Breeding biology of the Small Bee-eater *Merops orientalis* (Latham, 1801) in Nagapattinam District, Tamil Nadu, India

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Abstract: The breeding biology of Small Bee-eater *Merops orientalis* was studied in Nagapattinam District of Mannampandal, Tamil Nadu, India between 2005 and 2006. A total of 34 nests were studied and the bee-eaters were found to excavate long tunnels ranging in length from 79 to 125cm (104.9±123.48 cm) and ending in widened egg chambers. The mean diameter and circumference of the entrance hole opening was 8.94±1.03 cm and 26.9±3.55 cm respectively. They excavated nest holes at a mean height of 52.1±2.69 cm from the bottom and 158.7±4.11 cm from the top of sandy river banks. The clutch size varied from 3 to 6 with a mean of 3.5±0.88 and clutches of three were very common. The egg dimensions ranged between 23.0 x 20.0 mm and 18.0 x 14.0 mm. The weight of the eggs varied between 2.0 and 5.0 g (3.3±0.65 g). The mean incubation period of the Small Bee-eater was 14.4±1.01 days and both sexes took part in the incubation. The Small Bee-eater laid 56 eggs, of which 43 hatched (76.7%) and 36 flew out of the nest, making the fledging success 83.7%. The newly hatched nestlings were 3.16 g in weight and reached a maximum of 23.16 g on day 24. A reduction in weight was noticed in the last few days and 20.75g was reached on day 27. The other body parts attained maximum maturity from hatching to fledging.

Keywords: Eggs, hatching success, nest-site, nestling growth, Small Bee-eater

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INTRODUCTION

Bee-eaters (Aves: Meropidae) are a clade of 26 species with considerable diversity in social and breeding behaviors. The Small Bee-eater *Merops orientalis* is the most variable species in the family in regard to plumage color and can be subdivided into 6–8 geographically variable races (Fry 1984). They are common in open cultivated fields, nest on the face of perpendicular banks of ravines, sandy river banks and sandy bunds, gently sloping bare ground and around cultivated tracts (Sridhar & Karanth 1993). Small Bee-eaters are aerial insectivores and can be seen foraging frequently in agricultural fields. Over 95% of their prey comes from various insect's *viz.*, beetles, bees, dragonflies, butterflies, bugs and grasshoppers (Asokan 1998; Asokan et al. 2009b). The nest-site selection, helpers at nest and breeding performance of bee-eaters are discussed widely (Fry 1972; White et al. 1978; Lessells & Krebs 1989; Wrege & Emlen 1991; Kristin 1994; Kossenko & Fry 1998; Burt 2002; Boland 2004; Heneberg & Simecek 2004; Yuan et al. 2006). Information on the bee-eater in India includes studies on distribution, population and feeding (Hutson 1947; Inglis 1949; Ara 1951; Roy 1968; Lott 1985; Abrol 1994; Joshua et al. 1997; Asokan 1998; Nirmala 2000; Asokan et al. 2003). However, the breeding biology of the bee-eater is less exposed excepting for information on some aspects from certain parts of India (Neelakantan 1948; Bannerjee 1992; Sridhar & Karanth 1993; Asokan 1995). In this paper we address some detailed information on nesting season, nest-sites, clutch size, egg morphometry, incubation and nestling growth patterns of the Small Bee-eater in Nagapattinam District, Tamil Nadu, India.

MATERIALS AND METHODS

The study was conducted on the Cauvery River banks and the adjacent areas of Mannampandal (18˚18'N & 79˚50'E) in Nagapattinam District, Tamil Nadu, India between 2005 and 2006. Agriculture is the major economy of this area, contributing a high share of rice production in the state. Sugarcane, groundnut, green gram, black gram, cotton, etc are other major crops cultivated in this area. The river Cauvery and its tributaries are the major perennial water sources used for irrigation. The predominant wood plant species found in the study area includes *Cocos nucifera, Borassus flabellifer, Mangifera indica, Enterolobium saman, Tamarindus indicus, Ficus benghalensis, Acacia arabica,* and *Azadirachta indica.* Important shrub species are *Prosopis juliflora, Jatropha glandulifera, Adhathoda vesica.* Plantations of *Casuarina equisetifolia, Tectona grandis and Bambusa arundinacea* are also found in the study area. The north-east monsoon usually brings rain to the study area during October-December (65% of the total rainfall in a year); the dry season occurs between May and July.

During the breeding season, the study area was thoroughly searched to detect nests. The tunnel depth, diameter and circumference of the entrance opening, distance of the hole to the bank bottom and distance of the hole to the bank top of each nest was measured by using a standard measuring tape and wooden scale (Asokan 1995). The tunnel depth was measured after the completion of breeding activities *i.e.* nest was broken at the end of the nesting period. A tunnel was slowly and carefully dug from one direction of the nest-site, to reach the egg chamber. After the egg measurements were completed the egg chamber was closed with a dark steel plate for future use *i.e*. nestling measurements. The distance to the nearest agricultural lands, groves, human habitations, perch sites and electric lines were measured in meters with a marked rope.

The freshly laid eggs were numbered with a felt-tipped pen, measured with Vernier calipers and weighed to the nearest 0.5g with a spring balance and care was taken to avoid excessive disturbance, which might have attracted predators. The shape index of the eggs was computed using the formula (Prasanth et al. 1994) Si = B*100/L, where Si = shape index, B = breadth and L = length of the egg in centimeters. The incubation period was determined from the first egg laid till the first egg hatched.

The hatching success and fledgling success of the Small Bee-eater were calculated by using the following formulae:

Hatching success (%) = (No. of eggs hatched / total no. of eggs laid) x 100

Fledging success (%) = (No. of nestlings fledged / total no. of nestlings hatched) x 100

Growth changes in the Small Bee-eater nestlings were measured from hatching to fledging and the method of Pettingil (1985) was employed for measuring nestlings. All the nests were visited every 3 days for taking morphometric measurements of the body parts. Disturbances were minimized by handling the nestlings very carefully during the measurements. All the nestlings were allotted individual identification marks. Totally eight measurements were made (i) body weight, using a spring balance of 1g accuracy; (ii) body length, from the tip of the bill to the tip of the longest rectrix; (iii) bill length, from the tip of the upper mandible to the base of the culmen; (iv) bill depth, distance between the upper and lower mandible; (v) wing length, as the straight length from the bend of the wing to the tip of the longest primary; (vi) wing span, the distance from tip to tip of the longest primaries of the outstretched wings; (vii) tarsus length, measurement from the base of the tarsometatarsus to the base of the middle toe and (viii) tail length, the distance from the tip of the longest rectrix to the base of the middle rectrices.

Descriptive statistics are mean followed by standard deviation (SD). The Pearson simple correlation equation was used to test any relationship between egg weight and egg shape index. The significance of the test was assessed at p = 0.05. The MINITAB 13.1 statistical package was used for all the analyses. The results of the above analyses were interpreted using standard statistical procedures (Sokal & Rohlf 1981).

RESULTS

Nesting season

The nesting season of the Small Bee-eater was initiated in March and ended in June. Breeding was quite synchronous among the local populations of the Small Bee-eaters. Excavation of the nest cavities was in its final stages or complete by mid-March.

Nest and nest-sites

Totally 34 nests of the Small Bee-eater were recorded during the study period. Of these 15 nests were active and 19 were inactive. The inactive or old nests were identified by a typical hole pattern and undigested insect remains found in the nest hole and egg chamber. Nest burrows were located along the sides of river banks (95%) and sandy grounds (5%) (Image 1). Nests consisted of tunnels that measured 8.9±1.03cm in diameter (range 7.2-11.2cm) and 26.9±3.55 cm in circumference (range 18-36cm). The entrance tunnels were angled and it was impossible to see into the nesting cavity from outside the entrance. The posterior end of the tunnel was wide and formed the nesting chamber. The length of the nest tunnels varied from 79 to 125cm with a mean length of 104.9±13.48 cm (Table 1). The small Bee-eater excavated the nests at a mean height of 52.1±2.69 cm from bottom and 158.7±4.11 cm from top of the river banks. Distance to agricultural lands (13.2±2.87 m),

Image 1. Typical nest of the Small Bee-eater

Image 2. Eggs of the Small Bee-eater

perching sites (0.5±0.33 m) and electric lines (13.6±2.17 m) were closer to the nest-sites (Table 1).

Eggs and clutch size

The eggs of the Small Bee-eater are spherical and small in size (Image 2). In total 56 eggs were examined during the study. Longer and thinner eggs had lower shape index while shorter and thicker ones had higher index. No correlation could be found between weight and shape index ($r = -0.067$, $p = 0.1371$, df = 56). The eggs are white in color with no markings or spots. The highest weight of eggs examined during the study was 5g and lowest 2g and the average 3.3±0.65 g. The minimum length of the egg was 20mm and minimum width 14mm. The maximum egg length was 23mm and width 18mm. The mean length was 21±0.09 mm and the width 14±0.11 mm (Table 2). The clutch size varied from 3 to 6 with a mean of 3.7±0.88. Clutches of three and four were most common and had a percentage frequency of 46.6 and 40.0 respectively. Clutches of five and six were very rare (Fig. 1). The 56 eggs examined during the present study belonged to 15 clutches.

Incubation

Incubation started after laying the first egg. The incubation period of 41 eggs observed in the present study, ranged from 14-16 days. The mean incubation period was 14.4±1.01 days. Both the parents were observed to incubate the eggs. While one bird sat on the eggs, the other remained very close to the nest perched on small shrubs within reach, watching over the nest.

Hatching and fledging success

Out of 56 eggs examined for the purpose, 43 hatched; hatching success was 76.7%. Of the remaining eggs, four eggs were broken and nine remained unhatched. From the 43 hatched eggs, 36 nestlings were successfully flown out the nest and making the fledging success of 83.7%.

Table 1. Physical characteristics of Small Bee-eater nest holes and habitat around the nests (N = 34).

Variables	Mean±SD	Min.	Max.
Nest hole diameter (cm)	8.9±1.03	7.2	11.2
Nest hole circumference (cm)	26.9±3.55	18	36
Tunnel depth (cm)	104.9±13.48	79	125
Distance of the hole to the bank bottom (cm)	52.1±2.69	38.5	127
Distance of the hole to the bank top (cm)	158.7±4.11	82.3	196.1
Distance to nearest agricultural land (m)	13.2±2.87	8.5	24
Distance to nearest grove (m)	21.8±4.30	11	35
Distance to nearest perch-site* (m)	0.5±0.33	0.5	1
Distance to nearest electric line (m)	13.6±2.17	4	16.5
Distance to nearest human habitation (m)	455.3±7.21	250	550

*included small trees, shrubs and sticks

Plumage development

The freshly hatched nestlings were naked, with fleshy pink skin and closed eyes. The nestling had a bulging abdomen that was almost transparent. The bill was light black, slightly brighter yellow near the tip of the lower mandible. Six days later the skin turned pinker and the eyes began to partially open. Nestlings appeared ‘spiky’, with many pins now just out above the skin surface. Caudal tract was just visible as a few gray flecks. On day ten, contour feathers in the capital and dorsal areas began breaking their sheaths, slaty grey. Eyes were typically beginning to open. Bill was darkening with a gray tip and the nestling was able to produce soft clicking noises. On day 15, primaries and secondaries showed light tips. Several femoral and crural pins had emerged. Contour feathers were well broken from their sheaths, slaty in the dorsal, capital and throat regions. The caudal tract was

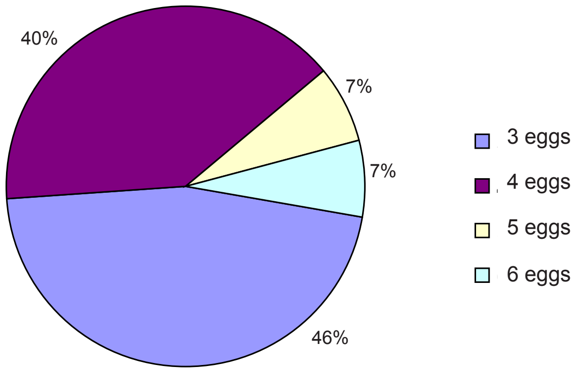

Figure 1. Clutch size in Small Bee-eater (N = 56)

well developed. At 20 days the nestlings' unsheathed green feathers were well developed throughout the body and the tips of the wing coverts appeared black coloured. The nestlings were very active, standing and jumping and produced typical calls. On day 25, the nestlings resembled adults. The body was fully covered with green feathers, head and neck were tinged with reddish-brown and the bill and legs were black.

Nestling growth patterns

In the Small Bee-eater, hatching was asynchronous. Nestlings grew from 3.16±0.28 g (N=43) at hatching to peak weight of 23.16±2.10 g (N=25) at day 24, then slowly declined and reached a weight of 20.75±0.57 g (N=16) on day 27 (Fig. 2). The body length of nestlings grew from 3.73±0.21 cm at hatching to 15.93±0.04 cm by the end of day 27. The bill length was 0.11±0.03 cm at hatching and it grew to 2.52±0.01 cm on day 27. The bill depth of the nestling was 0.11±0.03 cm at hatching and finally attained a size of 0.88±0.01 cm. At the time of hatching, the length of the wing was 1.39±0.11 cm and it gradually increased and attained a maximum length of 10.57±0.05 cm on day 27. The tarsus length of the nestlings grew from 0.26±0.06 cm at hatching to 2.63±0.01cm by the end of day 27. The tail length showed a considerable amount of growth during the nestling period. The growth was 0.14±0.05 cm at hatching and it increased to 4.17±0.04 cm by day 27 (Fig. 2).

DISCUSSION

The Small Bee-eater breeds from March to June depending on the food availability. Earlier, Asokan (1995) studied the breeding biology of the Small Bee-eater in the study area; he reported that it actively breeds during April to June. Sridhar & Karanth (1993) stated that the nesting season of the Small Bee-eater around Bangalore was February-August, with peak breeding around April-May. Various factors viz., temperature, rainfall, suitable nesting sites, food availability and helpers in the nest influenced

Table 2. Length, width and weight variations in the eggs of Small Bee-eater (N = 56)

	Length (mm)	Width (mm)	Weight (gm)
Mean	21	14	3.3
Standard Deviation	0.09	0.11	0.65
Minimum	20	14	2
Maximum	23	18	5

the breeding season of the bee-eater.

In the present study 95% of the nests were recorded in the sandy river banks. Earlier studies have also reported that bee-eaters, in general, preferred sandy river banks for nest construction (Sridhar & Karanth 1993; Kristin 1994; Asokan 1995; Burt 2002; Heneberg & Simecek 2004; Schmidt & Branch 2005; Yuan et al. 2006). Sandy soil preference for nesting were also reported of other soil excavating nest species *viz.,* White-breasted Kingfisher *Halcyon smyrnensis* (Madhuramozhi 2008), Eurasian Kingfisher *Alcedo atthis* (Heneberg 2004), Belted Kingfisher *Ceryle alcyon* (Brooks & Davis 1987) and Sand Martin or Bank Swallow *Riparia riparia* (John 1991; Heneberg 2003). Sandy soils have lower soil pressure, density and moisture than more clay-rich soils. Sandy soils probably provided faster and easier excavation of nest cavities. With high porosity, nest tunnels constructed in sandy soils would also have better ventilation, which is important to diffuse gases to maintain a tolerable level of O_2 and CO_2 in the nest cavities (White et al. 1978). Soil particle size could also affect the structure of the nest tunnels of the Small Bee-eater.

The Small Bee-eater excavated a tunnel from 79 to 125cm with a mean depth of 104.9cm. Ali & Ripley (1983) and Fry & Fry (1992) reported that the Small Bee-eater builds a one or two meter horizontal tunnel along river banks and sandy grounds. The nest entrance had a mean diameter of 8.9±1.03 cm while the circumference of the nest was 26.9±3.55 cm. These measurements are more or less similar to those reported by Ali & Ripley (1983) and Asokan (1995). It builds a tunnel 52.1cm above the ground and 158.7cm from the top of the river banks. Cornwell (1963) reported that the Belted Kingfisher constructed a nest at least five feet above the ground and 12 to 18 inches from the top of the embankment, near the bottom of the organic soil layer. The agricultural lands, perch sites and electric lines were closer to the nest-sites. The agricultural lands provided a variety of protein rich insect prey to the parents as well as to the nestlings. The nearest small trees, shrubs, sticks and electric lines served as a perching site for overseeing the nest and searching for prey (Asokan et al. 2008, 2009a). In this study, we found that the Small Bee-eater avoided placing nest cavities in areas with dense vegetation. Many bee-eater species have also been seen nesting on

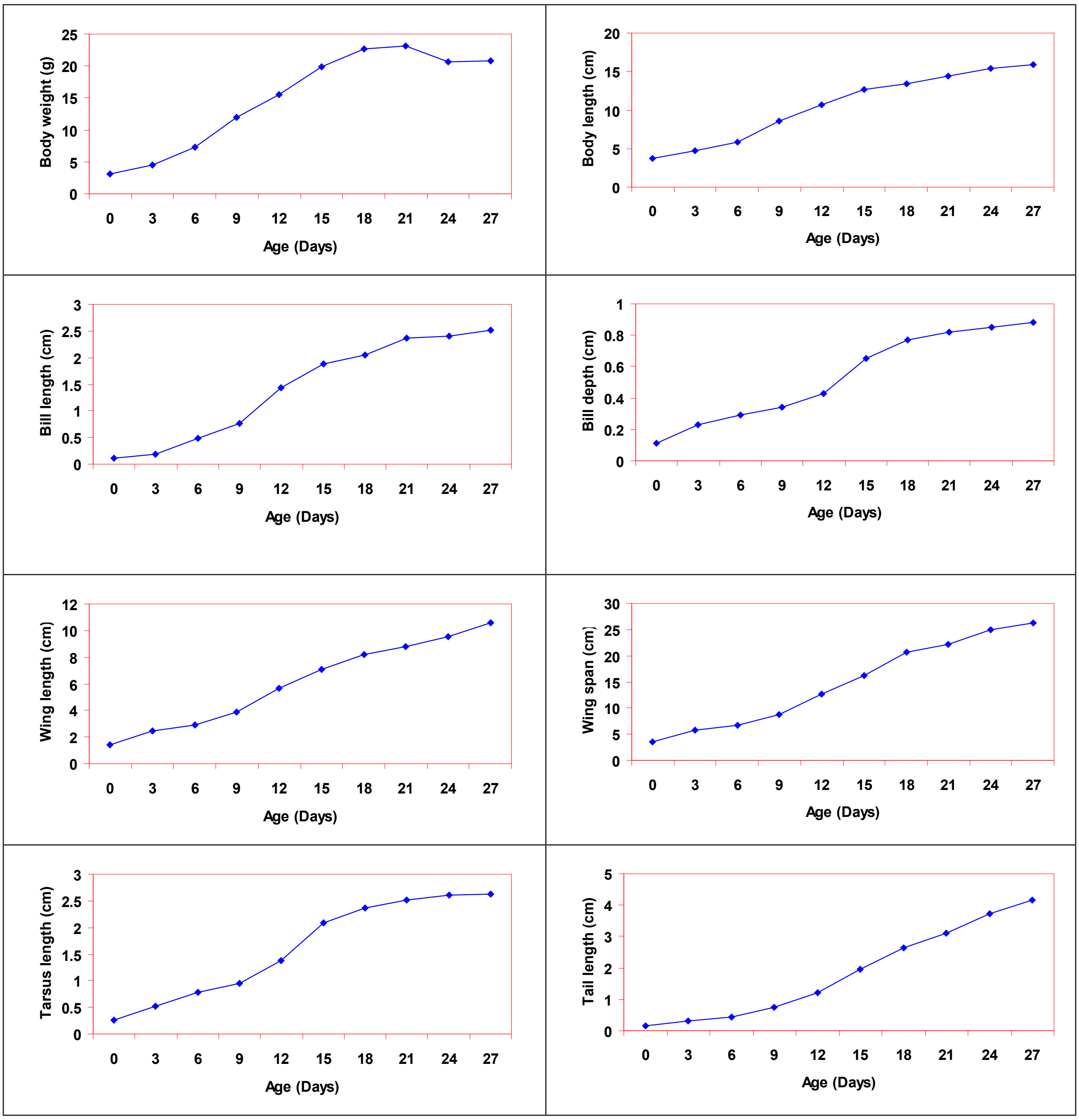

Figure 2. Growth patterns of several body structures of Small Bee-eater nestlings

river banks without much vegetation (White et al. 1978; Kossenko & Fry 1998; Boland 2004; Yuan et al. 2006). Predation is a constant threat to successful reproduction in this species and reduced vegetation at the nesting sites probably facilitates detection by predators and increases the effectiveness of mobbing behavior.

The Small Bee-eater was found to lay small eggs with a mean length and width of 21.0±0.09 mm and 14.0±0.11 mm and weighing 3.3±0.65 g. Asokan (1995) reported that egg measurements for the Small Bee-eater i.e., mean length, width and weight were 21.0mm, 18.0mm and 2.62g. Egg measurements in the present study are in full agreement with those of the previous report. Clutch sizes varying from 4 to 7 (Ali & Ripley 1983) and 2 to 5 per clutch (Asokan 1995) were reported. In the present study, clutch size of the Small Bee-eater varied from 3 to 6 and the majority (46.6%) was three. Similar clutch sizes have also been reported in different bee-eater species *viz.*, 1-4 in Black-headed Bee-eater *Merops breweri* (Schmidt & Branch 2005), 2-5 in White-fronted Bee-eater *M. bullockoides* (Wrege & Emlen 1991) and 2-6 in European Bee-eater *M. apiaster* (Hoi et al. 2002). Several factors might contribute to clutch size variability viz.,the condition of the breeding female, availability of resources necessary to produce eggs, presence of helpers at the nest, time of laying in the season and anticipated future availability of food for feeding nestlings (Klomp 1970; O'Connor 1984; Lessels & Krebs 1989; Asokan 1995). Wrege & Emlen (1991) recorded that insect availability and rainfall over the 3-month period before laying accounted for 16% of variations in clutch size of the White-fronted Bee-eater.

The mean overall hatching success as recorded in the present study was 76.7%. Earlier, Asokan (1995) recorded a similar hatching success (78.81%) in Small Bee-eater populations in the Mayiladuthurai area. During the present study the incubation and hatching sequence was found to be asynchronous. The majority of altricial bird species hatch their young asynchronously because incubation begins before the clutch is complete and eggs, therefore, hatch over a period of one or more days in approximately the order in which they were laid. Wrege & Emlen (1991) and Asokan (1995) have recorded asynchronous hatching patterns in bee-eater species. This enhances the ability of older nestlings to monopolize limited food supplies and results in selective death of the smallest nestlings first. Such brood reduction coupled with the ability of nestlings to slow their development rate in response to food stress, is considered an adaptation for coping with the unpredictable variations in food supplies commonly met by these birds.

In the present study the overall mean fledging success of Small Bee-eater was 83.7%. These values are relatively more than those reported for the White-fronted Bee-eater (41%) by Wrege & Emlen (1991) and the Small Bee-eater (79.13%) by Asokan (1995). This shows that lower clutch size for the Small Bee-eater in the present study was compensated by relatively high fledging success, thereby ensuring overall reproductive success of this species. Lessels & Krebs (1989) reported that among European Bee-eater fledglings, as or nearly as, asynchronous as hatching, the last chick to leave fledges about 32 days after the first chick hatches and 28 days after the last, at an age independent of hatching asynchrony. In the case of Small Bee-eater fledging was found to occur in 26-28 days. Lessels & Krebs (1989) reported that Bee-eaters continue to feed their young even after fledging because the capture of fast flying insects is a skill which may require time to acquire and as such Bee-eater chicks presumably continue to be dependent on their parents for sometime after fledging.

The weight of chicks on the first day was 3.16g which increased to 23.16g at 24 days of age. However, there was a drop in the mean weight of nestlings in last few days and reached 20.75g at the time of fledging. Many observers have noted a decrease in rate-of-gain in weight as feathers were being produced or as temperature control was being established. Banks (1959) reported that the decrease in actual and relative gain in weight in the final three days of nestling life in the White-crowned Sparrow *Zonotrichia leucophrys* was probably due to a shift in the energy budget, as more food was utilized in production of feathers and heat. Welty (1982) stated that many nestlings lost body weight a few days before leaving the nest. This loss was supposed to be due to the utilization of fat deposits and skeletal muscles for the energy to leave the nest. This body weight reduction is advantageous for moving out of the nest. Krebs & Avery (1984), Lessels & Ovenden (1989), and Emlen et al. (1991) recorded significant weight loss before fledging in the nestlings of *Merops* species. This loss of weight is found in some aerial insectivores like swallows, martins and swifts (Ricklefs 1968; Languy & Vansteenwegen 1989) and other bird species (Kumar & Rao 1984; Haggerty 1994; McCarty 2001; Nagarajan et al. 2002; Penteriani et al. 2005; Greeny 2008; Asokan et al. 2009a).

The development of the different structure of the nestlings was not uniform throughout the nestling period. The body length, bill length, wing length, wing span, tail length and tarsus length attained the maximum maturity at the time of fledging stage. The Small Bee-eater used above body parts immediately after fledging for successful survival. This growth allometry in the adaptive parts had been observed in several avian species (Pinkowski 1975; Best 1977; Olsen et al. 1982; Zach & Mayoh 1982; Kumar 1983: Teather 1996; Aparicio 2001; Pereyra & Morton 2001; Asokan et al. 2009a).

Variability in nestling growth rates might be due to many ecological factors. Ecological factors that influence the nestling growth of Small Bee-eaters are generally related to limitations in food availability, weather, habitat differences and quality, parasites, competition between nest mates and parental abilities.

REFERENCES

Abrol, D.P. (1994). Seasonal activity, population dynamics and behaviour of Bee-eater birds (Coraciiformes: Meropidae) attacking honeybees. *Pavo* 32: 153-159.

Ali, S. & S.D. Ripley (1983). *Handbook of Birds of India and Pakistan*. Oxford University Press, Bombay.

Aparicio, J.M. (2001). Patterns of growth and fluctuating asymmetry: the effects of asymmetrical investment in traits with determinate growth. *Behavioural Ecology and Sociobiology* 49: 273-282.

Ara, J. (1951). Distribution of the Bluebearded Bee-eater (*Alcemerops athertoni*). *Journal of the Bombay Natural History Society* 50(1): 175-176.

Asokan, S. (1995). Ecology of the Small Green Bee-eater, *Merops orientalis* Latham 1801 with special reference to its population, feeding and breeding in Mayiladuthurai, Tamil Nadu, South India. PhD. Thesis, Bharathidasan University, Thiruchirappalli, India.

Asokan, S. (1998). Food and feeding habits of the Small Green Bee-eater *Merops orientalis* in Mayiladuthurai. *Journal of Ecobiology* 10(3): 199-204.

Asokan, S, A.M.S. Ali & R. Manikannan (2008). Foraging ecology of the Black Drongo *Dicrurus macrocercus* (Vieillot) in an agro-environment, Nagapattinam District, Tamil Nadu. *Indian Journal of Ecology* 35(2): 170-172.

Asokan, S, A.M.S. Ali & R. Manikannan (2009a). Nest-site selection and nestling growth patterns of the Common Myna, *Acridotheres tristis* (Linnaeus, 1766). *Geobios* 36: 65-70.

Asokan, S, A.M.S. Ali & R. Manikannan (2009b). Diet of three insectivorous birds in Nagapattinam District, Tamil Nadu, India – a preliminary study. *Journal of Threatened Taxa* 1(6): 327-330.

Asokan, S., K. Thiyagesan & R. Nagarajan (2003). Studies on *Merops orientalis* Latham 1801 with special reference to its population in Mayiladuthurai, Tamil Nadu. *Journal of Environmental Biology* 24(4): 477-482.

Banks, R.C. (1959). Development of nestling White-crowned Sparrows in central coastal California. *Condor* 61: 96-109.

Bannerjee, A.K. (1992). Some observations on the breeding behaviour of Bluebearded Bee-eater and Indian Small Green Bee-eater. *Zoos' Print* 7(12): 19-21.

Best, L. (1977). Nestling biology of the Field Sparrow. *Auk* 94: 308-319.

Boland, C.R.J. (2004). Breeding biology of Rainbow Bee-eaters (*Merops ornatus*): a migratory, colonial, cooperative bird. *Auk* 121:811–823.

Brooks, R.P. & W.J. Davis (1987). Habitat selection by breeding Belted Kingfishers (*Ceryle alcyon*). *American Midland Naturalist* 117: 63-70.

Burt, D.B. (2002). Social and breeding biology of Bee-eaters in Thailand. *Wilson Bulletin* 114(2): 275-279.

Cornwell, G. (1963). Observations on the breeding biology and behavior of a nesting population of Belted Kingfishers. *Condor* 65: 426-431.

Emlen, S.T., P.H. Wrege, N.J. Demong & R.E. Henger (1991). Flexible growth rates in nestling White-fronted Bee-eaters: a possible adaptation to short-term food shortage. *Condor* 93: 591-597.

Fry, C.H. (1972). The social organization of bee-eaters (Meropidae) and co-operative breeding in hot climate birds. *Ibis* 114: 1-14.

Fry, C.H. (1984). *The bee-eaters*. T & A.D. Poyser, London, United Kingdom.

Fry, C.H. & K. Fry (1992). *Kingfishers, Bee-eaters and Rollers: A Hand Book*. Christopher Helm. A and C Black, London.

Greeny, H.F. (2008). Nestling growth and plumage development of the Spotted Barbtail (*Premnoplex brunnescens*). *Kempffiana* 4: 21-29.

Haggerty, T.M. (1994). Nestling growth and development in Bachman's Sparrows. *Journal of Field Ornithology* 65:224-231.

Heneberg, P. (2003). Soil particle composition affects the physical characteristics of Sand Martin *Riparia riparia* holes. *Ibis* 145: 392-399.

Heneberg, P. (2004). Soil particle composition of Eurasian kingfishers' (*Alcedo atthis*) nest sites. *Acta Zoologica Academiae Scientiarum Hungaricae* 50: 185-193.

Heneberg, P. & K. Simecek (2004). Nesting European bee-eaters (*Merops apiaster*) in Central Europe depends on the soil characteristics of nest sites. *Biologia* 59: 205-211.

Hoi, H., C. Hoi, K. Kristofik & A. Darolova (2002). Reproductive success decreases with colony size in the European bee-eater. *Ethology Ecology & Evolution* 14: 99-110.

Hutson, H.P.W. (1947). On the migrants of *Merops apiaster* Linnaeus and *Merops superciliosus* Linnaeus in the Middle East and India. *Ibis* 89(2): 291-300.

Inglis, C.M. (1949). The Bluebearded Bee-eater (*Alcemerops athertoni*) on the Nilgiris. *Journal of the Bombay Natural History Society* 48: 581-582.

John, R.D. (1991). Observations on soil requirements for nesting Bank Swallows, *Riparia riparia*. *Canadian Field Naturalist* 105: 251-254.

Joshua, J., V. Gokula & P. Sampathkumar (1997). Rare sighting and range extension of European Bee-eater (*Merops apiaster*). *Newsletter for Birdwatchers* 37: 15.

Klomp, J.R. (1970). The determination of clutch size in birds – review. *Ardea* 58(1): 1-124.

Kossenko, S.M. & C.H. Fry (1998). Competition and coexistence of the European Bee-eater Merops apiaster and the Blue-cheeked Bee-eater *Merops persicus* in Asia. *Ibis* 140: 2-13.

Krebs, J.R. & M.I. Avery (1984). Chick growth and prey quality in the European Bee-eater (*Merops apiaster*). *Oecologia (Berlin)* 64: 363-368.

Kristin, A. (1994). Breeding biology and diet of the bee-eater (*Merops apiaster*) in Slovakia. *Biologia Bratislava* 49: 273-279.

Kumar, T.S. (1983). Bill growth in the Spotted Owlet *Athene brama brama* (T). *Raptor Research Centre Publications* 2: 1-4.

Kumar, T.S. & J.V.R. Rao (1984). Some observation on the weights of nestling Spotted Owlet *Athene brama brama* (T) prior to flying. *Geobios* 11: 229-231.

Languy, M. & C. Vansteenwegen (1989). Influence of parental age on the growth of nestling Swallows (*Hirundo rustica*). *Ardea* 77(2): 227-232.

Lessels, C.M. & G.N. Ovenden (1989). Heritability of wing length in European Bee-eaters (*Merops apiaster*). *Condor* 91: 210-214.

Lessels, C.M. & J.R. Krebs (1989). Age and breeding performance of European Bee-eater. *Auk* 106: 375-383.

Lott, E.J. (1985). European Bee-eaters (*Merops apiaster*) in Karnataka. *Journal of the Bombay Natural History Society* 82: 411.

Madhuramozhi, G. (2008). Ecology of the White-breasted Kingfisher, *Halcyon smyrnensis* (Linnaeus 1758) with special reference to its population, foraging and breeding in Nagapattinam, Tamil Nadu, India. PhD. Thesis, Bharathidasan University, Thiruchirappalli, India.

McCarty, J.P. (2001). Variation in growth of nestling Tree Swallows across multiple temporal and spatial scales. *Auk* 118: 176-190.

Nagarajan, R., K. Thiyagesan, R. Natarajan & R. Kanakasabai (2002). Patterns of growth in nestling Barn-owls. *Condor* 104: 885-890.

Neelakantan, K.K. (1948). On the breeding of the Blue-tailed Bee-eater (*Merops superciliosus*) in Rajahmundri, East Godavari district. *Journal of the Bombay Natural History Society* 47: 741-742.

Nirmala, T. (2000). Foraging and feeding the fledgling of the Bluebearded Bee-eater. *Newsletter for Birdwatchers* 40(4): 55.

O'Connor, R.J. (1984). *The growth and development of birds*. Wiley and Sons, New York.

Olsen, P.D., J. Olsen, & N.J. Mooney (1982). Growth and development of Brown Goshawks (*Accipiter fasciatus*), with details of breeding biology. *Emu* 82: 189-194.

Penteriani, V., M.M. Delgado, C. Maggio, A. Aradis & F. Sergio (2005). Development of chicks and predispersal behaviour of young in the Eagle Owl (*Bubo bubo*). *Ibis* 147: 155-168.

Pereyra, M.E. & M.L. Morton (2001). Nestling growth and thermoregulatory development in subalpine Dusky Flycatchers. *Auk* 118: 116-136.

Pettingill, O.S. Jr. (1985). *Ornithology in Laboratory and Field*. Academic Press, London.

Pinkowski, B.C. (1975). Growth and development of Eastern Bluebirds. *Bird Banding* 46: 273-289.

Prasanth, J.J., V.V. Rao & V. Nagulu (1994). Nesting, egg size, incubation and factors affecting clutch size in Little Egret, *Egretta garzetta* at Nellore Andhra Pradesh. *Pavo* 32(1&2): 67-72.

Ricklefs, R.E. (1968). Patterns of growth in birds. *Ibis* 110: 419-451.

Roy, M.B. (1968). Occurrence of the European Bee-eater *Merops apiaster* Linnaeus, at Mettur Dam, Salem district, Madras. *Journal of the Bombay Natural History Society* 65: 776.

Schmidt, B.K. & W.R. Branch (2005). Nests and eggs of the

Black-headed Bee-eater (*Merops breweri*) in Gabon, with notes on other bee-eaters. *Ostrich* 76(1&2): 80-81.

Sokal, R.R. & F.J. Rohlf (1981). *Biometry*. W.H. Freeman and Company, New York.

Sridhar, S. & K.P. Karanth (1993). Helpers in cooperatively breeding Small Green Bee-eaters (*Merops orientalis*). *Current Science* 65: 489-490.

Teather, K. (1996). Patterns of growth and asymmetry in nestling Tree Swallows. *Journal of Avian Biology* 27: 302-310.

Welty, C.J. (1982). *The life of birds*. W.B. Saunders Company, London.

White, F.N., G.A. Bartholomew & J.L. Kinney (1978). Physiological and ecological correlates of tunnel nesting in the European Bee-eater, *Merops apiaster*. *Physiological Zoology* 51: 140-154.

Wrege, P.H. & S.T. Emlen (1991). Reproductive success in Bee-eaters. *Auk* 108: 673-687.

Yuan, H., D.B. Burt, L. Wang, W. Chang, M. Wang, C. Chiou & T. Ding (2006). Colony site choice of blue-tailed bee-eaters: influences of soil, vegetation and water quality. *Journal of Natural History* 40(7-8): 485-493.

Zach, R. & K.R. Mayoh (1982). Weight and feather growth of nestling Tree Swallows. *Canadian Journal of Zoology* 60: 1080-1090.

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