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Original Article

Effect of lunar cycle on active population density of scorpions, their potential prey and predators

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Abstract
In the present study, effects of the lunar cycle on the activities of three scorpion species, *Hottentotta tamulus, Odontobuthus odonturus,* and *Androctonus finitimus*, and their potential prey and predators were observed in the field. The result showed that *H. tamulus* and *A. finitimus* were more active during dark nights compared to moonlight nights; however, there was no obvious effect of the lunar cycle on the activity of *O. odonturus.* Young (Immature) individuals of all scorpion species were always high in numbers at night, even under moonlight conditions. The activity of scorpion prey had been always high during dark nights. No difference in numbers of scorpion predators (shrews, lizards, centipedes, mice and rats) was noted in the presence or absence of moonlight, but they were observed to be more active during the moonlight period than during moonless nights.
Keywords: moon light, active density, scorpions, predators, prey

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INTRODUCTION

Scorpions are the most primitive terrestrial arthropods (Ozkan *et al.,* 2007). They inhabit a wide range of allocations and are distributed in hot and dry environments throughout the world except Antarctica (Isbister *et al.,* 2003; Vatanapour, 2003). They can be easily identified due to their morphological structure (Ozkan *et al.,* 2006). At day time scorpions seek shelter under wood logs, rocks, stone cracks, in burrows or beneath the loose layer of substrates (Polis, 1990). Scorpions stay in their dwellings all the time and leave their dwelling only for purposes of feeding and reproduction (Lourenco and Cuellar, 1994).

Ecological factors, such as air temperature and relative humidity affect scorpion activities (Bridges *et al.,* 1997; Warburg *et al.,* 1980). The lunar cycle is also a factor that drives the activity of scorpions especially foraging and mating in the habitat. Castilla *et al.* (2010) studied the effect of moonlight on scorpion activity and discovered that scorpions minimized their activity during the nights under abundant moonlight. These authors also reported higher predation of scorpions under moonlight compared to dark nights.

Scorpions use air and surface vibrations to detect their prey, and their foraging behaviour is greatly affected by the lunar cycle (Skutelsky, 1996). The risk of their predation increases, many fold during moonlight periods. Scorpions avoid leaving their burrows under moon light conditions (Foster and Roenneberg, 2008; Hadley and Williams, 1968). Tigar and Osborne (1999) reported higher abundance of scorpions during dark nights than the nights when moonlight is present. In the present study, effects of the lunar cycle on the overall activities of common scorpion species of Sargodha division, Punjab, Pakistan were observed under field conditions. Also, effects of the lunar cycle on activity and availability of scorpion prey and their predators were studied.

MATERIALS AND METHODOLOGY

Study animal

Three common scorpion species, *i.e., Hottentotta tamulus* (Fabricius, 1798), *Odontobuthus odonturus* (Pocock, 1897) and

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Androctonus finitimus (Pocock, 1897) commonly occurring in Sargodha division, Punjab, Pakistan, were chosen for the study. All three scorpion species are primarily nocturnal, though *H. tamulus* can also be found during day time.

Study site and animal behaviour

Scorpion-rich habitats in Sargodha division were selected for the study. *A. finitimus* were studied at Shorkot (Kholara, 31°15'64"N, 72°19'86"E) and Sargodha (Dodha 32°06'54"N, 73°07'67"E), while *H. tamulus* due to their presence in old mud/ brick houses in rural areas were studied in rural areas of Sargodha (Chak # 76/SB, 32°06'70"N, 72°52'36"E; Chak # 34/SB, 31°55'55"N, 72°54'24"E; Chak # 24/SB, 32°02'05"N, 72°55'43"E; Bhagtanwala, 32°07'76"N, 72°57'74"E) and Mianwali (Chak # 16/DB, 32°38'71"N, 71°31´67"E). Whereas, *O. odonturus* scorpion was studied in semi-sandy areas of Jhang (Malumor, 31°06'67"N, 72°14'36"E; Aliabad, 31°16'57"N, 72°18'76"E) and Sargodha (Dodha 32°06'84"N, 73°07'68"E). For recording the geographical coordinates, a portable Garmin™ GPS V Plus device was used in the field. Battery operated portable ultraviolet (UV) lamps (SOGO-JPN-139) were used for studying the activity of the scorpions at night time. AcuRite (digital humidity and temperature monitor, model 325) was used to record air temperature and relative humidity during the field observations. The study was conducted from May to September during 2013, 2014 and 2015.

Effect of lunar cycle

To document the effect of moonlight on overall activities and prevalence of scorpions, field visits were made at night. Information concerning the phase of the moon cycle (new moon to 1st quarter, 1st quarter to full moon, full moon to 3rd quarter, 3rd quarter to new moon), location, scorpions seen (immature or adult), number of prey spotted, the number of scorpion predators seen, scorpion activity (mating or foraging) and the time of data collection were noted. In the scorpion habitats, the abundance of scorpions prey and predators and their activities were also monitored by using LED flashlights, SOGO-JPN-75. The availability of prey types, such as crickets, hoppers other insects and scorpions and predators (shrews, lizards, centipedes, mice and rats) were also observed. The prey and predator species of scorpions were identified only to the genus level. During the study a great care was taken to ensure that sampling effort and time is standardized across nights. We walked in a fixed transect (1.5 acre area) at a fixed pace and counted the number of individual scorpions, prey and predator, ensuring that individuals are counted only once. Visits were made between 8-11PM in all habitats. Selected individuals were brought to the Department of Zoology, University of Sargodha, Pakistan for identification. Abbreviations used in the figures are: NM = New moon; FQFM = First quarter to full moon; FMTQ = Full moon to third quarter and TQNM = Third quarter to new moon. The normality of the data was assessed before applying the statistical analysis. Pearson's correlation was used to find out the effects of temperature and humidity with the activity of scorpions. Kruskal-Wallis test was used to compare the active densities of scorpions during four different phases of moon cycle, i.e., new moon to 1st quarter, 1st quarter to full moon, full moon to 3rd quarter, and 3rd quarter to new moon. Statistical package SPSS (version 16) was used to analyze the data.

RESULTS

In total, 48 field visits were made to observe the effect of the lunar cycle on the activity of scorpions. During these visits, of 1236 scorpions were observed. of these, 361 were *H. tamulus*, 639 were *O. odonturus* and 236 were *A. finitimus*. Out of 361 *H. tamulus,* 57.08% were immature (0.5 - 5 mm) and 42.92% were larger adult (6 - 9 mm). *O. odonturus* was found to be the most active scorpion species. Out of the total *O. odonturus*, 56.21 % individuals were immature (0.4 - 4 mm) and 43.79 % were adults (5 - 8mm), whereas out of a total of 236 *A. finitimus*, only 34.32% were adults (6-12mm). Both immature and adult *H. tamulus* and *A. finitimus* were observed more during the dark nights (3rd quarter to new moon and new moon to 1st quarter) compared to well moonlight nights (1st quarter to full moon and full moon to third quarter) (Figs. 1a and 1c).

It is evident from Fig. 1 (b) that lunar cycle had no effect on the activity of *O. odonturus*. The number of the scorpion prey populations was also high in the dark nights compared to the moonlight nights (Fig. 2). The black crickets, white crickets, hoppers, spiders and moths were mostly found in *O. odonturus* and *A. finitimus* habitats, whereas cockroaches, houseflies, spiders, moths, butterflies, small and large black crickets, grasshoppers and praying mantis were the prey of *H. tamulus*.

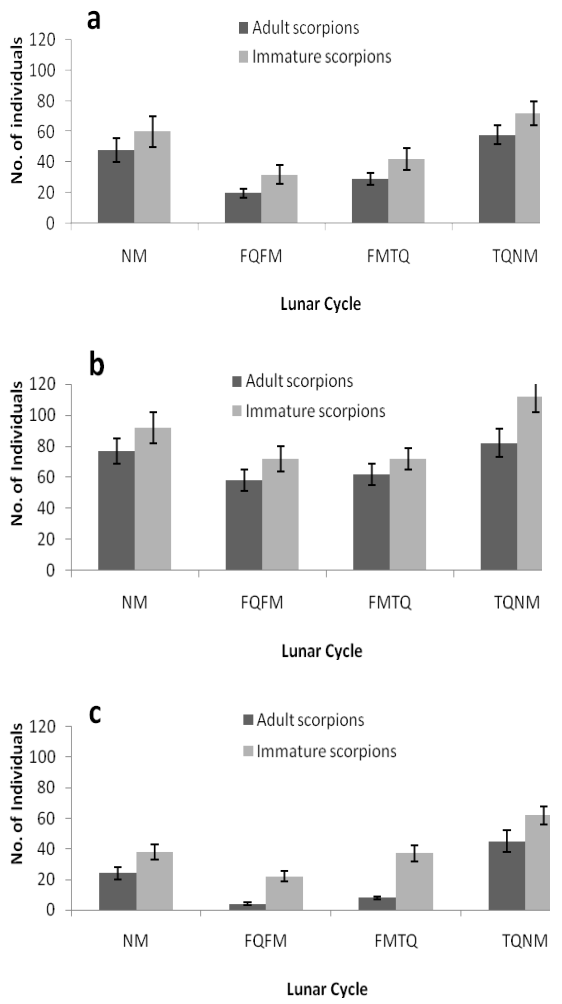

Figure 1 (a-c). Activity density of *H. tamulus* (a), *O. odonturus* (b), and *A. finitimus* (c) during different phases of lunar cycle.

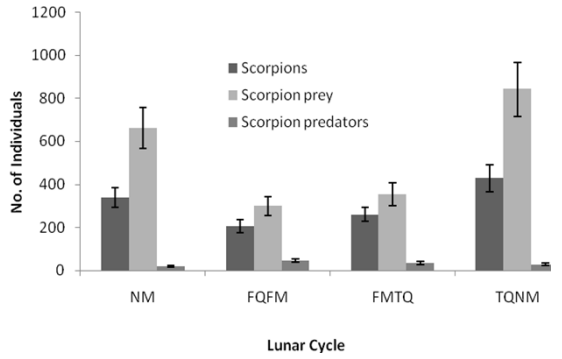

Figure 2 Comparison of density of scorpions, their potentials prey and predator during different phases of lunar cycle.

The lunar cycle did not affect abundance of scorpion predators (i.e., shrews, lizards, centipedes, mice and rats). All scorpion predators were more active during moonlight nights and they searched, attacked, and consumed scorpions aggressively (Fig. 2).

A significant, positive, correlation was found between temperature and the abundance of scorpions (r^2 = 0.749 for *H. tamulus*; r^2 = 0.739 for *O. odonturus*; r^2 = 0.791 for *A. finitimus*). However, scorpion abundance was negatively correlated with the humidity levels (r^2 = -0.494 for *H. tamulus* ; r^2 = -0.619 for *O. odonturus* and r^2 = -0.581 for *A. finitimus*). Results of Kruskal-Wallis test showed a significant difference in the active densities of scorpions during different phases of the moon cycle (P = 0.023; Fig. 1).

DISCUSSION

This field study revealed that *H. tamulus* and *A. finitimus* were more active in the dark (dark nights compared to moonlight nights). Previously, Warburg and Polis (1990), Milinski and Heller (1978), and Tigar and Osborne (1999) had reported similar observations. It is not surprising because the risk of predation is higher under moonlight condition and therefore they reduce their feeding activity during this period. Immature scorpions were high in numbers irrespective of darkness or moon light and this observation agrees with that of Skutelsky (1996). Every female scorpion lays an average of 8 eggs and juveniles appear from approximately all the eggs (Lourenco, 2000) therefore, the observed number of juveniles was always more than adults. This is due to the classical phenomenon of every species reproducing more for the continuation of their genetic lineage.

Relatively less effect of lunar cycle was observed on *O. odonturus*. This scorpion species was always found to remain in its habitat at night time during the summer season irrespective of the lunar cycle. The reason for this could be their specific lifestyle. The members of this scorpion species remains in their burrow most of the time with their pedipalps outside the burrow while rest of the body inside. They only leave their burrows for mating or foraging. When a predator approaches their burrow, they hide themselves inside the burrow. This strategy of defensive mechanism is helpful for the scorpion to avoid predation. Their highest

number in the field as compared to *H. tamulus* and *A. finitimus* could due to hiding strategies. This kind of hiding mechanism was also reported by Harington (1978), Shehab *et al.* (2011), and Cala-Riquelme and Colombo (2011) in scorpions.

Scorpion prey populations were high during dark nights. During dark nights different types of insects (crickets, moths, hoppers, etc.) gathered in huge number around the LED search light as soon as the light was turned on. However, during moonlight nights the numbers of these insects were low. This could be another reason for the occurrence of large numbers of *H. tamulus* and *A. finitimus* during the dark nights.

The number of predators of scorpions remained almost the same irrespective of the lunar cycle, but their activity was quite high during full moon nights. The reason could be that moonlight probably facilitates the predators in searching for the prey (scorpions) at night. These results are supported by Castilla *et al.* (2010) who reported high predator abundance and foraging activity during moonlit nights.

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