

THE MORPHOMETRIC SIZE OF THE FLYING LIZARDS GENUS *Draco* LINNAEUS, 1758 (SAURIA: AGAMIDAE) IN THAILAND

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ABSTRACT

The study of morphometric size of the flying lizards genus *Draco* in Thailand was carried out based on 494 preserved specimens of 9 *Draco* species from the collection of the Thailand Natural History Museum, National Science Museum, Pathum Thani Province, Thailand. According to the results, the morphometric analysis among 9 *Draco* species indicated that *D. maximus* could be distinguished from the other species by having the greater values ($P > 0.05$) of 21 morphometric characters than those of the other species. The mean and 95% confidence interval for mean of snout-vent length and snout-forelimb length can be used to classify the body size of 9 *Draco* species into the large sized species (*Draco maximus*), the medium sized species (*Draco blanfordii*, *Draco fimbriatus*, *Draco obscurus* and *Draco quinquefasciatus*), and the small sized species (*Draco maculatus*, *Draco melanopogon*, *Draco taeniopterus* and *Draco volans*). Univariate analysis showed significant difference ($P < 0.05$) in all morphometric characters and the other morphometric characters tend to be correlated with the body size.

Key words: Morphometrics, body size, snout to vent length, *Draco*, Thailand.

INTRODUCTION

The *Draco* lizards are the most remarkable and successful of gliding vertebrates. They are well-known as flying lizards or flying dragons due to their ability to glide long distance between trees with wing-like patagial membrane, supported by elongated ribs or rib-like dermal structures (McGuire, 1998; McGuire & Dudley, 2011). The habitats of *Draco* lizards are large, tall and thick forest with an open area for gliding, climb on and sheltered areas for hiding (Mori & Hikida, 1994). The *Draco* lizard species distributed in many regions of Thailand (Taylor, 1963; Musters, 1983; Nabhitabhata *et al.*, 2004). There are inconsistencies in number of species within this genus. Nine to eleven species were described at various times (Taylor, 1963; Inger, 1983; Musters, 1983; Nabhitabhata *et al.*, 2000; Uetz & Hallermann, 2014). This may due to different key characteristics used for identification. However, 9 species of *Draco* lizards in Thailand are in the list of protected species including *Draco blanfordii*, *Draco fimbriatus*, *Draco haematopogon*, *Draco maculatus*, *Draco melanopogon*, *Draco obscurus*, *Draco quinquefasciatus*, *Draco taeniopterus*, and *Draco volans* (Wild Fauna & Flora Protection Division, 2008).

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According to the previous studies there were unclear in the morphometric size of *Draco* lizard species in Thailand. Therefore, the purpose of this study was to discriminate the morphometric size of *Draco* species in Thailand. The result of this study may be used as diagnostic tool to preliminary discrimination of *Draco* lizard species in Thailand.

MATERIALS AND METHODS

The total of 494 preserved specimens in 70% ethanol from the collections of the Thailand Natural History Museum (THNHM), National Science Museum, Pathum Thani Province, Thailand were used in this study. These specimens were collected during 1967 to 2012 from various localities in Thailand. One hundred sixteen individuals of *Draco blanfordii* (DBI), 9 individuals of *Draco fimbriatus* (DFi), 202 individuals of *Draco maculatus* (DMa), 19 individuals of *Draco maximus* (DMx), 21 individuals of *Draco melanopogon* (DMe), 13 individuals of *Draco obscurus* (DOb), 8 individuals of *Draco quinquefasciatus* (DQu), 63 individuals of *Draco taeniopterus* (DTa), and 43 individuals of *Draco volans* (DVo) were measured 21 morphometric characters by using a vernier caliper to the nearest 0.05 mm (Figure 1). All morphometric characters were analyzed using univariate analysis including descriptive statistics (mean \pm standard deviation of the mean (S.D.)) and one-way ANOVA was applied to determine the characteristic differences among species by using post-hoc test Duncan in the software SPSS (version 16). The body size of the *Draco* lizards was discriminated among species using mean and 95% confidence interval for mean (95% CI).

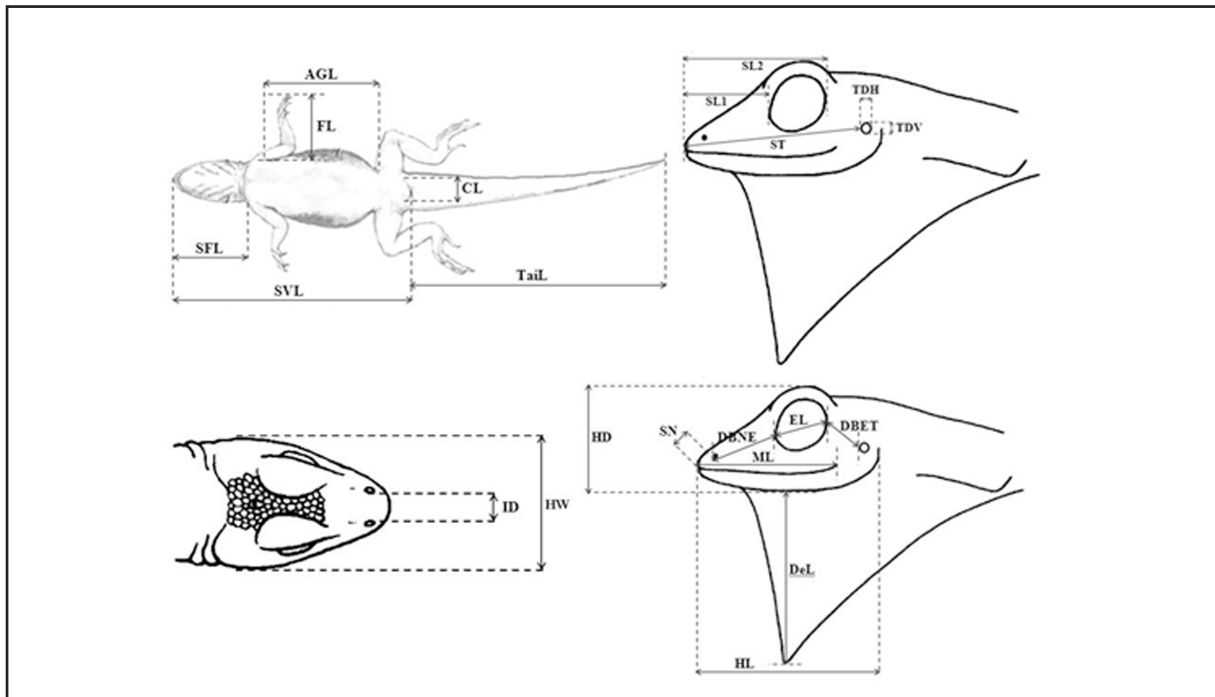


Figure 1 Illustration showing measurement characters (modified from Musters, 1983; Stebbins, 2003).

Abbreviations used for measurements: SVL = snout-vent length, SFL = snout-forelimb length, FL = forelimb length, AGL = axilla-groin length, Tail = tail length, CL = cloacal length, HW = head width, ID = internarial distance, HL = head length, HD = head depth, ML = mouth length, DeL = dewlap length, SN = snout to nostril, DBNE = distance between nostril to anterior edge of eye, DBET = distance between posterior edge of eye to anterior edge of tympanum, EL = eye length, SL1 = snout to anterior edge of eye, SL2 = snout to posterior edge of eye, ST = snout to anterior edge of tympanum, TDV = tympanum diameter in vertical, and TDH = tympanum diameter in horizontal.

RESULTS AND DISCUSSION

Univariate analysis

The mean values, standard deviation subsequent one-way ANOVA followed by post-hoc test Duncan for each of morphometric characters of the total (regardless of sex) of 9 *Draco* lizard species are summarized in table 1. The results showed that most of the morphometric characters of DMx are higher ($P > 0.05$) than those of the other species while the morphometric characters of DTa are lower ($P > 0.05$) than those of other species.

According to the SVL, there is no significant difference ($P > 0.05$) among 4 *Draco* species; DBI, DFi, DOb, and DQu but the previous 4 *Draco* species are significant difference ($P < 0.05$) from the other 4 species; DMa, DMe, DTa, and DVo.

Body size analysis

From the morphometric difference of snout-vent length (SVL) in univariate analysis, mean and 95% confidence interval for mean (95% CI) of SVL of 9 *Draco* species regardless of sex are used to classify the body size of *Draco* lizards into 3 groups (Figure 2). Small sized species (S, lower bound 66.98 – upper bound 82.09 mm) include *Draco taeniopterus* (DTa, mean = 69.29, lower bound = 66.98, upper bound = 71.59), *Draco maculatus* (DMa, mean = 71.86, lower bound = 70.55, upper bound = 73.18), *Draco volans* (DVo, mean = 73.31, lower bound = 70.62, upper bound = 76.01) and *Draco melanopogon* (DMe, mean = 80.20, lower bound = 78.31, upper bound = 82.09). Medium sized species (M, lower bound 83.61 – upper bound 108.56 mm) include *Draco obscurus* (DOb, mean = 91.56, lower bound = 83.65, upper bound = 99.47), *Draco fimbriatus* (DFi, mean = 96.08, lower bound = 83.61, upper bound = 108.56), *Draco blanfordii* (DBI, mean = 98.91, lower bound = 96.18, upper bound = 101.63) and *Draco quinquefasciatus* (DQu, mean = 103.24, lower bound = 98.86, upper bound = 107.61). The large sized species (L) is *Draco maximus* (DMx, mean = 123.62, lower bound = 113.77, upper bound = 133.47).

For support SVL character, the SFL character is used to classify the body size of *Draco* lizards into 3 groups (Figure 3). Small sized species (S, lower bound 21.75 – upper bound 25.54 mm) include *Draco volans* (DVo, mean = 22.55, lower bound = 21.75, upper bound = 23.34), *Draco taeniopterus* (DTa, mean = 22.87, lower bound = 22.12, upper bound = 23.62), *Draco maculatus* (DMa, mean = 23.65, lower bound = 23.24, upper bound = 24.06) and *Draco melanopogon* (DMe, mean = 24.73, lower bound = 23.92, upper bound = 25.54). Medium sized species (M, lower bound 27.46 – upper bound 37.03 mm) include *Draco quinquefasciatus* (DQu, mean = 30.16, lower bound = 28.48, upper bound = 31.83), *Draco obscurus* (DOb, mean = 30.16, lower bound = 27.46, upper bound = 32.86), *Draco blanfordii* (DBI, mean = 31.82, lower bound = 30.98, upper bound = 32.67) and *Draco fimbriatus* (DFi, mean = 32.99, lower bound =

Table 1. Mean \pm S.D. and one-way ANOVA of morphometric characters in the total (regardless of sex) of 9 *Draco* species in Thailand.

Measurements	DBI	DFI	DMa	DMx	DMe	DOb	DQu	DTa	DVo	P-value
SVL	98.91 \pm 14.82 ^{bc}	96.08 \pm 16.23 ^{bc}	71.86 \pm 9.48 ^e	123.62 \pm 20.44 ^a	80.20 \pm 4.15 ^d	91.56 \pm 13.09 ^e	103.24 \pm 5.23 ^b	69.29 \pm 9.15 ^e	73.31 \pm 8.76 ^{de}	0.000
SFL	31.82 \pm 4.59 ^{bc}	32.99 \pm 5.26 ^b	23.66 \pm 2.96 ^d	40.25 \pm 6.09 ^a	24.73 \pm 1.78 ^d	30.16 \pm 4.47 ^c	30.16 \pm 2.00 ^c	22.87 \pm 2.97 ^d	22.55 \pm 2.59 ^d	0.000
FL	41.27 \pm 5.36 ^b	37.36 \pm 6.54 ^c	30.31 \pm 3.86 ^d	52.10 \pm 9.07 ^a	40.21 \pm 3.07 ^{bc}	39.87 \pm 5.69 ^{bc}	40.06 \pm 1.79 ^{bc}	33.16 \pm 4.19 ^d	27.34 \pm 2.87 ^e	0.000
AGL	56.04 \pm 9.25 ^{bc}	52.61 \pm 7.63 ^c	39.83 \pm 5.38 ^c	70.89 \pm 11.76 ^a	48.02 \pm 2.06 ^d	51.78 \pm 8.18 ^{cd}	60.26 \pm 3.02 ^b	37.93 \pm 5.22 ^e	42.02 \pm 5.39 ^e	0.000
Tail	180.73 \pm 29.63 ^b	153.29 \pm 25.69 ^c	107.96 \pm 17.53 ^e	206.74 \pm 34.69 ^a	158.34 \pm 12.54 ^e	160.73 \pm 27.15 ^e	159.05 \pm 14.64 ^e	125.58 \pm 22.37 ^d	107.17 \pm 13.54 ^e	0.000
CL	5.45 \pm 0.89 ^{bc}	5.29 \pm 1.12 ^{bc}	4.93 \pm 0.89 ^{cd}	6.79 \pm 1.54 ^a	4.66 \pm 0.45 ^{de}	5.67 \pm 0.67 ^b	5.65 \pm 0.32 ^b	4.29 \pm 0.86 ^e	4.28 \pm 0.77 ^e	0.000
HW	10.62 \pm 1.53 ^c	13.68 \pm 1.89 ^b	8.58 \pm 1.04 ^d	15.28 \pm 2.98 ^a	8.03 \pm 0.78 ^{de}	9.92 \pm 1.63 ^c	10.75 \pm 0.92 ^c	7.43 \pm 0.98 ^e	7.40 \pm 0.96 ^e	0.000
ID	2.57 \pm 0.46 ^c	3.94 \pm 0.64 ^a	2.71 \pm 0.35 ^{bc}	2.61 \pm 0.51 ^{bc}	1.81 \pm 0.17 ^e	2.12 \pm 0.26 ^d	2.56 \pm 0.19 ^c	1.84 \pm 0.31 ^e	2.84 \pm 0.37 ^b	0.000
HL	18.99 \pm 2.59 ^{cd}	20.89 \pm 3.63 ^b	14.87 \pm 1.67 ^e	25.49 \pm 4.65 ^a	13.78 \pm 0.76 ^{ef}	17.69 \pm 2.58 ^d	20.01 \pm 1.15 ^{bc}	13.17 \pm 1.67 ^f	13.42 \pm 1.32 ^f	0.000
HD	8.71 \pm 1.03 ^c	9.01 \pm 2.06 ^c	7.28 \pm 0.83 ^d	11.91 \pm 2.04 ^a	6.84 \pm 0.52 ^{de}	8.58 \pm 1.19 ^c	9.69 \pm 0.71 ^b	6.57 \pm 0.82 ^e	7.20 \pm 0.79 ^{de}	0.000
ML	14.02 \pm 1.89 ^{cd}	15.26 \pm 2.74 ^b	11.37 \pm 1.35 ^e	18.77 \pm 3.37 ^a	10.01 \pm 0.74 ^f	13.24 \pm 1.83 ^d	14.95 \pm 0.83 ^{bc}	10.11 \pm 1.34 ^f	9.94 \pm 1.10 ^f	0.000
DeL	24.03 \pm 7.99 ^b	23.72 \pm 6.44 ^{bc}	20.96 \pm 8.36 ^{bcd}	30.69 \pm 13.06 ^a	20.21 \pm 7.17 ^{bcd}	22.97 \pm 6.93 ^{bc}	24.54 \pm 7.08 ^b	18.18 \pm 7.18 ^{cd}	15.49 \pm 5.56 ^d	0.000
SN	2.12 \pm 0.38 ^e	2.71 \pm 0.39 ^b	1.72 \pm 0.32 ^{ef}	3.11 \pm 0.66 ^a	1.28 \pm 0.18 ^h	1.82 \pm 0.31 ^{de}	2.03 \pm 0.16 ^{cd}	1.38 \pm 0.23 ^{gh}	1.59 \pm 0.29 ^g	0.000
DBNE	5.13 \pm 0.86 ^{cd}	6.03 \pm 1.25 ^b	3.65 \pm 0.52 ^e	6.57 \pm 1.38 ^a	3.47 \pm 0.29 ^{ef}	4.83 \pm 0.78 ^d	5.29 \pm 0.45 ^c	3.45 \pm 0.57 ^{ef}	3.08 \pm 0.44 ^f	0.000
DBET	3.96 \pm 0.54 ^c	4.46 \pm 0.82 ^b	3.25 \pm 0.43 ^d	5.63 \pm 1.06 ^a	2.92 \pm 0.29 ^e	3.78 \pm 0.71 ^c	4.43 \pm 0.26 ^b	2.70 \pm 0.43 ^e	2.70 \pm 0.36 ^e	0.000
EL	7.23 \pm 0.64 ^c	7.81 \pm 0.77 ^b	5.87 \pm 0.50 ^e	9.39 \pm 1.24 ^a	6.37 \pm 0.22 ^d	6.92 \pm 0.65 ^c	7.69 \pm 0.47 ^b	5.76 \pm 0.55 ^e	6.02 \pm 0.49 ^{de}	0.000
SLI	7.23 \pm 1.15 ^{cd}	8.18 \pm 1.47 ^b	5.51 \pm 0.76 ^e	9.66 \pm 1.78 ^a	4.89 \pm 0.25 ^f	6.66 \pm 1.21 ^d	7.34 \pm 0.35 ^c	4.80 \pm 0.73 ^f	4.97 \pm 0.64 ^{ef}	0.000
SL2	13.11 \pm 1.55 ^c	14.34 \pm 1.96 ^b	10.65 \pm 1.20 ^d	16.70 \pm 3.61 ^a	10.25 \pm 0.56 ^d	12.63 \pm 1.59 ^c	14.22 \pm 0.61 ^b	9.79 \pm 1.28 ^d	9.86 \pm 1.09 ^d	0.000
ST	16.44 \pm 2.16 ^{cd}	18.31 \pm 2.90 ^b	12.81 \pm 1.47 ^e	22.30 \pm 3.92 ^a	12.01 \pm 0.70 ^{ef}	15.58 \pm 2.09 ^d	17.50 \pm 0.96 ^{bc}	11.45 \pm 1.51 ^f	11.56 \pm 1.25 ^f	0.000
TDV	1.96 \pm 0.38 ^{bc}	2.73 \pm 0.44 ^a	1.86 \pm 0.33 ^{cd}	2.81 \pm 0.45 ^a	1.78 \pm 0.26 ^{cde}	1.84 \pm 0.34 ^{cd}	2.16 \pm 0.10 ^b	1.61 \pm 0.26 ^e	1.70 \pm 0.24 ^{de}	0.000
TDH	1.76 \pm 0.38 ^{bc}	2.47 \pm 0.35 ^a	1.55 \pm 0.24 ^{de}	2.34 \pm 0.54 ^a	1.61 \pm 0.20 ^{cde}	1.67 \pm 0.17 ^{bcd}	1.86 \pm 0.28 ^b	1.34 \pm 0.22 ^f	1.44 \pm 0.19 ^{ef}	0.000

28.94, upper bound = 37.03). The large sized species (L) is *Draco maximus* (DMx, mean = 40.25, lower bound = 37.32, upper bound = 43.19).

The results of univariate analysis of the total number of 9 *Draco* species regardless of sex indicated that most of the morphometric characters of *Draco maximus* were higher ($P > 0.05$) than those of the other species. Thus, *Draco maximus* was the largest species. This result was supported by the results of body size analysis using the mean and 95% confidence interval for mean of snout-vent length (95% CI of SVL) that classified *Draco maximus* as the large sized species, whereas *Draco blanfordii*, *Draco fimbriatus*, *Draco obscurus* and *Draco quinquefasciatus* were classified as the medium sized species. On the other hand, *Draco maculatus*, *Draco melanopogon*, *Draco taeniopterus* and *Draco volans* were classified as the small sized species. The body size of *Draco* species from this study is consistent with the study of Inger (1983) and Musters (1983). Thus, SVL is the most important morphometric trait for separating the body size of *Draco* lizards as well as the study of Roitberg *et al.* (2011), they use SVL to classify the body size in the lizard *Zootoca vivipara* population. Furthermore, the present study, SFL is used to classify the body size of *Draco* lizards is consistent with the SVL character. However, in the practical use, the morphometric characters may not be appropriate tool for identification the *Draco* species except *Draco maximus* but they could be used as an additional or diagnostic tool to support the qualitative characters.

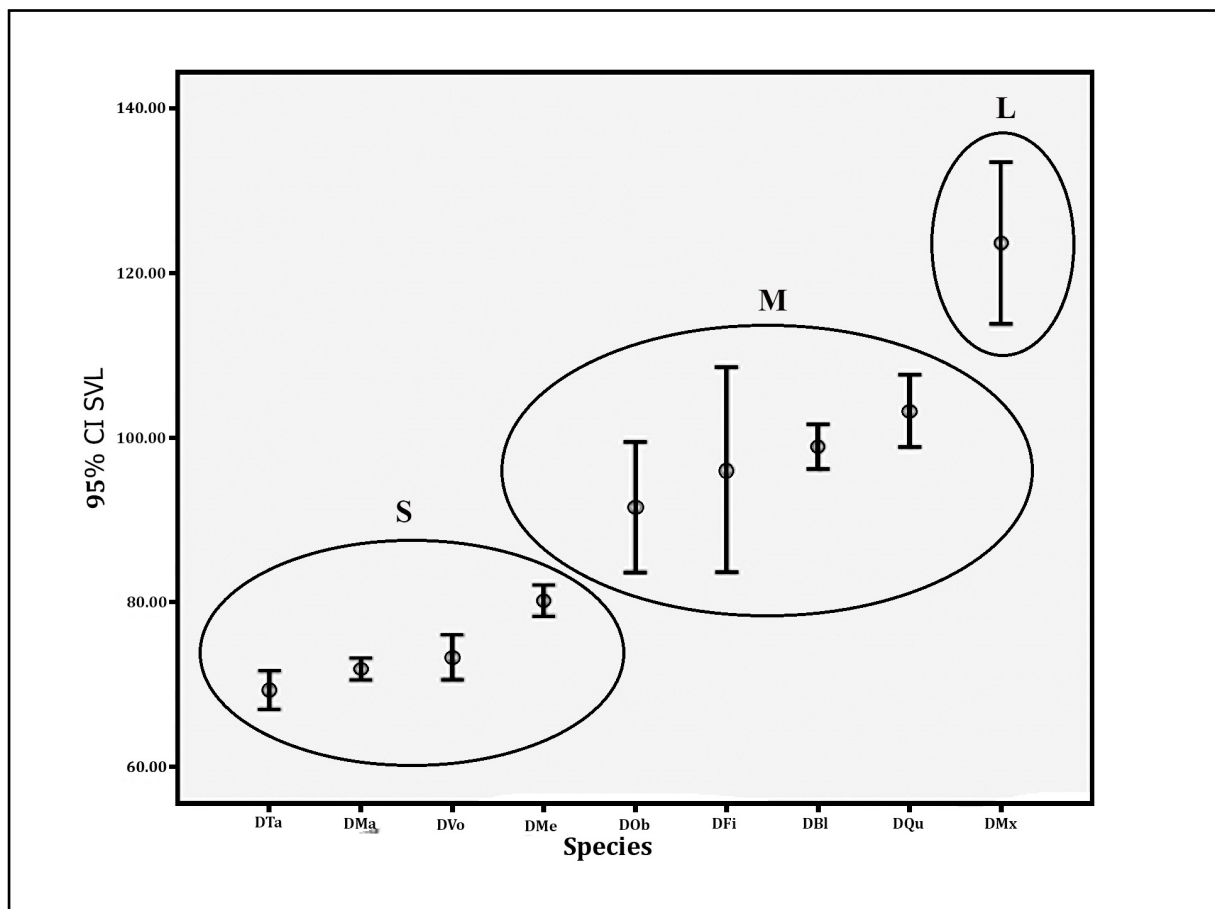


Figure 2 Mean and 95% confidence interval for mean (95% CI) of snout-vent length (SVL) classified the body size of *Draco* lizards into small (S), medium (M) and large (L) sized species.

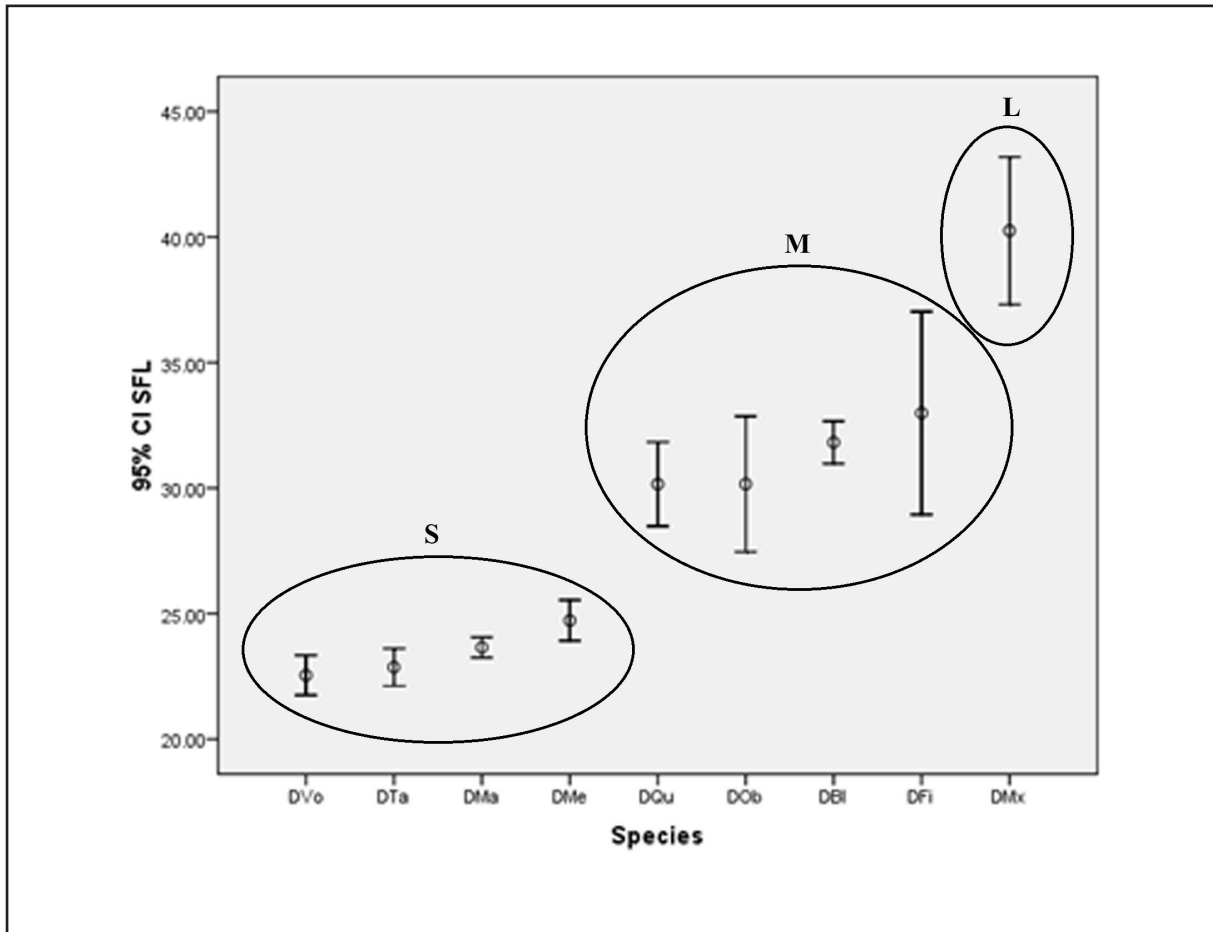


Figure 3 Mean and 95% confidence interval for mean (95% CI) of snout-forelimb length (SFL) classified the body size of *Draco* lizards into small (S), medium (M) and large (L) sized species.

CONCLUSION AND RECOMMENDATION

The morphometric analysis among 9 *Draco* species indicated that *Draco maximus* could be distinguished from the other species by having the greater values ($P > 0.05$) of 21 morphometric characters than those of the other species. The mean and 95% confidence interval for mean (95% CI) of snout-vent length (SVL) and snout-forelimb length (SFL) can be used to classify the body size of 9 *Draco* species into the large sized species (*Draco maximus*), the medium sized species (*Draco blanfordii*, *Draco fimbriatus*, *Draco obscurus* and *Draco quinquefasciatus*), and the small sized species (*Draco maculatus*, *Draco melanopogon*, *Draco taeniopterus* and *Draco volans*).

The future study should use the specimens from various sources and the live specimens in the field for their complete information.

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