Article

The locomotory rhythmic activity in scorpions: with a review

Michael R. Warburg
Dept. of Biology, Technion-Israel Institute of Technology, Haifa 32000, Israel
E-mail: warburg@tx.technion.ac.il

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Abstract
Locomotory rhythmic behavior is entrained by the change between photophase and skotophase and to some extent by thermal conditions. In many species studied most activity takes place during early night hours. Some species show completely a nocturnal activity pattern, whereas a few species are entirely diurnal. There does not appear to be a pattern related to the timing and extent of the photophase. Except perhaps for *Leiurus quinquestriatus* (Hemprich and Ehrenberg, 1829) which appears to be less active at the highest temperature. This subject was studied in 30 species of scorpions most of them buthids (53.3%), that were studied so far in 42 different studies.

Keywords Scorpiones; diel locomotory rhythm; thermal 'Zeitgeber'.

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1 Introduction

The behaviour of scorpions has received less attention than it perhaps should have (Warburg and Polis, 1990). Most cited studies were on rhythmic activity of scorpions. Here studies were divided between those on the optic 'Zeitgeber' or time giver that bring about rhythmic activity (Warburg, in preparation). However most studies were conducted on the behaviour of locomotory rhythmic activity. The activity patterns described here are entrained by ambient conditions largely photophase and skotophase and to a certain extent also by thermal factors. Such entrainment factor or 'Zeitgeber' is the factor that brings about this rhythmic activity (Cloudsley-Thompson, 1961, 1978).

Dube and Fleissner (1985) describe three types of movements while in the wheel-running apparatus: (1) slow pace movements typical of a circadian rhythms of 12L/12D light regime; (2) long-lasting runs, and (3) rapid locomotion.

It was already Wuttke (1966) who described the bimodal activity in *Euscorpius carpathicus* (Linnaeus, 1767). In some species no rhythmic activity was noticeable. Thus, Cloudsley-Thompson and Constantinou (1985) studying *Opisthacanthus* sp which did not show any rhythm. Cloudsley-Thompson (1973) found in *Buthotus minax* (Koch, 1875) that the circadian locomotory rhythm is entrained by regular transition from dark to light and by rising temperatures. A similar situation was seen in *Babycurus centrurimorphus* (Karsch, 1886) by Cloudsley-Thompson (1975) who studied this buthid and found that diurnal rhythm was entrained by shifts both from dark to light and changes in temperatures.

Many of these studies show that activity is highest during the first few hours of the night (Cloudsley-Thompson, 1978, 1980) whereas others show activity peaking at night. Thus, Cloudsley-Thompson found a peak of activity in *Scorpio maurus, Buthus occitanus* (Amoreux, 1789) and *Androctonus australis* (Linnaeus, 1758) during the hours of 1800-2000 PM. The latter species was largely nocturnal (Constantinou, 1980). In (1978) Cloudsley-Thompson (Tab. 1 therein) summarized the situation in the scorpion species studied up till then. El Bakary and Fuzeau-Braesch (1988) studied: *Leiurus quinquestriatus* (Hemprich and Ehrenberg, 1829) using three methods of detecting locomotory activity. They too found bimodal onset of activity coincides with onset of photophase and skotophases.

Benton (1992) studying *Euscorpius flavicaudis* (DeGeer, 1778), found them active at dusk and dawn. In this study I shall review the subject of locomotory rhythms in scorpions. This would include only the rhythmic activities involving locomotion and not any rhythmic physiological functions. These were discussed recently (Warburg, 2013). This subject was studied in 30 species of scorpions that were studied so far in 42 different studies, listed as the follows:

Buthidae (16 species):

1. *Androctonus australis* (Linnaeus, 1758)
   Constantinou (1980); Baz et al. (2009)
2. *Anomalobuthus rickmersi* (Kraepelin, 1900)
   Fet (1980)
3. *Babycurus centrurimorphus* Karsch, 1886
   Cloudsley-Thompson (1975)
4. *Buthus hottentotta* Fabricius, 1787
   Toye (1970)
5. *Buthus occitanus* (Amoreux, 1789)
   Constantinou (1980); Constantinou & Cloudsley-Thompson (1980)
6. *Buthotus occitanus* (Amoreux, 1789)
   Skutelsky (1996)
7. *Buthotus minax* (L. Koch, 1875)
   Cloudsley-Thompson (1963, 1973)
8. *Centruroides sculpturatus* Ewing, 1928
   Hadley & Williams (1968); Crawford & Krehoff (1975)
9. *Hottentotta judaicus* (E. Simon, 1872)
   Warburg & Ben-Horin (1979)
10. *Leiurus quinquestriatus* (Hemprich & Ehrenberg, 1829)
   Cloudsley-Thompson (1963); Abushama (1963); El Bakary & Fuzeau-Braesch (1988); Warburg & Ben-Horin (1979)
11. *Liobuthus kessleri* (Birula, 1898)
   Fet (1980)
12. *Mesobuthus gibbosus* (Brullé, 1832)
   Kaltsas & Mylonas (2010)
13. *Mesobuthus eupeus* (C. Koch, 1813)
   Fet (1980)
14. *Mesobuthus caucasicus* (Nordmann, 1840)
   Fet (1980)
15. *Orthochirus scrobilosus* (Grube, 1873)
   Fet (1980)
16. *Parabuthus villous* (Peters, 1862)
   Harrington (1981)

Euscorpiidae (2 species):

17. *Euscorpius carpathicus* (Linnaeus, 1767)
Wuttke (1966)
18. *Euscorpius flavicaudis* (DeGeer, 1778)
Cloudsley-Thompson & Constantinou (1983); Benton (1992)
Cloudsley-Thompson (1963)

Hemiscorpiidae (1 species):
19. *Hadogenes bicolor* (Purcell, 1899)
Constantinou (1980); Constantinou & Cloudsley-Thompson (1980)

Vaejovidae (3 species):
20. *Paruroctonus boreus* (Girard, 1854)
Tourtlotte (1974)
21. *Vaejovis mesaensis* probably *Paruroctonus mesaensis* now *Smeringurus mesaensis* (Stahnke, 1957)
Hadley & Williams (1968); Polis (1980)
22. *Vaejovis confusus* Stahnke, 1940
Hadley & Williams (1968)

Scorpionidae (8 species):
23. *Diplocentrus spitzeri*. Stahnke, 1970
Crawford & Krehoff (1975)
24. *Nebo hierichonticus* (Simon, 1872)
Warburg & Ben-Horin (1979)
25. *Pandinus gregoryi* (Pocock, 1896)
Constantinou (1980); Constantinou & Cloudsley-Thompson (1980)
26. *Pandinus exitialis* (Pocock, 1888)
Cloudsley-Thompson (1963)
27. *Pandinus imperator* (C.L. Koch, 1841)
Toye (1970)
28. *Scorpio maurus fuscus* Hemprich & Ehrenberg, 1829
Warburg & Ben-Horin (1979)
29. *Heterometrus swammerdami* (E. Simon, 1872)
Cloudsley-Thompson (1981)
30. *Heterometrus fulvipes* (C.L. Koch, 1838)
Babu, Reddy & Kasaiah (1988)

2 Materials and Methods

Measuring activity in scorpions was carried out largely by actograph use. The actograph used here consists of a Perspex box measuring 5 x 6 x 20cm that rotated at its mid-point on a pivot. At one side an electrical contact closed a circuit thereby signaling a change in the position of the actograph that resulted from the scorpion moving inside the box. These movements were recorded on a Model 712 Telrad Recorder during the 24h experiment. This actograph apparatus was placed into a Struers Refritherm where temperature was controlled at ±0.5^{0}C. The animals could be observed through a window in the Refritherm’s door (see Warburg and Ben-Horin, 1979).

The scorpion species studied here were collected from the field. Four scorpion species were used here: *Scorpio maurus fuscus* (Hemprich and Ehrenberg, 1829), *Nebo hierichonticus* (Simon, 1872) *Hotenttotta judaicus* (Simon, 1872) and *L. quinquestriatus*.

3 Results

Diel Activity in three scorpion species is given as percentage of time spent in activity during four-six hour watches (Fig. 1). In all three species studied here most activity (between 55.3-87.6%) was spent active during the 1st watch (06 PM- 12). The three scorpion species differed in the amount of time spent during the remainder of the day. Thus, whereas *N. hierichonticus* and *H. judaicus* had shown hardly any activity (12.3% and 21.8% respectively), *S. m. fuscus* was active also during the remaining of the day (44.8%).

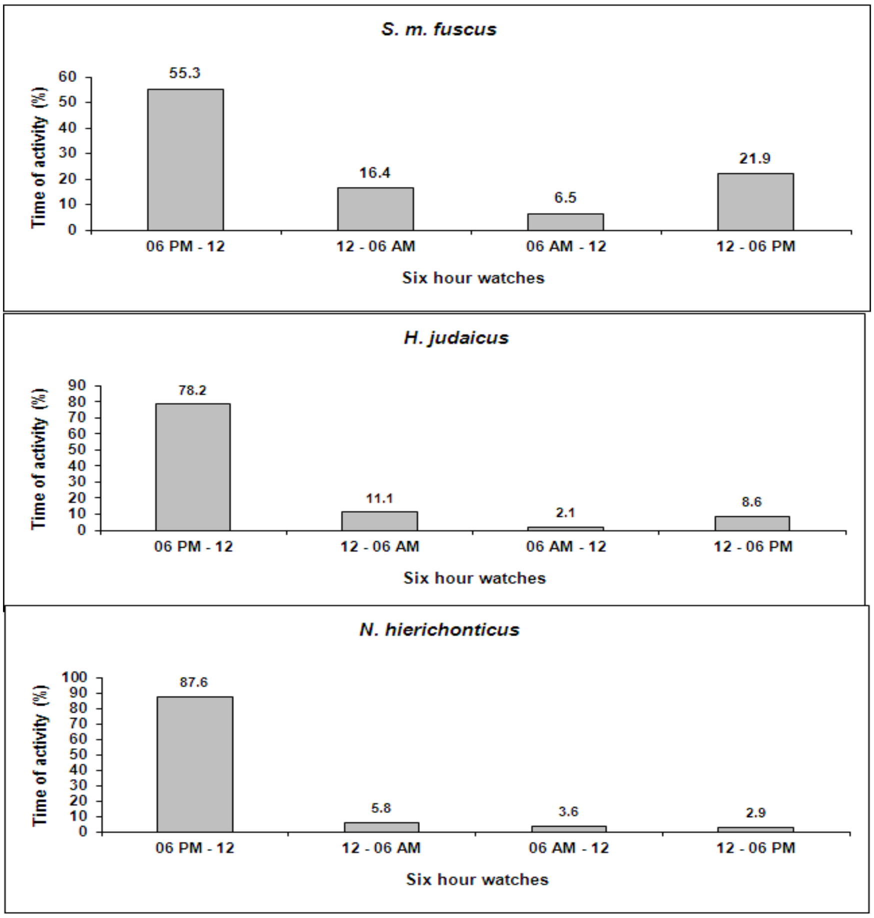

Fig. 1 Diel activity (%) in three scorpion species.

The number of activity runs at four temperatures (20^0C, 25^0C, 28^0C, 35^0C) was measured in four scorpion species (Fig. 2). These scorpion species differed in their response in a temperature gradient. Thus, the peak of activity was at the lowest temperature at 20^0C in *L. quinquestriatus* (55), and in *N. hierichonticus* (40.6), whereas for *S. m. fuscus* and *H. judaicus* it was at 25^0C (69.1 and 41 respectively). At the highest temperature tested here (35^0C) the two buthid species (*L. quinquestriatus* and *H. judaicus*) have shown the lowest activity (5.5 and 16.3 respectively).

When the number of activity runs was compared in illuminated and dark parts of the thermo-preferendum apparatus (Fig. 3), outstanding differences in the activity of the four scorpion species were noticeable. Thus in *N. hierichonticus* and *S. m. fuscus* there was no marked difference between the activity in the dark and illuminated parts of the thermo-preferendum apparatus. In the two species activity was higher in the illuminated part. In the first species it was 29.6 at 20^0C, whereas in the latter species it was 29.6 at 25^0C. In the two buthids activity was higher in the darkened part. Thus in *H. judaicus* it was highest at 25^0C (32.5) whereas in *L. quinquestriatus* it peaked at 28^0C (34.4).

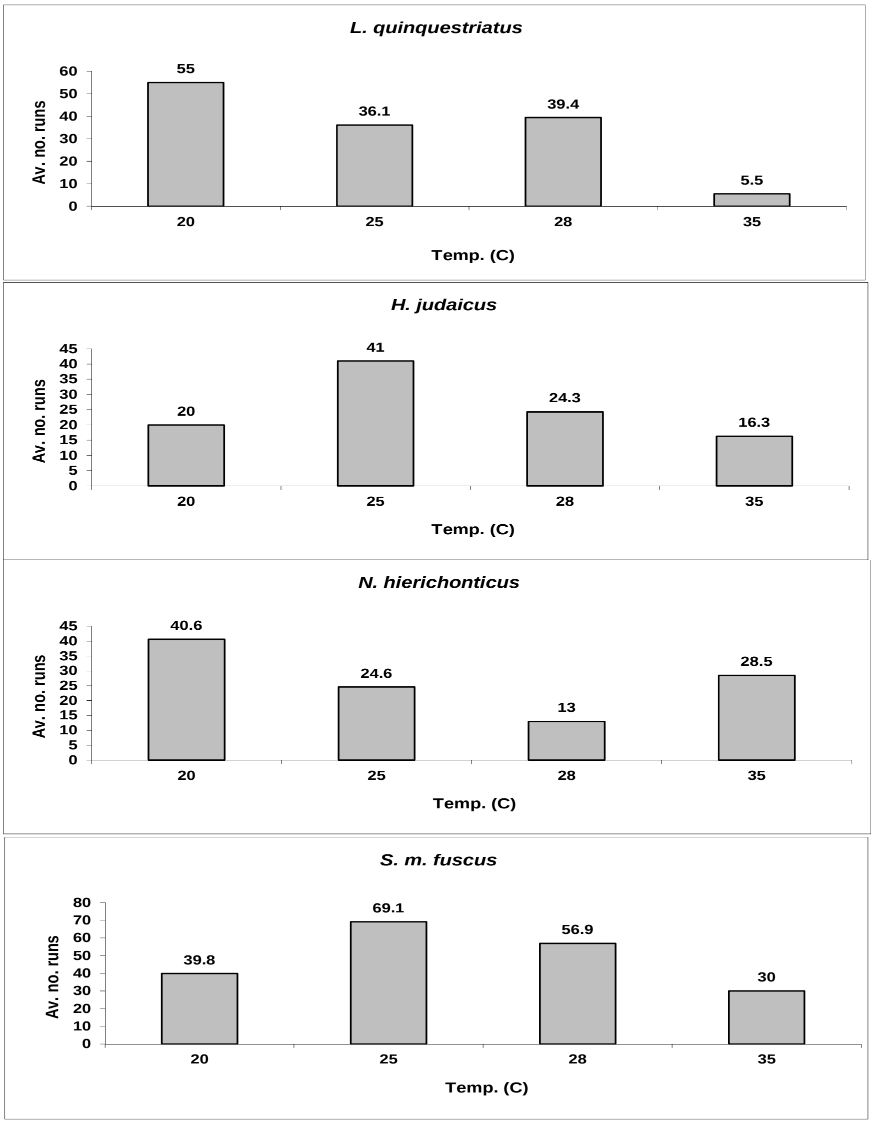

Fig. 2 Average number of activity runs at four temperatures in four scorpion species.

Lastly, the time spent in the thermo-preferendum apparatus was examined in detail in 30^0C thermal zones ranging between 15^0C–30^0C (Fig. 4). This was examined in *S.m. fuscus* and *N. hierichonticus*. Both species have shown similar results with activity rising between 21^0C-27^0C (27.8-37.3 in the first species, and 30-36.7 in the second species), dropping thereafter between 27^0C-30^0C (to 23.3 in the first species, and 8.7 in the latter).

4 Discussion

4.1 Activity during daytime

Constantinou (1980) studied four scorpion species: *Pandinus gregoryi* (Pocock, 1896) showed diurnal activity most of its time (63%), *Hadogenes bicolor* (Purcell, 1899) with 26% activity diurnal, *A. australis* was largely nocturnal, as was also *B. occitanus*. Constantinou and Cloudsley-Thompson (1980) studied four different scorpion species: *Scorpio maurus*, *B. occitanus*. *P. gregoryi* and *H. bicolor*. They found the last two are largely diurnal as was the case also with *Parabuthus villosus* (Peters, 1862) where Harrington (1981) found it to be diurnal.

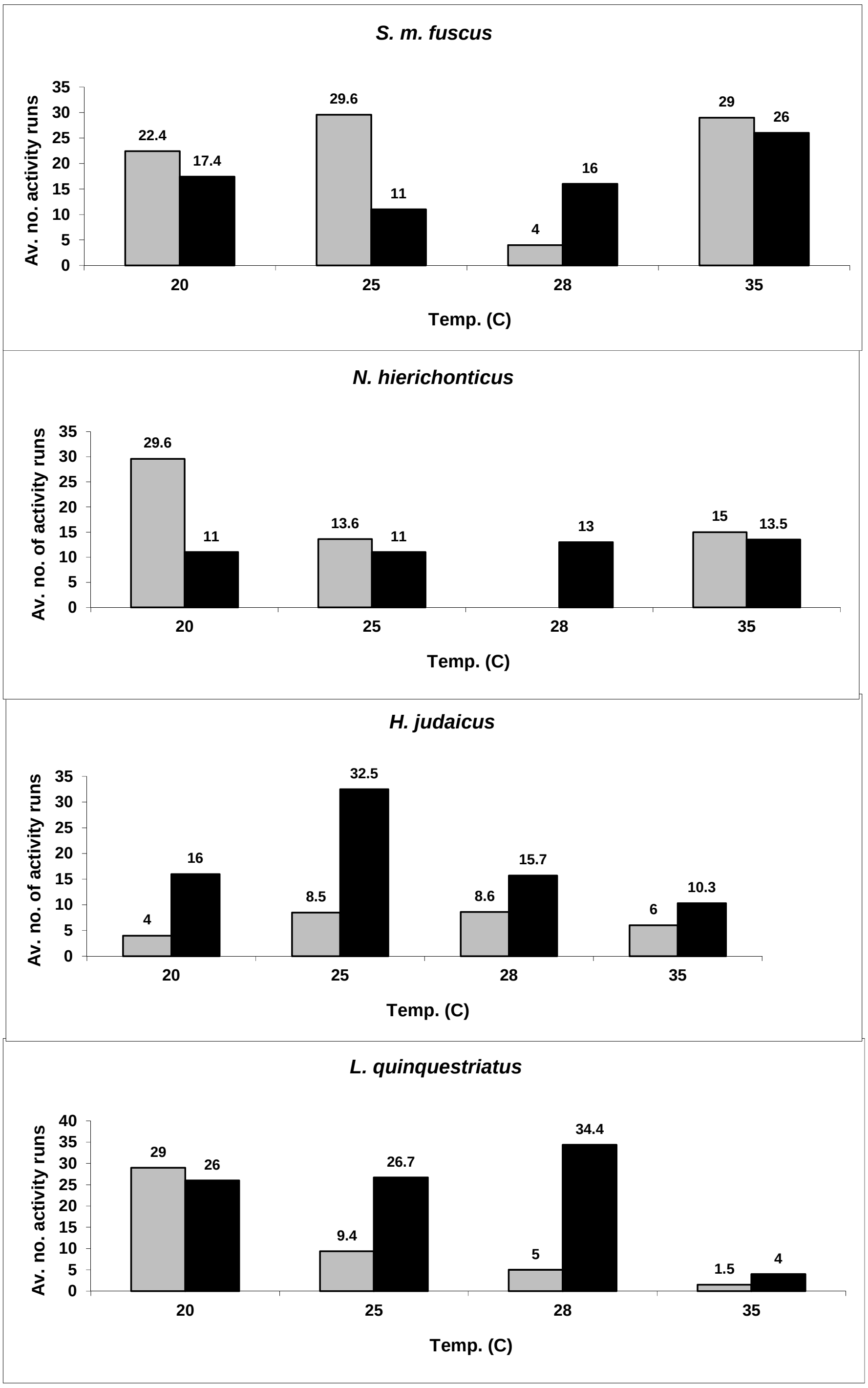

Fig. 3 Average number of activity runs in illuminated (grey bars) and dark arenas.

4.2 Activity during early evening

Hadley and Williams (1968) studied three species of scorpions: *Vaejovis confusus* (Stahnke, 1940), *V. mesaensis* (Stahnke, 1957) and *Centruroides sculpturatus* (Ewing, 1928). All of them showed peak activity in the evening. Similarly, Toye (1970) studying both *Pandinus imperator* (Koch, 1841) and *Buthus hottentotta* Fabricius, used an actograph made of celluloid tubes pivoting through transverse center. He too found that the peak activity was between 1500-1800h in both species. Polis (1980) studying the vaejovid *Paruroctonus mesaensis* (Stahnke), found that surface activity increases during early evening decrease after 1400AM.

Warburg and Ben-Horin (1979) studied effect of temperature on rhythm of three scorpion species in an actograph. They found in *S. m. fuscus* high activity 1200-1800h and 1800-2400h. This activity dropped drastically with rising temps (to 28^{0}C and 35^{0}C). *N. hierichonticus* showed high activity between 1800-2400hr during 06-12 hrs, whereas *H. judaicus* rhythm was not affected by temperature. Babu, Reddy and Kasaiah (1988) studied *Heterometrus fulvipes* (Koch, 1838) with an actograph.

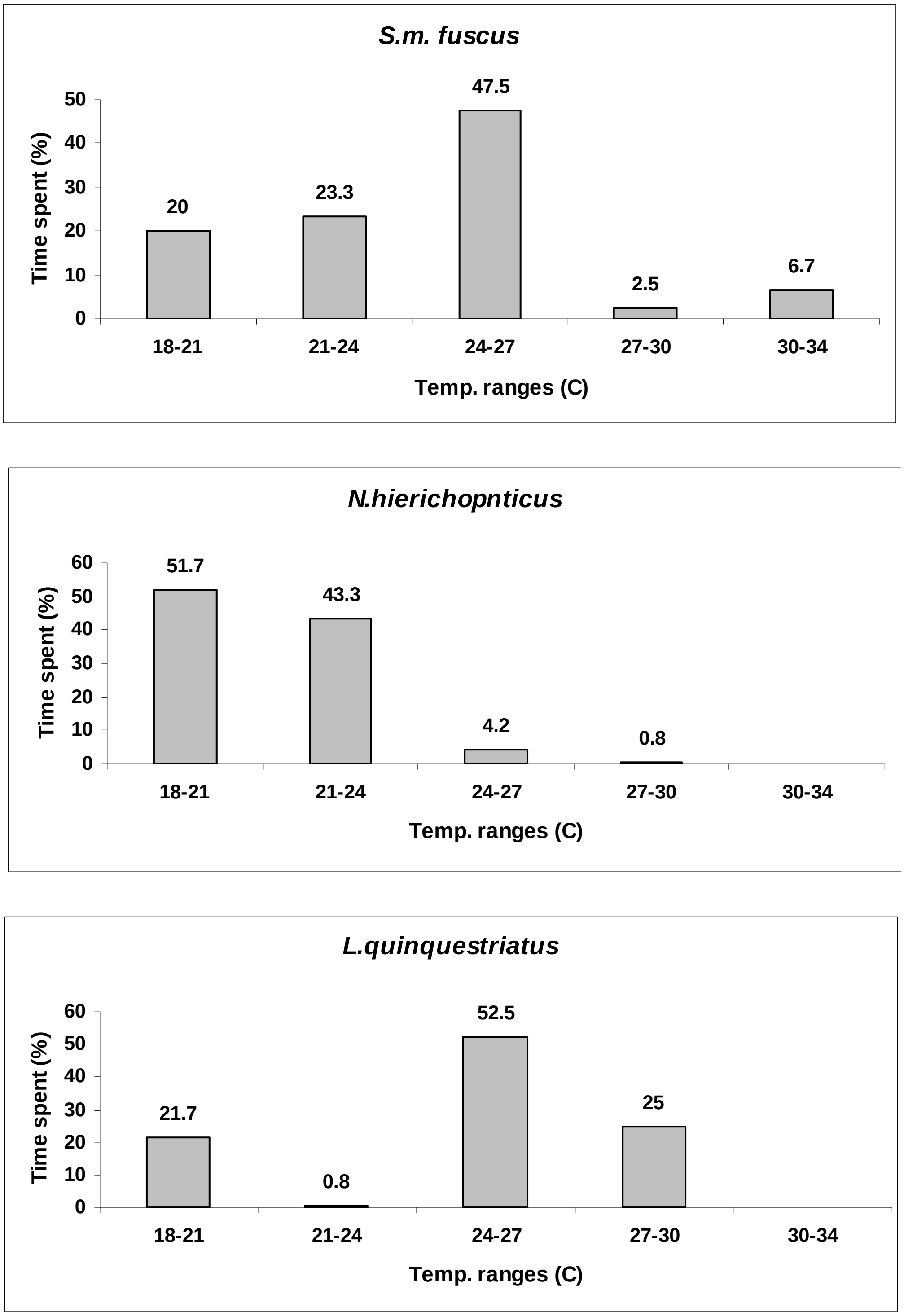

Fig. 4 Percentage time spent in the thermo-preferendum apparatus.

4.3 Activity during night

Cloudsley-Thompson (1963) Studied three scorpion species: *Pandinus exitialis* (Pocock, 1888), *L. quinquestriatus* and *Buthotus minax* (see Fig. 2 therein). All of these species were nocturnal. One of these scorpions *L. quinquestriatus,* was studied in an actograph apparatus box pivoted about its median transverse axis writing on a barograph drum that acted as a kymograph (Abushama, 1963). He too found it to be nocturnal following an endogenous factor of the rhythm.

On the other hand, Tourtlotte (1974) who studied surface activity of *Paruroctonus boreus* (Girard, 1854), found its activity peaked at 2130h. Likewise, Crawford and Krehoff (1975) studying *Centruroides sculpturatus* and *Diplocentrus spitzeri* (Stahnke, 1970), found that surface activity in the field peaked between 2030-2230h whereas, activity in the actograph showed nocturnal activity. Only *Centruroides spitzeri* showed endogenous circadian rhythm in constant darkness. Fet (1980) studied the buthids: *Orthochirus scrobilosus* (Grube, 1873), *Anomalobuthus rickmersi* (Kraepelin, 1900), *Mesobuthus eupeus* (Koch, 1813), *M. caucasicus* (Nordmann 1840) and *Liobuthus kessleri* (Birula 1898). In all these species activity peaked between 2100-0100 h.

Cloudsley-Thompson (1981) studied *Heterometrus swammerdami* (Simon, 1872) and found it active especially at night. Cloudsley-Thompson and Constantinou (1983) studying *E. flavicaudis* described their nocturnal habits in the field and during actograph studies.

Baz, Sallam and El-Naggar (2009) studied *A. australis* locomotor activity rhythm. It was synchronized with electroretinogram rhythm starting at night. Skutelsky (1996) studying: *Buthotus occitanus israelis*, found its activity dropped with full moon. Kaltsas and Mylonas (2010) studying *Meobuthus gibbosus* found their activity dropped with moonlight.

There are several points that emerge from this review:

1. Most of these studies (54%) were conducted on buthids that are usually the more active species.
2. Many of the studies did not remark anything about the ecology or physiological conditions of the scorpions studied. This is especially important since in many studies the scorpions were previously kept for sometime before the onset of the experiment.

3 The findings of these studies are not conclusive. Under what condition does a shift in behaviour of the scorpion's rhythmic activity take place?

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