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DAILY ACTIVITY OF *ARION LUSITANICUS* MABILLE, 1868 (*GASTROPODA: PULMONATA: ARIONIDAE*)

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Abstract: Studies on the daily activity of *A. lusitanicus* were conducted under field and laboratory conditions. Two main phases – the activity phase and the phase of resting – have been distinguished in the daily cycle of the slug. The observed activity was of different types, such as crawling, feeding and the state of semiactivity. It has been found that slug activity is determined by various atmospheric factors, mainly by light intensity, rainfalls and presence of dew. Slug activity is strongly influenced by their physiological 24 hr. life rhythm. Full activity was exhibited by all individuals after sunset and after the appearance of dew. They return to their shelters about three hours after sunrise. Feeding of *A. lusitanicus*, including periods of resting, lasts throughout the whole night, since their emergence from shelters until early morning hours. Most of the slugs start intensive feeding 2–3 hours after sunset.

Key words: slug, *A. lusitanicus*, daily activity

I. INTRODUCTION

Slugs are nocturnal animals. During the daytime they remain under cover, from which they emerge, most commonly after sunset. The majority of slugs return to their shelters before sunrise. The phase of slug activity is divided into the periods of feeding, crawling, resting and copulation (Newell 1966). Each slug species has its specific time of the maximum nocturnal activity (Lewis 1969). Slug activity depends on various climatic factors, which apparently stimulate initiation of its particular type (Dainton 1954; Karlin 1961; Nevell 1966; Lewis 1969; Baker 1973; Hunter and Runham 1971; Crawford-Sidebotham 1972; Kosińska 1980).

In common with other slugs, *Arion lusitanicus* is active mainly at night and at that time it causes most of the damage to plants (Kozłowski 1999; 2000a; b). Therefore, identification of periods, when the slug leaves its shelter, starts searching for food and feeding on plants is particularly important and indispensable to forecast this pest occurrence and to take relevant control measures against it.

These studies present an analysis of *A. lusitanicus* daily activity under different weather conditions. The timer distribution of particular phases of the slug behaviour was observed during consecutive half-hour time periods of a 24 hr. cycle.

II. MATERIAL AND METHODS

Field study on the daily activity of *A. lusitanicus* were carried out in the first decade of July 1998, in a horticultural crop habitat located at Wysoka near Łańcut. The slug population under study consisted of predominant sexually immature individuals about 5 cm long. Observations were conducted in the field of mowed clover. The selected field occupied a surface of 0.17 ha and it was located between vegetable crops and fruit bushes. On one side it bordered an irrigation ditch running along the field path. The slugs were very numerous on the balks surrounding the field and in further vegetable crops. In the central parts of the field they could be found only sporadically. In the middle of the field, three shelters were placed 15 m apart. They were made of roof tiles and covered with fibreboards. The soil under shelters was moistened. In two locations some food, such as moistened leaves, pieces of vegetables and wheat brans, was placed 3 m apart from each shelter as a bait to attract the slugs. The food was supplemented every several hours, but during the day when the weather was sunny, it was substituted every half-hour. Before placing shelters and food for slugs, the field was examined for the slug presence within a radius of 150 m from the central trap. In the course of this study that was repeated four times per 24 h. In the afternoon, 20 slugs caught in the vegetables crops were placed under each shelter for three consecutive days to allow them to become accustomed to the shelters and food left. Missing individuals were supplemented. Detailed observations were conducted for four selected days and nights in two types of weather – sunny and showery. Every hour at night and every 30 minutes at the daytime the slugs were counted in the shelters and on the food. The air temperature, the amount of rainfalls as well as the time of dew occurrence and its drying up were recorded. The time lapses of the slug activity and resting and moments, when they left their shelters and returned back, were determined.

Observations under laboratory conditions were conducted at the day temperature of 21°C ± 1°C, night temperature of 16°C ± 1°C, RH 95–98% and the day length of 15 hours (from 5.30 to 20.30 hrs.). Mature slugs were placed into three covered containers 24 hours before the beginning of observations. The containers made of transparent Plexiglas were divided into four chambers measuring 25×25×30 cm each. The bottom of each cell was covered with a 5-cm layer of moist soil, on which shelters for the slugs and food (oat brans, macaroni, pieces of vegetables, cereal seeds) were placed. The shelters used were plastic vessels measuring 8×14×6 cm each and having two holes. The slug behaviour and the place of its occurrence were observed for three consecutive days and nights. These observations were conducted on 36 slugs (12 slugs per container). Four types of the slug behaviour were distinguished and designated by the following numbers on the scale: 0 – the state of resting, 1 – the state of semiactivity, 2 – the state of activity while crawling, 3 – the state of activity while feeding. From the performed observation of the slug number with a definite type of behaviour, an average weighed type of behaviour of 12 slugs was determined for each of the 48 observation periods per 24 hours. For so defined traits the analysis of variance eliminating daily differences was carried out and Tukey's test at $\alpha = 0.05$ was applied.

Under the same conditions, the behaviour of 10 slugs placed in one 60×40×50 cm container was observed. The observations were conducted every 30 minutes during three con-

secutive days and nights. The type of behaviour and the place of presence of the slugs were recorded. Relations were determined between the duration of the slug presence in their shelters until they became fully active, until their resting outside shelter and until feeding on the offered food. For all the data, the variance analysis and Tukey's test at $\alpha = 0.05$ were performed.

III. RESULTS

1. Field observations

During sunny and dry weather, single slugs began to emerge from their shelters about four hours before sunset (about 16.30 hrs.), at the temperature of 19.5°C (Fig. 1). Their number on the baits gradually increased. Initially most of the slugs emerged from their home sites, hid under the baits and did not feed. They began feeding on the baits two hours before sunset, when their number reached more than 40%. The emergence of slugs from their shelters was more numerous (above 80%) after sunset (21.00 hrs.), when dew appeared on the soil and plants. The slugs remained active throughout the whole night until early morning hours. They crawled on the soil and baits and continued feeding. The period of their activity was interrupted by short resting periods. The first slugs started to return to their shelters, when dew dried up and the temperature reached 15.5°C. That occurred 3.5 hours after sunrise (8.00 hrs., Fig. 1). The remaining slugs returned to their shelters, within the next hour, with the except on of several individuals, which hid under the baits. In the

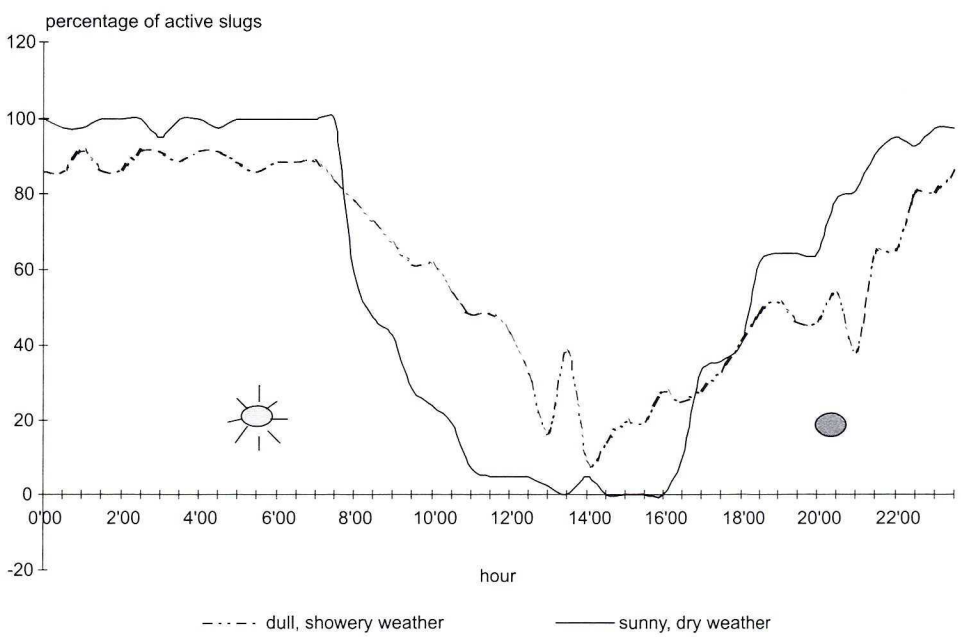

Fig. 1. Daily activity of *A. lusitanius* under field conditions (measured each 30 minutes)

shelters slugs fell into the state of numbness. They remained inactive for seven hours – from 10.00 to 17.00 hrs., and then they began to emerge from their shelters again.

During the day, when the weather was dull and showery, over 10% of slugs were active. The number of active slugs began to increase three hours before sunset (18.00 hrs., Fig. 1), at the temperature of about 12°C. Their numbers on the soil and food gradually increased. Over 50% of active slugs were observed already one hour before sunset. The percentage of active slugs remained high (70–97%) from 22.00 to 8.00 hrs. in the morning. Six hours after sunrise (10.30 hrs.), at the temperature of 11°C, more than one half of the slugs were active, whereas the remaining ones stayed in their shelters. During the next five hours (10.30–15.30 hrs.) the number of active slugs slightly decreased with large fluctuations, and then it began to increase again.

2. Laboratory observations

Observations on the slug behaviour under laboratory conditions showed that from the moment when light was switched off at 20.30 hrs., the activity of the slugs significantly increased (Fig. 2). The slugs remained active throughout the period of shade (night) until the first hours after the light was switched on (day). Their activity was found to be the highest during the third hour of shade. The type of the slug behaviour was related with the place of their occurrence. Individuals in the state of resting occurred mainly in their shelters. Slugs in the state of semiactivity and in full locomotory activity (crawling) were found mainly on the soil and on the container walls. A few of them were also found in the shelters and on the food or near it.

When analysing the behaviour of 10 slugs placed in one container, it was found that *A. lusitanicus* rested in their shelters most of the time (about 10 hours per day and night) (Fig. 3). They were also frequently observed in the state of full activity while crawling and

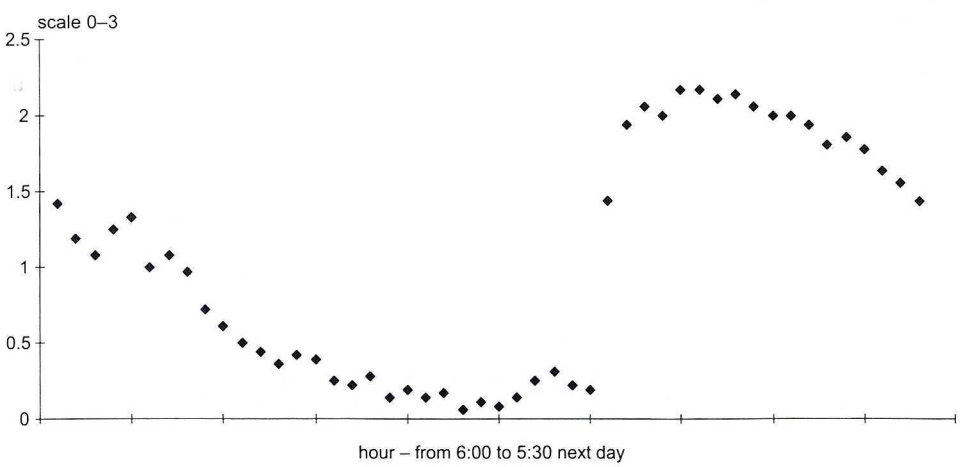

Fig. 2. Types of *A. lusitanicus* behavior under laboratory conditions (measured every 30 minutes with the scale: 0 – the state of resting, 1 – the state of semiactivity, 2 – the state of crawling, 3 – the state of feeding; means of 36 observations)

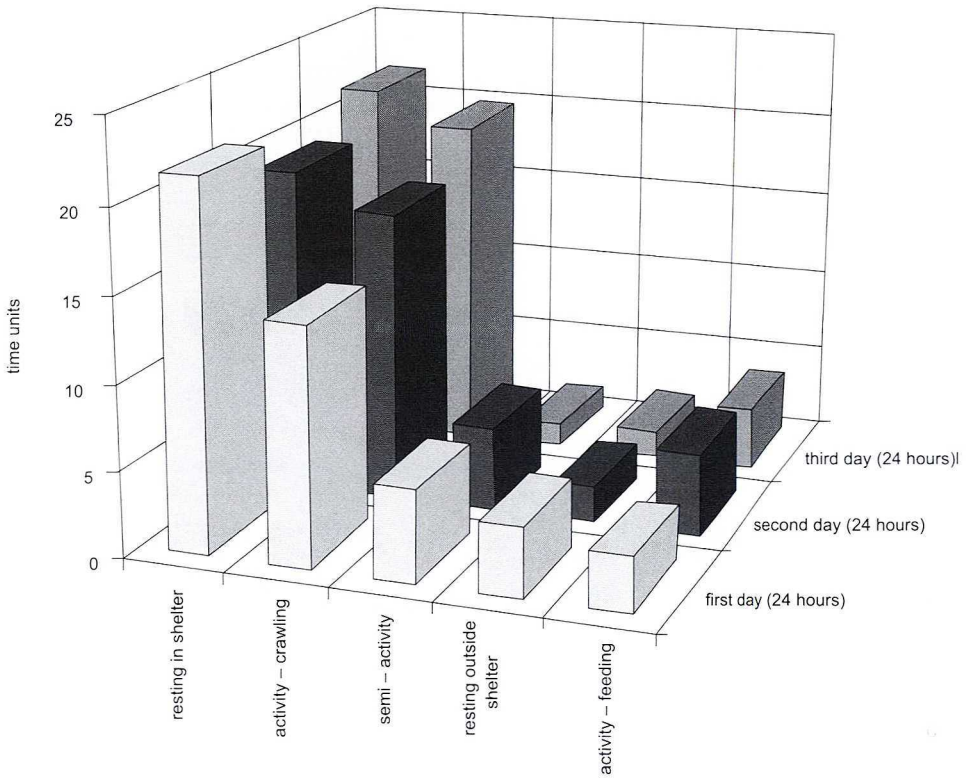

Fig. 3. Mean length of duration of different types of *A. lusitanicus* behaviour during three consecutive daily observations

feeding for about 8.5 h per day and night. However, they were observed in the state of activity on the food for 2 hours, on an average, and in the state of semiactivity on the soil or on the walls of the container for 2 hours. Totally, the ratio of the time of resting to the time of activity was 1:1 at the ratio of the day to night length equal to 5:3. The time ratio between different types of *A. lusitanicus* behaviour was determined by division of 24 hours into day and night (Fig. 4). During a 15-hour day (from 5.30 to 20.30 hrs.) the slugs were mainly in the state of resting in their shelters, whereas during shading most frequently they were in the state of full locomotory activity. The slugs fed mostly during the shade (at night), but also during the first hours of the day (Fig. 5). Like in the previous experiment, it was observed that slugs emerge from their shelters after switching the light off (beginning of night), whereas after switching the light on (day) they remained active for about 2–4 hours.

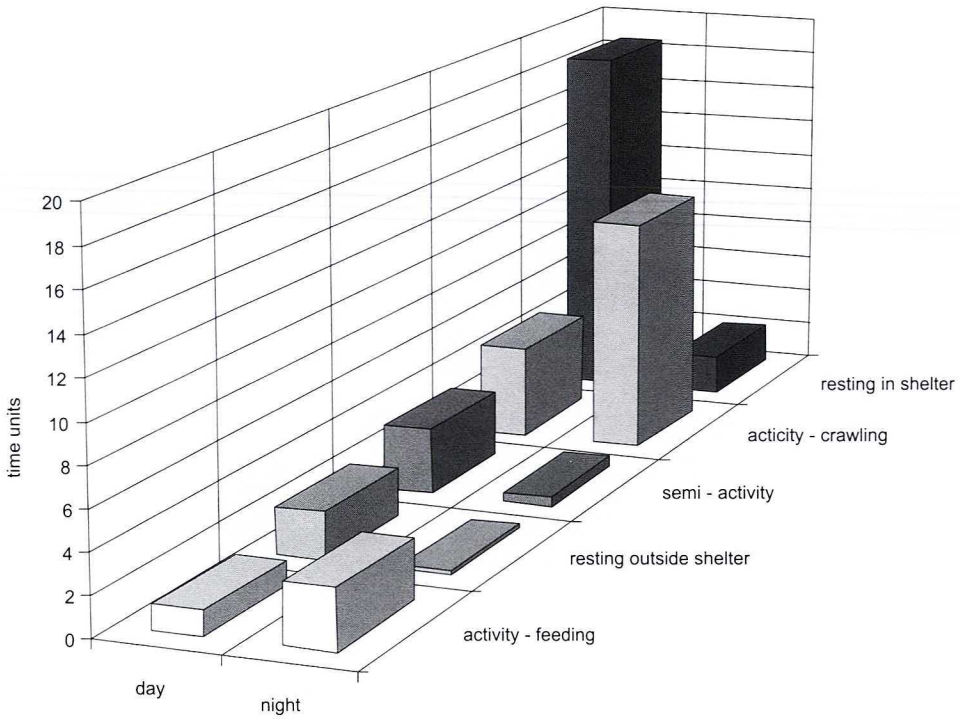

Fig. 4. Mean length of duration of different types of *A. lusitanicus* behaviour in the daytime and at night

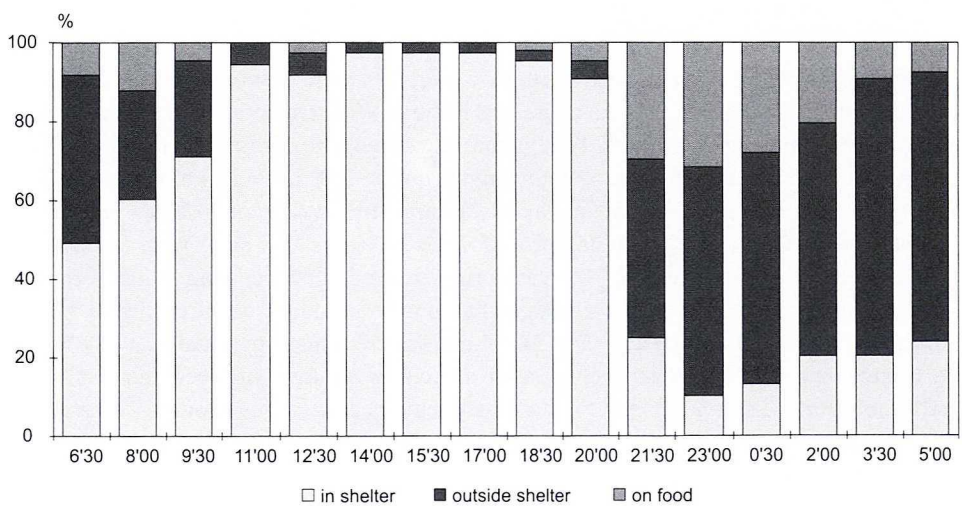

Fig. 5. Location of *A. lusitanicus* occurrence during consecutive 1.5-h day and night periods (from 6.00 to 5.30 hrs. on the following day)

IV. DISCUSSION

Two main phases are distinguished in the daily cycle of *Arion lusitanicus* i.e., the phase of activity and phase of resting. The activity phase is divided into the periods of crawling, feeding and copulation. Besides, there occurs the state of semiactivity in the behaviour of slugs, in which they remain motionless, but are not in the state of numbness as in the phase of resting.

In a sunny weather and when dew appears, all slugs are active after sunset. The first individuals leave their shelters already four hours earlier, and an hour before sunset about 50% of slugs are active. They remain in the phase of activity for nearly 2/3 of a day and night, though the activity of some individuals may be longer. In a sunny and dry weather and in the absence of dew, the activity exhibited by slugs is significantly lower. Observations of *A. lusitanicus* under such atmospheric conditions, conducted during the present studies, have showed that slugs emerge very slowly from their shelters. Only a few individuals were noted to feed on the baits during the first half of a night. According to Kosińska (1980) slugs begin their phase of activity at different temperatures and at different hours, but only in the presence of dew. The lack of dew in the evening causes that *Deroceras sturanyi* (Simroth) emerges from their shelters at later hours (Kosińska 1980). Also *D. reticulatum* emerge from their shelters only when the relative air humidity is close to saturation (Baker 1973). *A. lusitanicus* behave in a similar way. During dull and showery weather and at a high air humidity and ground moisture, a large proportion of slugs remains active independently of the time of a day and night. The number of active slugs is the largest at night and during early morning hours. During the day the number of active slugs decreases to 10%. These slugs intensively feed on wet plants and remain on the ground surface all the time. However, despite favourable conditions, most slugs return to their homes during the day as in a sunny weather.

The behaviour of slugs under scattered light in laboratory conditions is the same. Under both the field and laboratory conditions for the majority of slug individuals, the phase of resting begins at the third hour of the day. In the consequence, *A. lusitanicus* like other naked slugs avoids intensive light, since a direct action of sun light may kill most of naked slugs (Kosińska 1980; Wiktor 1989). Their naked body is liable to desiccation and the only protection for them is to move to moist sites. For that reason naked slugs are nocturnal animals. During the day they remain inactive hiding in their shelters from a drying effect of sunshine and high temperatures. It has been found that *A. lusitanicus* physiological rhythm is associated with the rhythm a bright sunny day. The phenomenon of inborn daily rhythm was observed also in *Arion ater* (Linnaeus) (Lewis 1969; Hunter and Runham 1971) as well as in *Deroceras reticulatum* (Müller) (Baker 1973). However, in *Deroceras sturanyi* (Simroth) this phenomenon probably does not occur. Slugs of this species, reared without sun light, loose their specific daily rhythmic, after a certain time (Kosińska 1980).

The performed observations suggest that the day length and direct action of sun light, besides inborn properties of the slug, have a strong effect on the activity of *A. lusitanicus*. Factors initiating and regulating naked slug activity were considered by many authors (Dainton 1954; Karlin 1961; Nevell 1966; Lewis 1969; Baker 1973; Hunter and Runham

1971; Crawford-Sidebotham 1972; Kosińska 1980). The most important of these factors are: temperature, humidity and water vapour pressure, which are indirect results of the action of sun light. According to Lewis (1969) light intensity determines the precise time of the onset of *A. ater* activity, whereas other external factors, such as wind, humidity and precipitation may influence the length of the activity phase. Newell (1968) found that rather a decrease in light intensity after sunset than falling of temperature initiates *D. reticulatum* locomotory activity. That indicates that light is the most important factor having effect on slug activity.

The mentioned atmospheric factors determine indirectly the intensity of *A. lusitanicus* feeding as one of the forms of the slug daily activity. Under both field and laboratory conditions, the highest activity of that slug was observed at the third hour of a night. After the emergence of slugs from their shelters, first of all they supplement their water demands by licking up drops from plants or by drinking from puddles. Then, they crawl in search of food, and after finding it, they begin intensive feeding. The time of intensive feeding during 24 h varies widely in different slug species. For instance, *D. sturanyi* feed most intensively during early hours, before dawn (Kosińska 1980).

Feeding of *A. lusitanicus*, including breaks for resting, generally lasts from their emergence from shelters throughout the whole night until early morning hours. Most of the slug individuals start intensive feeding 2–3 hours after sunset. At a high intensity of occurrence in plant crops during some nights this pest is able to destroy entire patches of young vegetable plants or large surfaces of oilseed rape and cereals (Kozłowski 1999; 2000a; 2000b). Under favourable atmospheric conditions (high air humidity and soil moisture) part of slugs remains active also during the daytime, feeding on plants and causing significant damages.

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AKTYWNOŚĆ DOBOWA *ARION LUSITANICUS* MABILLE, 1868 (*GASTROPODA: PULMONATA: ARIONIDAE*)

STRESZCZENIE

Badania nad aktywnością dobową *A. lusitanicus* prowadzono w warunkach polowych i laboratoryjnych. W cyklu dobowym ślimaka wyróżniono dwie główne fazy: fazę aktywności i fazę spoczynku. Obserwowana aktywność obejmowała różne typy zachowań, takie jak: pełzanie, żerowanie, stan półaktywności. Stwierdzono, że aktywność dobowa *A. lusitanicus* determinowana jest przez różne czynniki atmosferyczne, głównie intensywność światła, opady deszczu i obecność rosy. Zaobserwowano, że przy deszczowej pogodzie i wysokiej wilgotności powietrza w połowie dnia 10–30% ślimaków jest aktywnych. Natomiast przy słonecznej i suchej pogodzie większość osobników chroni się w kryjówkach. Prawdopodobnie duży wpływ na aktywność *A. lusitanicus* ma wrodzony rytm dobowy ślimaka. Ślimaki rozpoczynają wychodzenie z kryjówek cztery godziny przed zachodem słońca. Pełna ich aktywność występuje po zachodzie słońca i pojawieniu się rosy. Powrót do kryjówek przypada mniej więcej trzy godziny po wschodzie słońca. Okres aktywności większości ślimaków podczas słonecznej i suchej pogodzie, przy 16-godzinnym dniu, wynosi około 2/3 doby. Żerowanie *A. lusitanicus*, z przerwami na odpoczynek, trwa od wyjścia ślimaków z kryjówek przez całą noc do wczesnych godzin rannych. Większość osobników rozpoczyna intensywne żerowanie 2–3 godziny po zachodzie słońca. W doświadczeniach laboratoryjnych stwierdzono, że *A. lusitanicus* jest aktywny przez cały okres zaciemnienia oraz przez około 2–4 godziny po włączeniu oświetlenia. Łącznie, stosunek czasu spoczynku ślimaka do czasu aktywności wynosi 1:1, przy stosunku długości dnia do nocy 5:3.