Panda *et al. The Journal of Basic and Applied Zoology* (2021) 82:17
https://doi.org/10.1186/s41936-021-00216-z

The Journal of Basic and Applied Zoology

RESEARCH Open Access

Temporal morphometric analyses of *Pila globosa* in India for its use in aquaculture and food industry

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Abstract

Background: Although the apple snail *Pila globosa* is used as indicator species for human consumption locally and as fish feed, research on it in general is very scanty. It is used in food industry, in aquaculture as fish bait and used as food in many regions of India and many other countries, but research on it has been started in the 1970s. Only 40 articles are available on this organism in PubMed indicating an urgent need of basic research on it especially work on its spatiotemporal morphometry Therefore, sampling of *P. globosa* was done from different parts of India in different seasons (summer, winter and rainy), and different morphometric studies were performed on this organism to draw baseline information. Analysis was conducted to study morphometry, the relationship between shell length and the weight and relative condition factor of Indian apple snail *Pila globosa* collected from five zones (east, west, north, south and centre) of India during 2018–2019 year.

Results: The shell length (SL) (46.5 ± 13.33), shell width (SW) (40.22±11.5 mm), spire length (SPL) (2.99±0.15 mm), base length (BL) (12.53±2.94 mm), aperture length (AL) (21.95±4.36 mm), aperture width (AW) (2.74±0.47 mm) and shell weight (WT) (31.08±13.76 g) were observed to be varied among the individual sampled across India. Different relationships for SL/SW (Log SW=0.9889 Log SL + 0.9444), SL/SPL (Log SPL = 0.1452 Log SL+0.3815), SL/BL (Log BL= 0.7789 Log SL+0.5814), SL/AL (Log AL= 0.6518 Log SL+0.9111) and SL/AW (Log AW=0.4475 Log SL+0.1422) were observed by considering shell length as basic index. The relationship between shell length and shell weight was found to be Log WT=2.0263 Log SL+0.1098. The relative condition factor revealed uninterrupted and good environmental condition observed for apple snails. A negative allometric growth pattern was observed from the length–weight relationship.

Conclusion: The environments of apple snail in India are not contaminated, and the results can be used as baseline data in aquaculture for model analysis and can be used as a reference for drawing relationship among different morphometric indices of *P. globosa* in India, as there is no such information available on it. The data can also be used for mass scale production of *P. globosa* for consumption by human and use in aquatic industries as fish feed.

Keywords: Allometric growth, Apple snail, Fisheries, Length–weight relationship, Morphometry, Mollusc shell, *Pila globosa*

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Background

The phylum Mollusca is the second largest phylum after Arthropoda in the animal kingdom, and Gastropoda is the largest class in Mollusca. *Pila globosa* is one of the members of Gastropoda, and being amphibious in habitat, it inhabits both terrestrial and aquatic life moreover during starvation period and active period, respectively (Parveen et al., 2020; Prasuna, Narasimhulu, Gopal, Rao, & Rao, 2004; Swarnakar, Chowdhury, & Sarkar, 1991). *P. globosa* is also commonly known as the Indian apple snail because of its wide distribution in India especially in northern India. Being an important species in the freshwater ecosystem, it is used as a bio-indicator to study pollution, and also, it has clinical implications (Bhattacharya, Swarnakar, Mukhopadhyay, & Ghosh, 2016; Prasad et al., 2019). Owing to the importance of the species *P. globosa* and other snails, different aspects of these organisms are studied for its possible use in aquaculture industry (David, Mushigeri, & Prashanth, 2003; Mahilini & Rajendran, 2008; Ray, Bhunia, Bhunia, & Ray, 2013)

Morphometric studies provide paramount baseline data that can be used to quantify a trait of evolutionary significance and its use in aquaculture industry (Devi & Jauhari, 2008; Gu et al., 2019; Hirano, Kameda, Kimura, & Chiba, 2014; Kocot, Todt, Mikkelsen, & Halanych, 2019; McDougall & Degnan, 2018; Paital, 2018; Tirado, Saura, Rolán-Alvarez, & Quesada, 2016; Vaux et al., 2018). Changes in the shape of animals give basic information to deduce relevant data on their ontogeny, function or evolutionary relationships, even physiology, and finally, their possible exploitation in aquaculture (Lozouet & Krygelmans, 2016; Dominguez & Abdala, 2019). A major objective in morphometrics is to statistically test hypotheses about the factors related from production to reproduction (Soares & Simone, 2019; Thorson et al., 2017; Van Bocxlaer, Ortiz-Sepulveda, Gurdebeke, & Vekemans, 2020; Vinther, Parry, Briggs, & Van Roy, 2017). Since length and width of the animal determines the body shape, the morphometric analyses can be used as a tool for drawing relationships among morphological parameters such as shell length, shell width, spire length, aperture length and aperture width that may be useful for taxonomy in aquatic organisms in general and in snails in particular (Dominguez & Abdala, 2019; Naresh, Krupanidhi, & Rajan, 2013; Okabe & Yoshimura, 2017; Xu, Wu, Wang, Yang, & Yan, 2019). The relationships between length and weight of the body are most crucial in every organism as it can be useful to determine its growth pattern as well as the condition of its habitat (Dominguez & Abdala, 2019). From age old, *P. globosa* is found to be used as diet due to its low fat and high protein content (Krishnamoorthy, 1968); therefore, its mass culture is recommended. Moreover, the relation between length and weight can be applied in the field because measuring the length in the field is easier than measuring weight of animals (Dominguez & Abdala, 2019).

Albeit 2290 hits are observed when searched with the term *P. globosa* as of the end of August 2020 in PubMed, only 39 articles contributed to its physiology and other aspects, and only a single article is available on its morphology. It indicates that, although the species has multiple consumption and aqua feed values, research on this species especially on its morphology is desirous (Dempsey, Burg, & Goater, 2019; Neiber & Hausdorf, 2015). Although many morphometric studies investigated on fishes, a scanty amount of literature was available on molluscs in general and on *P. globosa* in particular. Among the molluscs, most investigated on prosobranchs, but there are a very few literature available on apple snails especially on Indian apple snail *P. globosa*. Saha et al. (2016a, b) investigated morphometric analysis with the relationship of length to weight of apple snail in Bangladesh. Sarkar and Krupanidhi (2018) studied the length, weight and breadth of *P. globosa* with other gastropods through regression analyses. Similarly, despite the presence of a high population in India, Meganathan and Jeevanadham (2017) conducted length–weight relationships on *P. globosa* at Tamil Nadu which seems one and only such type of investigation in India. Along with length–weight relationship, we therefore established the relationships among other essential parameters additionally. For example, we have studied relative condition factor as well as Fulton's condition factor and their relationships with shell length in Indian apple snails collected from the five different major zones of India. Results can be used as reference for future research on *P. globosa* in India on temporal and spatial basis.

Methods

P. globosa were sampled randomly from five zones of India, i.e., from Uttar Pradesh, Gujarat, Tamil Nadu, Odisha and Madhya Pradesh as northern, western, southern, eastern and central zones respectively in rainy, winter and summer seasons during the year 2018–2019. A total of 149 snails (both male and female without distinct separation) were selected for suitable morphometric analysis. For morphometric analysis, shell length (SL), shell width (SW), spire length (SL), base length (BL), aperture length (AL), aperture width (AW) and weight of snails were measured as per Saha et al. (2016a, b) (Fig. 1). Weight of the snails was measured in the weighing machine while all other measurements were performed with the help of the Vernier slide callipers. Linear regression analyses were done considering all the above studied parameters, and relationships among them

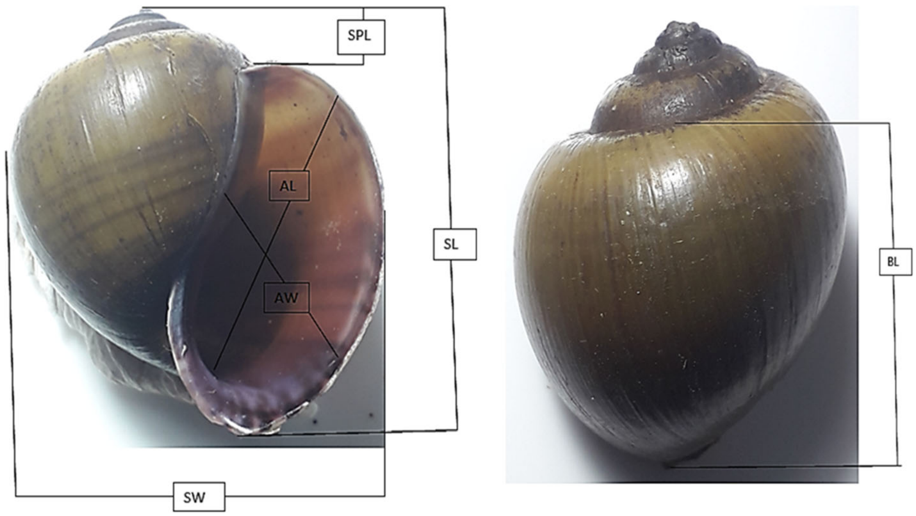

Fig. 1 Schematic diagram of apertural (**a**) and abapertural (**b**) view of shell of *Pila globosa* with parameters selected for morphometric analysis

were established by counting SL as basic index. Correlation and linear regression was calculated according to Agrawal (1988). Peterson polygon method was applied to perform size frequency distribution with 10-mm class interval.

The relationship of length to weight was established by converting aL^b (Le Cren, 1951) into logarithmic form which is Log WT= Log a+ b Log SL, where SL is the length, WT is the weight and "a" is the constant and an exponent. The values of "a" and "b" were determined imperially from data. The relative condition factor was calculated (K_n) by the formula $K_n = K_O/K_C$ where K_O and K_C are ecological factors from the observed value and calculated values, respectively. K_O was determined empirically from the values "a" and "b" in the relationship graph of length to weight. Fulton's condition factor (K) was determined by the formula $K=100W/L^b$ (Bagenal & Tesch, 1978) where K is Fulton's condition factor while W and L are the weight and length in grammes and millimetres respectively, where "b" is the constant that was calculated empirically from the data.

Statistics

Data are presented as mean ± S.D. values of 149 samples. Correlation and other calculations described above were done using Microsoft Excel version 2010.

Results and discussion

Since the sampling was done throughout different seasons, the obtained data are represented as function of annual distribution. Although the relationship of shell length to weight of the animal varied according to the changing environment as well as availability of food, factor "b" being the peculiar characteristic of every animal does not vary to a large extent. However, factor "a" can be changed by the influence of habitats (Santos, Gaspar, Vasconcelos, & Monteiro, 2002).

Size frequency distribution

A size frequency distribution graph of a total of 149 snails is presented in the Fig. 2 at 10-mm class interval. The significance variation of size in frequency distribution graph shows relative abundance of this species with respect to size and shell length in concerned habitats. It indicates the dynamic nature of the snail which may be due to the effects of environment as well as availability of the food resources. Size frequency distribution revealed that shell lengths of most of the snails were varied within 40 to 60 mm, whereas the highest frequency was observed within the range between 50 and 60 mm. Out of 149 samples, 148 snails were found below 80-mm length, whereas only a single snail was found to have length between 90 and 100 mm. There were no snails found having shell lengths in the range at 0–10-mm, 70–80-mm and 80–90-mm class intervals. Briefly, the size frequency distribution curve shows heterogeneousness of the apple snail population resulting in confirmation of the presence of different age groups and a balanced population (Saha et al., 2016a, b).

Length of snails

The SL value was found to be varied from 11.13 to 98.35 mm with an average of 46.5 ± 13.33 mm. The SW value ranged from 9.59 to 85.36 mm with an average 40.22 ± 11.5 mm. Minimum spire length was found to be 2.47 mm, and maximum spire length was found to be 3.36 mm with an average 2.99 ± 0.15 mm. Base length was found to be varied from 4.14 to 22.36 mm with an average 12.53 ± 2.94 mm. The AL ranged from 8.49 to 35.61 mm with an average 21.95 ± 4.36 mm. The AW was

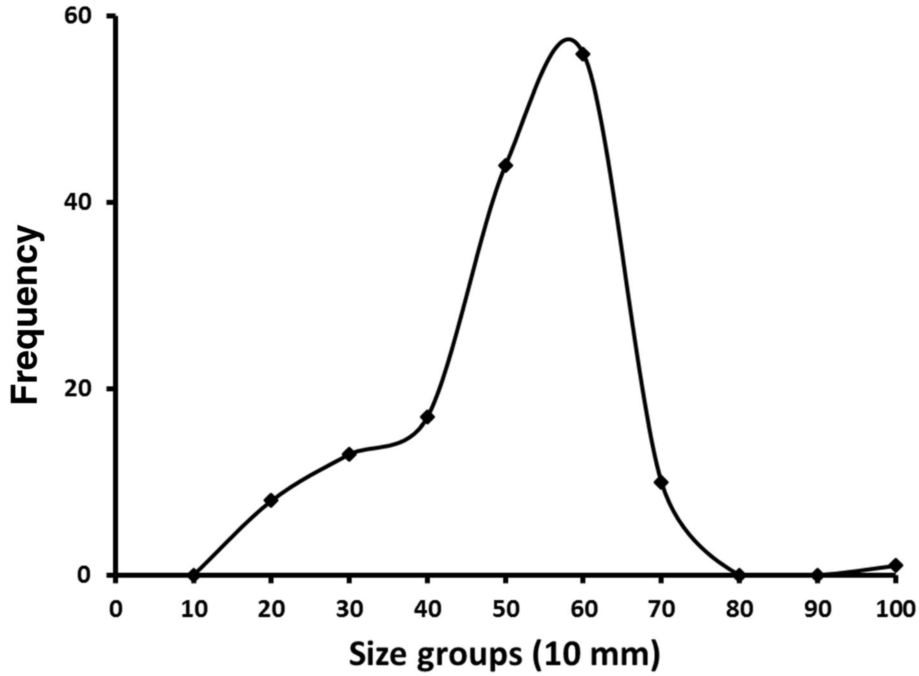

Fig. 2 Size frequency distribution of *Pila globosa* sampled from different locations of India

found to vary from 1.25 to 3.65 mm with an average 2.74 ± 0.47 mm. The WT value varied from 0.91 to 88.29 g with an average 31.08±13.76 g.

Correlation results

The correlation and linear regression analyses of all the parameters are presented in Table 1. The correlation coefficient (*r*) shows that a positive and strong correlation was observed among all the parameters; however, the relationship between shell lengths and aperture width was found to be weakly correlated as compared to other studied parameters. A very high correlation coefficient value observed implies the strong relationships among the parameters especially the relationship of shell length against body weight, although weak relationships were found between the shell lengths and aperture width.

Table 1 Results of establishment of relationships between different parameters of *Pila globosa* through correlation and regression studies

Parameters	*a*	*b*	Correlation coefficient (*r*)
SL/SPL	1.46448	0.1452	0.98
SL/BL	1.788541	0.7789	0.994
SL/AL	2.487057	0.6518	0.998
SL/AW	1.152807	0.4475	0.838
SL/WT	1.116055	2.0263	0.983
SL/SW	1.152807	0.4475	0.997

The shell length (SL), shell width (SW), spire length (SPL), base length (BL), aperture length (AL), aperture width (AW) and shell weight (WT) were analysed by taking shell length as basic index. The relationship between shell lengths and shell weight Log WT, The abreviations "a" and "b" are two constants drwan form the equation Log WT= Log a+ b Log SL

Relationships among parameters

Shell width to length was established (Fig. 3) by the equation Log SW=0.9889 Log SL + 0.9444 (Fig. 3b). The relationship between spire length and shell length was expressed by Log SPL = 0.1452 Log SL+ 0.3815 (Fig. 3c). Base length and shell length were related with an equation Log BL=0.7789 Log SL+0.5814 (Fig. 3d). Aperture length–shell length relationship was established by the formula Log AL= 0.6518 Log SL+0.9111 (Fig. 3e). The aperture width was related to the shell length by the equation Log AW=0.4475 Log SL+0.1422 (Fig. 3f).

Weight–length relationship

Weight to length relationship was established by linear relationship by the logarithm of length to logarithm of weight graph, and the established equation was found as Log WT=2.0263 Log SL+0.1098 with "*r*" value 0.983 that implies a strong correlation value (Fig. 3a). Works on *P. globosa* by Saha et al. (2016a, b) in Bangladesh found that the value of "*b*" was 2.29 in the combined sex as compared the values 2.0263 observed in the present study. The value of *b* was also found less than three in the sand lobster, *Thenus orientalis* (Hossain, 1985), that correlates the present finding. Muley (1978) also found the same range of *b* value as 2.63 with proportional growth in freshwater prosobranch *Melania scabra*. For isometric growth, the *b* value should be equal to three

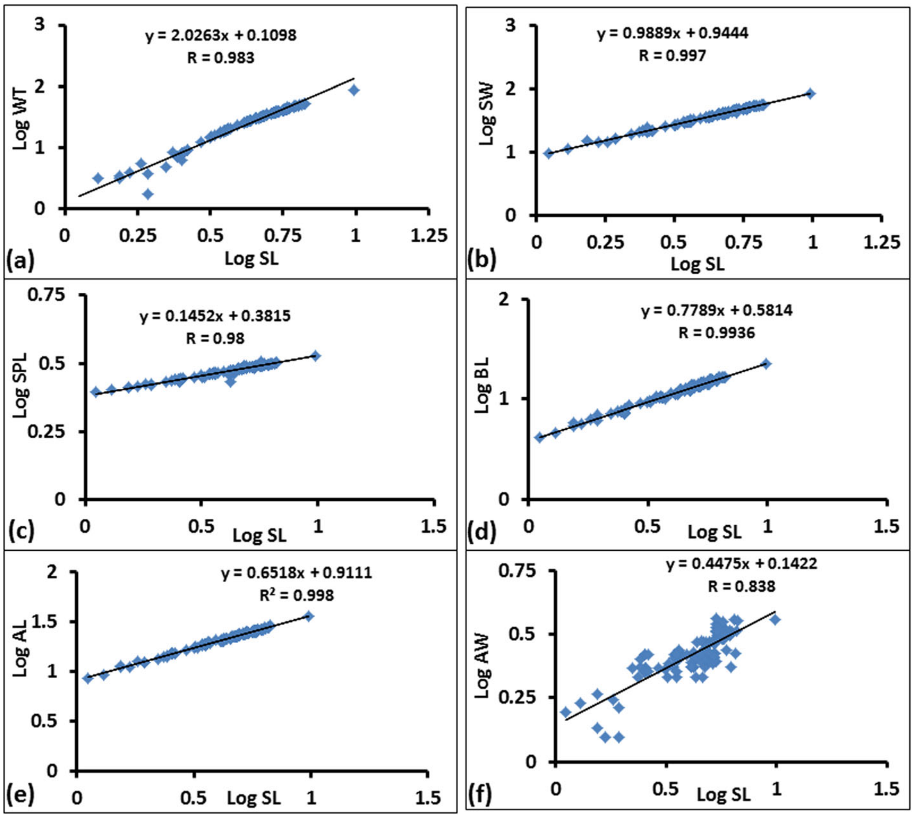

Fig. 3 Relationships between different parameters by taking logarithm of parameters. WT, shell weight; SW, shell width; SL, shell length; SPL, spire length; BL, base length; AL, aperture length; and AW, aperture width

which follows cube law, but frequency of such results are very rare with few exceptions as observed by Prasad and Ali (2007) on cyprinid fish. Jaiswar and Kulkarni (2002) also found the value of *b* in molluscs ranging from 2 to 3.

Similarly, Ngor et al. (2018) found a negative allometric growth in *P. virescens* and *P. ampullacea* with "*b*" value less than three, although the authors also had observed a little higher *b* value during rainy season which may be due to aggregation of nutrients during that period. Therefore, our value of *b* does not show isometric growth but rather shows the negative allometric growth that implies the length of the snail grows faster than weight. This negative allometric growth result implied that the individuals sampled were young individuals because in young individuals the growth of the shell is faster than the growth of the weight. Although factor *b* is influenced by many factors, this type of growth pattern was found in most of the animals especially in snails. The negative allometric growth indicates invasion of the species towards the land area because of its overproduction. But it may become a great hazard in agricultural field especially in paddy fields as *P. globosa* eats seedling of rice and other agricultural plants as diet (Ngor et al., 2018). The overproduction of this species can create intercompetition with other gastropods which may change the dynamic of the freshwater ecosystem because many gastropods are being used as food for many in the freshwater ecosystem. Thus, it can have adverse effects on freshwater ecosystems that may affect human at the end (Saleky, Setyobudiandi, Toha, Takdir, & Madduppa, 2016).

Fulton's condition factor

Fulton's condition factor varied from 0.4 to 1.8 with an average 1.22 ± 0.14 that shows the growth condition of the animal. The graphs of Fulton's factor (Fig. 4) revealed that the continuous growth of the snail was increased up to 40-mm size; then, the cumulative growth of the shell decreased or stops with respect to its weight. It may be due to the use of the energy by the snails for the physiological activities like reproduction rather for growth (Shanmugam, 1997).

Relative conditional factor

The ecological factor from the calculated value (K_C) varied from 1.38 to 114.64 mm with an average of 27.25± 14.22 mm. The relative ecological factor (K_n) was

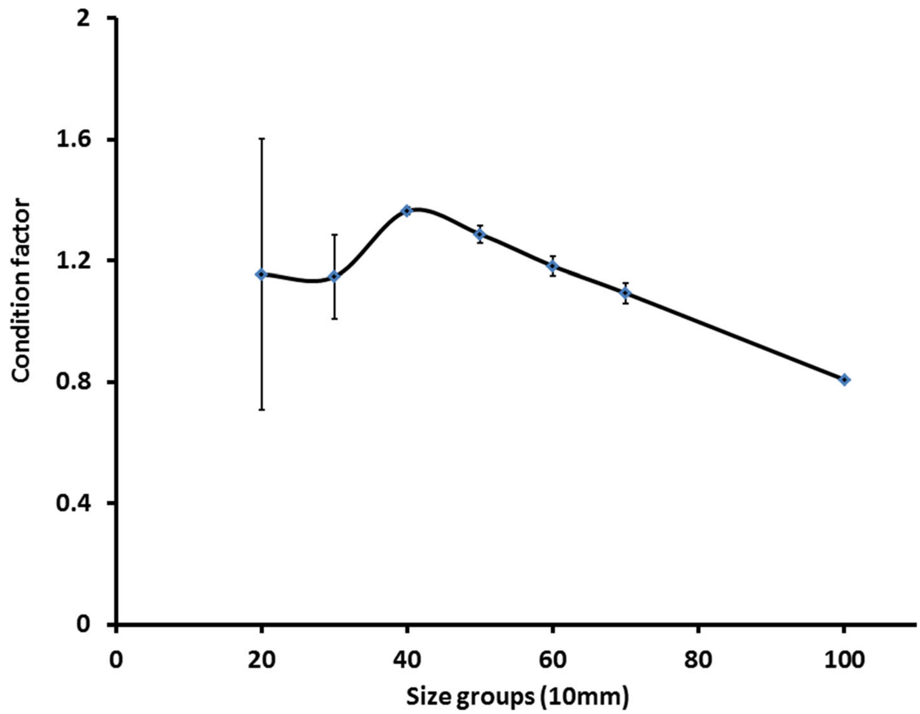

Fig. 4 Relationship between condition factors with different size groups of *Pila globosa*

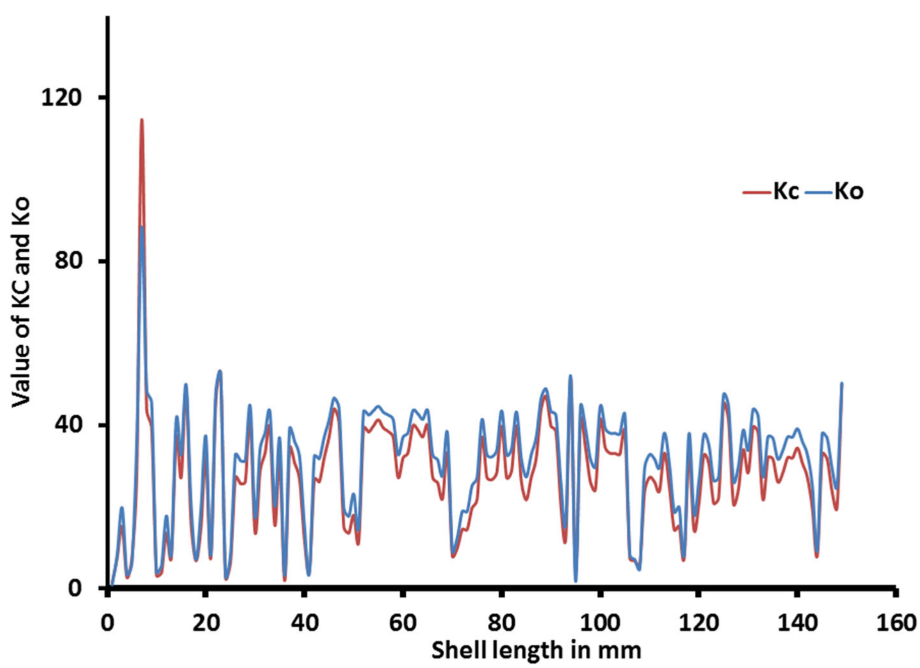

Fig. 5 Relationship between shell length and calculated weight (K_C) and observed weight (K_O)

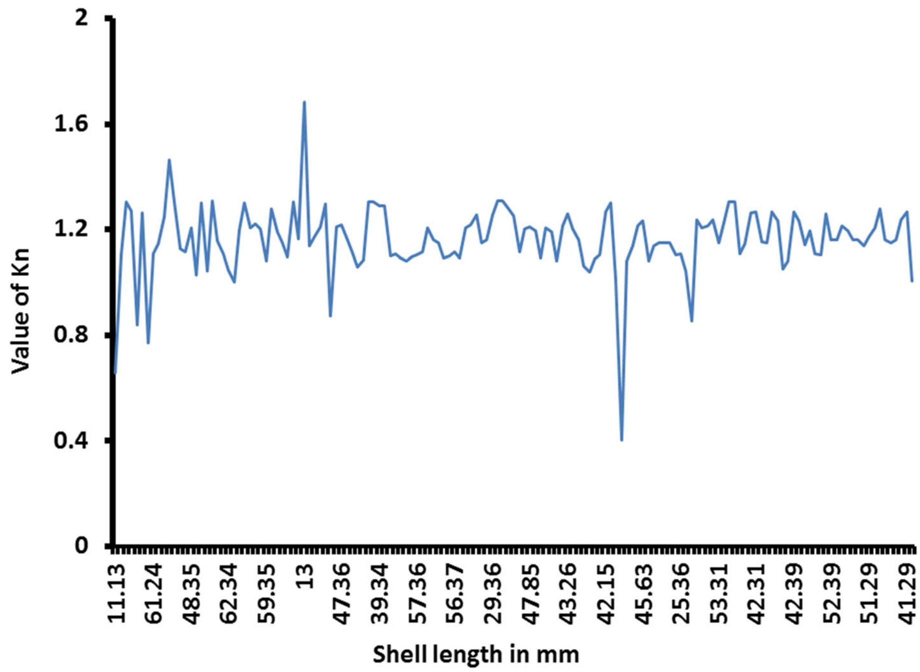

Fig. 6 Relationship between shell length and value of relative condition factor K_n

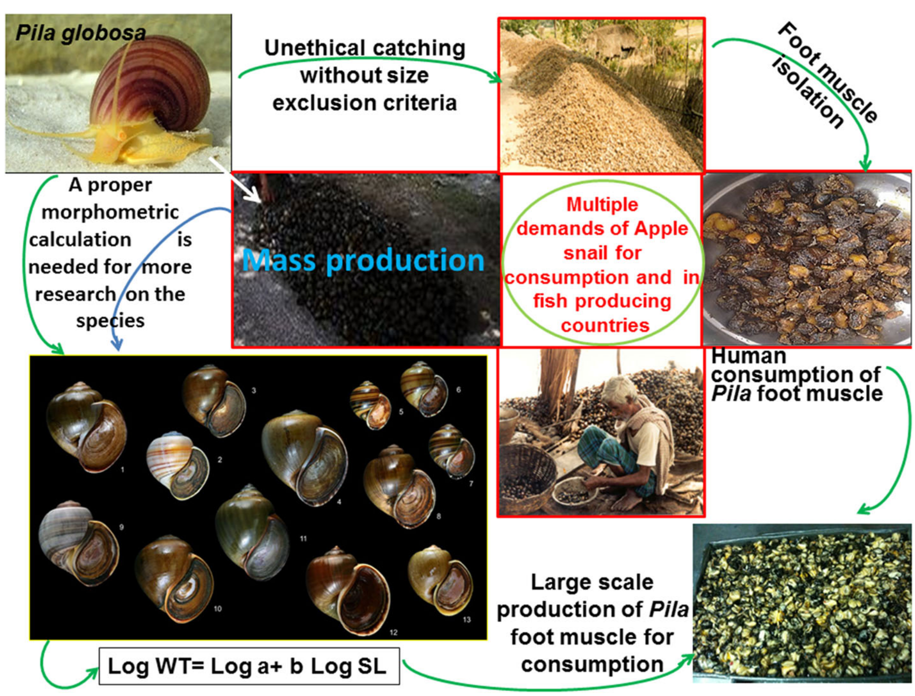

Fig. 7 Mass production of *Pila globosa* for its current and future use. Figure indicates that the apple snail *P. globosa* has a tremendous current use. They are used as fish bait and fish feed in many conventional aquaculture subsystems. For mass production and morphological segregation, a county-wise morphometric study is there for suggested. Pila is directly used for human consumption in many parts across the world. At least 13 varieties of the species are identified and consumed both by human and in aquaculture fields

calculated from the ratio between ecological factor from the observed value to that of calculated value, and it was found to be 1.16± 0.13. The relative ecological factor was found to vary from 0.763 to 1.449 in the combined sex in *P. globosa* (Saha et al., 2016a, b). So, the greater value observed for K_n suggests that the snails were in good conditions. The relationship between shell length and K_O and K_C and K_n is presented in Figs. 5 and 6, respectively.

Conclusions

Results of the present study show negative allometric growth of apple snail, and from the length to weight relationship, the calculated weight of the snail was found to be nearer to the observed weight. It implies that good quantities of vegetation were available in the freshwater for the snails in India. However, this type of growth pattern indicates its invasion possibility that may become a great threat towards the agricultural field and may create disturbance in food chain. It can have adverse effects on freshwater ecosystems through increase in inter-competition with other gastropods (Fig. 7). Thus, proper management strategies or their calculated use in aquaculture sectors is suggested to control the population density of *P. globosa*. Use of this specimen as fish feed is highly recomended. Results of the study may help in illustration of the growth pattern of apple snail that can be used in aquaculture sectors. Being taken as a diet in some parts of India, especially in rural areas experiencing malnutrition, it can be used as an alternative diet if fish is less copious. It will be helpful for improvement of the rearing method as well as selection of brood stocks. Moreover, *P. globosa* can be very useful to monitor the environmental health status. More biochemical studies could be the future approcah for this specimen. Data of the present study can also be useful for other snails for studying their growth patterns. Present study gives a baseline data for the morphometric studies.

Abbreviations

AL: Aperture length; AW: Aperture width; BL: Base length; *K*: Fulton's condition factor; K_C: Ecological factors for the calculated value; K_O: Ecological factors for the observed value; L: Length; SL: Shell length; SPL: Spire length; SW: Shell width; W: Weight; WT: Shell weight

Acknowledgements

Helps rendered by HoD, Department of Zoology for laboratory facilities, and Director CBSH, OUAT, are acknowledged.

Authors' contributions

BRP conceptualized the study, did fund acquisition and project administration and edited the MS. FP collected the data, analysed and interpreted and drafted the MS. SGP, AB, SM and NS interpreted data and edited the MS. All authors read and approved the final manuscript.

Funding

Schemes (number ECR/2016/001984 by the Science Engineering Research Board, DST, Govt. of India, and 1188/ST, Bhubaneswar, dated 01.03.17, ST-(Bio)-02/2017 Department of Biotechnology, DST, Govt. of Odisha, India) to BRP are acknowledged. Fellowships to FP and SGP from the above schemes, respectively, to carry out the work is acknowledged. Fellowship (1264/ST/BT-MISC-0034-2018) to Abhipsa Bal under Biju Patnaik Research Fellowship to pursue Ph.D. course in Biotechnology, by Department of Science and Technology, Government of Odisha, India, is acknowledged.

Availability of data and materials

All data generated or analysed during this study are included in this published article.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interest.

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Received: 11 November 2020 Accepted: 18 March 2021
Published online: 01 April 2021

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