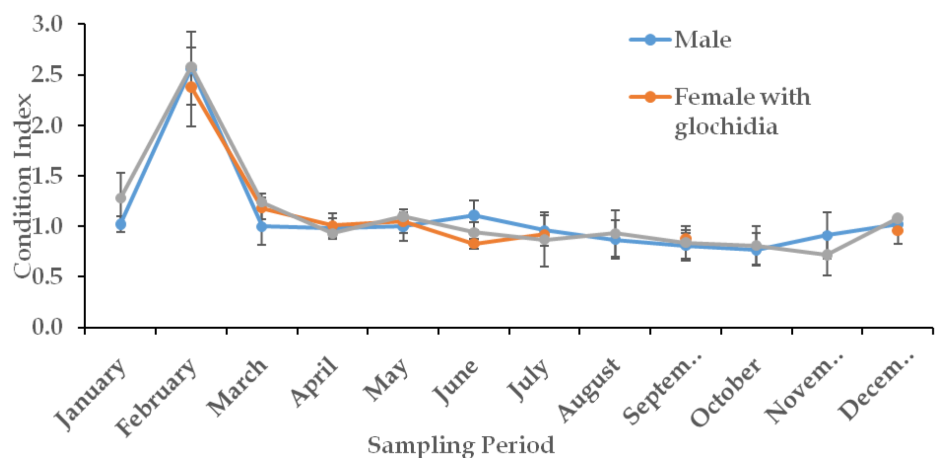

Figure 5. Comparison of condition index of *L. jenkinsianus* males, females with glochidia larvae and females without glochidium larva

Over the course of the twelve-month study period, the condition index of female *L. jenkinsianus*without glochidia larvae showed one peak that demonstrated noteworthy temporal changes that were clearly identifiable (Fig. 5). It was revealed that the condition index was highest in February and lowest in November. After February, there was an abrupt fall in the trend of CI, and after March, there was a steady decline. A slight increase in CI was seen in May. Following that, it progressively decreased from June to December until increasing twice more in August and December.

All females lack glochidia larvae in January, August, October, and November. In the current investigation, CI that displayed one peak over the course of the twelve-months study period and demonstratednotable temporal changes (Fig. 5). The highest peak of CI was recorded in February (2.38 ± 0.39), when 75% of females had glochidia in their gill chamber, while the lowest mean CI was reported in June (0.83 ± 0.05), when 33.33% of females were recognized as having glochidia in their gill chamber. After January, condition indexes grew, reaching their initial peak in February. After February, there was a sharp reduction in CI, followed by a steady decline after March, which was consistent with glochidial incidence. After April, CI gradually increased. By June, CI declined to some extent, but by July, they had started to rise once again. By September, there was an abrupt drop in the trend of CIs and thereafter, a slight increase in CI was seen in December.

From the investigation, it was noticed that both males and females had no significant differences ($p > 0.05$) in CIs. CIs also revealed no significant difference ($p > 0.05$) between females having or lacking glochida larvae (Fig. 5). Therefore, it was reported that occurrence of glochidia larvae have no significant effects on CIs of freshwater mussel, *L. jenkinsianus*.

Discussion

The study revealed that female *L. jenkinsianus* had glochidia larval incidence in the gill chamber for eight months from February to July, September, and December with the exception of January, August, October, and November. Glochidia were present in 75% of the females in February, however this number sharply dropped to 60% in March, indicating glochidial release. In contrast to the current work, Salam et al. (2024) noted that female *L. marginalis* demonstrated glochidia larvae in the gill chamber for five months from October to March, with the exception of January from the same habitat. No glochidia larvae of *L. corrianus*were seen between September to January (Salam et al., 2023).Hastie and Young (2003) reported that some environmental factors especially the availability of host fish species trigger the glochidial discharge from females into the environment. According to Blakeslee and Lellis (2019), spats usually result from abrupt changes in river level or water temperature. Glochid discharge started in April and may be early May, when the reported fish host's reproductive season started (Haggerty & Garner, 2000). In line with the glochidial release of *Elliptiodilatata*, *Cyclonaias tuberculata*, and *Tritogonia verrucosa* (Jirkaand Neves, 1992), the current study showed that glochidial release begins in March. The percentage of females who had glochidia, however, suggested that the larval release phase may begin in early March. The little variations between the research stated above may be due to different geographic locations and species since the degree and number of spawning phases of unionids vary substantially from one population to another (Misra et al., 2010). Behera et al. (2014) stated that freshwater mussels spawn year-round, with the peak spawning period occurring from July to September. However, Soler et al. (2018) reported that glochidial release in *Margaritiferaauricularia* occurs in April.

In contrast to fish, where the gonad is usually able to be isolated from the rest of the body, in bivalves (with the exception of scallops), the gonad is entangled in the visceral mass and is therefore practically hard to isolate. This makes it difficult to assess reproductive health in bivalves using the gonadosomatic index, a technique that is frequently used for fish. Alternatively, the Condition Index (CI) is frequently employed in bivalves as a measure of reproductive and nutritional health (Seed &Suchanek 1992; Smaoui-Damaket al., 2006; Uddin et al., 2010). The condition index identifies modifications to an organism's physiological state. Since the mantle contains specific storage tissues as a prelude to the start of the subsequent spawning cycle, CI may not always accurately reflect the quantity of gametes present (Duinkeret al., 2008). According to Salam et al. (2023), the highest CI was seen in April (1.35), when all females (100%) had glochidia larvae in their gill chamber.

In the present study, the highest mean CI (2.43 ± 0.24) was found in February, when 75% of females were found to have glochidia in their gill chambers, and the lowest mean CI (0.88 ± 0.24) was found in June, when 33.33% of females were found to have glochidia in their gill chambers. Then, by July, September, and December, CI had gradually risen. The condition index for females with larvae was not possible todeterminein January, August, October, and November because none of the females carried glochidium larvae during these months. The greater mean value of CI indicates that the gonad is ripening, whereas the lower CI indicates that gamete release resulted in weight loss and a corresponding loss of energy for spawning activity (Siddique et al., 2020). A considerable reduction in CI is often used to detect the release of gametes during spawning (Seed and Suchanek, 1992). In contrast to the present findings, Siddique et al. (2020) reported three CI peak times in *L. marginalis* from a lentic habitat in Mymensingh. According to the conflicting findings of Niogeeet al. (2019), the condition index decreased between November and July while the CI peaked in October and June. This discrepancy could be due to species differences.In accordance with Salam et al. (2024) the highest CI peak (0.79) was seen in December, when all females (100%) had glochidia in their gill chambers.The current study was conducted with *L. jenkinsianus,* while Niogeeet al. (2019) and Siddique et al. (2020) carried out their investigations *L. marginalis*whichmight be reasonreported on the for discrepancies of CIs.Furthermore, the disparity between peak CI and the previously indicated statistics could possibly be the consequence of differences in environmental conditions and habitat types. When choosing whether to impose a harvest ban period for a specific population, fisheries managers may greatly benefit from this distinction. It was essential to determine the ideal time of the year to collect quality mussels. A greater CI often indicates a higher quality, which leads to the best time for harvesting, and a lower CI generally indicates a lower quality for consumers. According to Siddique et al. (2020), the best time to harvest mussels was when CI first began to increase. From the CI data it is suggested that February could be the most suitable time for harvesting good quality *L. jenkinsianus* from the beel. However, CI data along with reproductive cycle through histology could specify the best time of harvesting bivalves without interfering their major spawning events.

In the current study, no significant differences ($p > 0.05$) in CIs of males, females without glochidia and females with glochidia were reported over the study period. This finding implies that CIs are not affected by males and females as well as by females having or lacking glochidia. CIs are principally related with the spawning cycle of the bivalves (Seed and Suchanek, 1992). The values generally increase with the initiation of gametogenesis and peaks during ripe stage. CIs drop suddenly at spawning due to evacuation of gametes (Uddin et al., 2010). However, in unionid bivalves, internal fertilization takes place in modified supra-branchial chambers of females called marsupia where the embryos develop into mature larvae called glochidia (Mackie, 1984). Glochidia may be held within the marsupia for varying lengths of time until being passed to the supra-branchial canal and discharged through the excurrent siphon. The values of Condition Indices (CIs) are not considerably impacted by the presence of glochidia larvae or internal fertilization. In other words, neither the discharge of gametes nor the development of glochidia larvae significantly affect the general well-being or physical state of *L. jenkinsianus* individuals. These findings are significant because they show that elements connected to reproduction, like internal fertilization or the presence of larvae, have no negative effects on *L. jenkinsianus* health.

In conclusion, glochidia larval occurrence in females does not affect the condition indices (CIs) of *L. jenkinsianus* as evidenced from the insignificant differences ($p>0.05$) in its value among males, females without glochidia, and females with glochidia.It is expected that females with glochidia would expend more energy for incubating larvae in their gill chambers may balance the weight of tiny larvae. The findings are intended to support fisheries management decisions, including harvest restrictions by utilizing the timing of larval occurrence and CIs. This data can be used by hatchery managers to schedule breeding operations, improving hatchery performance and conservation initiatives.

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Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts of interest that could have appeared to influence the work reported in this paper.

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