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Length-weight relationship and exploitation of *Macrobrachium* species in the Burhi Gandak River, North Bihar, India

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Abstract

Three species of the Palaemonidae family, namely *Macrobrachium dayanum* (Henderson, 1893), *Macrobrachium lamarrei* (Milne Edw., 1837) and *Macrobrachium malcolmsonii* (H. Milne Edw., 1844) were investigated for their length-weight relationship and exploitation status in the Burhi Gandak River between July 2020 and June 2021. A total of 907 specimens of *M. lamarrei*, 942 *M. dayanum* and 962 *M. malcolmsonii* were collected using trap net (locally named Ghana Jal), Saalbhar Jal, Pelni, Dhonijal and Khorjal and traditional boats such as Nauka and Donga. *M. lamarrei* was found to be the dominant species among them in the catch composition. Peak landing was observed from June to August. The maximum length was recorded for *M. malcolmsonii* (16.8 cm) followed by *M. dayanum* (8.0 cm) and *M. lamarrei* (6.1 cm). The length-weight relationship of *M. lamarrei*, *M. dayanum* and *M. malcolmsonii* indicated negative allometric growth with slope (b) values of 2.7692, 2.6027 and 2.7513, respectively. The von Bertalanffy growth parameters *viz.,* asymptotic length (L_{∞}), growth coefficient (K) and age at zero length (t_0) were 5.67 cm, 2.3 y^{-1} and -0.5913 y^{-1} for *M. lamarrei* ; 10.08 cm, 0.990 y^{-1} and 0.6684 y^{-1} for *M. dayanum* and 16.59 cm, 0.730 y^{-1} and -0.7289 y^{-1} for *M. malcolmsonii* , respectively. Fishing mortality was lower than natural mortality which was estimated as 1.71 for *M. lamarrei,* 0.15 for *M. dayanum* and 0.18 for *M. malcolmsonii*. The present study revealed that the smaller length groups had higher natural mortality, whereas larger length groups had higher fishing mortality. The current exploitation rate was 0.26 for *M. lamarrei*, 0.06 for *M. dayanum* and 0.09 for *M. malcolmsonii*. The research fills a critical gap providing essential insights into the population dynamics and exploitation of the three prawn species in the Burhi Gandak River, revealing their underexploited status, highlighting opportunities for sustainable harvesting and informed fishery management to support biodiversity conservation and local livelihoods.

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Introduction

The Palaemonidae family comprises a diverse range of crustacean species that live in a variety of water sources, including freshwater as well as brackishwater. Jaychandran and Joseph (1992) provided criteria for identifying *Macrobrachium* species from Indian water bodies. The taxonomy and distribution of freshwater prawns from Indian water bodies were previously reported by many researchers (Choprae, 1939; Choprae and Tiwari, 1949; Rajyalakshmi, 1974, 1980; Jaychandran and Joseph, 1988, 1992).

Prawns are the most common of all crustaceans from Indian waters and the most of the research has been conducted on the biology and fishery of economically important prawns. Holthuis (1980) reported seven genera across the globe under the Palaemonid family. *Macrobrachium* is a genus with over 100 species globally and 40 species were reported from India (Jayachandran and Joseph, 1992). *Macrobrachium rosenbergii*, *Macrobrachium malcolmsonii* and *Macrobrachium gangeticum* are the three larger varieties from Indian waters (Ling, 1969). *Macrobrachium dayanum* and *Macrobrachium lamarrei* are two smaller

and entirely freshwater varieties of *Macrobrachium* spp., which have been found in water bodies of eastern Uttar Pradesh along with *M. gangeticum* a larger, semi-migratory species (Singh and Srivastava, 1991). The prawn fishery in freshwater bodies of India forms an ecologically and economically important resource and from fisheries point of view, 15 species are significantly important and are overexploited as a result of overfishing (Jayachandran and Joseph, 1992). *M. dayanum* is a small (5-7 cm) freshwater prawn found in northern India which is an important food source for the inhabitants of the Gangetic Plain. *M. lamarrei* is a small (3-5 cm) freshwater prawn found in rivers, ponds and other wetlands in the Indian subcontinent.

The length-weight relationship is an important tool for describing growth and identifying possible changes between the same species in different populations (Lalrinsanga *et al.,* 2012). It is useful in fisheries management for estimation of biomass and health status of fish stocks (Vivekanandan, 2005; Gerritsen and McGrath, 2007). Hopkins (1992) highlighted the significance of utilising models in growth studies, emphasising the application of morphometric measurements in fisheries research. The length-weight relationship of *M. lamarrei* (Ara *et al.,* 2014), *Macrobrachium assamense peninsulare* (Kumar *et al.,* 2014), *M. rosenbergii* (Kurup *et al.,* 2000; Lalrinsanga *et al.,* 2012, 2014), *Macrobrachium lar* (Sethi *et al.*, 2012), *Macrobrachium equidens* (Jayachandran and Sebastian, 2010) and *Macrobrachium assamense* (Rana and Kumar, 2014) have been studied from the Indian waters. Studies on the growth and mortality parameters of different *Macrobrachium* species in Indian waters are limited (Khan *et al.,* 2009; Jayachandran and Indra, 2010; Shaha *et al.,* 2014).

Prawn species in the river Ganga have been studied for their fisheries and biology; however, there is no published information on the age, growth and mortality parameters of freshwater prawn species from the Burhi Gandak River in Bihar. These parameters of prawn species from river Burhi Gandak are intended to provide a more precise estimate of population and fisheries characteristics to assess the state of the fishery and maximum sustainable yield (MSY) levels, which might be useful in developing management practices to ensure long-term utilisation. Therefore, the present investigation was conducted to study the length-weight relationship and stock assessment of selected prawn species from river Burhi Gandak in North Bihar.

Materials and methods

Study area

The Burhi Gandak River originates from Chautarwa Chaur in the West Champaran District in Bihar. The catchment area of the river is spreadacross 12,500 sq km. The river primarily, flows through India and it is a significant perennial river in North Bihar (Singh *et al*., 2018). The sampling sites comprised upstream waters Motihari (Site-1: 26°56'06"N, 85 °05'13"E), middle stream waters - Muzaffarpur (Site-2: 25°61'14"N, 85°63'70"E), and downstream waters - Khagaria (Site-3: 25°50'08"N, 86°48'12"E) along the Burhi Gandak River in Bihar. (Fig. 1).

Sampling methods and data collection

Experimental samplings for collection of the three species of Palaemonid prawns namely *M. dayanum*, *M. lamarrei* and *M. malcolmsonii* (Fig. 2) were conducted during July 2020 to June 2021, during the first week of each month. Samples were collected from all three sampling locations with the help of local fishermen using traditional boats and locally made nets such as Ghana traps and cast nets (Fig. 3). The collected samples were identified using the available literature (Jayachandran, 2001; Mariappan and Richard, 2006).

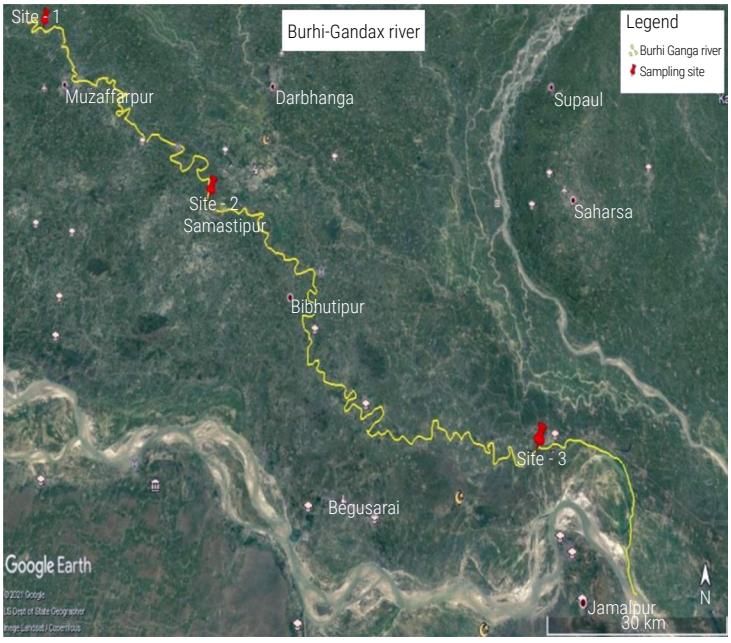

Fig. 1. Map depicting fish landing centers along the Burhi Gandak River

(a) (b) (c)

Fig. 2. Palaemonidae species occuring in Burhi Gandak River: (a) *M. lamarrei* (Milne Edw., 1837); (b) *M. dayanum* (Henderson, 1893) and (c) *M. malcolmsonii* (H. Milne Edw., 1844)

(a) (b) (c)

Fig. 3. Nets and traps used during sampling. (a) and (b) Ghana jal and (c) Pelni jal

Length-weight parameters

The total length (from the inside of the eye socket to the posterior part of the telson) and weight of prawns were measured in cm and grams, respectively. The length-weight relationship was calculated following Le Cren (1951):

$W = a L^b$

where W = Total body weight (g) , L=Total length (cm), a and b are constants. This equation can be linearly interpreted as:

Log W = Log a + b Log L

Growth and stock assessment parameters

The ELEFAN I module of the FiSAT II software was used to estimate the asymptotic length (L_∞) and growth coefficient (K) of von Bertalanffy growth (K) given by Gayanilo *et al.* (2005).

$Lt = L_\infty (1 - e^{-k(t - t_0)})$

where, L_∞ = Asymptotic length, K = Growth coefficient, t = Age at given length and t_0 = Age at length zero

The performance indicator for growth (Ø) was computed as phi-prime (Ø) = log K + 2 log L_∞), as given by Pauly and Munro (1984) using asymptotic length (L_∞) and growth coefficient (K) values. The following formula was used to determine the t_0 value (Pauly, 1980):

Log ($-t_0$) =-0.3922 - 0.2752 log L_∞-1.038 log K

Using FISAT II, the length converted catch curve methods were used to calculate the total instantaneous mortality rate (Z). Pauly's (1980) equation gave the natural mortality (M) using the mean annual habitat temperature (28.5ºC), L_∞ and K. The formula Z = F + M was used to determine the fishing mortality (F). The exploitation rate (E) was computed using the formula E = F /Z given by Gulland (1979).

Results

In the present study, *M. dayanum* (Henderson, 1893), *M. lamarrei* (Milne Edw., 1837) and *M. malcolmsonii* (H. Milne Edw., 1844) were found to be the most common species of the Palaemonidae family, in the catch from Burhi Gandak River and were accessible throughout the year. Among the 3 species, *M. lamarrei* had the largest representation followed by *M. dayanum* and *M. malcolmsonii*. A total of 907 *M. lamarrei,* 942 *M. dayanum* and 962 *M. malcolmsonii* specimens were sampled during the study. *M. lamarrei* ranged in total length from 1.8-6.1 cm and weighed 0.10 g-3.26 g. *M. dayanum* recorded a size range of 1.6-8.0 cm TL and 0.10-9.52 g weight.. *M. malcolmsonii* had 3.8-16.8 cm TL weighing 0.89-125.58 g The number of specimens in different length groups is shown in Fig. 4 (a, b, c).

Length-weight relationship

The relationship between total length and weight was estimated for *M. lamarrei, M. dayanum* and *M. malcolmsonii* and its parabolic and logarithmic equations are shown in Table 1. Fig. 5 (a, b, c) show the logarithmic relationship between length and weight for *M. lamarrei, M. dayanum* and *M. malcolmsonii* respectively. The study observed a negative allometric growth pattern in all three prawn species, with the 'b' values for *M. lamarrei* (2.769), *M. dayanum* (2.602) and *M. malcolmsonii* (2.751) being less than

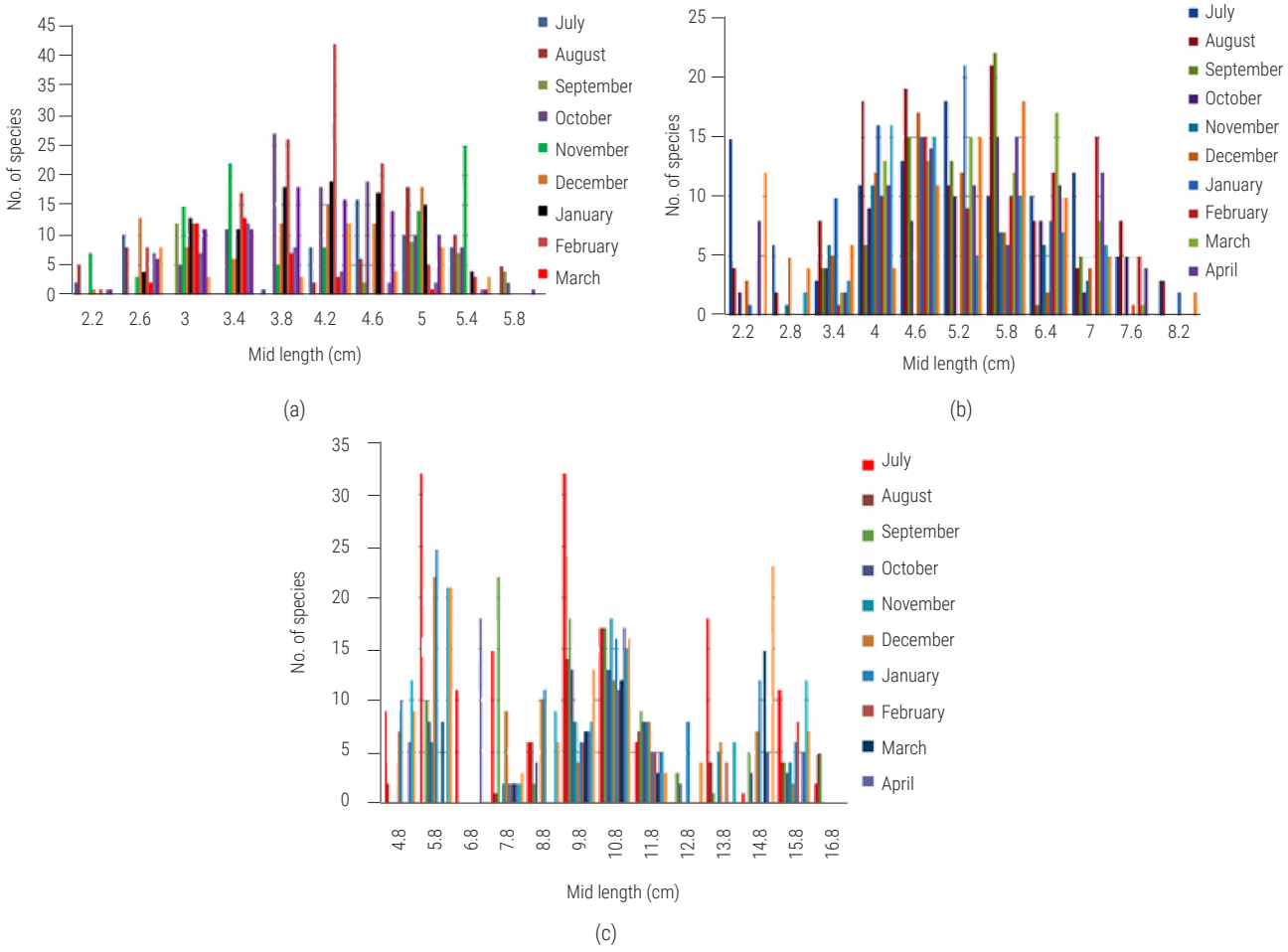

Fig. 4. Number of (a) *M. lamarrei;* (b) *M. dayanum* and (c) *M. malcolmsonii* in different length groups

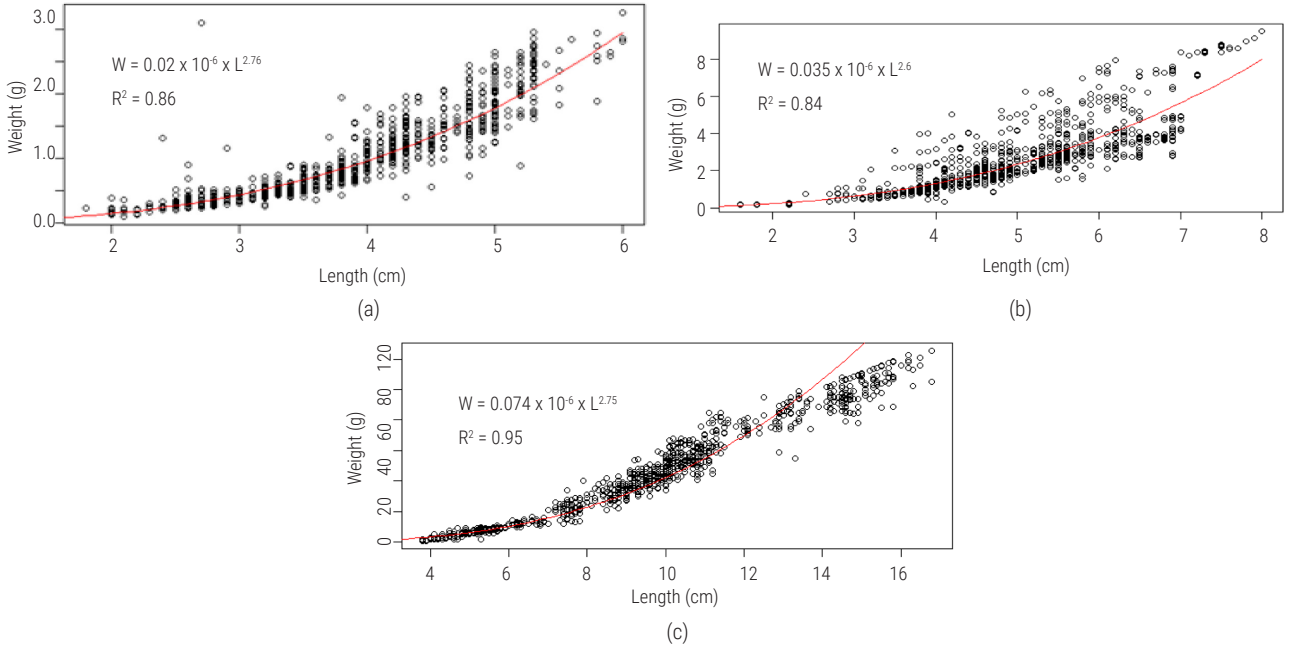

Fig. 5. Length-weight relationship of (a) *M. lamarrei;* (b) *M. dayanum* and (c) *M. malcolmsonii*

Table 1. Parabolic and logarithmic equations of selected *Macrobrachium* spp.

Species	Parabolic	logarithmic equations
M. lamarrei	$W= 0.02*10^{-6} * L^{2.76}$	Log W= -1.68496 + 2.76 Log L
M. dayanum	$W= 0.035*10^{-6}* L^{2.6}$	Log W= -1.44808 + 2.6 Log L
M. malcalmsonii	$W= 0.074*10^{-6}*L^{2.75}$	Log W= -1.1257 + 2.75 Log L

the ideal value of 3. This pattern indicates that as the prawns grow in length, their weight increases at a slower rate compared to an ideal isometric growth. Negative allometric growth suggests that these species allocate more energy towards activities other than growth in weight, such as reproduction or survival strategies. This energy allocation could be a response to environmental conditions or predation pressures in the Burhi Gandak River. Species exhibiting negative allometric growth often reach reproductive maturity at smaller sizes. This can lead to higher reproductive output over their lifespan, which is beneficial in fluctuating environments. The slower weight gain relative to length might enhance survival by reducing the risk of predation, as larger, bulkier individuals are often more vulnerable. This adaptation could contribute to their resilience in variable ecological conditions. Understanding the length-weight relationship and growth patterns helps in predicting the population structure and dynamics of these species. The significant relationship between length and weight (coefficient of determination: *M. lamarrei* - 0.86, *M. dayanum* - 0.84, *M. malcolmsonii* - 0.95) indicates reliable data for stock assessments.

Growth and population parameters

The ELEFAN I program was used to estimate the growth parameters, asymptotic length (L_∞) and growth coefficient (K). The asymptotic length (L_∞) and growth coefficient (K) for *M. lamarrei* were 5.67 cm and 2.3 y^{-1}, respectively. The estimated value of L_∞ and K for *M. dayanum* was 10.08 cm and 0.990 y^{-1} respectively and for *M. malcolmsonii* the values were 16.59 and 0.730 respectively. The estimated t_0 value and the von Bertalanffy equation are given in Table 2. Based on the growth parameters, the estimated lengths at different ages for all three species are given in Table 3 and growth curves of all three species fitted using growth parameters are presented in Fig. 6 (a, b, c) respectively.

Stock assessment

Mortality and exploitation rate

The estimated total instantaneous mortality (Z) of *M. lamarrei, M. dayanum* and *M. malcalmsonii* by length converted catch curve method was 6.65, 2.57 and 1.91 respectively and natural mortality (M) estimated through Pauly's formula was 4.94, 2.43 and 1.73 respectively. The fishing mortality (F) of *M. lamarrei, M. dayanum* and *M. malcalmsonii* was 1.71, 0.15 and 0.18 respectively and the estimated exploitation rate (E) of *M. lamarrei, M. dayanum* and *M. malcalmsonii* was 0.26, 0.06 and 0.09 respectively, which indicated natural mortality as higher than fishing mortality. These smaller forms prey for many carnivorous fishes, because the population of large groups of fishes is under-represented and these species are predicted to have a high natural mortality rate. Among the three species, the highest natural mortality (M) was recorded for *M. lamarrei* (4.94) and the lowest was 1.73 for *M. malcalmsonii*. The total instantaneous mortality (Z) of *M. lamarrei* (6.65) was the highest among the three species,whereas the lowest total mortality was observed in *M. malcalmsonii* (1.91). The fishing mortality of *M. lamarrei* (1.71) was the highest whereas the lowest fishing mortality was observed in *M. dayanum* (0.15). The exploitation rate (E) of *M. lamarrei* (0.26) was higher than *M. dayanum* (0.06) and

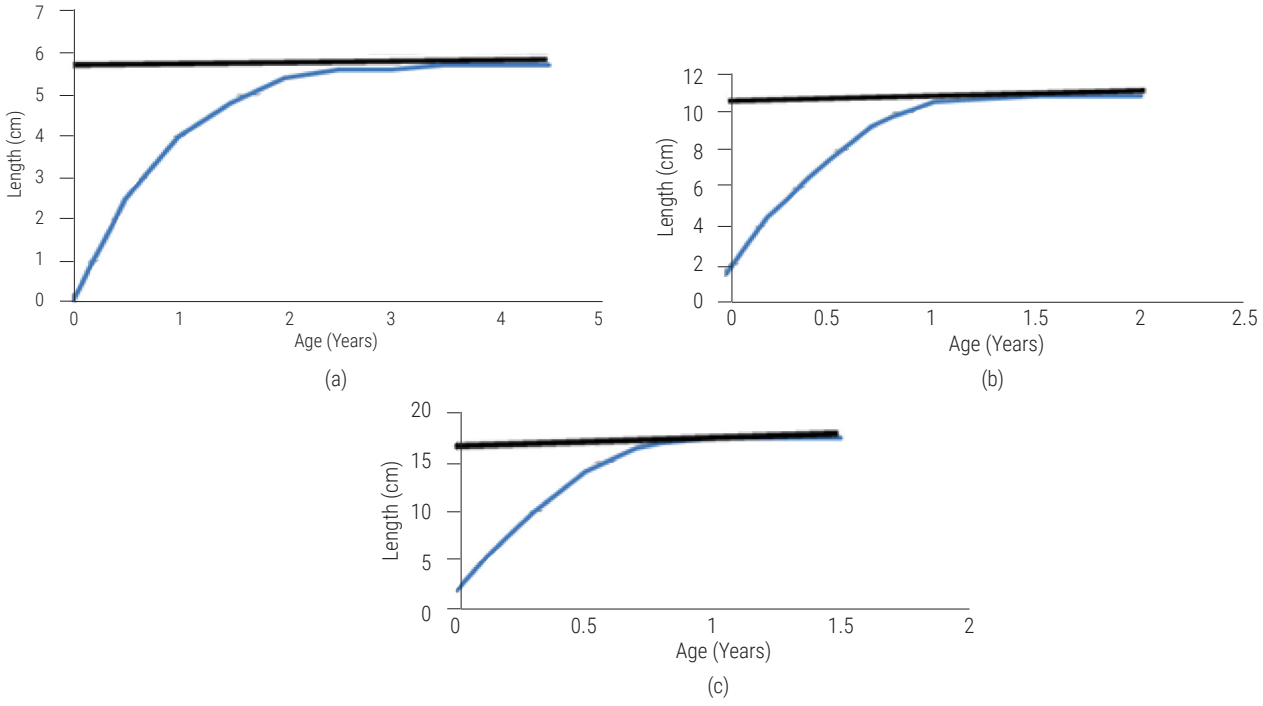

Fig. 6. Growth curve of (a) *M. lamarrei;* (b) *M. dayanum* and (c) *M. malcolmsonii*

Table 2. Growth parameters of selected *Macrobrachium* spp. in Burhi Gandak River

Species	Asymptotic length (L_∞)	Growth co-efficient (K)	t_o	The von Bertalanffys Equation
M. lamarrei	5.67	2.3	-0.5913	L (t) = 5.67* [1- exp {2.3 [t - (--0.5913)]}].
M. dayanum	10.08	0.990	-0.6684	L (t) = 10.08* [1- exp {0.990 [t - (-0.6684)]}].
M. malcolmsonii	16.59	0.730	-0.7289	L (t) = 16.59* [1- exp {0.730 [t - (-0.7289)]}].

Table 3. Estimated lengths at different age of *M. lamarrei, M. dayanum* and *M. malcolmsonii* by fitting von Bertalanffy growth parameters

M. lamarrei		*M. dayanum*		*M. malcolmsonii*	
Age (t) (year)	Length at given age (cm)	Age (t) (year)	Length at given age (cm)	Age (t) (year)	Length at given age (cm)
0.4	2	0.5	7.5	0.4	12
0.5	2.5	0.7	9.3	0.5	14
1	4	0.8	9.8	0.7	16.5
1.5	4.8	0.9	10.2	0.8	17
2	5.4	1	10.6	0.9	17.3
2.5	5.6	1.5	10.9	1	17.5

the estimation of natural mortality and fishing mortality of the three *Macrobrachium* species indicates that natural mortality is higher for these species than the fishing mortality.

Discussion

In the present study, the maximum size of *M. lamarrei* observed was 6.1 cm which is higher than the earlier reported values of 1.91 cm by Ara (2014) in Bangladesh and 5.3 cm by Purohit and Vachhrajani (2018) in pond of Dabhoi in Gujarat, India. This maximum observed length is comparatively higher than the values reported for related species *Macrobrachium vollenhovenii* of 5.36 cm observed by Konan *et al*. (2014) in rivers of Corted Ivoire and 1.47 cm reported for *M. macrobrachion* by Konan *et al*. (2017) in rivers of Corted Ivoire. The maximum length of this species was observed at 5.3 cm in Bangalore (Shakuntala, 1977) which was lesser than the observation in the present study. The maximum size of *M. dayanum* observed during the study was 8 cm which is higher than the previous record of 5 cm by Sarkar *et al.* (2012) in the ponds of different localities of West Bengal. The maximum length of this species was observed at 5.9 cm in the river Padma, Bangladesh (Bhuiyan *et al*., 2007) and 5.2 cm in Gho-Manhasan, Kheri and Nagri, Jammu (India) (Langer *et al.,* 2016) which was found lesser than the present study. This maximum observed length is comparatively higher than the related species *M. vollenhovenii* (Konan *et al*., 2014) and *M. macrobrachion* (Konan *et al*., 2017) in rivers of Corted Ivoire. The maximum recorded size of *M. malcolmsonii* during the present study was 16.8 cm which is lower than the earlier recorded value of 21 cm by Soomro *et al.* (2012) in the Lower Indus River. Hossain *et al.* (2012) recorded a smaller size of *M. malcolmsonii* compared to the present study and the size ranged from 3.54 to 11.76 cm in the Padma River, Bangladesh. This maximum observed length is comparatively lower than the reported values for related species of *M. rosenbergii* by Kunda *et al.* (2008) from Bangladesh; Rajeevan *et al.* (2018) in reservoirs of Northern Province, Sri Lanka; Indarjo *et al.* (2021) in North Kalimantan estuary systems in Indonesia and similar length reported for *Macrobrachium lar* (16.7) by Sethi *et al.* (2012) in Andaman and Nicobar Islands.

In the present study, the estimated b value for *M. lamarrei* is 2.769 which indicates negative allometric growth pattern and similar growth pattern in the species was observed by Ara *et al.* (2014) in Mymensingh, Bangladesh, Purohit and Vachhrajani (2018) in a pond in Dabhoi Gujarat and Shakuntala (1977) from Bangalore, India. In the present study, the calculated 'b' value for *M. dayanum* was 2.60 indicating negative allometric growth, where Bhuiyan *et al*. (2007), Sarkar *et al*. (2012) and Langer *et al.* (2016) stated that *M. dayanum* exhibited negative allometric growth along the river Padma (Rajshahi, Bangladesh), Gho-Manhasan, Kheri and Nagri, Jammu (India) and ponds of different localities of West Bengal. The calculated 'b' value for *M. colmsonii* was 2.751 which is lower than the ideal value of 3, indicating negative allometric growth. A Similar result was observed by Soomro *et al.* (2012) (2.97) for male population of *M. malcolmsonii* along the Lower Indus River, Pakistan. Negative allometric growth (4.2) was also reported in *M. rosenbergii* in Northern Province in Sri Lanka (Rajeevan *et al*., 2018). Hossain *et al*. (2012) reported isometric growth (3.00) in the Ganges River in North-Western Bangladesh.

Ara *et al*. (2014) reported asymptotic length (L_∞) and growth coefficient (K) for *M. lamarrei* from north-eastern Bangladesh as 4.24 cm for males and 2.09 cm for females which is lower than that recorded in the present study. , In *M. equidens* from south-east Nigeria, L_∞ was found higher and K was observed lower than the present study (Nwosu *et al*., 2008). Yakub (2010) reported that L_∞ and K of *M. macrobrachion* were 10.02 cm and 3.76 y^{-1} respectively which is higher than the present study. The L_∞ and K in this study were 10.08 cm and 0.990 y^{-1} for *M. dayanum*. Similar to other species reported by Yakub (2010) L_∞ and Kfor *M. felicinum* from Ogun River (South-west Nigeria) was 6.90 cm and 1.00 y^{-1} respectively,. Yakub (2010) found that the L_∞ and K for *M. macrobrachion* from Lower Ogun River, South-west Nigeria as 10.02 cm and 0.97 y^{-1} respectively, which is similar to that reported in the present study. Nwosu *et al.* (2007), Yakub (2010) and Alhassan and Arma (2011) reported asymptotic length (L_∞) as 18.0, 21.36 and 14.2 cm and growth co-efficient as 0.91 , 1.24 and 1.0 $y^{-1}$for *M. vollenhovenii* from West Africa, Cross River Estuary, Nigeria, Ogun River (South-west Nigeria) and Dawhenya, Ghana. Studies by Khan *et al.* (2009) estimated the $L_\infty$and K for *M. malcolmsonii* from Wyra, India as 20.3 cm and 0.63 y^{-1} with L_∞ being higher and K value lower compared to the present study. The asymptotic length and growth co-efficient of *M. rosenbergii* (reported by Nwosu *et al.,* (2007) from

Nigeria, were higher than the present study and also Indarjo *et al.* (2021) observed growth parameters of *M. rosenbergii* from North Kalimantan, Indonesia to be lower than the present study. Frédou *et al.* (2010) estimated the L_{∞} and K for *M. amazonicum* from Combu Island, Amazon Estuary and they found the parameters to be lower than the present study. Enin (1995) reported that in *M. macrobrachion* from Nigeria L_{∞} is lower and K value higher than the values observed in the present study.

Ara *et al*. (2014) reported natural mortality (M) (1.024) higher than the fishing mortality (0.143) in *M. lamarrei* which is similar to the present study. Nwosu (2008) estimated the mortality parameter of *M. equidens* caught in Cross River Estuary, South-east Nigeria and reported a higher total mortality (4.97 y^{-1}). In these cases, the natural mortality (2.69 y^{-1}) was higher than the fishing mortality (2.28 y^{-1}) which is similar to the present study. The earlier estimation of natural mortality by Alhassan and Armah (2011) indicated that the total mortality of *M. vollenhovenii was* 5.36 $y^{-1}$and the natural mortality (2.20 y^{-1}) was less than the fishing mortality (3.16 y^{-1}) from Dawhenya Impoundment, Ghana which agrees with the present study. Nwosu *et al.* (2007) estimated the mortality parameters of *M. Vollenhovenii* from Cross River Estuary (Nigeria) and reported that both male and female have a total mortality of 3.93 and 6.85 y^{-1}respectively and in the case of male the natural mortality (2.21 y^{-1}) is higher than the fishing mortality (1.72 y^{-1}), while in female the natural mortality (2.27 y^{-1}) is less than the fishing mortality (4.58 per year) respectively which is similar to the observations in the present study. Total mortality of *M. malcolmsonii* was Z=2.23 and the natural mortality (1.50) was higher than the fishing mortality (0.73) (Khan *et al.,* 2009), which is similar to findings of the present study. Nwosu *et al.* (2007) reported that *M. rosenbergii* from Nigeria has higher total mortality of 9.53 y^{-1}.

The exploitation rate recorded for *M. lamarrei, M. dayanum* and *M. malcolmsonii,* in the present study were 0.26, 0.06 and 0.09 respectively. The earlier reports of Nwosu (2008) and Khan *et al.* (2009) stated that *Macrobrachium species* were under-exploited along West Africa, Wyra (India) and Cross River Estuary (South-east Nigeria). Enin (1995) and Nwosu *et al*. (2007) observed that *M. macrobrachion* and *M. rosenbergii* were over-exploited along the river estuary, Nigeria. Similar observations were made by Fredou *et al.* (2010) and Alhassan and Armah (2011) for freshwater prawns along the Combu Island, Amazon Estuary and Dawhenya Impoundment, Ghana.

The study's findings have important implications for local communities that rely on prawn fishing for their livelihood. The observations from the present study, that *M. dayanum*, *M. lamarrei* and *M. malcolmsonii* in the Burhi Gandak River are underexploited suggests that there is potential to increase harvesting efforts sustainably. This can enhance local fisheries and provide economic benefits to the communities. Sustainable management practices based on data from this study can ensure long-term availability of these resources, contributing to food security and stable income for fishermen.

The observed maximum sizes and negative allometric growth patterns of these prawn species provide valuable information for aquaculture development. The maximum sizes recorded for *M. lamarrei* (6.1 cm), *M. dayanum* (8 cm) and *M. malcolmsonii* (16.8 cm) indicate that these species can reach significant sizes, making them suitable candidates for aquaculture. The negative allometric growth patterns (b values less than 3) observed in all three species imply that as these prawns grow in length, their weight increases at a slower rate. Understanding these growth dynamics is crucial for optimising feeding practices and growth conditions in aquaculture settings. Establishing aquaculture practices for these prawns can diversify income sources for local fish farmers and reduce pressure on wild populations. Developing aquaculture for these prawn species can create employment, boost local economies, and contribute to sustainable resource management. It can also provide a controlled environment for studying and mitigating issues such as diseases and environmental impacts, promoting overall ecosystem health.

This research significantly contributes to the understanding of the population dynamics and exploitation rates of prawn species in the Burhi Gandak River, filling a crucial gap in the existing literature. Our findings indicate that the three *Macrobrachium* species studied are currently underexploited, presenting a unique opportunity for sustainable harvesting and management practices. By highlighting the potential for breeding and culturing these species, this study opens new avenues for aquaculture development, offering promising economic benefits for local communities. The insights gained from this research not only support biodiversity conservation efforts but also enhance local economic development, underscoring the importance of integrating ecological knowledge with sustainable resource management.

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