Research Article

Length Frequency Distribution, Length-Weight Relationships and Condition Factors of *Nandus nandus* (Hamilton, 1822) from Upper Brahmaputra Basin, Assam, NE India

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ABSTRACT

Background: Studies on length-weight relationships and associated aspects like length frequency distribution, sex ratio and condition factors are of paramount importance for sustainable management and conservation of concerned fish species. This study was undertaken keeping in view the lack of such relevant fisheries information on *Nandus nandus*, a commercially important fish species from this region whose natural population has been declining considerably over the years. **Aim:** This study was carried out to ascertain and describe the sex ratio, length-frequency distributions (LFDs), length-weight relationships (LWRs) as well as condition factors of *Nandus nandus* and their seasonal variation from the floodplain wetlands of upper Brahmaputra basin, Assam. **Materials and Methods:** A total of 517 specimens of *Nandus nandus* were collected randomly between January, 2023 and May, 2024. The sex ratio was expressed as number of females divided by the number of males while length-frequency distributions were done following standard method. The LWR is determined by using the formula $W= aL^b$ and the equation Log W= Log a + b Log L (LeCren, 1951). Relative condition factor (Kn) and Fulton's condition factor (K) was calculated using the formula $Kn= W/aL^b$ and $K=100W/L^3$, respectively. All the recorded data were presented seasonally and statistically analyzed using standard methods. **Results:** Observations on LFDs suggest no significant size differences between the sexes; 10-12 cm being the most dominant length group of the species. The species has a female dominant population; the females significantly outnumbered the males in all the seasons except pre-monsoon. The relationships between total length and total weight are found to be highly significant ($P<0.01$) and showed positive allometric growth for the species with exception in winter. The calculated b values ranged from 2.961 (post-monsoon) to 4.124 (winter) for males and from 3.101 (winter) to 3.538 (post-monsoon) for females. Calculated mean Kn value ranges between 1.00 and 1.07 with minimum seasonal variation for both the sexes while mean K value is found to be slightly higher in females than males for most part of the study. **Conclusion:** The findings of the present study pertaining to sex ratio, LFDs, LWRs as well as condition factors would serve as basic information towards better understanding of the biology of *Nandus nandus* to other workers from this region entailing further research in associated aspects of fisheries for this species.

Keywords: Condition factor, Floodplain wetlands, Length weight relationship, Length-frequency distributions, *Nandus nandus*, NE India, Upper Brahmaputra basin.

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INTRODUCTION

The Gangetic leaf fish or mud perch, *Nandus nandus* (Hamilton, 1822) (Anabantiformes: Nandidae) is one of the perches found to inhabit the lentic water bodies in south-eastern Asia, particularly India and its adjacent countries.[1,2] Morphologically, this fish species is

characterized by deeply compressed body having large vertical patchy blotches, highly protrusible jaws and cryptic colouration. Despite having large, patchwork markings on its body and spinous fins, the fish is considered to be delicious for its excellent nutritional content (52.5% protein, 2% fat, 0.21% carbohydrate and 5.7% mineral)[3] and as such enjoys higher consumer demand in various parts of the region.[2] Moreover, this species is also considered as a prominent aquarium fish due to its unique colour pattern and hardiness and exported from India to other countries regularly.[4] Presently, this species is placed in the 'Least Concerned' (LC) category in the global conservation list of fishes by IUCN (2021). Though once very commonly available in this region, the abundance of the natural population of this fish species has been dwindling in recent past as reflected by their poor catches and limited availability due to various reasons.

The relationship between length and weight of a fish species is one of the most important aspects of study in fish biology as it can provide some of the much needed fisheries information of the species concerned. Such length-weight relationships helps to calculate the weight of an individual fish at a certain age,[5] enables seasonal variations in fish growth to be followed[6] and also to determine whether the somatic growth is allometric or isometric.[7] Moreover, length weight relationships can also be used to estimate condition factor-a measure of general well-being of a fish and determines the success of the population both present and in the future through effects on growth, reproduction and survival.[8] Further, such information is highly desirable to formulate species-specific conservation strategy and inclusion of *Nandus nandus* in aquaculture diversification programmes, as the species being viewed as a potential candidate for that.

Different aspects of biology including length-weight relationship of *Nandus nandus* has been reported by a few workers, particularly from different parts of India and Bangladesh.[9-13] However, no specific reports have been available on these aspects of *Nandus nandus* from this part of the country till now. As such the present study is intended to describe the length frequency distribution, seasonal length-weight relationship and condition factor of *Nandus nandus* from the floodplain wetlands in upper Brahmaputra drainage, NE India.

MATERIALS AND METHODS

Study area

The specimens of *Nandus nandus* for the present study (from January, 2023 to May, 2024) were collected from the floodplain wetlands (locally called as *beels*) from Sivasagar and Dibrugarh districts in upper Brahmaputra valley. Floodplain wetlands in the upper Brahmaputra basin are biologically rich and highly productive ecosystems including fisheries. These wetlands in this region constitute a major source of livelihood for the indigenous fisher folks and other local people.

Fish Sampling

For the present study, a total of 517 specimens of *Nandus nandus* were collected either by visiting different fishing grounds at least twice a month or procured randomly from the local fish landing sites and markets of the area. The local fishermen used different types of fishing nets (such as gill nets and cast nets) and fishing traps to capture the fishes from the *beels* including *Nandus nandus*. The collected fish specimens were immediately stored in containers having ice and brought to the laboratory for further study. Upon arrival in the laboratory, fish specimens were preserved in 10% formalin solution after properly washing them with running tap water for further analysis.

Fish (Length-Weight) measurement

In the laboratory, the measurement of each preserved specimen was undertaken for Total Length (TL) and Total Weight of the body (BW). The TL is measured to the nearest 0.1 cm using a measuring ruler while TW was recorded to the nearest 0.01 g using a digital balance. Then the specimens were sorted by sex (after determining the sex by dissecting individual specimen). All recorded data on length and weight are presented seasonally as pre-monsoon (March-May), monsoon (June-August), post-monsoon (September-November) and winter (December-February).

Sex ratio and Length-Frequency Distributions (LFDs)

For the present study, the sex ratio was expressed using the formula:

$$\text{Sex ratio} = \frac{\text{Number of females}}{\text{Number of males}}$$

On the other hand, normal length-frequency distributions were fitted to the pooled length-frequency data for each sex as suggested by Hasselblad's maximum likelihood method.[14]

Length-Weight Relationships (LWRs) and condition factor

The LWR is determined by using the formula $W = aL^b$, where W is the total body weight (g), L is the total length (cm) while 'a' and 'b' represents the body form-related

coefficients (i.e., 'a'-intercept of the regression line and 'b'-slope of the regression line). The LWR has been logarithmically translated into the equation Log W=Log a+b Log L and the coefficient values were ascertained empirically.[15] Any considerable divergence of the b-value from 3 implies allometric growth (positive when b>3 or negative when b<3), whereas b=3 indicates isometric growth.[16] The observed average weight was plotted in Y-axis and the observed average length was plotted in X-axis to examine the nature of parabola.

While the relative condition factor was determined using the formula, $Kn= W/aL^b$.[15] Fulton's condition factor (K) was approximated using the formula, $K=100W/L^3$.[17]

Data analysis

All the relevant statistical analysis of the recorded data was done by MS Excel (Windows XP version).

RESULTS

Sex ratio and Length-Frequency Distributions (LFDs)

The sample size, the minimum, maximum and mean length as well as the minimum, maximum and mean body weight of the collected specimens of *Nandus nandus* are given in Table 1. In the present study, out of the total 517 individuals of *Nandus nandus*, 187 (i.e., 36.17%) were male while the remaining 330 (i.e., 63.82%) were female. The TL of collected specimens was ranged from 6.8 to 13 cm in males and from 6.4 to 15.6 cm in females whereas BW ranged from 3.5 to 35.2 g and from 2.2 to 65.1 g for males and females, respectively. Observation on sex ratio of *Nandus nandus* during the study period showed a 1:1 (df=1, χ^2=0.000, p=1) in pre-monsoon whereas in other seasons, the sex ratio (male to female) observed to be 1:2.09 (in monsoon), 1:1.93 (in post-monsoon) and 1:2.05 (in winter); females significantly outnumbered the males (Table 2).

Table 2: Seasonal variation of sex ratio of *Nandus nandus* from upper Brahmaputra basin, Assam, NE India.

Seasons	Male	Female	Total	Sex ratio	Chi-square (df=1)	P value
Pre-monsoon	45	45	90	1:1	0.000	1.000
Monsoon	11	23	34	1:2.09	4.235	0.039
Post-monsoon	60	116	176	1:1.93	17.81	2.403
Winter	71	146	217	1:2.05	25.92	3.555

Again, the overall Length-Frequency Distributions (LFDs) for the species showed similar pattern in both the sexes. According to LFDs, the 10 cm TL size was dominant in both sexes, constituting 77% and 89% of its population, for males and females respectively (Figure 1a and b).

Length-Weight Relationships (LWRs)

The relationships between Total Length (TL) and Body Weight (BW) of *N. nandus* in different seasons during

Table 1: The descriptive statistics of the length (cm) and body weight (g) measurements in *Nandus nandus* from upper Brahmaputra basin, Assam, NE India.

Seasons	Sex	Number of Samples (n)	Total length (cm)			Body weight (g)		
			Minimum	Maximum	Mean value±SD	Minimum	Maximum	Mean value±SD
Pre-monsoon	Male	45	7.6	11.4	9.91±1.05	6.58	27.4	15.05±4.68
	Female	45	8.8	13.9	10.75±1.3	10.9	42.4	21.85±9.66
	Combined	90	7.6	13.9	10.33±1.2	6.58	42.4	18.45±8.29
Monsoon	Male	11	8.7	13	11.33±1.7	8.52	35.2	24.30±10.6
	Female	23	7.8	13	10.77±1.6	7.81	40.5	22.30±11.0
	Combined	34	7.8	13	10.95±1.6	7.81	40.5	22.95±10.8
Post monsoon	Male	60	8	12.2	9.72±0.86	7.34	27.4	14.17±4.54
	Female	116	6.4	14.6	10.61±1.6	2.24	47.5	19.49±9.45
	Combined	176	6.4	14.6	10.31±1.5	2.24	47.5	17.67±8.49
Winter	Male	71	6.8	11.5	9.90±0.74	3.53	20.5	12.17±4.90
	Female	146	7.9	15.6	10.47±1.4	7.6	65.1	20.44±10.5
	Combined	217	6.8	15.6	10.28±1.2	3.53	65.1	17.73±9.85

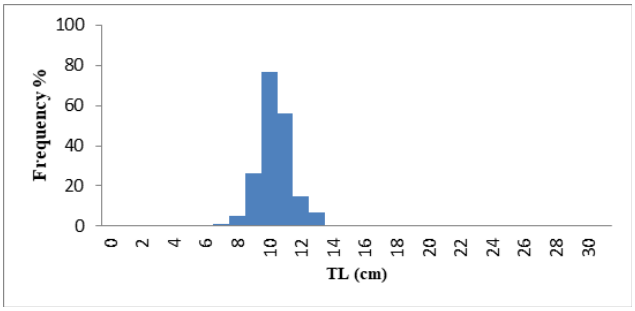

Figure 1a: Length-frequency distribution of males (pooled data) of *Nandus nandus*.

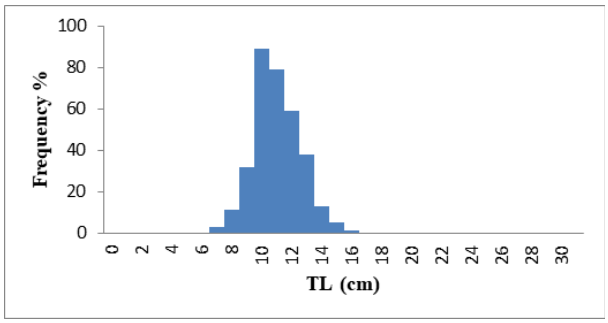

Figure 1b: Length-frequency distribution of females (pooled data) of *Nandus nandus*.

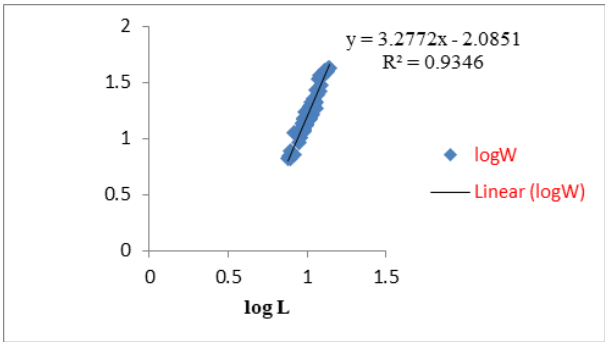

Figure 2a: Length-weight relationship of *N. nandus* (combined sex) in pre-monsoon.

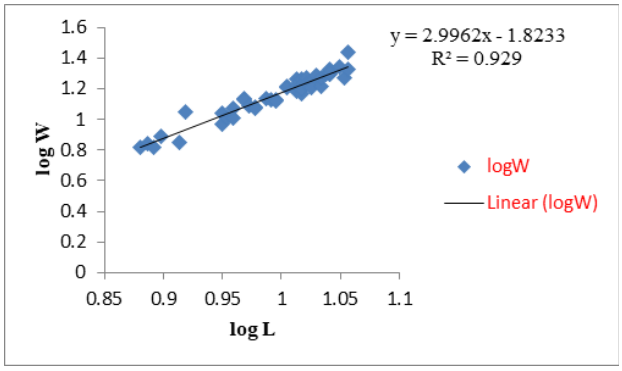

Figure 2b: Length-weight relationship of *N. nandus* (male) in pre-monsoon.

the period of study are summarized in Table 3. Similarly, Table 3 and Figure 2(a-c), Figure 3(a-c), Figure 4(a-c) and Figure 5(a-c) provide the regression parameters 'a' and 'b' of LWR, 95% confidence intervals of 'a' and 'b', the coefficient of determination (R^2) and growth type of *Nandus nandus*.

All the relationships between total length and total weight are found to be highly significant ($p<0.01$). In the present study, the calculated allometric coefficient 'b' for the males of *Nandus nandus* indicates isometric growth i.e. b=3 in both pre-monsoon and post-monsoon, while in monsoon they exhibit positive allometric growth i.e. b>3 whereas in winter they showed negative allometric growth i.e. b<3. On the other hand, females of *Nandus nandus* exhibit positive allometric growth for all the seasons as the estimated value of allometric coefficient b is greater than 3 (i.e., b>3).

Table 3: Calculated parameters of length-weight relationships for *Nandus nandus* from upper Brahmaputra basin, Assam, NE India.

Seasons	Sex	Logarithmic equation	a	b	95% CI of a	95% CI of b	R^2	Growth type
Pre-monsoon	Male	-1.823+2.996x	0.0150	2.996	-2.076-1.569	2.741-3.251	0.928	I
	Female	-2.082+3.292x	0.0082	3.292	-2.343-1.822	3.038-3.545	0.941	A+
	Combined	-2.085+3.277x	0.0082	3.277	-2.271-1.899	3.093-3.460	0.934	A+
Monsoon	Male	-2.152+3.322x	0.0070	3.322	-2.416-1.893	3.077-3.574	0.990	A+
	Female	-2.208+3.405x	0.0061	3.405	-2.464-1.952	3.156-3.653	0.974	A+
	Combined	-2.16+3.348x	0.0069	3.348	-2.355-1.964	3.160-3.537	0.976	A+
Post-monsoon	Male	-1.788+2.961x	0.0162	2.961	-2.171-1.406	2.573-3.348	0.801	I
	Female	-2.386+3.538x	0.0041	3.538	-2.532-2.243	3.396-3.680	0.955	A+
	Combined	-2.253+3.416x	0.0055	3.416	-2.390-2.116	3.280-3.551	0.934	A+
Winter	Male	-3.062+4.124x	0.0008	4.124	-4.163-1.196	3.018-5.280	0.445	A+
	Female	-1.883+3.101x	0.0130	3.101	-2.00-1.757	2.977-3.224	0.944	A+
	Combined	-2.377+3.539x	0.0042	3.539	-2.701-2.054	3.218-3.859	0.688	A+

"a", intercept; "b", slope; "CI", Confidence Interval; "R2", Coefficient of Determination; "I', isometry; "A+", positive allometry, "A-", negative allometry

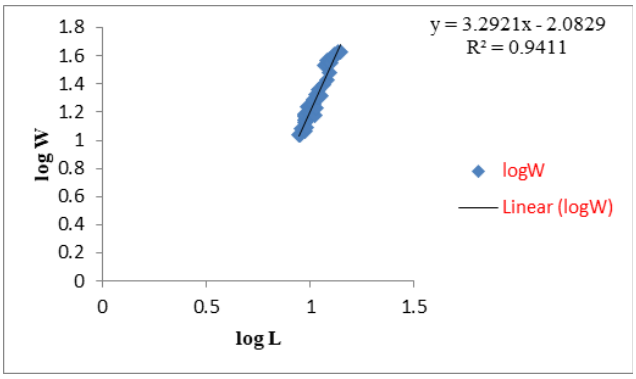

Figure 2c: Length-weight relationship of *N. nandus* (female) in pre-monsoon.

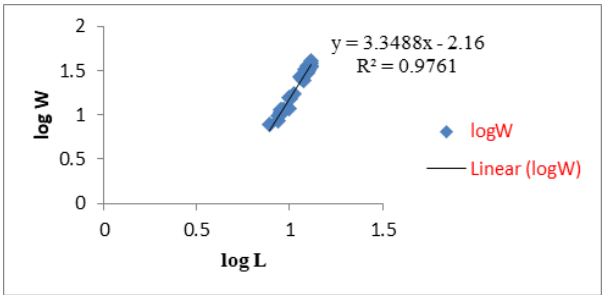

Figure 3a: Length-weight relationship of *N. nandus* (combined sex) in monsoon.

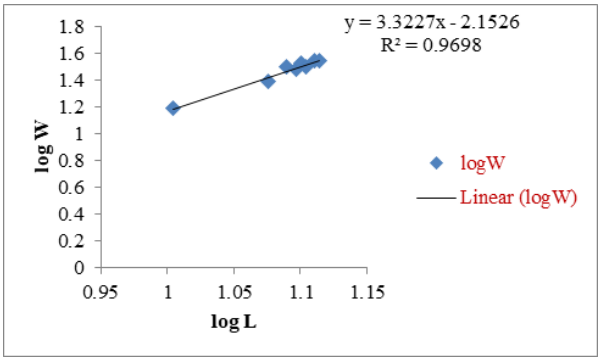

Figure 3b: Length-weight relationship of *N. nandus* (male) in monsoon.

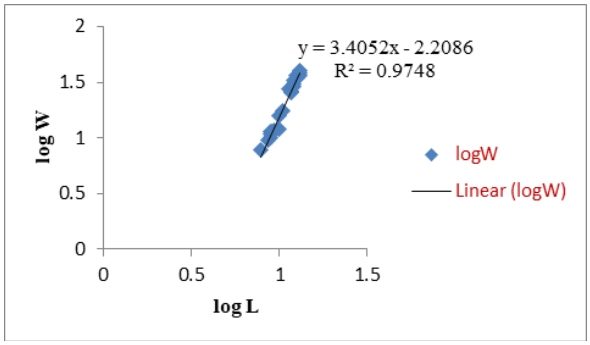

Figure 3c: Length-weight relationship of *N. nandus* (female) in monsoon.

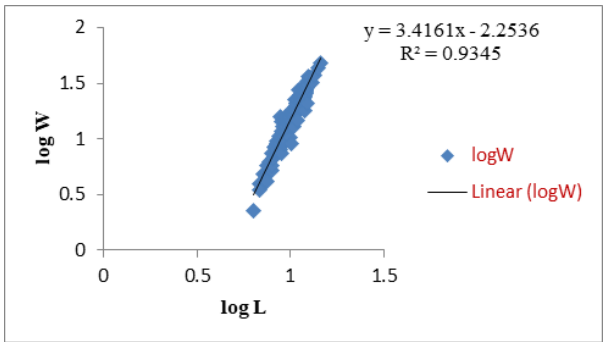

Figure 4a: Length-weight relationship of *N. nandus* (combined sex) in post-monsoon.

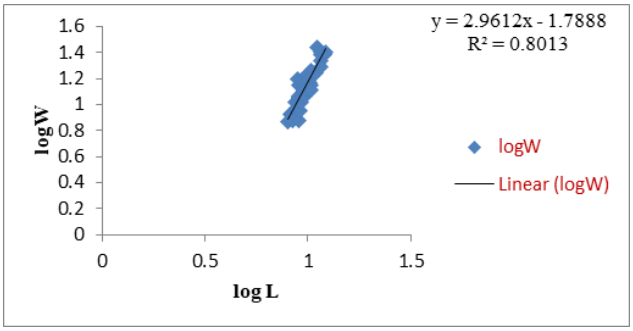

Figure 4b: Length-weight relationship of *N. nandus* (male) in post-monsoon.

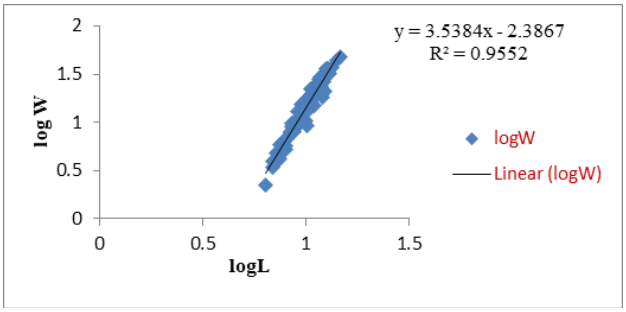

Figure 4c: Length-weight relationship of *N. nandus* (female) in post-monsoon.

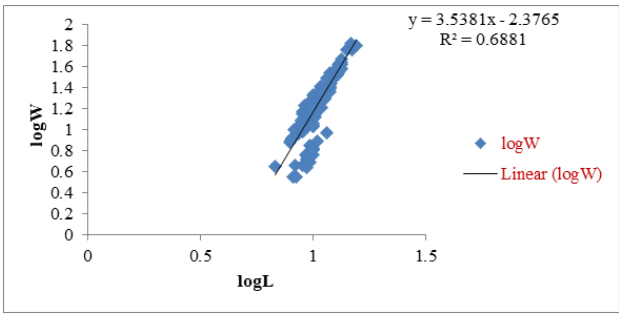

Figure 5a: Length-weight relationship of *N. nandus* (combined sex) in winter.

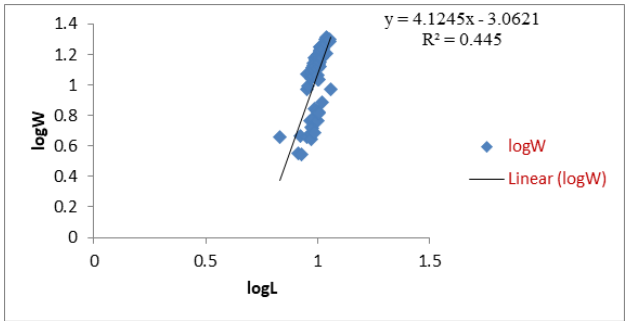

Figure 5b: Length-weight relationship of *N. nandus* (male) in winter.

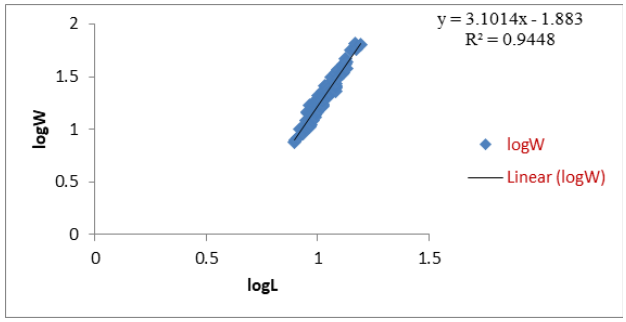

Figure 5c: Length-weight relationship of *N. nandus* (female) in winter.

Seasonal variations in LWRs are also observed for both the sexes of *Nandus nandus*. The calculated b values ranged from 2.961 (post-monsoon) to 4.124 (winter) for males and from 3.102 (winter) to 3.538 (post-monsoon) for females. The logarithmic equations for length-weight relationship for all the groups (males, females and combined sex) in all the seasons are listed in Table 3. The values for co-efficient of determination (R^2) indicate a strongly positive linear relationship between length and weight throughout the year.

Condition factor

The descriptive statistics of the Kn and K for all the seasons are given in the Table-3. The value of Kn ranges from 0.45 to 1.55 (mean value 1.00-1.07) for males, from 0.60 to 2.01 (mean value 1.00-1.01) for females whereas the same for the combined sexes ranges from 0.36 to 1.63 (mean value 1.00-1.04). The maximum mean Kn value for males and females was recorded as 1.07 (in winter) and 1.01 (pre-monsoon, monsoon as well as post-monsoon), respectively. On the other hand, calculated mean K value ranges from 0.19 (winter) to 2.23 (post monsoon) for males and from 0.85 (post-monsoon) to 2.17 (winter) for females while the same for the combined sexes ranged from 0.53 (winter) to 2.23 (post monsoon).

DISCUSSION

Nandus nandus (Hamilton, 1822) is a prominent indigenous food and aquarium fish found in the floodplain wetlands (‘*beels*’) of upper Brahmaputra basin. During the present study, certain aspects of the important biological features, viz., sex ratio, LFDs, LWRs as well as condition factor of *N. nandus* from this part of the globe have been studied and the observed data for the same are presented in Tables 1-4 and Figure 1 (a and b), 2(a-c), 3(a-c), 4(a-c) and 5(a-c).

To understand the ecological and life history traits of a fish population, LFD analysis is crucial.[18] In the present

Table 4: Relative condition factor (Kn) and Fulton’s condition factor (K) for *Nandus nandus* from Upper Brahmaputra basin, Assam, NE India.

Seasons	Sex	Kn			K		
		Minimum	Maximum	Mean value±SD	Minimum	Maximum	Mean value±SD
Pre-monsoon	Male	0.86	1.32	1.00±0.09	1.28	1.97	1.49±0.14
	Female	0.79	1.24	1.01±0.10	1.30	2.11	1.65±0.17
	Combined	0.80	1.33	1.00±0.10	1.28	2.11	1.57±0.17
Monsoon	Male	0.92	1.07	1.00±0.05	1.29	1.69	1.54±0.12
	Female	0.76	1.17	1.01±0.08	1.18	1.91	1.62±0.16
	Combined	0.77	1.16	1.00±0.08	1.18	1.91	1.59±0.15
Post-monsoon	Male	0.69	1.50	1.01±0.14	1.02	2.23	1.50±0.21
	Female	0.62	1.29	1.01±0.12	0.85	1.88	1.47±0.21
	Combined	0.61	1.63	1.02±0.13	0.85	2.23	1.48±0.21
Winter	Male	0.45	1.55	1.07±0.36	0.19	0.53	1.21±0.38
	Female	0.60	2.01	1.00±0.25	1.33	2.17	1.66±0.16
	Combined	0.36	1.50	1.04±0.22	0.53	2.17	1.51±0.33

study, in case of LFDs, no significant differences observed in size between the sexes of *Nandus nandus* throughout the study period [Table 2; Figure 1(a and b)] where 10-12 cm TL group found to be the most dominant group for both the sexes as 77% of males and 89% females of its population are represented by this length group.

Likewise, sex ratio is an important aspect of the population dynamics of a fish species where it is presumed that there are equal numbers of males and females in the population. Though deviation of sex ratio from 1:1 is not expected for a natural population of a fish species, some fish populations may show strong deviation from this ratio. During the present study, significant female dominance has been observed in *Nandus nandus* population from this region, with an overall sex ratio of 187 males to 330 females. Moreover, seasonal variation of sex ratio has also observed with female dominance throughout the year except pre-monsoon (Table 2). Earlier workers Das and Zamal, 2000 and Pal *et al.*, 2003 reported male dominance in *Nandus nandus* population while Parameswaran *et al.*, 1971 and Mredul *et al.*, 2021 recorded female dominance in the population of the species elsewhere.[9,19-21] A difference of sex ratio of a fish population could be attributed to a variety of factors including differential growth rate, life span, sex-reversal, diseases and excessive fishing pressure prior to breeding season.[22-25]

Fishes usually continue to grow throughout their life where the weight of the fish increased logarithmically with an increase in length following the Cube law. During the present study, the recorded maximum total length and total body weight of *N. nandus* is 15.6 cm (range 6.4 -15.6 cm) and 65.1 g (range 3.5 to 65.1 g) respectively. The maximum length and body weight of *N. nandus* recorded during the present study is, however, higher than the values reported previously for the species from other parts of the region.[12,13,25,26] A marked variation in total length and body weight has been recorded with respect to the season and sex (Table-1). This difference in length and weight between males and females could be the reason for the significant differences observed in case of slope of length and weight relationship between the two sexes of the species.

The calculated 'b' value of the LWRs of *Nandus nandus* in the present study ranged between 2.961 and 4.124 which is within the suggested typical range for the 'b' values (i.e., between 2.5 and 4.0) for fish species.[27] The calculated b-values of the LWRs of *Nandus nandus* indicate overall positive allometric growth in all the seasons. Higher proficiencies in feeding, availability of food and other associated factors are said to be responsible for positive allometric growth in different species of fishes.[28-34] Abundant food supply in their natural habitat and other favorable factors facilitates rapid growth in fishes while non-availability of food may be a reason for slow growth in some part of the year along with other ecological and physiological factors. Moreover, present findings of LWRs and calculated 'b' values, also suggests that the fish species maintains its shape throughput the study period.

A little variation for the growth co-efficient (b) of *Nandus nandus* has been observed for different seasons and also between the sexes. In case of fish population, the variation in 'b' values depends primarily on the shape and fatness of the species, other factors particularly quality and quantity of food, feeding, sex, stages of gonadal developmental, especially the weight of ovary and maturity stage are also responsible for such a variation among the sexes and seasons.[15,27,35-37]

Fish health, condition and fatness can be assessed using the Kn factor, a measure that tracks growth rate and feeding intensity.[38] According to Bagenal and Tesch (1978) larger fish are often in better shape for a given length.[39] Fish with high 'Kn' values are heavier relative to their length whereas those with low 'Kn' values are relatively lighter. Nonetheless, a 'Kn' value >1 denotes improved fish health.[14] The mean 'Kn' value of *Nandus nandus* for both the sexes is found to be in the range of 1.00-1.07 during the period of study with no significant seasonal variation. On the other hand, the 'K' value for the species (male, female and combined) found to be varying seasonally with a minimum of 0.19 in winter to a maximum of 2.23 in post-monsoon. However, the calculated mean 'K' value of *Nandus nandus* exhibits little seasonal variation within a narrow range of 1.21-1.66 and also shows little variation between the sexes. A seasonal change in K value may be considered to be associated with sexual maturation in fish.[40] Moreover, this illustrates how gonad weight affects the K value in fishes while other factors such as availability of food, flooding, heat, change in temperature, pH, presence of contaminants in water, etc. are also responsible for variation in condition factors.[41]

CONCLUSION

Nandus nadus has been considered as a potential candidate for aquaculture diversification programme. Considering the market prospects of this species as

food and ornamental fish in one hand and the decline in the wild population of this species over the years (as envisaged by poor landing and limited availability) on the other, the findings of the present study will serve as a much-needed set of basic information for further research on different biological aspects for sustainable management and conservation of this species in this region. Additionally, these findings will provide an input towards studies on other life history traits of *Nandus nandus* as well as their captive rearing and breeding programmes for utilization of the species in a more sustainable way.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

NE: North East India; **LC:** Least Concern; **IUCN:** International Union for Conservation of Nature; **LFD:** Length- Frequency Distributions; **LWR:** Length-Weight Relationship; **TL:** Total Length; **BW:** Body Weight; **cm:** centimeter; **g:** gram; **SD:** standard deviation.

SUMMARY

The present communication highlights the findings of the study on selected biological aspects, viz., sex ratio, LFDs, LWRs and condition factors of *Nandus nandus*, a prominent economically important indigenous fish species of the upper Brahmaputra basin, Assam. Observations on sex ratio indicate a significant female dominance in the population of Nandus nandus and also suggest no significant size difference between the sexes of this species. Correlation and regression analysis between the total length and total weight shows highly significant ($p<0.01$) relationships for both the sexes of the species. Logarithmic equations for length-weight relationship and the R^2 values reflect a strongly positive linear relationship between length and weight of the species throughout the year. The estimated b values also show seasonal variation though exhibit positive allometric growth for most part of the year. The mean 'Kn' value for both the sexes recorded in the range of 1.00-1.07 with no significant seasonal variation. However, the calculated mean 'K' value exhibits little variation (within a narrow range of 1.21-1.66) sex-wise and also between different seasons. The findings of this study would be helpful in better understanding of the biology of this species and provide scope for further research involving other life history traits as well as development of captive breeding protocol for mass propagation of this commercially important species augmenting their population sustainability in this region.

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