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Morphometry and length-length relationship of *Jagora* spp. collected from the river and stream of Aurora Province, Philippines

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Abstract
The general objective of this study was to determine the shell morphometry of *Jagora* spp. collected from the river and stream of Aurora province, Philippines. Specifically, this study aimed to assess the shell length-length relationship of the snail species. The average shell measurements of *Jagora* spp. were: shell length (SL) = 34.58±24.80 mm, aperture length (AL) = 11.77±8.41 mm, whorl height 1 (WH1) = 4.82±1.62 mm, whorl height 2 (WH2) = 3.93±1.46 mm, whorl height 3 (WH3) = 3.32±1.69 mm, aperture width (AW) = 8.60±6.82 mm, whorl width 1 (WW1) = 13.32±15.26 mm, whorl width 2 (WW2) = 16.08±17.73 mm, body whorl width (BWW) = 19.25±20.15 mm and interior aperture length (AILL) = 6.73±3.73 mm. The correlations of SL to the rest of measurements were very strong or r value is from 0.80 to 0.99. These equations could be used to predict the value of AL ($0.66\ SL^{0.97}$), WH1 ($1.12\ SL^{0.40}$), WH2 ($0.95\ SL^{0.44}$), WH3 ($0.64\ SL^{0.64}$), AW ($0.67\ SL^{0.86}$), WW1 ($0.20\ SL^{1.71}$), WW2 ($0.26\ SL^{1.59}$), BWW ($0.38\ SL^{1.42}$) and AILL ($1.06\ SL^{0.52}$) if SL is given.

Keywords: morphometry, gastropod, *Jagora*, length-length relationship

Introduction

One of the freshwater species under superfamily Cerithioidea is *Jagora* spp. that is recorder in the northern part of the Philippines. This genus was named after the German naturalist and anthropologist Andreas Feodor Jagor (1817-1900), who between 1859 and 1860 travelled through the Philippine archipelago. It can grow up to 50 to mm length and 18 mm width. Its shell is highly towered, usually dark brown in color. The body is gray to black with filiform antennae [1, 2].

Phenotypic plasticity of bivalve shell morphometry has long been reported in a number of literatures [3, 4]. Various ecological factors are known to influence bivalve shell morphometry, including latitude [5], depth of distribution [6], tidal excursion or shore level [7], water movements [8], type of sediment [9] and trophic conditions [10]. Morphological and morphometric studies in snails are important for species identification even in the advent of molecular tools [11]. Likewise, the study of length-weight and length-length relationships is very important and widely practiced tool in the fishery for different purposes, especially in the study of population dynamics, ecology, Taxonomic differences, Event in life history like metamorphosis, maturity and stock management [12-17].

The pragmatic relationship between the shell morphometrics of the pachychilidae as represented by *Jagora* spp. enhances the knowledge regarding the commercially important pachychilidae species. Unfortunately, limited works have been done on the relationship of shell morphometrics of pachychilidae in the Philippines. The general objective of this study was to determine the shell morphometry of *Jagora* spp. collected from the river and stream of Aurora province, Philippines. Specifically, this study aimed to assess the shell length-length relationship of the snail species.

Materials and Methods

Collection and preparation of samples

Forty-five (45) pieces freshwater snail that were morphologically identified as *Jagora* spp. were collected from the river and stream of Maria Aurora, Dingalan and Dipaculao in the province of Aurora, Philippines. Snail samples were brought home for cleaning and visceral mass removal.

Measurement of shell morphology

A total of 10 shell morphometrics (Figure 1) were measured using a caliper following the works of Sherely [18]. The detailed shell morphometrics and characteristics are shown in Table 1.

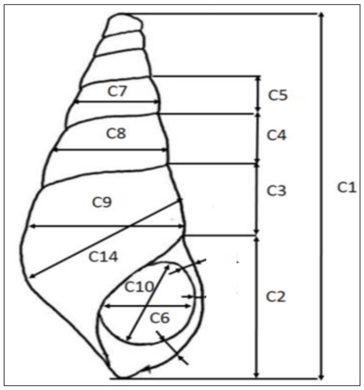

Fig 1: Shell characteristics that were considered in this study (Sherely, 1996)

Table 1: Abbreviations and descriptions of Pachychilidae shell morphometrics (Sherely, 2006)

Measurement Number	Abbreviation	Description
C1	SL	Shell length: Maximum length of shell
C2	AL	Aperture length: maximum outside dimension of the aperture measured along an offset line to the right of the long axis of the shell
C3	WH1	Whorl height: measured from the intersection of the outside margin of the apertural lip and the edge of the periostracum on the first whorl that meets the apertural lip to the suture between adjacent whorls
C4	WH2	Whorl height: between top and bottom sutures of adjacent whorls
C5	WH3	Whorl height: between top and bottom sutures of adjacent whorls
C6	AW	Aperture width: maximum width of the aperture measured from the line demarcating the edge of the periostracum on the columella to the outer edge of the apertural lip
C7	WW1	Whorl width: dimensions were taken along lines parallel to the sutures from the midpoints of arcs formed by the outer edges of successive whorls
C8	WW2	Whorl width: dimensions were taken along lines parallel to the sutures from the midpoints of arcs formed by the outer edges of successive whorls
C9	BWW	Body whorl width: dimensions were taken along lines parallel to the sutures from the midpoints of arcs formed by the outer edges of successive whorls
C10	AINL	Interior aperture length: maximum interior length of the aperture measured from the interior edges of the apertural lip

Determination of degree of association between shell measurements

The degree of association between the shell length (SL) and aperture length (AL), whorl heights (WH), aperture width (AW), whorl width (WW), body whorl width (BWW) and interior aperture length (AINL) was based on the computed correlation coefficient (*r*) using trendline analysis in Microsoft (MS) Excel. The interpretation of correlation coefficient scale is provided in Table 2.

Table 2: Correlation coefficient scale

+ r values	Positive	- r values	Negative
1.00	Perfect	1.00	Perfect
0.80-0.99	Very strong	0.80-0.99	Very strong
0.60-0.80	Strong	0.60-0.80	Strong
0.40-0.60	Moderate	0.40-0.60	Moderate
0.20-0.40	Weak	0.20-0.40	Weak
0.00-0.20	Very weak	0.00-0.20	Very weak

Estimation of shell length-length relationship

The length-length relationship of the snail samples was estimated using the formula:

$X = e^a (SL^b)$.

Where:
SL = shell length in mm
X = the other lengths in mm (AL, WH, AW, WW, BWW and AINL)
a = intercept
b = slope

Results and Discussion

Measurement of shell morphology

Provided in Table 3 are the shell measurements of 45 pieces of *Jagora* spp. that were collected in the river and stream of Maria Aurora, Dingalan and Dipaculao in the province of Aurora, Philippines. Ten (10) shell measurements were considered in this study namely shell length (SL), aperture length (AL), whorl height 1 (WH1), whorl height 2 (WH2), whorl height 3 (WH3), aperture width (AW), whorl width 1 (WW1), whorl width 2 (WW2), body whorl width (BWW) and interior aperture length (AILL).

The snail SL ranged from 17.5 to 79.0 mm (34.58±24.80 mm) with 21 mm as the most common; AL was from 6.0 to 29.0 mm (11.77±8.41 mm) with 15 mm as the most frequent; WH1 was from 3.5 to 9 mm (4.82±1.62 mm) with 4 and 5 mm as the dominant; WH2 fluctuated from 3.0 to 8.0 mm (3.93±1.46 mm) with 3 mm as foremost; WH3 ranged from 2.0 to 8.0 mm (3.32±1.69 mm) with 2.5 mm as the most frequent; AW was recorded from 4.0 to 27.0 mm (8.60±6.82 mm) with 5 mm as the dominant width; WW1 ranged from 3.0 to 42 mm (13.32±15.26 mm) with 4 mm as the leading width; WW2 ranged from 5.0 to 53.0 mm (16.08±17.73 mm) with 15 mm as the most common; BWW was from 6.5 to 65 mm (19.25±20.15 mm) with 7.5 mm as the most frequent; and AILL varied from 4.5 to 20.0 mm (6.73±3.73 mm) with 5 mm as the dominant (Table 3).

Table 3: Average shell measurements of *Jagora* spp. collected from the river and stream of Aurora Province, Philippines.

Shell Morphometry	Average Measurement (mm)
Shell Length (SL)	34.58±24.80
Aperture Length (AL)	11.77±8.41
Whorl Height 1 (WH1)	4.82±1.62
Whorl Height 2 (WH2)	3.93±1.46
Whorl Height 3 (WH3)	3.32±1.69
Aperture Width (AW)	8.60±6.82
Whorl Width 1 (WW1)	13.32±15.26
Whorl Width 2 (WW2)	16.08±17.73
Body Whorl Width (BWW)	19.52±20.15
Interior Aperture Length (AILL)	6.72±3.73

Species discrimination can be done through shell morphology and morphometric variations [19]. Morphological and morphometric studies of gastropod shells are important, even though present-day molecular technology is widely used to identify organisms precisely [11]. The usage of morphometric analysis has obtained wide acceptance in the current biological scene as it is increasingly used as a necessary complement to molecular studies due to its reasonable cost and tolerable resolving power of discrimination. Species identification can be done *in-situ* based on morphological observation and this helps to avoid the misidentification of species [20]. Common shell characteristics used in morphometric studies are shell length, shell width, body whorl length, penultimate whorl width, aperture length and aperture width [21].

There were no available published studies on the shell morphometrics of *Jagora* spp., thus, it is impossible to compare the generated morphometrics from this present study. In several studies, bivalve shell morphometry is influenced by ecological factors such as latitude [5], depth of distribution [6], tidal excursion or shore level [7], water movements such as waves, turbulence and currents [8], type of sediment [9] and trophic conditions [10]. Morphometric studies are valuable for the identification of the specimens [11].

Determination of degree of association between shell measurements

A correlation coefficient measures the statistical relationship between two variables, in this case, the correlation between SL and the rest of shell morphometrics. The correlations of SL to all measurements were very strong or r value is from 0.80 to 0.99 (SL-AL = 0.99, SL-WH1 = 0.88, SL-WH2 = 0.88, SL-WH3 = 0.93, SL-AW = 0.88, SL-WW1 = 0.99, SL-WW2 = 0.99, SL-BWW = 0.98 and SL-AILL = 0.80). All paired variables showed direct relationship as indicated by positive b values (SL-AL = 0.97, SL-WH1 = 0.40, SL-WH2 = 0.44, SL-WH3 = 0.64, SL-AW = 0.86, SL-WW1 = 1.71, SL-WW2 = 1.59, SL-BWW = 0.142 and SL-AILL = 0.52), thus, an increase of 1 unit in the X variable will result to a certain unit of increase in the Y variable (Table 4). The first three highest r value was recorded between SL-AL, SL-WW1 and SL-WW2, thus, the value of AL, WW1 and WW2 could be best predicted given that SL is known. The generated r and b values in this study are impossible to compare because of unavailability of literatures.

Table 4: Intercept (a), slope (b), coefficient of determination (r^2) and correlation coefficient (r) of the paired shell morphometrics.

Paired Variable	a	b	r^2	r
SL-AL	-0.42	0.97	0.98	0.99
SL-WH1	0.11	0.40	0.77	0.88
SL-WH2	-0.05	0.44	0.77	0.88
SL-WH3	-0.44	0.64	0.87	0.93
SL-AW	-0.40	0.86	0.78	0.88
SL-WW1	-1.63	1.71	0.98	0.99
SL-WW2	-1.36	1.59	0.98	0.99
SL-BWW	-0.97	1.42	0.97	0.98
SL-AILL	0.06	0.52	0.64	0.80

Length-length relationship equation

In Table 5, the summary of length-length equations are provided. These equations could be used to predict the value of AL (0.66 $SL^{0.97}$), WH1 (1.12 $SL^{0.40}$), WH2 (0.95 $SL^{0.44}$), WH3 (0.64 $SL^{0.64}$), AW (0.67 $SL^{0.86}$), WW1 (0.20 $SL^{1.71}$), WW2 (0.26 $SL^{1.59}$), BWW (0.38 $SL^{1.42}$) and AILL (1.06 $SL^{0.52}$) if SL is given. The first three highest r value was recorded in pairs SL-AL, SL-WW1 and SL-WW2, thus, the value of AL, WW1 and WW2 could be best predicted using the length-length equation provided that SL is known.

Table 5: Length-length relationship (LLR) equation of the paired shell morphometrics.

Paired Variable	LLR Equation
SL-AL	$AL = 0.66\ SL^{0.97}$
SL-WH1	$WH1 = 1.12\ SL^{0.40}$
SL-WH2	$WH2 = 0.95\ SL^{0.44}$
SL-WH3	$WH3 = 0.64\ SL^{0.64}$
SL-AW	$AW = 0.67\ SL^{0.86}$
SL-WW1	$WW1 = 0.20\ SL^{1.71}$
SL-WW2	$WW2 = 0.26\ SL^{1.59}$
SL-BWW	$BWW = 0.38\ SL^{1.42}$
SL-AILL	$AILL = 1.06\ SL^{0.52}$

It is necessary to use standard measures for all populations to render the results more reliable when making comparisons between populations. Therefore, the length- length relations of species under various environmental conditions should be known. The length-length relationship is also of great importance for comparative growth studies [22]. In fisheries studies, length can often be measured more rapidly and easily than mass. The knowledge of the length-weight relationship makes it easier to determine the mass where only the length is known [22].

Conclusion

The correlations of shell length (SL) to the rest of measurements (AL = aperture length, WH1 = whorl height 1, WH2 = whorl height 2, WH3 = whorl height 3, AW = aperture width, WW1 = whorl width 1, WW2 = whorl width, BWW = body whorl width and AILL = interior aperture length) were very strong or r value is from 0.80 to 0.99. These equations could be used to predict the value of AL (0.66 $SL^{0.97}$), WH1 (1.12 $SL^{0.40}$), WH2 (0.95 $SL^{0.44}$), WH3 (0.64 $SL^{0.64}$), AW (0.67 $SL^{0.86}$), WW1 (0.20 $SL^{1.71}$), WW2 (0.26 $SL^{1.59}$), BWW (0.38 $SL^{1.42}$) and AILL (1.06 $SL^{0.52}$) if SL is given.

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