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Behavioral Ecology, Breeding Period, Sexual Dimorphism and Ovipositional Behavior of *Psammophilus blanfordanus* (Family: Agamidae): Case Study

KEYWORDS: Sexual dimorphism, *Psammophilus blanfordanus* and ovipositional behavior

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ABSTRACT *Behavioral ecology, breeding period, sexual dimorphism and ovipositional behavior were investigated in the lizard, Psammophilus blanfordanus in Mayurbhanj of Odisha. It was found that they regularly bask in the morning to maintain elevated body temperatures. However, the maximum number of adult males and the gravid females of Psammophilus blanfordanus are usually found from May through July months of the year. Males acquired larger body sizes than females during breeding season. Eggs are laid in clutches of up to eight in numbers. The observed sexual dimorphism in body size, head size and body colouration in males to hold more number of females in their territory. This is the first described observation of the ovipositional behavior of Psammophilus blanfordanus. The ovipositional behavior consisted of digging a hole to lay eggs, laying the eggs, burrying the eggs, emergence of hatchlings from the burrow.*

INTRODUCTION

Blanford's Rock Agama (*Psammophilus blanfordanus*) is an agamid lizard found in Peninsular India and is named after William Thomas Blanford (1832–1905), member of the Geological Survey of India. In reptiles, patterns of daily activity range from nocturnal to diurnal with various intermediate conditions and in some cases activity rhythms are not encountered (Heatwole and Taylor, 1987; Zug *et al.*, 2001; Winne and Keck, 2004). Many lizard species have distinct preferences for particular substrates, perch shape, vegetation densities or other aspects of habitat structure (Heatwole, 1977; Arnold, 1987; Hussein, 1994; 2000). Population dynamics, microhabitat use and activity pattern are the important components of animal ecology. The time of day when animals emerge from refuge and engage in activities such as basking, foraging, searching for mates and so on may be restricted to certain periods of the day or year. Indeed, most reptiles exhibit high activity during discrete times of the day/ year and the factors controlling such periodicity interact in a complex manner (Schoener, 1977; Heatwole and Taylor, 1987; Underwood, 1992; Zug *et al.*, 2001). Lizard communities may achieve resource partitioning by spatial or temporal separation in their activity patterns depending upon the habitat, prey availability and thermal ecology (Schoener, 1977; Heatwole and Taylor, 1987; Davis and Verbeek, 1972; Zucker, 1986; Martin and Salvador, 1997; Howard and Hailey, 1999; Melville and Schulte, 2001; Leal and Fleishman, 2002). Growth pattern is a key aspect in the life history of any species (Andrews, 1982; Sinervo and Aldoph, 1989; Roff, 1992; Arendt, 1997) and reproduction is the most costly event in an animal's life. Body size and growth rate are particularly important life history traits because of their relation to reproductive output, longevity, age at first reproduction, and so on (Andrews, 1982; Bauwens and Verheyen, 1985; Ferguson and Talent, 1993; Clobert *et al.*, 1998; Lorenzon *et. al.*, 1999; Bronikowski, 2000).

Reproduction is an important event in the life history of all organisms. Female body size, clutch/egg and offspring body sizes are the basic components of life-history traits. Oviparous reptiles show complex interrelationships among maternal body size, clutch and egg sizes. In lizards, clutch size varies with proximate climatic factors, food availability and fat body reserves (Vitt, 1992; Dunham, 1994; Schwarzkopf, 1994; Shanbhag, 2002; 2003). Even if sexual selection is responsible for the initial morphological divergence in body and head sizes, ecological factors may act either to constram or amplify this initial sexually selected difference (Shine, 1989; 1991). Unlike the other species, the male in breeding season has a brilliant red head and crest with black coloration dorso-laterally and ventrally. They are found mainly on rocks. The male displays with head nodding (Smith, 1941). From snout to vent they are about 10 cm long and the tail is about 20 cm. Females are slightly smaller than the males. Most studies on growth rates in lizards are mainly based on mark and recapture surveys (Bellairs, 1969; Jenssen and Andrews, 1984; Shine, 1988; James, 1991; Sugg *et al.*, 1995; Allan *et al.*, 2006) or on frequency distribution of individuals in a population collected at different points of time in a year (Andrews, 1976; Ferguson and Brockman, 1980; Bishop and Echternacht, 2003).

The information on the ecology and natural history of this species is limited. Though the peak breeding months seems to be June through August, the breeding behavior or ovipositional behavior has not been clearly documented. No information is available about its clutch size, incubation duration and about the hatchling. In this paper, we describe the ovipositional behavior, duration of time taken by a hatchling to emerge out from an egg and hatching success of this species for the first time were described.

MATERIALS AND METHODS

In the present study, ecology, sexual dimorphism, breeding period and ovipositional behavioral of *Psammophilus blanfordanus* was observed very closely in residential areas of Mayurbhanj, Odisha and the important events were recorded by the help of camera and also recorded the hatchling success. The behavior of different activities of *Psammophilus blanfordanus* were observed silently from 2 m away through unaided eye. The animal was not disturbed during observation. The nest soil was loosely packed and consisted of a mixture of sandy and clayey soil. The weather was hot and humid. The atmospheric temperature was noted as 27° C. The study site was surveyed twice a day (at 8:30 am and 4 pm). A female *Psammophilus blanfordanus* was observed in a residential area on 23 June 2011 between 12:23-12:48 pm digging a hole on a small hip of sands. The lizards were spotted and their day-to-day behavior, during their breeding period, their sexual dimorphism, body colouration, sex recognition, ovipositional behavior and hatching success were also noted. The egg size could not be measured accurately because handling the eggs might have affected their incubation.

RESULT AND DISCUSSION

(A) Behavioral Ecology

Psammophilus blanfordanus are usually diurnal, and are he-

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liotherms that regularly bask to maintain elevated body temperatures. Basking occurs mainly in the morning between ten and noon. Many temperate zone species actually spend only a few hours each day above the ground and thus spend most of the day in different retreats depending on the thermal properties of the retreat site. The aggregation of individuals in such retreats usually considered to be of thermoregulatory significance. The larger males take up higher perch positions (Radder *et al.*, 2006a). They flatten their bodies when birds fly overhead (Radder *et al.*, 2006b). Densities of about 90 lizards per hectare have been noted (Radder *et al.*, 2005). *Psammophilus blanfordanus* are predominantly carnivores, preying largely on arthropods by using a sit-and-wait foraging behavior. Another interesting and rare behavior was came into noticed that this lizards was seen bathing in a small pool of water an also drinking droplets of rain water falling from the leaves surface.

(B) Breeding Period

The species of agamids breed from pre-monsoon through post-monsoon periods (April-October) and the peak breeding months seems to be June through August. However, the maximum number of mature males and the gravid females of *Psammophilus blanfordanus* are usually found from May through July. During early monsoon, both sexes are found to be active and mating usually occurs during the day. Occasionally, the hatchlings and the juveniles of the species have been collected from May through August, which is indicative of even early breeding before May. The breeding season is typically March-May with eggs being laid in June-September during the season after the rains.

During the non-breeding season, (late November-early March) though the sexes look alike, *Psammophilus blanfordanus* does not show much displacement from their native sites. During the pre-breeding season (late March-early May) mature males establishes their territory to show their dominance over others. During their breeding season, the dominant males show much displacement from their inhabiting sites in search of mature females. Males may hold six or more females in their territory for breeding. During courtship, the male bobs his head to impress the female. Many lizards communicate by head-bobbing. This display is apparently useful in species recognition. Gravid females were seen to raise their tail when a courting male approaches the female. Sometimes, females initiate courtship by offering their hindquarters to the male and then running until he is able to catch up. Occasionally, the females tried to escape from other males of second rank which shows their non-receptivity behavior towards second rank males. During copulation, the male grasps the female by the neck and one hemipenis is inserted for less than half a minute in *Psammophilus blanfordanus*. Gravid females have up to eight eggs in their ovaries.

(C) Sexual Dimorphism and Breeding Colouration

Sexual dimorphism is a common and sometimes prominent feature of the animal world. In some lizards, though the sexes look alike outside the breeding season, male and female lizards can differ in many traits including body shape and size. Within sexes, body shape and size are important life-history traits that influence physiology, behavior, ecology and reproductive success (Shine, 1989; Cox *et al.*, 2003). Males and females differ in a variety of aspects; however, the vast majority of comparative studies of sexual dimorphism have focused only on size dimorphism (Fairbairn, 1997), with relatively few examining variation in shape (Selander, 1966; Dayan *et al.*, 1990; Dayan and Simberloff, 1994; Emerson, 1994; Jablonski and Ruliang, 1995; Willig and Hollander, 1995; Brana, 1996). Sex differences in ecology (food and/or habitat) associated with shape dimorphism are known from many reptiles (e.g., Schoener, 1967, 1968; Schoener and Gorman, 1968; Lister, 1970; Schoener *et al.*, 1982; Hebrard and Madsen, 1984; Powell and Russell, 1984; Shine, 1991; Vitt *et al.*, 1996).

Table 1: Important events of *Psammophilus blanfordanus* from non-breeding months to the emergence of hatchlings from the eggs.

Sl No.	Events	Date	Reference figures
1	Unidentified sex of *Psammophilus blanfordanus* are seen during non-breeding season	26th March	1
2	During breeding season adult male in breeding colours along with adult female were noticed in the residential areas	14th April	3,4
3	Copulation between male and female takes place	28th May	_
4	Laying of eggs by the female	23th June	9,10
5	Incubation	23rd June - 08th June	11,12,13
6	Release of hatchlings from the eggs	08th August	14,15,16

Fig. 1: Unidentified sex of *Psammophilus blanfordanus* during non-breeding season.

Fig. 2: Adult male in the pre-breeding season.

Fig. 3: Adult male in breeding colours during breeding season.

Fig. 4: Adult female (A) during breeding season.

In our present study young lizards of *Psammophilus blanfordanus* are olive-brown above, spotted or marbled with brown spots very similar to the female but often have a series of large, lozenge shaped, dark brown spots with pale centres on the back and tail. The body coloration of both male and female varies largely with the breeding cycle. In the breeding season, between April and September (Daniel, 2002; Das, 2002), adult males of *Psammophilus blanfordanus* develop a brilliant red head and crest with black coloration dorso-laterally and ventrally (Fig. 3); adult females develop a slaty-black coloration with reddish orange throat (Fig. 4 and 6). The colouration is very cryptic, especially the females, matches with that of the rocks among which they live. Outside the breeding season both sexes of *Psammophilus blanfordanus* look alike (olive brown; Fig. 1)

(D) Ovipositional Behavior

The following are the ovipositional behavior of female *Psammophilus blanfordanus*.

1) Digging the nest hole

A female *Psammophilus blanfordanus* was observed on 23 June 2011 between 12:23-12:48 pm. The lizard lifted the anterior part of its body using its forelimbs and looked around for about 13 minutes. The lizard repeatedly turned its head 180° six times, without moving its body (Fig. 9). The lizard began excavating the egg laying burrow with its right forelimb alternatively, scraping the sand out with its claws and its head was partially inside the small hole during the process of digging and throwing the sand towards its right hand side though its hind limbs was raised. This digging process continued for approximately 3 minutes. After that it stopped digging and looked around for approximately 5 minutes. Again the lizard repeatedly turned its head 180° three times. Again, the female continued digging the hole continuously for approximately 5 minutes. The hind-limbs were stretched as wide as possible (Fig. 10). After that, it continued to dig the hole for around 25 minutes, taking break for four times for 3 minutes each, to take rest. The process of looking around and digging was repeated several times before the completion of the burrow. The whole process spanned 32 minutes resulting in the completion of the excavation. The final hole was 87.2 mm deep and 67.8 mm in diameter.

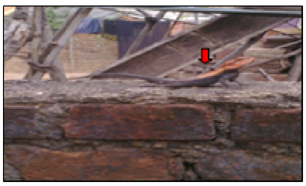

Fig. 5: Adult male in breeding colours approaching towards adult female.

Fig. 6: Adult female (B) during breeding season.

Fig. 7: Gravid female carries eggs in her abdomen.

Fig. 8: Gravid female searching for nest building site.

Fig. 9: Resting from excavating to scan the surrounding area.

Fig. 10: Female aligning its cloacal aperture to lay eggs.

Fig. 11: Packing its nest after laying the eggs.

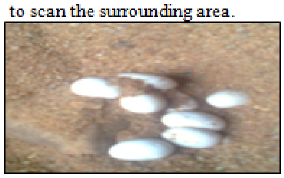

Fig. 12: Clutch size and status of eggs on the laying day.

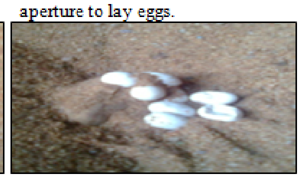

Fig. 13: Status of eggs after two and half months.

Fig. 14: Young emerging from its burrow.

Fig. 15: Hatchling emerging from its burrow with its egg shell.

Fig. 16: Size of hatchling after emerging from its burrow.

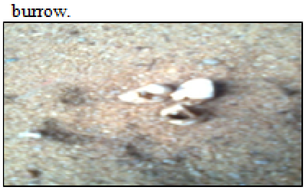

Fig. 17: Broken egg shells on the nesting site.

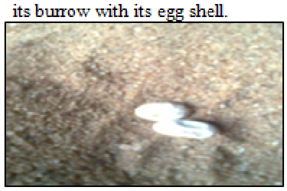

Fig. 18: Two damaged or undeveloped eggs

Fig. 19: Juvenile *Psammophilus blanfordanus*.

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2) Laying of the eggs
Following completion of digging, the female lizard stretched her hind-limbs as wide as possible and placed both its hind-limbs upon the burrow and began laying eggs by taking deep breaths as it pushed the eggs out. During egg laying the lizard repeatedly turned its head 180° three times, without moving its body (Fig. 9). Eight eggs were laid (Fig. 12). The eggs were pure white and elliptical. The whole process spanned about 2 minutes resulting in the completion of egg laying behavior.

3) Burying the eggs
After the eggs were laid, the female lizard resumed from the excavating position and started looking around for 5 minutes. Then the female lizard began to drag the sand towards the hole using its right fore-limb (Fig. 11). After dragging the soil for about 8 minutes, the lizard repeatedly turned its head 180° four times, without moving its body to look into the surrounding.

Then the lizard began pressing the soil with the anterior half of its lower jaw for 5 minutes. Then wait for 5 minute near the nest without any movement and then ran towards the garden.

4) Emergence of hatchlings from the burrow
After 1 hour of burial of eggs in soil, the nest was examined and the no. of eggs were counted. The bottom of the nest was conical and the soil was soft, dark and wet. Finally the eggs were again buried in the same hole to hatch. After approximately two and half months, hatchlings were coming out from the nest. The young have to re-excavate the tunnel before they can emerge (Fig. 14, 15). The first hatchling comes out from a small hole at 08: 06 am in the morning. Then one by one hatchlings were coming out from their nest and the process of release of hatchlings from their nest continues till 1:20 pm. Important events and duration of time taken by a hatchling to emerge out from an egg of *Psammophilus blanfordanus* (Fig. 20-28) was described in table 2. The total time taken to complete all the events was noted to be 5 hours 13 minutes. In most of the case it was observed that the hatchling face of difficulties in breaking their own egg shell. However, hatchlings after a long period of struggle able to break their egg shell but attach to the broken egg shell by means of some structure. At last it was found that three to five broken egg shells of *Psammophilus blanfordanus* were present inside their nest (Fig. 17). Empty nest did not contain any remnant of egg shell, as they are suspected to be eaten out by the ants. Eight eggs were laid by the female. Out of the eight eggs, only six hatchlings were able to hatch out from the eggs. Two of them were unable to hatch out from the eggs (unable to incubate properly) and were damaged (Fig. 18). Therefore, the hatching success in our study was 75 %.

Table 2: Important events and duration of time taken by a hatchling to emerge out from an egg of *Psammophilus blanfordanus*.

Sl No.	Events	Time durations	Reference figures
1	Some kind of movement got started in an egg of *Psammophilus blanfordanus*	08:07 am	20
2	A little crack appear on the surface of an egg	08:15 am	21
3	Small portion of the head comes out first from the egg	08:20am	22
4	Further head comes out	08:40 am	23
5	Full head and neck comes out from the egg	10:54 am	24
6	Small portion of tail comes out from the egg	10:59 am	25
7	Whole tail comes out from the half broken egg	11:01 am	26
8	Eyes are open for the first time	11:10 am	27
9	Complete hatchling comes out from the egg	1:20 pm	28
Total time taken to complete all the events		5 hours 13 minutes	

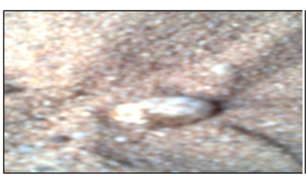
Fig. 20: Some kind of movement got started in an egg

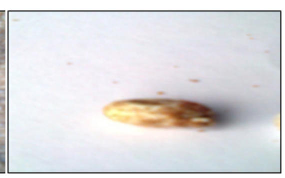
Fig. 21: A little crack appear on the surface of an egg

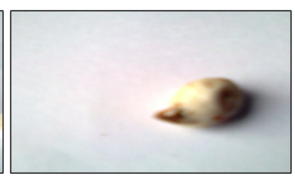
Fig. 22: Small portion of the head comes out first from the egg


Fig. 23: Further head comes out from the egg


Fig. 24: Full head and neck comes out from the egg


Fig. 25: Small portion of tail comes out from the egg


Fig. 26: Whole tail comes out from the half broken egg


Fig. 27: Eyes are open for the first time


Fig. 28: Complete hatchling comes out from the egg

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A few photographs and brief descriptions of *Psammophilus blanfordanus* are available in popular journals, books, internet and magazines but almost nothing exists on the pre and post mating behavior, egg laying behavior and their hatchlings. In addition *Psammophilus blanfordanus* is an endemic, rare species and therefore it may become extinct if their population does not increase. For such a situation to be achieved, studies on the habitat requirements and survival rates of these lizards are essential to strengthen its conservation.

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