DETERMINATION OF EGG CHARACTERISTICS FOR THE MEDITERRANEAN GECKO (*Hemidactylus turcicus*) IN TEXAS

THESIS

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INTRODUCTION

The relationship between female body size, clutch size, and the size of reptile eggs (length, width, and mass) has been investigated in lizards (Ferguson et al., 1982; Ferguson and Snell, 1986; Vitt, 1986; Sinervo, 1990), turtles (Congdon and Gibbons, 1987; Rose et al., 1996), snakes (Seigel et al., 1986; Ford and Seigel, 1989), alligators and crocodiles (Deeming and Ferguson, 1990), and various other reptiles (Iverson and Ewert, 1991). However, there is a paucity of information on the actual shape and volume of reptile eggs, and those factors that control egg shape and volume.

Authors of the mentioned studies showed that reptilian eggs exhibit considerable variation in shape and size. There is a nearly 4900-fold range in mass with shapes varying from spherical to ellipsoid to bicone (Iverson and Ewert, 1991). The range of elongation of reptile eggs far exceeds that of birds. Within reptiles, lizards and snakes have the most variable eggs with 14.5- and 7.1- fold ranges in elongation, respectively (Iverson and Ewert, 1991). Douglas (1990) and Iverson and Ewert (1991) concluded that suggested that two additional parameters, asymmetry and the bicone ,were needed. The formula proposed by Preston appears to describe the reptilian egg shape effectively, but a method for accurately measuring these parameters is lacking (Maritz and Douglas, 1994). There is clearly a need for a better description of the shape of lizard eggs and for a method by which to estimate volume.

The Mediterranean gecko *(Hemidactylus turcicus*), an Old World lizard subsumed in the family Gekkonidae, is indigenous from western India through Somalia, and occurs along coastal areas on both sides of the Mediterranean Basin to Spain, Morocco and the Canary Islands (Conant and Collins, 1975). In North America, the species is adventive with a distribution from the Gulf Coast states of the United States into northern Mexico (Fig. 1). This small reptile has been spread by human mechanisms, such as transport in lumber, fruit and vegetable crates, and other imported goods. The species has been reported from Miami (Barbour, 1936) and Gainesville, Florida (King, 1958) in the east, westward to El Paso, Texas (Davis, 1974). The first substantiated report of this lizard in Texas was from Ted Beimur of Brownsville, Texas in January 1950 (Davis, 1974).

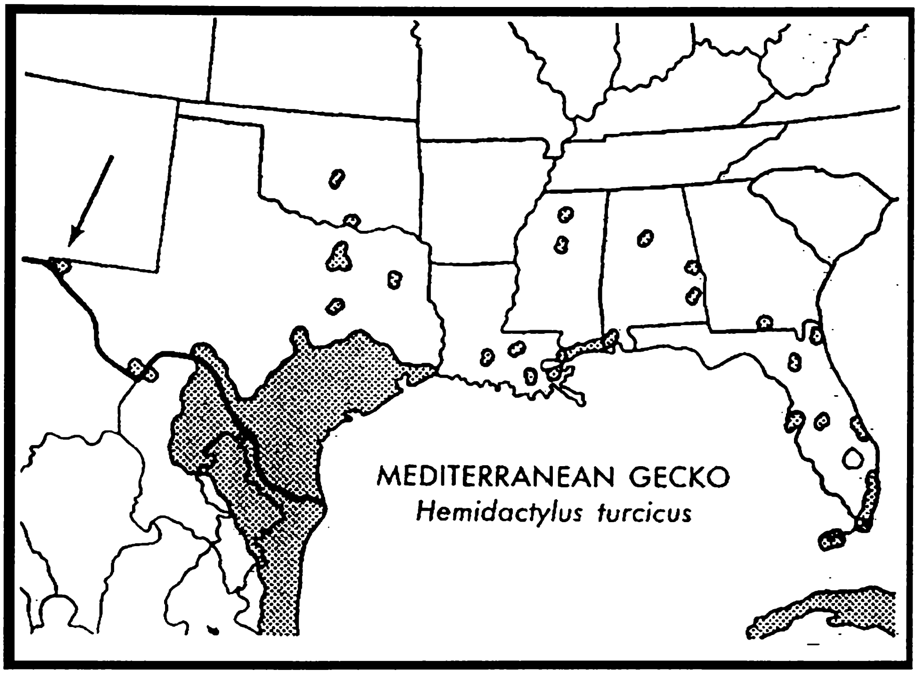

Figure 1: The Distribution of *Hemidactylus turcicus* in the United States.

The breeding season of *H. turcicus* extends from early April through late August. Each female usually produces two clutches of eggs; occasionally three if she lays her first clutch early in the spring. Young females mature during winter and spring of their second year. Members of the Gekkonidae usually have two eggs per clutch. Eggs of *H. turcicus* are relatively large for the female's body size and are ovoid in shape (Rose and Barbour, 1968).

The objectives of my study were to evaluate the general external morphology of *H. turcicus* eggs, to select a mathematical formula that accurately estimates the volume of eggs based on simple measurements and shape parameters, and to determine if an estimate of volume can be achieved using a single variable. This would allow a prediction of egg volume based on a size parameter without having to sacrifice eggs or handle the eggs excessively.

MATERIALS AND METHODS

Collection of Specimens

Pregnant female *H. turcicus* were collected from two sites; the Isle Condos in Port Aransas, Texas (n=7), and various housing developments in Austin, Texas (n=9). These sites were chosen because of the abundance of geckos and ease of collection. Geckos were located and collected from sides of buildings usually near a light source, between 2100 h and 0200 h, during two periods (18 May - 10 June 1995) and (10 June - 20 July 1996). A small minnow net provided an easy method to capture specimens. Once the individual's sex was determined, males were released, and females were examined to determine the presence or absence of developing eggs. Eggs are easily seen through the thin skin of the female's abdomen. Only pregnant females were retained and placed in five gallon buckets until eggs were laid.

Captivity and Feeding

The bottom of the holding tanks (five gallon buckets) were covered with grass clippings, strips of wood and small rocks taken from the environment where the lizard was collected. One half of a large styrofoam cup provided shelter. Rose and Barbour (1968) reported that pregnant females constructed nests for their eggs when materials were available and covered their eggs with small grass sprigs or wood strips. Water was provided *ad libitum*. Lids of holding tanks had the centers replaced with screen wire to facilitate air exchange and for ease of observation. All geckos were fed pinhead size crickets (each 2-3 mm total length) and small meal worms *ad libitum*. Insects were sprinkled with Reptocal to supplement dietary calcium. After two weeks of observation, it was apparent that crickets were the preferred food, so meal worms were discontinued in the diet. Holding tanks were checked daily for the presence of eggs or nest building activity. The general condition of each female also was noted, i.e., (coloration of the skin, activity, and appetite). After a female laid her eggs, they were collected and placed in small plastic containers with air tight lids. The number of the female was written on the container, and the eggs were stored in a refrigerator. The female was then released.

Collection of Data

I used 25 eggs from 16 clutches in my study. Eggs were not selected according to shape, rather all available eggs were included in the analysis. A small piece of surgical wire was attached to one end of each egg using Duco cement to facilitate handling while working with the eggs. The cement was allowed to set for at least 1 h to assure strong adhesion. Because of the fragile nature of the eggs, a thin coat of clear enamel was sprayed over the surface. This allowed me to handle the delicate eggs without breaking the shell. After the enamel dried, the maximum length and maximum diameter or width of each egg were measured to the nearest 0.01 mm, using Mitutoyo digital calipers. Because of the egg's thin, fragile shell, I could not measure the volume of eggs by removing the internal contents with positive pressure through a hole at each end by the method described by Rose et al (1996). Instead, I used water displacement to measure volume (Thomas and Lumsden, 1981; Morris and Chardine, 1986). Water was displaced by the egg in a buret cylinder, and the change in volume was measured to the nearest 0.01 ml.

Length (L), width (W) and elongation (E = L/W) values for each egg were used to calculate a theoretical volume to compare with the measured volume. The purpose of this calculation was to determine if the volume of an egg could be accurately estimated using the length, width or elongation factor. Two calculation methods were examined. First, volume was calculated using the bicone method (Maritz and Douglas 1994). This equation states that the volume of a bicone (denoted Vb) is calculated as follows:

$$c = \lambda\,(E^{1/2} - 1) \qquad Vb = \Pi/6\,\frac{(3c^2 + 14c + 35)}{35}\,LW^2$$

c is a measure of the bluntness of the ends of the egg. If the calculated c is negative, the ends of the egg are pointed, if c is positive they are blunt, and if c=0, the egg is an ellipse. E is an elongation factor which is calculated as E= L/W.

The second volume calculation was for an ellipse. In this equation (Iverson and Ewert, 1991) volume of an ellipse (denoted Ve) is calculated as follows:

$$Ve = (\Pi/6000)\,LW^2$$

Volume data were plotted against diameter and length of each egg using the Sigma Plot program. A scatter plot was produced and trends examined using a linear regression. The elongation factor was plotted against bicone and ellipse volumes, and regression values calculated. A student's t-test was used to determine if the formulae used for calculating volume were significantly different than the observed or measured volume.

RESULTS

The mean values (± one standard error, and minimum and maximum) calculated from measured values (Table 1) of the 25 eggs used in this study were: length 11.46 ± 0.105 mm (10.08-12.19); width, 8.67 ± 0.053 mm (8.15 -9.21); and volume, 0.46 ± 0.008 ml (0.4 -0.5). The elongation factor was 1.32 ± 0.013 (1.13 - 1.41).

Comparisons of the mean measured and calculated volumes (bicone and ellipse) showed no significant difference ($p > 0.05$) between the measured and the calculated volumes (Table 2). The calculated volume by the bicone formula was the same as the mean measured volume (0.46 ml).

	Egg Characteristics				Calculated Volumes	
Egg #	Length (L)	Diameter (D)	Elongation factor (L/W)	Volume (V)	Bicone	Ellipse
1	11.40	8.38	1.36	0.40	0.43	0.42
2	11.38	8.82	1.29	0.50	0.47	0.46
3	11.42	8.89	1.28	0.50	0.48	0.47
4	11.34	8.80	1.29	0.45	0.47	0.46
5	11.33	8.31	1.36	0.40	0.42	0.41
6	11.18	8.57	1.30	0.45	0.44	0.43
7	12.08	8.62	1.40	0.50	0.48	0.47
8	11.58	8.15	1.41	0.41	0.41	0.40
9	11.20	8.36	1.34	0.40	0.42	0.41
10	10.08	8.91	1.13	0.45	0.42	0.42
11	11.50	9.10	1.26	0.50	0.50	0.50
12	11.77	8.73	1.35	0.50	0.48	0.47
13	12.11	8.70	1.39	0.50	0.49	0.48
14	10.08	8.50	1.19	0.40	0.38	0.38
15	11.33	8.61	1.32	0.45	0.45	0.44
16	11.36	8.40	1.35	0.40	0.43	0.42
17	11.80	8.89	1.33	0.50	0.50	0.49
18	11.31	8.81	1.28	0.45	0.47	0.46
19	12.08	8.62	1.40	0.45	0.48	0.47
20	12.19	8.76	1.39	0.50	0.50	0.49
21	12.13	8.69	1.40	0.50	0.49	0.48
22	11.48	9.21	1.25	0.50	0.52	0.51
23	11.88	8.69	1.37	0.45	0.48	0.47
24	11.16	8.27	1.35	0.42	0.41	0.40
25	11.52	9.01	1.28	0.50	0.50	0.49

Table 1. Measured and calculated data (length (mm), diameter (mm), elongation factor (L/W), and volume (ml)) for *Hemidactylus turcicus* eggs.

Statistic	**Volume (ml)**		
	measured (ml)	**bicone (ml)**	**ellipse (ml)**
mean	**0.46**	**0.46**	**0.45**
standard deviation	**0.041**	**0.037**	**0.036**
standard error	**0.008**	**0.007**	**0.007**
maximum	**0.50**	**0.52**	**0.51**
minimum	**0.40**	**0.38**	**0.38**

Table 2. Measured and calculated volumes for 25 *Hemidactylus turcicus* eggs

Based on the measurements of *H. turcicus* eggs, diameter had a higher correlation with volume (r=0.79; Fig. 2) than either length (r=0.66; Fig. 3), or elongation factor (r= 0.00; Fig. 4), and was a more accurate estimator of egg volume. When calculating the volume of an egg by the bicone or ellipse formulae, there was a higher correlation between diameter and volume using the ellipse formula (r=0.81; Fig. 5) than the bicone formula (r=0.79; Fig. 6). However, there was a higher correlation between length and volume using the bicone formulae (r=0.70; Fig. 7) than the ellipse formula (r=0.66; Fig. 8). The elongation factor was the least accurate estimator of volume by both the ellipse formula (r=0.11; Fig. 9) and bicone formulae (r=0.17; Fig. 10).

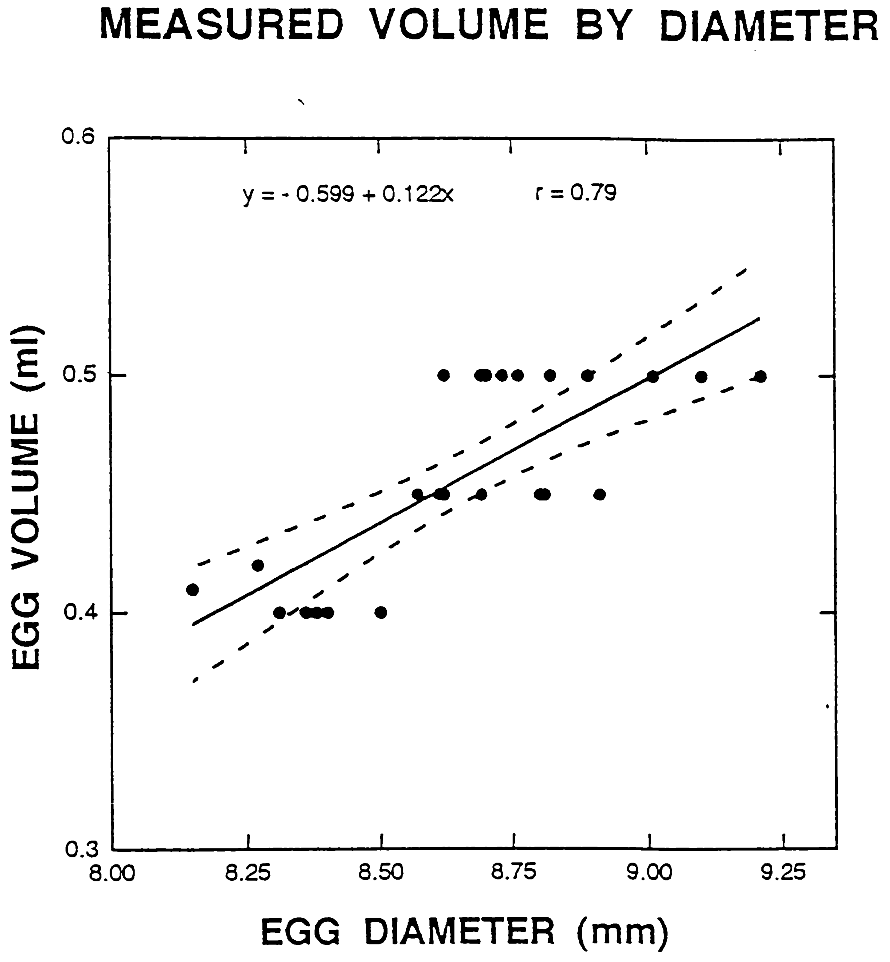

Figure 2. A bivariate plot depicting measured egg volume of *Hemidactylus turcicus* as a function of egg diameter.

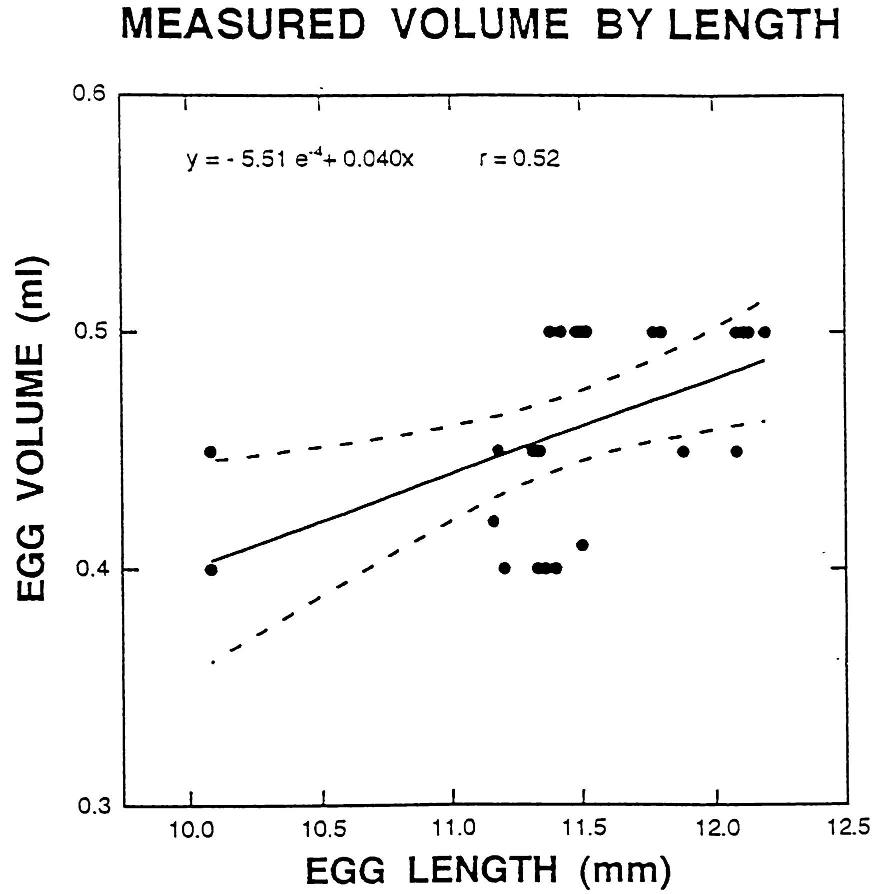

Figure 3. A bivariate plot depicting measured egg volume of *Hemidactylus turcicus* as a function of egg length.

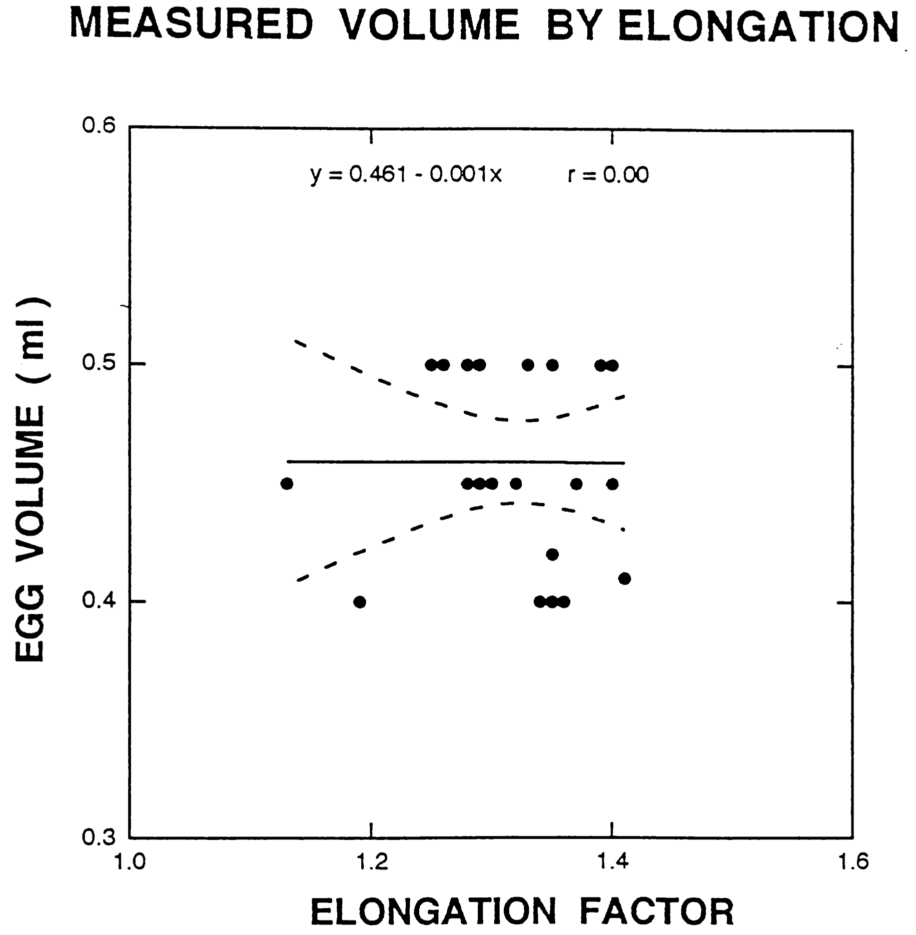

Figure 4. A bivariate plot depicting measured egg volume of *Hemidactylus turcicus* as a function of egg elongation.

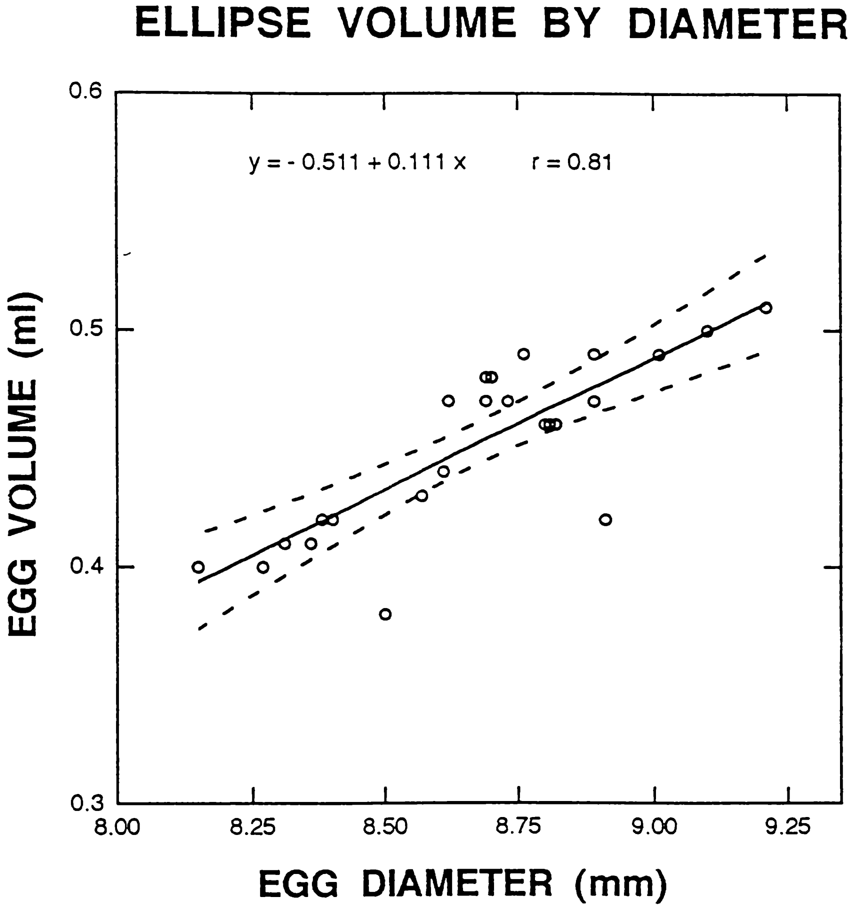

Figure 5. A bivariate plot depicting measured egg volume of *Hemidactylus turcicus* as a function of egg diameter using an ellipse estimate.

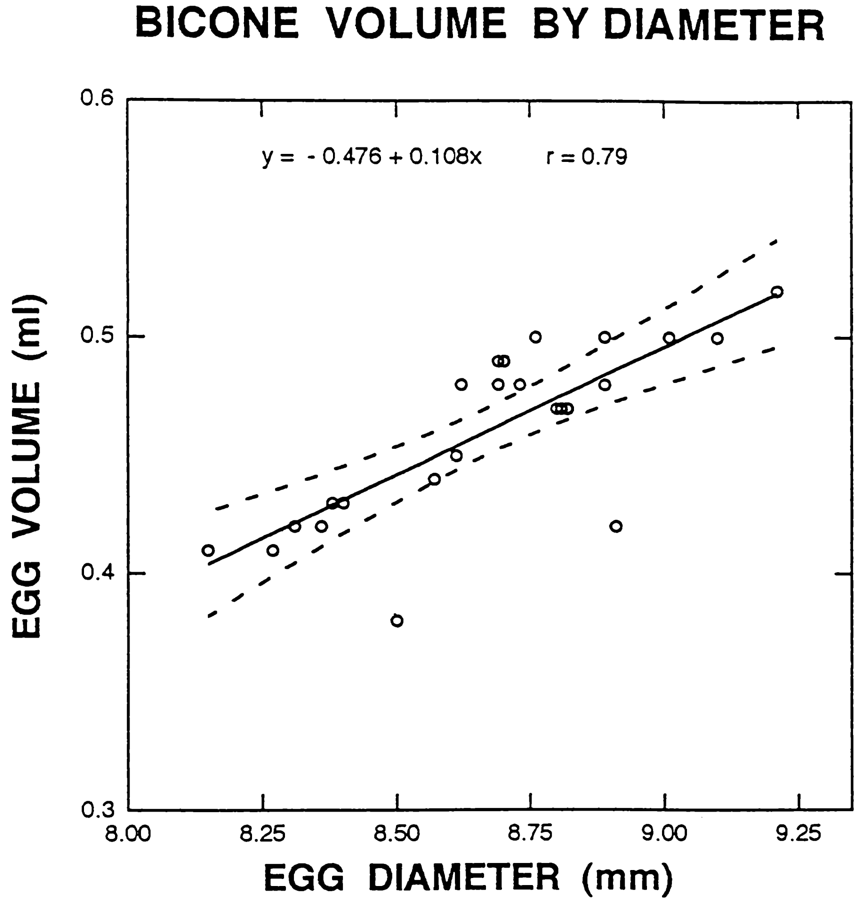

Figure 6. A bivariate plot depicting measured egg volume of *Hemidactylus turcicus* as a function of egg diameter using a bicone estimate.

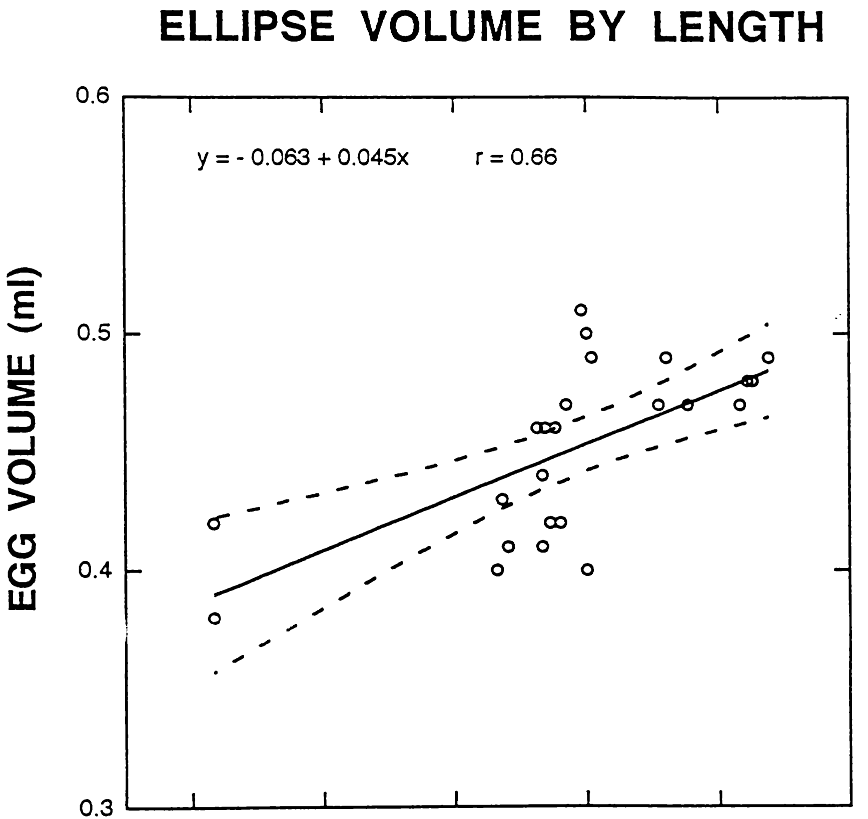

Figure 7. A bivariate plot depicting measured egg volume of *Hemidactylus turcicus* as a function of egg length using an ellipse estimate.

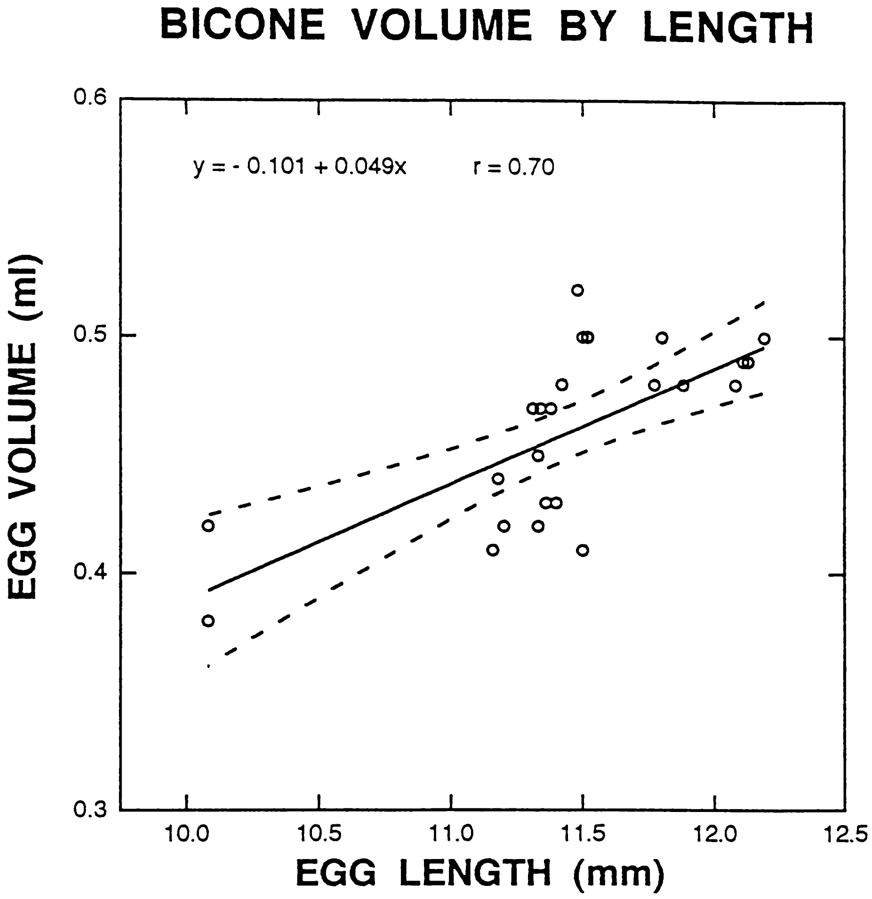

Figure 8. A bivariate plot depicting measured egg volume of *Hemidactylus turcicus* as a function of egg length using a bicone estimate.

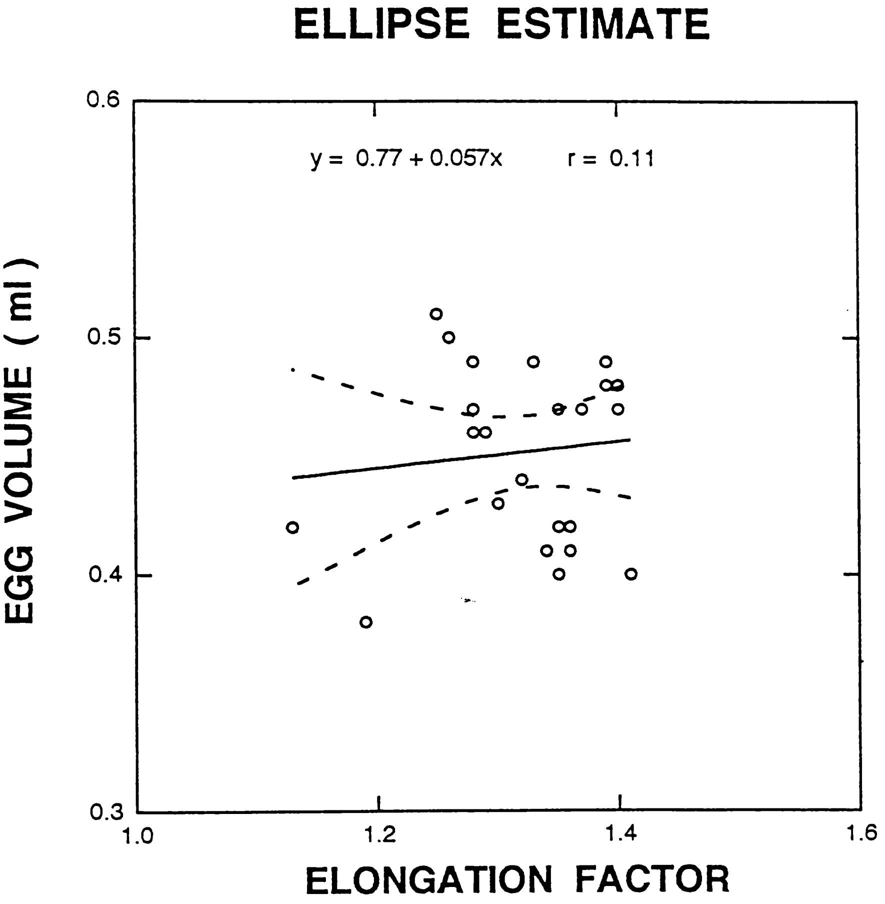

Figure 9. A bivariate plot depicting measured egg volume of *Hemidactylus turcicus* as a function of the elongation factor using an ellipse estimate.

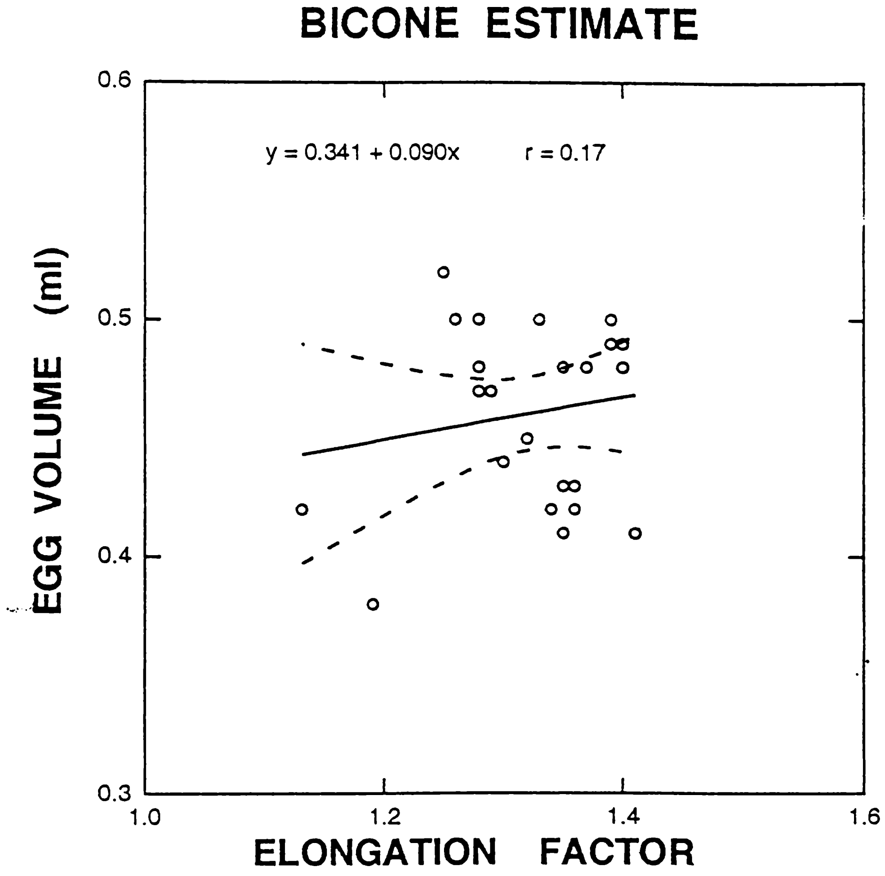

Figure 10. A bivariate plot depicting measured egg volume of *Hemidactylus turcicus* as a function of the elongation factor using a bicone estimate.

DISCUSSION

I found that mean egg length (11.46 mm), width (8.67 mm) and elongation (1.32) of *Hemidactylus turcicus* eggs in my study differed somewhat from those reported by Rose and Barbour (1968) (L=10.9 mm, W= 8.9 mm, and mean E= 1.22) for *H. turcicus* in Louisiana. Iverson and Ewert (1991) suggested that such differences in egg characteristics of a single species could be attributed to a number of factors affecting the different populations. Gaseous conditions of the nest, local environmental conditions, female age and size, and reproductive histories of the females can all effect egg size within a species at different locations.

Hemidactylus turcicus eggs are somewhat larger than a *Lygodactylus klugei* egg (Vitt, 1986), and are smaller than a *Ptyodactylus hassilquistii* egg (Werner, 1989). In some lizards, egg size is often affected by the availability of food and seasonality of clutch development. Large clutches with smaller eggs are produced early in the reproductive season, and small clutches with larger eggs are produced later in the season (Ferguson et. al., 1982; Ferguson and Snell, 1986; Sinervo, 1990). The elongation factor of

1.32 in *H. turcicus* is between that of 1.28 for the crocodilian *Gavialis gangeticus* (Ferguson, 1985), and that of 1.4 for the snake *Coluber constrictor* (Fitch, 1963). Crocodilian eggs are described as positive bicones (i.e. more blunt on ends than an ellipsoid egg). The adaptive advantage to having an oblong, positive bicone egg may be related to the physiological functioning of the egg. By increasing the surface area, exchange of gases with the environment has a selective advantage for the egg. Hummingbirds produce the most reptilian-like egg of the class Aves with an elongation factor of 1.48. Because these eggs are small, this increase in elongation, and thus surface area, is a response to the selective pressure for an increased gas exchange area (Seymour and Ackerman, 1980; Booth and Seymour, 1987).

The results of my study showed that the formula for calculating the volume of a bicone (Maritz and Douglas, 1994), estimates best the volume of the ovoid *Hemidactylus turcicus* eggs, in that their eggs are more bicone than ellipsoid in shape. This calculation provided volume estimates nearest those of the measured values. Maritz and Douglas (1994) suggested that when using the bicone formula, it is best to measure the length, width and bicone of each egg separately to calculate volume. The ellipsoid calculation underestimated egg volume. I found the elongation factor to be, as did Rose et al. (1996), the least accurate predictor of volume. Diameter was the more useful parameter as an independent variable for estimating volume in eggs of *H. turcicus.* Based on my results, future researchers can estimate volume of *H. turcicus* eggs by linear regression. This allows the researcher to account for the slight variation in shape commonly found in reptilian eggs

By doing egg research, we as scientist are able to understand and familiarize ourselves with the reproductive biology and strategies of many organisms. These studies are performed in one of two places generally; the organism's natural habitat, or a laboratory. In either place, the normal state of the nest and the eggs must be maintained as much as possible. Often, in the search for data, this is overlooked by biologist. Simple egg measurements (length and width) can be made without excessive handling or manipulation using digital calipers. With these data, other characteristics (volume, surface area, and elongation) can then be calculated using formulae. This reduction in human involvement with the eggs, gives us a more representative picture of the reproductive biology of the organism itself. Hopefully techniques similar to these can replace ones employed by researchers today, and provide the scientific community with a more accurate information base on which to build.

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