CHAPTER - 2

Diagnostic Characters, Morphometry and Annual Breeding Cycle
INTRODUCTION

Rana cyanophlyctis Schneider is closely related to Rana hexadectyla Lesson, though it is smaller in size and possesses perfectly webbed toes. The systematic position of Rana cyanophlyctis is as follows:

- Phylum: Chordata
- Sub-Phylum: Gnatostomata
- Class: Amphibia
- Order: Anura
- Sub-order: Phaneroglossa
- Series: Firmisternia
- Sub-family: Ramidae
- Genus: Rana Linnaeus
- Species: cyanophlyctis Schneider

The first record of this species was made as early as 16th century when Emperor Babar, noticed that it skips over the surface of water like ricocheting stone (Daniel, 1975). Because of this peculiar habit it is popularly called "water skipper" or "skipper frog" and due to its aquatic habit it is also called "Tani Benga" or "water frog". It is a common and most easily available species inhabiting different biotopes throughout the Indian sub-continent. It is often seen floating on the surface
Fig. 2: A female *Rana cyanophlyctis* Schneider.
or squatting along the edges of many ponds, rain puddlers, tanks, streams, temporary, perennial, running or stagnant clear or foul waterbodies and other such stretches. Annandale (1917) recorded them at Quetta (Pakistan) floating on a water body whose edges were frozen. McCann (1933) recorded them from cisterns and open gutters where the water was very foul, full of refuse, often discoloured with saffron curry material. He noticed them to move away from the drains when hot water was poured and returned when the water cooled. Daniel (1975) has reported them from water bodies having industrial effluents and brackish water.

Satyamurti (1967) has provided a detailed description of this species from South India and has mentioned it to be a widely distributed species from Malay Peninsula, up to Arabia including Nepal, India, Pakistan, Afghanistan, Iran, Iraq, and Bangladesh, and in the north from Himalayas to Sri Lanka in south. Boulenger, Annandale Wall and Regan (1907) recorded it at an altitude of 4,500 to 6,400 feet above sea level (a.s.l.) at the hills from Bhimtal and Nainital. Acharji and Kriplani (1951) recorded it at Kangra and Kulu valleys in Darjeeling District and other parts of Eastern Himalayas at 6,000 feet a.s.l. Annandale (1909) recorded it at Kotagin and Nilgiri hills from 5,700 feet a.s.l. It is a common species of frog.
available in North-Eastern hills of India, Assam, Arunachal Pradesh and Manipur (Pillai and Chanda, 1976).
In the present investigation, the frog has been recorded in abundance at Gauhati as well as at Shillong throughout the year.

Although detailed contributions are available on the biology, systematics and distribution of the Rana cyanophlyctis (Boulenger, 1890 and 1920; Annandale, 1909 and 1917; Narayan Rao, 1915 and 1920; McCann, 1933 and 1940; Satyamurti, 1967; Daniel, 1973 and 1975), information on morphometric analysis of the populations available at Gauhati and Shillong are lacking. More and more information has been pouring in on morphometric analysis of different anuran species (see Brown and Boschung, 1954, Duellman and Kluss, 1964; Metter, 1964; Zweifel, 1964 and 1972; Hyers and Peter, 1971; Tyler and Martin, 1975 and Tinsley (1973 and 1975). Clarke (1974) and Mohanti-Hejmadi (1974) derived correlation between SV length and tibia length in Rana tigrina and Bufo woodhousie, Schroeder's (1975) contribution on the relationship between SV length and tympanum diameter at different age groups of Rana catesbiana, Terent'ev's (1960) observation on relationship between SV length and fecundity, Koskela and Pasanen (1975) contribution on regression relationship of different body parts of Rana temporaria, are some
of the noteworthy contributions highlighting the significance of such investigations and intra-specific variations.

In the present chapter, an analysis of absolute measurements and morphometric ratios of various morphological structures of the samples of *Rana cyanophlyctis* populations collected at Gauhati and Shillong has been presented. This includes the description of morphological features and relationships between snout-vent length (SVL) and body weight (BW) of the two samples of this species. A 12-month analysis of its relative condition has been worked out to know the size availability and robustness of the frogs during different months of the year. In this connection, coefficient correlation of the two variables mentioned has been worked out. In addition to these an account of its annual breeding cycle has also been included.
REVIEW OF LITERATURE

Boulenger (1882) classified and catalogued the Batrachia, Sailentia and Eucaudata collected at the British Museum on the basis of their morphological characters. The first contribution on the morphology of the Indian anurans seems to be in the year 1888 and that of Dr. Edgar Thurston the then superintendent, Government Central Museum Madras. He compiled a concise book entitled "Catalogue of the Batrachia, Sailentia and Apoda of Southern India". It contained descriptions of thirteen plates of the specimens present in the collections of Madras Museum and British Museum of Natural History, London. This book is now out of print and also out of stock (Satyamurti, 1967). Boulenger's monumental monograph "Reptiles and Amphibia" published in 1890 in the Fauna of British India is an record
on the anurans of this continent. It is even today considered as a standard reference for the study of anuran morphology, taxonomy and systematics. This monograph is also out of print and its copies available in the libraries and museums are often so fragile that one cannot use them freely for reference.

Boulenger (1882, 1890 and 1920), Thurston (1888), Annandale (1909 and 1917), Narayan Rao (1915 and 1920), McCann (1933, 1940 and 1945), Acharji and Kripalani (1951) and other earlier workers contributed mainly to the morphology, taxonomy, distribution, habits and behaviour of the anurans. The morphology was often restricted to provide the diagnostic characteristics explained with the help of absolute measurements. Workers like Bragg (1950) and Taylor (1951) added absolute measurements of many more body parts for the study of morphology apart from analysing their diagnostic characters in both
sexes. Later, Brown and Baschung (1954), Duellman and Klass (1964), Matter (1964), Zweifel (1964), Tinsley (1973, 1975) used absolute measurements as well as ratio study for the morphology. Morphologist like Hoyer and Peters (1971), Zweifel (1972), and Tyler and Martin (1975) used absolute measurements and ratio analysis for the study of races in population, collected from different ecological conditions and lastly workers like Clarke (1974) and Tabin et al. (1977) used correlation between two different structures. Pasanen and Koskela (1974) and Koskela and Pasanen (1975) investigated relationship between SV length and various biometrics of Rana temporaria and thereafter provided regression equations enabling to calculate the weight of ovaries, weight of oviduct, egg number and egg size, from the known measurements of SV length and body weight of the frog.

The important references for the past two decades are as follows:

Bragg (1950) in Bufo conicus, Taylor (1951) in Bufo simus and Brown and Boschung (1954) in Rana palustris, made morphological study and absolute morphological measurements to describe the morphological variations in populations inhabiting at different environmental conditions. Brown and Alcala (1963) applied the following three ratios (1) breadth of third finger
disc/length of third finger; (2) Head width/Snout-Vent length; and Head width/length of Tibia along with absolute morphological variations and description for the identifications of a new frog belonging to genus Cornufer (Ranidae). On the morphological analysis of the skin structure colourations, 7 absolute measurements, and 6 morphological ratios in hylid frog populations Duellman and Klass (1964) recorded a new species Triprion petastus. Describing the utility of the ratio study in animals Cochran (1953) remarked that morphological ratios studies provide a better understanding of the morphological structure and variations, it also compensates the natural variation of sizes. He noted that an average ratio, derived, by finding the specific ratio for each individuals and then dividing the total by the number of individuals was less accurate than the ratio obtained by dividing the sum of numerators by the sum of denominators. Metter (1964) applied Cochran’s technique to 8 ratios and 10 absolute measurements for a morphological comparison of the two populations of tailed frog Ascaphus truci. Similarly, Zweifel (1964) in Rana viticaria and Martin and Littlejohn (1966) in Hyla jervisians used ratio study to describe the morphology of the frog. Heyer and Peters (1971) observed the synonyms in Leptodactylids collected from Ecuador, and Zweifel (1972) reviewing the available preserved specimens of genus Leochrides used
various indices of ratio and absolute measurements, for morphological understanding. Similarly the population studies in *Bufo mexicanus* (Webb, 1972) and *Leptodactylids* (Tyler and Martin, 1975) were made by analysing the morphological ratios and absolute counts. Tinsley (1973 and 1975) used 9 indices, showing ratios between various body part and 18 absolute measurements for the study of the biology, systematic and synonyms in *Xenopus laevis*, *Xenopus vestitus*, *Xenopus bunyoniensis*, *Xenopus victorianus* and *Xenopus kigesiensis*. However, Van Dijk (1966) showed the utility of the ratio in the systematic studies of anuran larvae.

Some references on the morphology and measurements of Indian anurans of the recent decades can be reviewed as follows:

Daniel (1963, 1963b, 1975) described habit and habitat, distribution and morphology of anurans from western India, Satyamurti (1967) from southern India, Behura (1965) and Mohanty-Hejmadi (1974) from Orissa. Pillai and Chanda (1973, 1976) described 40 amphibian species from North-eastern India. The description contained 3 anuran records namely *Rana danieli*, *Rana mawplangensis* and *Philautus shillongensis* identified with the help of 22 absolute and 6 ratio morphological counts. Dubois (1976) collected anuran fauna from Nepal and
recorded the presence of two uncommon black eye *Rana cyanophlyctis*. Recently Roy (1979) made morphological description of *Rana limnocharis* of Shillong population with the help of absolute and ratio morphological measurements as described by Tinsley (1973, 1975).

These days morphological characters are frequently accompanied by biometric studies. Among anurans such studies are very few specially when compared to fishes. Rao (1964) while describing *Hilsa kanagente* applied (1) length frequency distribution i.e. the occurrence of more or less same length group in different season. It also reflects the size group of animals predominating the habitat during different months, (2) length weight relationship, i.e. length group (cm) plotted against the corresponding average weight (gm). In the above two bivariates (length and weight) showed linear relationship and has been expressed by \( W = a + bL^3 \) (where \( W \) and \( L \) being weight (gm) and length (cm) of the animal respectively and \( a \) and \( b \) as equation constants). Similar length frequency distribution and length weight relationship have also been studied in Gizzard Shad (Babu Rao, 1965) in *Otolithoides microdon* (Sinha and Rao, 1965); in *Stipinna godavariensis* (Rao, 1967) and in *Hilsa ilisha* (Rao, 1969).
LeCren (1951) derived a relationship between body length and weight \( K = \frac{W}{L^5} \times 10^5 \) and noted that the relative conditions of the organism can be predicted with the help of the above equation. Following the above technique, the relation condition has been estimated in various animal such as *Hilsa kangenta* (Rao, 1964); in *Otolithoidees microdon* (Sinha and Rao, 1965) and in *Hilsa ilisha* (Rao, 1969). It is observed that in all the above cases the maximum relation condition (constant) has been observed during spawning period.

Bayless (1969) plotted regression equations and relationship between SV length and Tibia length of *Ascris crepitans* and compared it with *Bufo woodhousei floweri*. Tinsley (1973) derived various biometric relationship in body part of *Xenopus kigesiensis* Schroeder (1974) in the body part and Tympanum length of adult *Rana catesbeiana*. Clarke (1974) used Tibia measurements as a growth indicative in *Bufo* and noted that SV length and Tibia length have significant correlation, with high correlation coefficient of \( (r = 0.998) \). Labanick and Schlucler (1976) observed that relationship between tibia length and SV length appeared to be linear and can be expressed by least square regression lines \( y = 2.37x + 1.45 \), when \( y \) and \( x \) are Tibia and SV length respectively. Koskela and Viro (1976) observed linear relationship in body length with animal weight and with tail length in harvest mouse.
A method for racial analysis suggested by Mahalonobis (1936) has been followed by certain workers. He mentioned that the distance/difference between the two population, $D_p^2$ can be estimated by the analysis and comparison of the variables and means difference of the two populations. Kesteven (1950) noticed that $D_p^2$ analysis on statistical 'F' test, if yields values, below or equal to 1%. Probability level ($P = 0.01$), indicates that the populations inhabiting in two environments are morphometrically non distinct and indiscriminent functions can be developed between them. Such population can be considered as homogeneous stock. Rao (1952) and Keeping (1964) further reported that covariance and mean difference in the variables of the two populations can be used for the racial studies. Gupta (1970) applied the $D_p^2$ analysis (Mahalonobis, 1936; Rao, 1952) in the meristic counts of different populations of Polynemus paraliscus for the racial study. Similarly, Pathak (1979) took help of the above described technique for the reacial study in Cirrhinus ruba collected from two different hydrographical and physico-chemical conditions, namely Ganga and Yamuna riverines and noted minor structural difference in the two populations of the fish, although not statistically significant on $D_p^2$ analysis, to assign them two different races.
MATERIAL AND METHODS

Adult specimens of *Rana cyanophyllys* were collected at the study sites at Gauhati and Shillong at regular intervals throughout the year. After collection the Snout-Vent length (SVL) of each frog was recorded and its body weight (BW) was taken after blotting the body surface. Their colour pattern was noted and they were killed with chloroform, their guts and gonads were removed and preserved in 10% formalin.

Range, mean, standard deviations of various measurements were calculated separately for samples of two populations in various size groups of male and female to compensate for the natural variations in sizes.

(a) Absolute measurements of the morphological character:

For females, following 17 and for males following 18 absolute measurements were recorded with the help of divider to the order of 0.1 mm accuracy.

(1) Snout-Vent Length (SVL): The measurement between tips of snout and vent of the animal.
(2) Body width (B.W.) : Measurement of the widest part of the body.

(3) Head length (H.L.) : Measurement from the anterior length of the animal to occipital condyl.

(4) Head width (H.W.) : Measurement at the widest region of the head.

(5) Snout length (S.L.) : Measurement of the perpendicular distance from the tip of the nose to the anterior most end i.e. the anterior level of the premaxillae bone.

(6) Snout width (S.W.) : The measurement of the widest point of the snout lying just below the nose.

(7) Eye diameter (E.D.) : The transverse distance across the exposed eye orbit.

(8) Inter ocular distance (I.O.D.) : The shortest distance between two eyes.

(9) Tympanum diameter (T.D.) : The measurement between annulus tympanicus across tympanic membrane.

(10) Inter tympanal distance (I.T.D.) : The shortest distance across head between two tympanic membranes.

(11) Inter nasal distance (I.N.D.) : The distance between the inner margins of the flaps bordering nostrils.
(12) **Hind limb length (H.L.L.)**: Total distance from the vent to the tip of the 4th toe.

(13) **Tibia length (T.L.)**: Median measurement along the dorsal surface of tibia.

(14) **4th toe length (4.t.l.)**: Measurement of the outer ventral surface of the 4th digit.

(15) **Forelimb length (F.L.L.)**: Measurement from the origin of forelimb to the tip of 1st finger.

(16) **Radio-Ulna length (RU_L.)**: Median measurement along the dorsal surface of the radio-ulna.

(17) **1st finger length (F.L.)**: Measurement from the base to the tip of the 1st digit.

(18) **Vocal slit's length (V.St.L.) (only for males)**: Measurement from the anterior edge to the posterior edge of the slit.

(b) **Morphometric ratios**:

Cochran's (1953) method has been applied for the ratio count analysis of the frog. The ratio has been obtained for each count by dividing the sum of the total numerator by the sum of total denominator. Following the ratio counts were estimated:
(1) SV length/Hind limb length (SVL/HLL)
(2) SV length/Snout length (SVL/SL)
(3) SV length/Snout width (SVL/SW)
(4) SV length/Tympanum diameter (SVL/TD)
(5) SV length/Head width (SVL/HW)
(6) SV length/Eye diameter (SVL/ED)
(7) Head length/Head width (HL/HW)
(8) Tibia length/Hind limb length (TL/HLL)
(9) 4th toe length/Total fore limb length (4th L/FLL)
(10) Lower fore limb length/Total fore limb length (LF/FLL)
(11) Head length/Internarial distance (HL/IND)
(12) SV length/Total fore limb length (SVL/FLL)
(13) Snout width/Snout length (SW/SL)
(14) Internarial distance/Inter tympanum distance (IND/ITD)
(15) Head width/Inter tympanum distance (HW/ITD)

(c) **Length-weight relationship**:

For length and weight relationship, graphs were plotted with length on 'X' axis and weight on 'Y' axis. From the trend of the distribution of the observations, the equation with the minimum sum of the squared differences between length and weights were taken as the best fit, regression expression. The correlations (r-value) between length and weight were calculated for males and females separately as well as together. The length and weight measurements of both the sexes, were applied to LeGren's (1951) formula given below and subsequently the equation constant, namely initial growth index (c) and
equilibrium constant \( n \) were found out.

\[ W = cL^n \]
\[ \log W = \log c + n \log L \]

where
\( W \) = weight
\( L \) = length
\( c \) = initial growth constant
\( n \) = equilibrium constant

(d) **Relative conditions:**

The relative condition variations in the mixed samples of frog population, collected at Shillong and Guwahati from January to December, was calculated, with the help of LeCren's (1951) formula

\[ K = \frac{W \times 10^5}{L^3} \]

where
\( K \) = condition factor
\( W \) = weight of frog
\( L \) = length of frog

The condition factor so derived was also correlated with environmental conditions of the sites such as temperature, relation humidity and rainfall, separately and jointly.
OBSERVATIONS

The observations include:

Diagnostic Features and Colour pattern, Distinguishing characters of male and female *Rana cyanophlyctis*, Morphometric measurements, (Absolute measurements and Morphometric ratios), of Gauhati and Shillong population of *Rana cyanophlyctis*, Length-Weight relationship and Relative condition and Annual breeding cycle.

**Diagnostic Features:**

*Rana cyanophlyctis* is characterised by following features.

1. Snout blunt, more or less rounded, scarcely projecting beyond mouth (Figs. 2.1, 2.2, 2.9 & 2.8).
2. Head flattened and compressed dorsoventrally (Fig. 2.3).
3. Head, slightly broader than long in adults and as long as broad among immature and juveniles (Figs. 2.1, 2.2, 2.10 & 2.8).
Fig. 2.1: Dorsal view of *Rana cyanophlyctis* - female
SNT = Snout; TYM = Tympanum; WTS = Warts;
F.L = Fore limb; H.L = Hind limb.

2.2: Dorsal view of *Rana cyanophlyctis* - male
Na = Narial; VS = Vocal sac;

2.3: Ventral view of *Rana cyanophlyctis* - female
Ab = Abdomen; Wb = Web.

2.4: Ventral view of *Rana cyanophlyctis* - male
VS = Vocal sac; Ab = Abdomen.
4. Nostrils at equal distance from eyes and from the tips of the snout (Figs. 2.2 & 2.3).

5. Distance between nostrils approximately equal to the inner orbital width, however, narrower than the distance between the upper eyelids (Figs. 2.2 & 2.3).

6. Tympanum distinct and approximately 3/4 of the total eyelid diameter (Figs. 2.2, 2.10 & 2.13).

7. Inner orbital space much smaller than eyelids.

8. The vomerine teeth are disposed in small round or oblique groups and situated at level with posterior border of the choanae, or just behind them.

9. Skin warty with small tubercles and with rows of pores dorsally, smooth and colourless ventrally (Figs. 2.1, 2.4, 2.9 & 2.13).

10. Flanks warty with pores arranged in single line (Figs. 2.3, 2.4 & 2.9).

11. Presence of a strong skinfold between the eye and the shoulder (Figs. 2.1 & 2.2).

12. Subarticular tubercles small and feebly prominent. The tarsal folds either absent or poorly developed with small dermal fringes present on outer toe (Figs. 2.5 & 2.14).

13. Outer tubercles absent but pointed digitiform inner metatarsal tubercles present (Figs. 2.3 & 2.5).
Fig. 2.5: Hind limb of *Rana cyanophlyctis* - female

Wb = Web.

2.6: Fore limb of *Rana cyanophlyctis* - male
Fig 25

H.Limb

Wb

Fig 26

F.Limb
14. Fingers thin pointed and feebly developed (Figs. 2.6 & 2.13).

15. First and second fingers almost equal in length (Figs. 2.6 & 2.13).

16. Toes completely webbed (Figs. 2.5 & 2.14).

17. Toe tips swollen, rounded or dilated into very small discs having well developed broad web reaching the tips (Figs. 2.5 & 2.14).

18. The 4th toe moderately large than others (Figs. 2.5 & 2.14).

19. Inner metatarsal tubercles, small elongated and conical (Figs. 2.5 & 2.14).

20. Outer metatarsals separate up to their bases (Fig. 2.14).

2.4.1 (b) **Colouration**:

Normally the colour pattern of the animal seems to be dependent on its surroundings. The riparian collected from foul and dirty place have dull colouration as compared to those collected from clean running water. The colouration of head and body on the dorsal side varies from brownish to dirty green, greyish or olive-brown, spotted or marbled with numerous dark olive marking of irregular shape (Figs. 2.1, 2.2, 2.8 & 2.12).
Fig. 2.13: Fore limb of *Rana cyanophlyctis* - male. × 1.0

Fig. 2.14: Hind limb of *Rana cyanophlyctis* - male. × 1.0
On the head, however, the number of black markings are less. Colouration of limbs is like rest of the body. Ventral aspect of the limbs is creamy white or creamy tans (Figs. 2.4 & 2.9). Incomplete dark brown cross bands are present on the limbs (Figs. 2.1, 2.2, 2.6 & 2.10). The upper part of fore limbs are often lighter in colour than their lower parts. Flanks have identical colour like that of dorsum although bit lighter in shade. Often one or two black streaks with white margin are present at the hinder aspect of the thighs below the vent (Figs. 2.4 & 2.11). There are feebly distinct light black edges and bands on each flanks and thighs, which being more prominent in males and juveniles than females. Chin, throat, belly (Fig. 2.13) and other ventral surfaces are creamy white, pale yellowish or dirty white (Figs. 2.4 & 2.9). The ventral surface of the juveniles are without markings or spots. The large size adults often have marbled spotted, dotted or vermiculated surface with black colouration on the dorsolateral region (Figs. 2.3 & 2.11). Such dots are sometimes seen on the ventral surface of the throat and belly also (Figs. 2.3 & 2.11).

Distinguishing characteristics of the males and females:

Following are distinguishing characteristics of
Fig. 2.7: A comparison of male and female adult *Rana cyanophlyctis* × 1.0

2.8: Lateral view of *Rana cyanophlyctis* - male. × 2.0
males and females.

(a) **Males** (Figs. 2.2, 2.4, 2.9 & 2.10)

1. The males are identified by their small size (SVL from 4.0 cm to 5.20 cm) and weight from 7.0 gm to 19.0 gm (Fig. 2.7).

2. They possess prominent greyish or blackish external vocal sacs on each side of throat, close to the posterior half of the mandibular ramus. The sacs are enclosed in separate slits and project out while croaking. The size of slit approximately equal to the 1st finger and larger than eye ball.

3. They produce "breeding call", apart from occasional "pain release call". The breeding call ressembles, some what low pitched rattles of bones kept up for a short while (McCann, 1933)

4. The 1st finger is slightly enlarged and thickened than others. Thumb pads, as seen in other frog species during breeding seasons are not present in *Rana cyanophlyctis*.

5. The colouration of males is brighter than that of female in the same population.

6. Their black and dark oliver marking on back are more conspicuous than those on females.
Fig. 2.10: Dorsal view of *Rana cyanophlyctis* - ♀ male x 1.5

Fig. 2.9: Ventral view of *Rana cyanophlyctis* - male x 1.5
7. The black streaks with white granular bodies found in females are either absent or feebly developed in males.

8. Their abdomen is slender, lesser in diameter than pectoral region.

9. While sitting they keep their head above the body line.

10. They are active swimmers and are often seen floating on water surface.

11. They and their juveniles occupy the territorial edges of the deep water bodies.

12. They are active during day as well as night almost throughout year.

(b) Females (Figs. 2.1, 2.3 & 2.11)

1. They are much larger and heavier than males. SVL ranging from 5.10 cm to 7.20 cm and weight from 22.0 gm to 38.5 gm (Fig. 2.7).

2. They are not capable of producing any voice except rare "pain or release call".

3. Their fingers do not show any difference at any period.

4. Their skin possesses larger number of tubercles, warts and pores than that of males.
Fig. 2.11: Ventral view of *Rana cyanophlyctis* - female × 0.66

2.12: Dorsal view of *Rana cyanophlyctis* - female × 0.66
5. They are dull coloured when compared with that of males in the same population.

6. The black dark olive marking on their back are either feebly developed or absent.

7. Their black streak with numerous white granular bodies on the vent is more conspicuous and better developed than in males.

8. Their abdomen is often swollen and larger in diameter than pectoral region.

9. They appear more shy and sit with body and head approximately parallel to the substrate.

10. They are less agile and during leisure are found sitting on the edges of the water bodies. On approach they skip and dive in water bodies for hiding.

11. They prefer middle core of the deep water bodies.

12. They do not feed during breeding phase and spawning.

Morphometric measurements:

The morphometric measurements were taken in samples of mixed specimens collected all around the year.
### Table 2.1

**Body dimensions of Rana cyanophlyctis**

*(Shillong population)*

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Characters</th>
<th>Males (sample size 35)</th>
<th>Female (sample size 43)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Range (cm)</td>
<td>Mean (cm)</td>
</tr>
<tr>
<td>1.</td>
<td>Body length (SV length)</td>
<td>4.00 - 5.30</td>
<td>4.830</td>
</tr>
<tr>
<td>2.</td>
<td>Body width</td>
<td>1.45 - 2.35</td>
<td>1.860</td>
</tr>
<tr>
<td>3.</td>
<td>Head length</td>
<td>1.25 - 1.90</td>
<td>1.667</td>
</tr>
<tr>
<td>4.</td>
<td>Head width</td>
<td>1.05 - 1.61</td>
<td>1.315</td>
</tr>
<tr>
<td>5.</td>
<td>Snout length</td>
<td>0.25 - 0.40</td>
<td>0.331</td>
</tr>
<tr>
<td>6.</td>
<td>Snout width</td>
<td>0.40 - 0.70</td>
<td>0.624</td>
</tr>
<tr>
<td>7.</td>
<td>Eye diameter</td>
<td>0.30 - 0.60</td>
<td>0.494</td>
</tr>
<tr>
<td>8.</td>
<td>Inter orbital distance</td>
<td>0.20 - 0.25</td>
<td>0.222</td>
</tr>
<tr>
<td>9.</td>
<td>Tymanum diameter</td>
<td>0.30 - 0.45</td>
<td>0.360</td>
</tr>
<tr>
<td>10.</td>
<td>Inter tympanum diameter</td>
<td>1.00 - 1.35</td>
<td>1.181</td>
</tr>
<tr>
<td>11.</td>
<td>Lower nasal diameter</td>
<td>0.25 - 0.40</td>
<td>0.332</td>
</tr>
<tr>
<td>12.</td>
<td>Hind limb length</td>
<td>6.05 - 8.50</td>
<td>7.315</td>
</tr>
<tr>
<td>13.</td>
<td>Tibia length</td>
<td>1.40 - 2.40</td>
<td>2.085</td>
</tr>
<tr>
<td>14.</td>
<td>4th toe length</td>
<td>2.00 - 2.50</td>
<td>2.267</td>
</tr>
<tr>
<td>15.</td>
<td>Total fore limb length</td>
<td>2.10 - 2.80</td>
<td>2.462</td>
</tr>
<tr>
<td>16.</td>
<td>Lower fore limb length</td>
<td>1.45 - 1.85</td>
<td>1.644</td>
</tr>
<tr>
<td>17.</td>
<td>1st finger length</td>
<td>0.70 - 1.00</td>
<td>0.834</td>
</tr>
<tr>
<td>18.</td>
<td>Slit length</td>
<td>0.65 - 1.05</td>
<td>0.877</td>
</tr>
</tbody>
</table>
(a) **Absolute measurements:**

1. **Shillong specimens**

   Measurements of 77 frogs (35 males and 43 females) were taken. The SV length of the males ranges from 4.0 to 5.2 cm and that of the females 5.10 cm to 7.10 cm. The measurements of 18 body parts for males and 17 for females are illustrated in Table 2.1.

2. **Gauhati specimens**

   Measurements of 54 frogs (20 males and 34 females) were taken. The SV length of the male ranges from 4.0 cm to 5.0 cm and that of the females from 5.0 to 6.75 cm. The measurements of 18 body parts for males and 17 for females are illustrated in Table 2.2.

A comparison of the measurements of the two types of samples reveal that on an average, the samples of frogs examined, both males and females were larger in size at Shillong than at Gauhati. But the males showed some distinguishing features. The head of males collected at Shillong, particularly snout length was smaller than those of the Gauhati frog by about 0.01 cm. This is reflected by other features, such as eye diameter, internarial distance and tympanum diameter. The average lower fore limb length was also less in the male frogs of Gauhati by about 0.04 cm.
### Table 2.2

Body dimensions of *Rana cyanophlyctis*
(Gauhati population)

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Characters</th>
<th>Males (Sample size 20)</th>
<th>Female (Sample size 34)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Range (cm)</td>
<td>Mean (cm)</td>
</tr>
<tr>
<td>1.</td>
<td>Body length (SV length)</td>
<td>4.00 - 5.10</td>
<td>4.530</td>
</tr>
<tr>
<td>2.</td>
<td>Body width</td>
<td>1.30 - 2.00</td>
<td>1.665</td>
</tr>
<tr>
<td>3.</td>
<td>Head length</td>
<td>1.30 - 2.00</td>
<td>1.592</td>
</tr>
<tr>
<td>4.</td>
<td>Head width</td>
<td>1.25 - 2.05</td>
<td>1.545</td>
</tr>
<tr>
<td>5.</td>
<td>Snout length</td>
<td>0.30 - 0.40</td>
<td>0.347</td>
</tr>
<tr>
<td>6.</td>
<td>Snout width</td>
<td>0.45 - 0.70</td>
<td>0.575</td>
</tr>
<tr>
<td>7.</td>
<td>Eye diameter</td>
<td>0.40 - 0.60</td>
<td>0.507</td>
</tr>
<tr>
<td>8.</td>
<td>Inter distance orbital</td>
<td>0.20 - 0.30</td>
<td>0.252</td>
</tr>
<tr>
<td>9.</td>
<td>Tymanum diameter</td>
<td>0.30 - 0.50</td>
<td>0.410</td>
</tr>
<tr>
<td>10.</td>
<td>Inter tymanum diameter</td>
<td>1.00 - 1.25</td>
<td>1.130</td>
</tr>
<tr>
<td>11.</td>
<td>Inter narial distance</td>
<td>0.30 - 0.40</td>
<td>0.327</td>
</tr>
<tr>
<td>12.</td>
<td>Hind limb length</td>
<td>7.15 - 7.60</td>
<td>7.215</td>
</tr>
<tr>
<td>13.</td>
<td>Tibia length</td>
<td>1.95 - 2.35</td>
<td>2.077</td>
</tr>
<tr>
<td>14.</td>
<td>4th toe length</td>
<td>1.80 - 2.40</td>
<td>1.932</td>
</tr>
<tr>
<td>15.</td>
<td>Total fore limb length</td>
<td>2.40 - 2.80</td>
<td>2.400</td>
</tr>
<tr>
<td>16.</td>
<td>Lower fore limb length</td>
<td>1.35 - 2.00</td>
<td>1.680</td>
</tr>
<tr>
<td>17.</td>
<td>1st finger length</td>
<td>0.65 - 1.05</td>
<td>0.847</td>
</tr>
<tr>
<td>18.</td>
<td>Slit length</td>
<td>0.60 - 1.00</td>
<td>0.815</td>
</tr>
</tbody>
</table>
(b) **Morphometric ratios:**

The morphometric ratios of various body parts have been compiled in Table 2.3. The SV length of males frogs from Shillong population ranges 4.00 cm to 5.30 cm and those of Gauhati frogs ranged from 4.00 cm to 5.10 cm and female frogs from Shillong population showed SV length ranges from 5.15 cm to 7.15 cm and Gauhati frog population from 5.00 cm to 6.75 cm.

Morphometric ratios among Shillong frogs population were more than Gauhati. However, few ratios such as SVL/SW (7.87), LFL/FLL (0.70) and IND/ITD (0.29) of Gauhati males were higher than those observed in Shillong frog population. Such measurements being 7.74, 0.67 and 0.28 respectively. Female frogs of Gauhati had higher SVL/SL (14.55), SVL/SW (8.31), SVL/HW (2.77), SVL/ED (10.21), HL/HW (1.00), HL/IND (5.36) and IND/ITD (0.27) that those of Shillong females. These ratios in Shillong females were 14.53, 7.96, 2.73, 9.89, 0.98, 5.16 and 0.26 respectively.

(a) **Length weight relationship:**

Length and weight relationship has been worked out for a sample of 30 male and 30 female frogs. The SV length of males varied from 4.05 cm to 4.90 cm and
Table 2.3

Morphometric ratio of *Rana cyanophlyctis* from two population (1) Shillong (2) Gauhati

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Character's for ratio</th>
<th>SV length (Range)</th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(4.00 - 5.30)</td>
<td>(4.00-5.00)</td>
<td>(5.15 - 7.15)</td>
<td>(5.00-6.75)</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Snout-vent length/Hind limb length</td>
<td>0.6602</td>
<td>0.6278</td>
<td>0.6425</td>
<td>0.6326</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Snout-vent length/Head width</td>
<td>2.9893</td>
<td>2.9320</td>
<td>2.7344</td>
<td>2.7718</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Head length/Head width</td>
<td>1.0318</td>
<td>1.0307</td>
<td>0.9814</td>
<td>1.0006</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Tibia length/Hind limb length</td>
<td>0.2851</td>
<td>0.2879</td>
<td>0.3050</td>
<td>0.2984</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>4th toe length/Fore limb length</td>
<td>0.3099</td>
<td>0.2678</td>
<td>0.3050</td>
<td>0.2984</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Lower fore limb length/Fore limb length</td>
<td>0.6676</td>
<td>0.7000</td>
<td>0.6806</td>
<td>0.6734</td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>Head length/Internarial distance</td>
<td>4.8540</td>
<td>4.7175</td>
<td>5.1623</td>
<td>5.3630</td>
<td></td>
</tr>
<tr>
<td>12.</td>
<td>Snout-vent length/Fore limb length</td>
<td>1.9611</td>
<td>1.8875</td>
<td>1.9635</td>
<td>1.8448</td>
<td></td>
</tr>
<tr>
<td>13.</td>
<td>Snout width/Snout length</td>
<td>1.8836</td>
<td>1.6546</td>
<td>1.8240</td>
<td>1.7509</td>
<td></td>
</tr>
<tr>
<td>14.</td>
<td>Internarial distance/Inter Tympanum distance</td>
<td>0.2817</td>
<td>0.2898</td>
<td>0.2563</td>
<td>0.2685</td>
<td></td>
</tr>
<tr>
<td>15.</td>
<td>Head width/Inter Tympanum distance</td>
<td>1.3675</td>
<td>1.3672</td>
<td>1.4550</td>
<td>1.4402</td>
<td></td>
</tr>
</tbody>
</table>
the weight from 6.44 gm to 13.40 gm. The SV length of females varied 5.45 cm to 7.15 cm and the weight from 18.17 gm to 49.02 gm (Table 2.4). The graph plotted between SV length versus the corresponding weight of male and female frog separately and jointly showed a linear relationship. LeCran (1951) expressed such relationship by a regression equation.

\[ W = C L^n \]
\[ \log W = \log C + n \log L \]

where

- \( W \) = weight of frog
- \( L \) = length of frog
- \( C \) = initial growth index
- \( n \) = equilibrium constant

The constant of the above equations such as initial growth index 'C' and equilibrium constant 'n' have been found out from the slope and trend of the Figs. 2.15, 2.16 & 2.17 for males and females separately as well as together. The SV length and body weight of the male and female frogs were deduced in the formulae, to find out the initial growth index 'C' and equilibrium constant 'n'. The values of these constants were found to be same by (1) method of least square and (2) method
Table 2.4

Comparison between body weight taken and standard weight estimated as per the regression equation at given SV length of *Rana cyanophlyctis* males and females

<table>
<thead>
<tr>
<th>S. No.</th>
<th>SV length (cm)</th>
<th>Weight taken (gm)</th>
<th>Weight estimated (gm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>4.05</td>
<td>7.42</td>
<td>6.79</td>
</tr>
<tr>
<td>2.</td>
<td>2.05</td>
<td>6.44</td>
<td>6.79</td>
</tr>
<tr>
<td>3.</td>
<td>4.10</td>
<td>7.60</td>
<td>7.13</td>
</tr>
<tr>
<td>4.</td>
<td>4.10</td>
<td>6.86</td>
<td>7.13</td>
</tr>
<tr>
<td>5.</td>
<td>4.10</td>
<td>7.46</td>
<td>7.13</td>
</tr>
<tr>
<td>6.</td>
<td>4.15</td>
<td>7.10</td>
<td>7.49</td>
</tr>
<tr>
<td>7.</td>
<td>4.15</td>
<td>6.96</td>
<td>7.49</td>
</tr>
<tr>
<td>8.</td>
<td>4.15</td>
<td>7.00</td>
<td>7.49</td>
</tr>
<tr>
<td>9.</td>
<td>4.20</td>
<td>8.72</td>
<td>7.86</td>
</tr>
<tr>
<td>10.</td>
<td>4.20</td>
<td>7.20</td>
<td>7.86</td>
</tr>
<tr>
<td>11.</td>
<td>4.20</td>
<td>6.70</td>
<td>7.86</td>
</tr>
<tr>
<td>12.</td>
<td>4.20</td>
<td>8.00</td>
<td>7.86</td>
</tr>
<tr>
<td>13.</td>
<td>4.20</td>
<td>7.40</td>
<td>7.86</td>
</tr>
<tr>
<td>14.</td>
<td>4.25</td>
<td>8.36</td>
<td>8.24</td>
</tr>
<tr>
<td>15.</td>
<td>4.30</td>
<td>11.70</td>
<td>8.64</td>
</tr>
<tr>
<td>16.</td>
<td>4.30</td>
<td>9.60</td>
<td>8.64</td>
</tr>
<tr>
<td>17.</td>
<td>4.30</td>
<td>6.95</td>
<td>8.64</td>
</tr>
<tr>
<td>18.</td>
<td>4.40</td>
<td>8.38</td>
<td>9.47</td>
</tr>
<tr>
<td>19.</td>
<td>4.40</td>
<td>8.80</td>
<td>9.47</td>
</tr>
<tr>
<td>20.</td>
<td>4.45</td>
<td>9.19</td>
<td>9.91</td>
</tr>
<tr>
<td>21.</td>
<td>4.45</td>
<td>12.01</td>
<td>9.91</td>
</tr>
<tr>
<td>22.</td>
<td>4.45</td>
<td>9.30</td>
<td>9.91</td>
</tr>
<tr>
<td>23.</td>
<td>4.45</td>
<td>10.28</td>
<td>9.91</td>
</tr>
<tr>
<td>24.</td>
<td>4.45</td>
<td>10.20</td>
<td>9.91</td>
</tr>
<tr>
<td>25.</td>
<td>4.50</td>
<td>11.63</td>
<td>10.37</td>
</tr>
<tr>
<td>26.</td>
<td>4.50</td>
<td>11.40</td>
<td>10.37</td>
</tr>
</tbody>
</table>
Table 2.4 continued

<table>
<thead>
<tr>
<th>S. No.</th>
<th>SV length (cm)</th>
<th>Weight taken (gm)</th>
<th>Weight estimated (gm)</th>
<th>SV length (cm)</th>
<th>Weight taken (gm)</th>
<th>Weight estimated (gm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>4.50</td>
<td>12.00</td>
<td>10.37</td>
<td>7.05</td>
<td>47.25</td>
<td>43.16</td>
</tr>
<tr>
<td>28</td>
<td>4.65</td>
<td>12.60</td>
<td>11.83</td>
<td>7.05</td>
<td>45.63</td>
<td>43.16</td>
</tr>
<tr>
<td>29</td>
<td>4.80</td>
<td>13.40</td>
<td>13.45</td>
<td>7.15</td>
<td>49.02</td>
<td>45.19</td>
</tr>
<tr>
<td>30</td>
<td>4.90</td>
<td>12.90</td>
<td>14.61</td>
<td>7.15</td>
<td>45.53</td>
<td>45.19</td>
</tr>
</tbody>
</table>

Equation for Male

\[
\log W = -1.6106 + 4.0214 \log L \\
W = 0.0245L^{4.0214}
\]

Equation for Female

\[
\log W = -1.1278 + 3.2575 \log L \\
W = 0.0745L^{3.2575}
\]

where \( W \) = weight of the frog (gm)  
\( L \) = length of the frog (cm)
Fig. 2.15: Length-weight relationship in male populations of *Rana cyanophlyctis*

2.16 Length-weight relationship in female population of *Rana cyanophlyctis*
of calculator programming. The initial growth index 'C' and equilibrium constant 'n' for males were found to be 0.0245 and 4.0214, for females 0.0745 and 3.2575 and for males and females jointly as 0.0422 and 3.125 respectively. Thus, the relationship between weight and length of the frogs were found to be as follows.

\[
\begin{align*}
W &= 0.0245L^{4.0214} \text{ for males} \\
W &= 0.0745L^{3.2575} \text{ for females} \\
W &= 0.0422L^{3.125} \text{ for combined frogs}
\end{align*}
\]

(See Figs. 2.15, 2.16 & 2.17)

Applying Peaksonian Product Movement equation the linear relationship and correlation coefficient has been calculated as under:

\[
\begin{align*}
r &= \frac{\sum XY}{n \cdot OX \cdot OY} \\
&= \frac{\sum (X_i - \bar{X})(Y_i - \bar{Y})}{n \cdot OX \cdot OY}
\end{align*}
\]

where

- \(X & Y\) = two variables (length and weight of the frog)
- \(r\) = correlation coefficient
- \(\bar{Y}\) = arithmetical mean of \(Y\)
- \(\bar{X}\) = arithmetical mean of \(X\)
- \(OX\) = standard deviation of variable 'X'
- \(OY\) = standard deviation of variable 'Y'
Fig. 2.17: Length-weight relationship in male and female taken together.
\[ T = 0.9138 \]

\[ \log w = -1.0375 + 3.125 \log L \]

\[ w = 0.0422 L^{3.125} \]
The bivariate distributions of length and weight in male and female frog separately and jointly were assessed for the degree of mutual relationship. The coefficient correlation of two variables, length and weight were found to be 0.8624, 0.9612 and 0.9138 respectively for male, female and male-females taken together respectively. The coefficient of correlations thus calculated were compared with the tabulated values and were found to be significant at 1% and 5% level of confidence,

The length of male and female frogs (Table 2.4) were applied to the derived "length and weight" relationship for formulae above, of male and female respectively, and thereafter the standard length and weight of each frog was calculated (Table 2.4). The measured weight and standard weight calculated were compared to find out the difference. The standard weight calculated represents ideal weight at given SVL for the frogs of Gauhati and Shillong population.

(b) Relative condition:

The relative condition, showing relationship between size and weight of the frog has been worked out for different seasons of the year. The adult frogs of
Table 2.5

Relative condition of *Rana cyanophlyctis* of Shillong and Gauhati make populations

<table>
<thead>
<tr>
<th>Months</th>
<th>Length</th>
<th>Weight</th>
<th>Relative condition constant</th>
<th>Mean((X))</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan.</td>
<td>5.30 - 6.00</td>
<td>16.20 - 23.40</td>
<td>(0.1088 \times 10^5 - 0.1178 \times 10^5)</td>
<td>0.1126 (\times 10^5)</td>
<td>0.0047 (\times 10^5)</td>
</tr>
<tr>
<td>Feb.</td>
<td>4.40 - 6.30</td>
<td>14.10 - 28.95</td>
<td>(0.1132 \times 10^5 - 0.1514 \times 10^5)</td>
<td>0.1265 (\times 10^5)</td>
<td>0.0170 (\times 10^5)</td>
</tr>
<tr>
<td>Mar.</td>
<td>5.20 - 6.30</td>
<td>14.90 - 29.60</td>
<td>(0.1001 \times 10^5 - 0.1183 \times 10^5)</td>
<td>0.1111 (\times 10^5)</td>
<td>0.00776 (\times 10^5)</td>
</tr>
<tr>
<td>Apr.</td>
<td>5.20 - 5.90</td>
<td>16.35 - 24.52</td>
<td>(0.1161 \times 10^5 - 0.1307 \times 10^5)</td>
<td>0.1182 (\times 10^5)</td>
<td>0.00691 (\times 10^5)</td>
</tr>
<tr>
<td>May</td>
<td>6.60 - 6.80</td>
<td>34.94 - 37.45</td>
<td>(0.1201 \times 10^5 - 0.1349 \times 10^5)</td>
<td>0.1285 (\times 10^5)</td>
<td>0.00671 (\times 10^5)</td>
</tr>
<tr>
<td>Jun.</td>
<td>6.85 - 7.15</td>
<td>36.42 - 49.02</td>
<td>(0.1132 \times 10^5 - 0.1372 \times 10^5)</td>
<td>0.1299 (\times 10^5)</td>
<td>0.0112 (\times 10^5)</td>
</tr>
<tr>
<td>Jul.</td>
<td>6.60 - 6.95</td>
<td>34.16 - 38.36</td>
<td>(0.1078 \times 10^5 - 0.1247 \times 10^5)</td>
<td>0.1158 (\times 10^5)</td>
<td>0.00745 (\times 10^5)</td>
</tr>
<tr>
<td>Aug.</td>
<td>5.10 - 6.70</td>
<td>16.90 - 41.50</td>
<td>(0.1274 \times 10^5 - 0.1379 \times 10^5)</td>
<td>0.1326 (\times 10^5)</td>
<td>0.0054 (\times 10^5)</td>
</tr>
<tr>
<td>Sep.</td>
<td>5.10 - 5.60</td>
<td>12.80 - 15.45</td>
<td>(0.0892 \times 10^5 - 0.0965 \times 10^5)</td>
<td>0.0921 (\times 10^5)</td>
<td>0.003 (\times 10^5)</td>
</tr>
<tr>
<td>Oct.</td>
<td>5.40 - 5.90</td>
<td>14.95 - 16.70</td>
<td>(0.0813 \times 10^5 - 0.0949 \times 10^5)</td>
<td>0.0869 (\times 10^5)</td>
<td>0.0059 (\times 10^5)</td>
</tr>
<tr>
<td>Nov.</td>
<td>5.20 - 6.10</td>
<td>15.50 - 28.95</td>
<td>(0.1086 \times 10^5 - 0.1314 \times 10^5)</td>
<td>0.1197 (\times 10^5)</td>
<td>0.0117 (\times 10^5)</td>
</tr>
<tr>
<td>Dec.</td>
<td>4.50 - 5.85</td>
<td>10.34 - 22.65</td>
<td>(0.1117 \times 10^5 - 0.1167 \times 10^5)</td>
<td>0.1138 (\times 10^5)</td>
<td>0.002 (\times 10^5)</td>
</tr>
</tbody>
</table>
mixed sex with snout-vent length varying from 4.40 cm to 7.10 cm and weight 10.34 gm to 49.02 gm were used for the study. The average best relative condition during December was found to be $0.1326 \times 10^5$ in comparison to smallest size $0.0869 \times 10^5$ available during October. The range, mean and standard deviation of relative condition of frogs for different months have been shown in Table 2.5. The collection during June were predominated by large size and heavy female with mature ova. An ascending trend in the relative condition from March onwards has been recorded which reached its peak during June. June onward a decline in length and weight relationships have been noticed, reaching to its minimum during September and October. The second peak of robustness was observed during December. Table 2.6 shows correlation coefficient value of the relative condition of the frogs during different months with environmental factors like average atmospheric temperature, average aquatic temperature, humidity and rainfall of the Shillong site. Multiple correlation of all the above factors and relative condition of the frog have also been derived (Table 2.6). On 'F' test the correlation and multiple correlation have been found to be highly insignificant at 1% and 5% probabilities.
Annual Breeding Cycle

The frog does not hibernate and can be easily found in the vicinity of the water bodies throughout the year. Its annual breeding cycle does not show well demarcated phases as observed in the other terrestrial frogs. It has a prolonged breeding period. Based on availability of spawn, larvae, froglets, juveniles, adults and gravid females the annual breeding cycle of this species can be divided into 3 phases: (1) Pre breeding phase; (2) breeding phase and (3) post-breeding phase.

(1) Pre breeding phases:

The early breeding phase extends from mid-February till the end of April. The temperature during the period ranges from 8°C to 21°C and rainfall 0.0 to 84.4 mm. The population census in the first half of the period is marked by the predominance of juveniles. The second half period which is marked by an increase in atmospheric temperature from (6.8°C to 20°C) and in rainfall from (20.0 mm to 40.0 mm), shows an increase in the adult population on land. At the atmospheric temperature approximately 18°C and rainfall around (40.0 to 50.0 mm) the activities of male frog population are enhanced earlier than the female population. The population census of the frog on land at this stage reflects equal proportions of
male and juvenile frogs. The activities in female frog enhances remarkably at the end of the phase, when temperature reaches above 20°C and average rainfall around 100 mm.

During the last phase of this period (late April) a population of the female frog with enlarged abdomen and mature ovary are often encountered. In permanent water bodies amplexus can also be recorded. However, spawns and embryonic stages are not recorded. The induced breeding with the help of homoplastic pituitaries during this period is although a success, but produces small spawn size.

(2) Breeding phase:

*Rana cyanophlyctis* has an acyclic, prolonged breeding period. Its active breeding period extends from May and last till the early September. The period is marked by an increase in temperature (17°C to 28°C) and rainfall (120.0 to 460.0 mm). The noticeable feature of this period is increase in activities and abundance in frog population on land. The population structure assessed through random frog collection represents an almost equal number of males, females and juveniles. The large size female frogs often encountered in the period contain abdomen ladden by mature ova, however, their guts remain empty. Amplexus in nature are also observed in large number. Spawns and tadpoles of various developmental stages
are recorded abundantly, both in slow running and stagnant permanent water bodies. In the present observation the maximum number of amplexus and spawns have been recorded in June, indicating a period when they are most actively involved in breeding (temperature 22.0°C and average rainfall above 450 mm). A large number of froglets population are observed during September (temperature around 21°C and average rainfall around 250 mm) probably a result of July spawning. Under laboratory condition the development from a fertilized ovum to a froglet requires more than two months. The induced breeding experiments performed were most successful and resulted into spawning of large number of ova.

(3) Post-breeding phase:

During the post-breeding phase the environmental conditions are marked by lowering in temperature from (25.5°C to 4.7°C) and rainfall (240.0 mm to 0.0 mm). With the decline in temperature and rainfall the relative abundance of frogs on land also shows a decreasing trend. This has been more marked in adult frog populations. The movement in adult population what so ever are restricted within or around water bodies. The juveniles and sub-adults however, remain active and are observed in abundance on land. At this period amplexus are rarely observed.
Moreover, large number of tadpoles of different developmental stages and sizes are recorded in abundance from the permanent water bodies. The females encountered at this stage often show few or reduced numbers of ova. Their guts are mostly filled with various types of food items. During warm evenings soon after rains, a marked increase in the abundance of various size group of frogs are recorded on land. Induced breeding at this stage although successful results in small spawn size.

Winter months at low temperatures (4.5°C to 15.0°C) and negligible rain, frogs are observed mostly restricted in the water bodies. Here adults and large size animals occupy the middle core and juveniles, the shallow edges of deep water bodies. The abundance of various size and sex of the frog on land has been marked at it lowest. The movement during cold months get reduced and restricted near the water bodies. During sunny hours frogs are observed basking and even floating in the water bodies (Fig. 3A). Few large size tadpoles of advanced developmental stages can still be recorded till the middle of the December in permanent water bodies, along with juveniles and froglets which have been recently metamorphosed. Records of the breeding of the frogs in nature as well as with homoplastic pituitaries injections could not be achieved. No amplexus or spawn were observed during this period.

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DISCUSSION

*Rana cyanophlyctis* has been described since 16th century A.D. Daniel (1975) records that the ability of this species to skip over the surface of water like a ricocheting stone was remarked upon by the great Mughal Emperor Babar. The nomenclature, *Rana cyanophlyctis* was given by Schneider (1799) in History Amphibian Part I (see Boulenger, 1920). There are a number of references such as Thurston (1888); Boulenger (1890, 1920); Ananda (1909); Boulenger *et al.* (1907); McCann (1933, 1940, 1945); Narayan Rao (1915); Acharji and Kriplani (1951); Satyamurti (1967); Mohanty-Hejmadi (1974) and Daniel (1975). These descriptions are based mainly on the population available in the central, western and southern part of India. In the present investigation morphometry of its population available in the north-eastern part of India have been analysed. It would be noted that absolute measurements may vary depending upon the size of the animal but morphometric ratios are species specific.

(a) Absolute measurements:

(1) Male

Absolute measurements of 17 body parts of a sample of 20 frogs from Gauhati and 35 from Shillong have been presented in Tables 2.1 and 2.2. Boulenger
(1920) recorded largest males of *Rana cyanophlyctis* up to 6.6 cm from Aithalhim near Aden, 6.4 cm from South Arabia, and 4.5 cm from Travancore (India). In the present investigation the maximum SV length recorded for a male frog from Shillong was 5.3 cm and 5.1 cm from Gauhati. This size is larger than 4.4 cm recorded from western India (Daniel, 1975) and 4.2 cm recorded from South India (Satyamurti, 1967). Boulenger (1920) recorded that at Quetta the size of *Rana cyanophlyctis* collected in hills was larger than that of the plain ones. In the present finding also the Shillong hill frogs (1428 m a.s.l.) were found to be larger than Gauhati frogs (49.4 m a.s.l.) though certain morphological parts such as snout length, inter narial distance, tympanum and eye diameter were larger in Gauhati specimens. The size of head was large in Shillong frogs.

(ii) Female

Absolute measurements of 17 body parts of a sample of 34 frogs from Gauhati and 43 frogs from Shillong have been presented in Tables 2.1 & 2.2. The maximum SV length for female frogs from Shillong was 7.15 cm and 6.75 cm from Gauhati. However, Boulenger (1920) recorded 9.2 cm as maximum SV length of a female frog from Aithalhim near Aden. He reported largest SV length 6.5 cm from Kashmir (India), whereas Daniel (1975) reported
approximately 6.0 cm from western India and Satyamurti (1967) recorded 6.2 cm from South India. All the measurements of female frogs were recorded to be larger for Shillong frogs than those of Guwahati frogs. This is in accordance to the Boulenger's (1920) observation at Quetta.

(b) **Morphometric ratios:**

Bragg (1965) while discussing the importance of ratio counts of morphological structures in intraspecific variation quotes that as far as a definition of difference between various forms are concerned, various well chosen ratios of different body parts provides values of much greater information. Thus, many anuran biologists of recent past such as Brown and Boschung (1954); Duellman and Klass (1964); Metter (1964); Heyer and Peters (1971); Tyler and Martin (1975); Tinsley (1973, 1975) and Roy (1979) have laid more emphasis on various ratio count studies than the absolute measurements. In the present investigation techniques of Cochran (1953) and Metter (1964) for estimating morphometric ratios among various body parts were followed. All together 15 ratio counts have been estimated for samples of frog populations of Guwahati and Shillong at 0.5 cm class interval. The table 2.3 contains the pooled data of the ratio counts
for males (SV length range 5.3 to 4.0 cm for Shillong frogs and 5.1 to 4.0 cm for Gauhati frogs) and females (SV length range 7.15 to 5.15 cm for Shillong frogs and 6.75 to 5.00 cm for Gauhati frogs). The data for male and female frogs have been compiled in Tables 2.1 & 2.2. The ratio counts samples of the two population showed little difference. Further, the values obtained were subjected to student 't' test (see Chapter 3) and the differences were found to be insignificant. Rodolfo (1957) reported that *Rana pipiens* collected from different latitudes and altitudes of Florida, Mexico and South Western United States showed little variation in the morphological measurements. However, they were not so major or significant to assign them a new race. Similarly, the *Rana cyanophlyctis* inhabiting Gauhati and Shillong do show little morphometric variation but not so significantly (Figs. 2.15, 2.16, 2.17) so as to assign them a different race or strain.

**(c) Length-weight relationship:**

The length-weight relationships of *Rana cyanophlyctis* of samples collected from Gauhati and Shillong show a linear regression (Figs. 2.15, 2.16, 2.17). The correlation coefficient derived among the two variables of males and females frogs separately and in pooled conditions show significant 'r' values at both 1% and 5% confidence level.
Among anurans two types of the breeders have been recognised (1) Explosive breeder or single night breeder (2) Prolonged breeder or whole year breeder (Mastof, 1953; Blair, 1968 and Wells, 1977). *Rana cyanophlyctis* shows continuous breeding habit in environmentally favourable localities (McCann, 1933; Ramaswami and Lakshman, 1959 and Gopalakrishnan and Rajasekarasetty, 1978). Gopalakrishnan and Rajasekarasetty noticed continuous acyclic breeding in *Rana cyanophlyctis* and cyclic and seasonal breeding in *Rana tigrina* and *Rana hexadactyla*. In an explosive breeder, the weight of the frogs gets greatly reduced after its single night oviposition. Thus the SV length and weight, in such frogs does not show significant correlation coefficient in monthly samples or in the collection of whole year. It was noted that the weight of ova in mature and larger female constitute 1/5 of the total animal weight. Minimum record weight of the ovary was 1.71 gm and maximum was 11.59 gm. Further, the minimum number of ova was 1522 and the maximum was 6695 in *Rana cyanophlyctis* (see Table 7.10). It has been noted that *Rana cyanophlyctis* could be induced bred from March to October (see Chapter 6). However, the egg released on induced ovulation never exceeded 100 except during peak rainy seasons, when it was recorded maximum to be 667 ova. Further the spawn laid in nature hardly contains
over 200 eggs (recorded by Ramaswami and Lakshman, 1959; Gopalakrishnan and Rajasekarasetty, 1977 and 1978). Hence, the maintenance of linear length-weight relationship in female throughout the year is attributed to a small spawn size.

Clarke (1974) and Labanick and Schluter (1976) observed linear regression and correlation between body length and Tibia length of anurans. However, the constant of the regression equation and correlation coefficient which shows the trend of dependence and relationship was found varying. This indicates that the frogs of different species and different populations varies in the morphological and morphometrical relationship. However, the calculated weight and weight actually taken for samples of two population in the present investigation showed little difference. This suggests that the animals are identical and ideally placed at the two sites. From the regression equations derived, the length/weight relationships of the frogs at Shillong or Guwahati can be estimated if these measurements are known for any of the two populations.

Relative condition

The relative condition is a relation of total length at a constant weight. The robustness, the bivariate and multivariate correlation relationship with annual environmental
condition like atmospheric and aquatic temperature, humidity and rainfall did not showed much variations and had insignificant correlation coefficient ($r = 0.29; 0.36; 0.20; 0.40$ respectively and $P > 0.01$). Although annual fluctuation in relative condition of the frogs have been observed varying little, the maximum robustness were recorded during May, June and July probably due to better maturity of the gonads. During this period the random collection of frogs from nature showed maximum number of large sized and heavy weight female frogs. The minimum relative conditions were observed during October and at this stage the random collection showed many light female with spent ovaries. From October onward an improvement in the relative condition (Fig. 2.18) seems to be associated with gonadal growth and post breeding ravenous feeding activities. The knowledge of relative condition of any frog in an annual estimation will provide a information of the robustness and subsequently the period when availability of heavy frogs of any size group are more. In *Rana cyanophlyctis* it is calculated to be May and June, when the availability of heavy frog should be maximum. This has also been recorded in population dynamics estimations (see Chapter 3). Hence, May–June collection of frog shall be an ideal for the procurement of healthy frogs for academic and economic purposes, including export to affluent countries as edible items.
Annual breeding cycles:

Reproduction in the anuran can be divided into two categories (1) prolonged and (2) explosive. Wells (1977) recorded that prolonged breeding is probably more common although information on tropical species is so sketchy that generalization is hard to make. Many frogs in tropical regions breed every month (see Church, 1960; Inger and Greenburg, 1963; Berry, 1964; Inger and Bacon, 1968; Brown and Alcala, 1970; Duellman, 1970; and Crump, 1974). The prolonged breeding activities in Indian anuran has not been worked out in detail although Daniel (1963, 1975) and Satyamurti (1967) have described anuran from western and southern part of India. McCann (1933) noted that Rana cyanophlyctis can be heard croaking in the permanent water bodies throughout the year, and under favourable condition it can also breed during winter months. In the present investigation it has been noted that the frog does not hibernate and can be easily found in the vicinity of permanent water bodies throughout the year at Shillong and Guwahati. Koskela (1975) in Rana temporaria and Roy (1979) in Rana limnocharis noted that their annual life cycle are divisible in two distinct phases (1) spawning, larval and active terrestrial phase and (2) wintering and hibernating phase. Koskela (1975) has further noted that Rana temporaria found inhabiting near water environment can be seen throughout the year.
near or within water bodies. In *Rana cyanophlyctis*, the annual cycle does not show demarcated phases as noted for terrestrial frogs. However, the annual periodicity can be observed in growth and behaviour of frog among its biological functions and environmental reactions. Based on the activities of the frog population and breeding pattern the annual cycle of *Rana cyanophlyctis* has been divided into three phases: (1) early breeding, (2) breeding and (3) post breeding. The maximum activity in *Rana cyanophlyctis* population has been observed during breeding phase when temperature and rainfall both are recorded maximum. At low temperature and negligible rainfall the activities in the population gets greatly reduced. Further, the bivariate correlation coefficient observed between environmental conditions (temperature and rainfall) and activities also indicated high significant relationship (Table 3.4).
This chapter deals with an analysis of morphological characters, morphometric measurements (absolute as well as ratio counts) and length-weight relationship and annual breeding cycle of Gauhati and Shillong populations of *Rana cyanophlyctis*. This species is identified by somewhat broader than long depressed head, equal size of first and second fingers, slightly dilated and completely webbed toes and warty skin with pores and tubercles. Males are smaller and lighter (SVL 4.0 - 5.30 cm and body weight 7.0 - 19.0 gm) and females larger and heavier (SVL 5.10 - 7.20 cm and body weight 22.0 - 38.5 gm). Among the two populations, the frogs of Shillong population are larger and heavier than those of Gauhati population. However, the size of the head, internarial distance, diameter of the eye and tympanum of male frogs of Shillong were smaller than those of Gauhati frogs. Slight differences in certain ratio counts have been attributed to lentic and lotic habitats of the two places. There was a linear relationship between length and weight in the males \( r = 0.86; W = 0.0245 L^{4.0214} \); females \( r = 0.96; W = 0.0745 L^{3.2575} \) as well as males and females taken together \( r = 0.91; W = 0.0422 L^{3.125} \). The relative condition of the frog did not show any marked variation.
The annual breeding cycle of the frogs is divisible into 3 phases: (i) Pre breeding (February to April), (ii) Breeding (May to September), (iii) Post breeding (October to January). They do not hibernate and are most active during breeding period. During winters their activity is at lowest pitch and at close vicinity of water bodies and are often seen basking in morning hours.


