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Pattern of yolk internalization by hatchlings is related to breeding timing in the garden lizard, *Calotes versicolor*

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Pattern of yolk internalization by hatchlings born in early (May–June), mid (July–August) and late (September–October) breeding season in relation to maternal, egg and hatchling sizes was studied in *Calotes versicolor*. The maternal snout-vent length (SVL), body mass, clutch size, clutch mass and egg mass were recorded. Eggs from five clutches each, from early, mid and late breeding periods were incubated at ambient room temperature until hatching. At hatching, SVL and body mass of the hatchlings, and amount of yolk internalized by hatchlings were recorded. The internalized yolk mass of hatchlings was not related to maternal SVL, body mass, clutch mass and hatchling SVL. Internalized yolk mass was positively correlated with egg mass and hatchling body mass. Significantly greater amount of yolk was internalized by hatchlings born in the later part of the breeding season. Production of heavier hatchlings with greater amount of internalized yolk appears to be an important strategy to enhance the fitness of hatchlings of later clutches that have to compete for food with conspecific hatchlings of earlier clutches.

HIGHER vertebrates expedite the growth of their offspring by providing post-natal parental care, especially by feeding the young. Parental care is uncommon among reptiles[1]. However, reptiles aid their offspring's post-natal nutritional state by deposition of extra yolk than actually required by the developing embryos. The portion of yolk that remains unutilized at the time of hatching (often referred to as 'residual yolk') is drawn into the body of the hatchling before it emerges from the egg[2,3]. The residual yolk represents reserve energy to offspring during their early post-hatching activities[2,4–6]. In turtles, residual yolk serves as reserve energy during their dispersal from nest to water[2,6].

Inter-clutch variation in the amount of residual yolk is reported in a single species of lizard, *Iguana iguana*[5]. In this lizard, the inter-clutch variation in the internalized yolk is attributed to the difference in the availability of nutrients to the mother. All the previous studies on reptiles concerned with yolk internalization are on species that lay eggs in a single clutch or those have not been examined for the influence of maternal body size, clutch size and mass, and egg size, if any, on the pattern of yolk internalization between clutches oviposited at different times of the breeding season. Hence, the actual consequences of breeding time on yolk internalization are poorly understood in reptiles.

Calotes versicolor is a multiclutched lizard and has an extended breeding season (May–October)[7,8]. Therefore, it serves as a good model to study the pattern of yolk internalization by hatchlings from eggs laid at different times of the breeding season. The present study was undertaken to know whether maternal size, clutch and egg size, and breeding timing have any influence on residual yolk mass of hatchlings in *C. versicolor*.

The eggs from gravid *C. versicolor* were obtained during the breeding period (May–October 1999) from surrounding areas of Dharwad city (15°17′N and 75°3′E). The maternal snout-vent length (SVL; cm) and mass of body (g), clutch (g) and eggs (mg), and total number of eggs (clutch size) were recorded for these lizards. The clutches were categorized as early (May–June), mid (July–August) and late (September–October) depending upon the capture of gravid lizards following the procedure described previously by Shanbhag *et al.*[8]. For each

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part of the breeding season, five clutches were used. The eggs were incubated in the laboratory at an ambient temperature of 25.6–28.5°C following the procedure of Radder et al.[9]. At the first sign of piping, the hatchlings were monitored continuously. At hatching, the body mass (mg), SVL (cm) and the amount of residual yolk (mg) of the hatchlings were recorded.

Mean and standard error for the selected variables were calculated from untransformed data. For further analyses the data were log (base 10) transformed to meet the assumptions of parametric statistics. For data analyses, body mass of the hatchlings was obtained by subtracting mass of internalized yolk from body weight (inclusive of internalized yolk) of hatchling to avoid the Type-II error. Relationship between various traits was computed by Carl Pearson correlation coefficient analyses. Variations in the amount of internalized yolk among early, mid and late breeding periods were analysed by One-way analysis of variance (ANOVA) followed by Scheffe's multiple range test. Mean figures from each clutch were used for data analyses to avoid statistical non-independence and pseudo-replication. Significance level was accepted at $P < 0.05$. All analyses were performed using SPSS (version 6.1.3 for Windows).

All recorded traits are summarized in Table 1. In general, the residual yolk mass showed no relationship with maternal SVL ($r = 0.35$, $P > 0.05$, $n = 15$ clutches), body mass ($r = 0.21$, $P > 0.05$, $n = 15$ clutches) and clutch mass ($r = 0.35$, $P > 0.05$, $n = 15$ clutches). However, the amount of internalized yolk increased with an increase in mean egg mass ($r = 0.78$, $P < 0.01$) and also with the advancement of breeding season ($r = 0.71$, $P < 0.01$, $n = 15$ clutches). The amount of internalized yolk was positively correlated with hatchling body mass ($r = 0.85$, $P < 0.01$, $n = 15$ clutches), but not with its SVL ($r = 0.43$, $P > 0.05$, $n = 15$ clutches).

Analyses of data with respect to breeding timing showed significant variations in egg mass (ANOVA, $df_{2,12}$, $F = 12.30$, $P < 0.001$; Figure 1), amount of yolk internalized (ANOVA, $df_{2,12}$, $F = 12.60$, $P < 0.001$; Figure 1), and body mass (ANOVA, $df_{2,12}$, $F = 11.79$, $P < 0.001$, Figure 1) of hatchlings. The above three para-
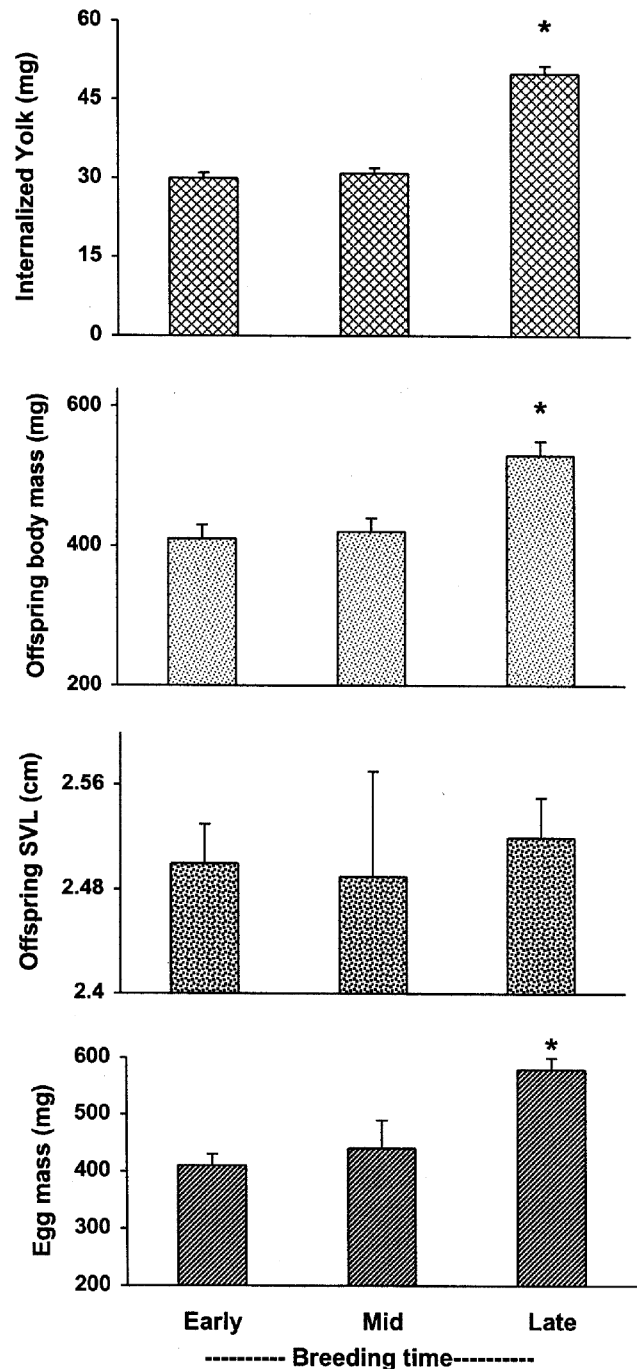

Figure 1. Variation in egg mass, offspring SVL, offspring body mass and internalized yolk among early, mid and late breeding periods in C. versicolor. *, Significant difference among early, mid and late breeding periods based on ANOVA followed by Scheffe's multiple range test. Note there was no variation in the offspring SVL during different parts of the breeding period.

Table 1. Mean ± SEM of various recorded traits in adult and hatchling *Calotes versicolor* ($n = 15$ clutches)

Variable	Mean ± SE	Range
Maternal SVL (cm)	9.68 ± 0.22	8.50–12.00
Maternal body mass (g)	35.27 ± 2.20	22.0–52.00
Clutch size	17.00 ± 0.78	12–21
Clutch mass (g)	7.78 ± 0.39	5.39–11.02
Egg mass (mg)	480.0 ± 20	362.0–698.0
Offspring SVL (cm)	2.50 ± 0.02	2.42–2.62
Offspring body mass (mg)	460.0 ± 20	370.0–580.0
Internalized yolk (mg)	40.0 ± 01	21–53

meters measured greatest in the later part of the breeding season compared to early and mid breeding periods (Figure 1). There was no significant variation in the offspring SVL hatched during different phases of the breeding season (ANOVA, $df_{2,12}$, $F = 0.19$, $P > 0.05$; Figure 1).

The present study on *C. versicolor* revealed that there is no relationship between internalized yolk mass and maternal body size and mass, and clutch mass, but is significantly influenced by breeding time through the egg mass. The internalized yolk mass that is significantly more in hatchlings born in the late breeding season is correlated with their egg mass. Interestingly, the heavier eggs in the later part of the breeding season did not produce large-sized hatchlings in terms of SVL compared to those arising from the smaller eggs of early clutches. Instead, there was an increase in the body mass as well as the amount of internalized yolk in hatchlings born in the late breeding season. In reptiles, hatchling size alone is not an important correlate of hatchling survivorship, but internalized yolk is also a component of fitness for species whose hatchlings have to face competition for food and adverse environmental conditions like winter. Therefore, production of similar sized (SVL) hatchlings with greater body mass and residual yolk is beneficial for immediate post-hatching activity and survival[3]. The hatchlings of *C. versicolor* born later in the season may have to compete with the larger conspecific hatchlings of earlier clutches. Therefore, maximizing post-hatching energy through internalized yolk in the later part of the breeding season may indeed outweigh the advantages, if any, of maximizing the linear body size. Hence, in *C. versicolor*, selection has favoured greater amount of body mass and residual yolk to enhance fitness of late-born hatchlings.

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Fractal dimension and *b*-value mapping in northeast India

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The statistical characteristics of seismicity, fractal dimension and *b*-values are mapped in the NE India region using permanent microearthquake network data and teleseismic data. The maps revealed the seismogenic structures and the crustal heterogeneities, which are useful for earthquake risk evaluation.

NORTHEAST India and adjacent areas are highly vulnerable to earthquake hazards. Any realistic seismic hazard assessment requires identification of seismic sources, evaluation of seismic characteristics with space and time, and frequency–magnitude relation for individual tectonic zones governed by the characteristics of faults.

Magnitude of an earthquake is the most commonly used parameter of earthquake size. The statistical distribution of sizes, for a group of earthquakes, is very complicated. Gutenberg and Richter[1] have provided a simplest earthquake reoccurrence or magnitude–frequency relation as $\log_{10} N = a - bM$, where N is the number of earthquakes in the group having magnitudes larger than M, a and b are constants. The estimated coefficient b known as the b-value, varies mostly from 0.7 to 1.3, depending on the tectonics of the region. The variability of b-values in different regions may be related to structural heterogeneity and stress distribution in space[2–4]. The b-value represents a statistical measurement of the relative abundance of large and small earthquakes in the group. A higher b-value means that a smaller fraction of the total earthquakes occur at the higher magnitudes, whereas a lower b-value implies a larger fraction occur at higher magnitudes. The higher levels of motion at a site are dominated by occurrences of the larger earthquakes. If b is large, large earthquakes are relatively rare. It has been observed that the b-value shows systemic variations in the period preceding a major earthquake[5–7]. Hence it is the most investigated equation in seismology, observationally as well as theoretically. It has wide applications, e.g. for estimating the magnitude of future earthquakes, and to perform probabilistic hazard analysis.

The earthquake phenomenon possesses fractal structure with respect to time, space and magnitude. The Gutenberg–Richter[1] relation for frequency vs magnitude is a power law involving magnitude. Similarly, the after-