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MATING BEHAVIOUR OF *ARION LUSITANICUS* MABILLE, 1868 (GASTROPODA: PULMONATA: ARIONIDAE)

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ABSTRACT: Studies on gastropod mating are important for understanding various taxonomic and ecological problems. Field observations on the copulation of *Arion lusitanicus* Mab. revealed four phases: recognition of the partners, courtship dance, copulation and spermatophore transfer, separation and parting of the partners; the slug behaviour during these phases and their duration are described.

KEY WORDS: slug, *Arion lusitanicus*, mating

INTRODUCTION

Studies on gastropod mating behaviour have been carried out for many years with regard to a variety of species. Mating is a complicated process; it involves various kinds of behaviour, and differs between species. The knowledge of the mating behaviour is of importance for taxonomic and phylogenetic studies, it may help understand morphology and function of copulatory organs, and determine ecological requirements of the animals.

Among slugs of the family Arionidae, most studies focused on *Arion rufus* (Linnaeus) while mating of some other species, e.g. *Arion lusitanicus* Mabille, remained almost completely unknown. Few papers dealing with reproduction of the latter species focused on the structural details of its copulatory organs with a view of applying them as taxonomic characters (QUICK 1952, DAVIES 1987, NOBLE 1992, CASTILLEJO & RODRIGUEZ 1993).

In this paper we present the results of observations on mating behaviour of *Arion lusitanicus* in consecutive phases of courtship and copulation, from recognition to spermatophore transfer and separation of the partners.

MATERIAL AND METHODS

Mating behaviour of *A. lusitanicus* was observed in August 1998, in allotment gardens in Rzeszów (SE Poland) and in vegetable crops in Wysoka near Lańcut (SE Poland). The observations included several consecutive days, and lasted from the evening till the early morning hours, and on cloudy, rainy days also during the daytime. The time and place of mating were noted, and the length of mating individuals was assessed. The observations included 38 mating pairs.

Continuous, whole-night observations of all the stages, from search for a partner till separation, included 10 pairs. The observations were performed during a rainy weather, the air temperature in the night was 14–17°C. The time of the beginning and end of mating, and the duration of particular phases were determined; photographs of each phase were taken.

RESULTS AND DISCUSSION

Arion lusitanicus copulates in very different places, such as cultivated fields, meadows, balks, shrubs, waste land, roads, river banks etc. The copulation takes place in a horizontal position, on a humid soil under growing plants, or on the soil devoid of vegetation, on grass, paths, pavements, tree stumps and plant leaves.

The mean length of mating slugs is 6.5 cm. The smallest mating individuals are ca. 3 cm long, while the largest are ca. 8.5 cm long; adult individuals reach a length of ca. 12 cm (KOZŁOWSKI 2000). Mating pairs with one partner small and the other large are frequent. Thus, like in some other species, mating slugs may not be fully grown. WIKTOR (1989) reports that slugs of various species on their first mating often have their albumen glands not fully developed.

A. lusitanicus mates at various hours of day and night, mainly after sunset and before sunrise, and during a cloudy, rainy weather also during daytime. Most individuals mate in the evening and night. The initial phase of courtship starts most often in the evening, after the slugs have left their shelters, 1–2 hours before sunset. The last pairs start their courtship before sunrise. On sunny days, the last mating pairs can be observed from 8.00 till 9.00 (2.5–3.5 hours after sunrise). Full sun usually forces the slugs to interrupt or complete mating and seek shelter. In shaded places (under trees, among shrubs or dense high vegetation) some pairs may mate by 1 or 2 hrs longer.

The mating behaviour includes the following phases.

Initial phase – it starts with a meeting of two slugs or finding a partner along the mucus trail on the soil surface. Having found a partner, the slug follows it, from time to time eating the mucus it left or mucus blobs from its posterior body part; it rasps the partner with its radula and touches it with the tentacles (Fig. 1). Sometimes the slugs change their roles, and the above activities are repeated by the other partner. The phase, its purpose being recognition of the partners and stimulation of the courtship dance, results in widening and swelling of atria which are visible as elliptical swellings of ca. 0.5 cm, and an abundant mucus secretion. Sometimes this reaction is observed only as late as during the courtship dance. The initial phase lasts from 10 to 24 minutes, in that time the slugs cover a distance of 1.5 to 2.5 m.

Courtship dance – it starts when the first of the crawling slugs makes a full circle and follows its partner. The slugs approach each other with their right flanks and start circling. Both partners move quickly, making clockwise circles around the same point and producing large amounts of mucus. The circling slugs lick the mucus from the partner's tail and sides. After several minutes the slugs' movements become slower, and the circles gradually smaller. Then the slugs approach each other, bend arc-like, and their mouths move more towards the partner's anterior part. The partners rasp each other with their radulae, touch with their tentacles and lick mucus from the region of caudal gland; their pneumostomes open and close from time to time. At that moment the dance is sometimes interrupted and one of the partners leaves. It is possible that one of the partners is not at a proper stage of sexual development or its behaviour is not acceptable to the partner which precludes copulation. Such a behaviour is fairly frequent in various slug species (WIKTOR 1989). When the recognition gives a positive result, the courtship dance continues. The slugs circle increasingly slower, approach each other and move their bodies so that their gonopores face each other. Then they stop circling, only minimum changes in body position being observed from time to time. The time from the first full circle made by the first partner to the end of circling amounts to 2–3 minutes. During the next 9–24 minutes (mean 17 minutes) the slugs evert their atria and press them against each other strongly (Fig. 2). The everted organs force the slug bodies apart. During this stage the atrial openings are not visible. The whole courtship dance, till the eversion of atria, lasts on an average 19.5 minutes.

Copulation and spermatophore transfer – starts from full eversion of atria and adjacent parts of copulatory organs (Fig. 3). At this stage the slugs bend their heads towards the partner. The anterior parts of their bodies, when the organs are everted, shrink which makes the slugs look as if their heads were narrowed. On the underside of the everted atria (invisible from above), the basal part of epiphallus and spermatheca duct evert. The slugs press them against the partner's genitalia intermittently and become completely motionless. At the end of the motionless period pulsating movements of atria can be observed. During these movements the spermatophores, formed in the epiphallus, are inserted into the everted spermatheca duct of the partner. The tentacles of the slugs are half retracted and the pneumostomes opened. In some copulating pairs also convexities of everted oviduct margins are visible. According to some authors during copulation the slugs evert both oviducts and ligulae (DAVIES 1987). The ligula takes part in stimulation and ensures stability of the slugs (DAVIES 1987). However, our observations have not confirmed this. The motionless period lasts from 3 hrs 10 min to 4 hrs 15 min (mean 3 hrs 43 min).

When this time has elapsed, one of the partners starts moving, partly everts its tentacles and slowly licks mucus from the partner's sides and the everted genitalia, and bites its mantle and posterior part of its back. This stimulates the partner to a similar behav-

Fig. 1. Initial phase of mating. Search for and recognition of the partner (photo J. KOZŁOWSKI)

Fig. 3. Copulation – full eversion of atria and copulatory organs, connection and remaining motionless (photo J. KOZŁOWSKI)

Fig. 2. Courtship dance – circling, eversion and connection of atria (photo J. KOZŁOWSKI)

Fig. 4. Copulation – partial retraction of atria and copulatory organs (photo J. KOZŁOWSKI)

Fig. 5. Copulation – further retraction of atria and copulatory organs, spermatophores remaining in the partner's body (photo J. KOZŁOWSKI)

Fig. 6. Copulation – separation and completion of spermatophore transfer (photo J. KOZŁOWSKI)

Fig. 7. Post-copulation phase – almost complete retraction of atria and copulatory organs (photo J. KOZŁOWSKI)

Fig. 8. Post-copulation phase – parting (photo J. KOZŁOWSKI)

iour. As a result, the atria and other organs are partly retracted (Fig. 4). The slugs start circling slowly around the same point, being still connected by their spermatophores which are partly (for ca. 2/3 length) inserted in the partner's copulatory organs. The connection is rather strong due to the presence of numerous sharp denticles on the edges of the spermatophores. The denticles anchor the spermatophore very strongly in the recipient's body (when one of the slugs is lifted, the other one hangs by the spermatophore). Slowly circling, the connected slugs move their mouths initially to the middle of the partner's body, and then, still licking the mucus, move them more posteriorly. There is a further retraction of copulatory organs (almost half retraction), but the slugs remain connected. After another half-circle the slugs start moving increasingly quicker and suddenly rapidly detach their copulatory organs. There is a further retraction of atria, but the spermatophore still remains in the partner's body (Fig. 5). The separation and retraction of the copulatory organs take from 5 to 15 seconds. During the separation the slugs still lick mucus, have completely everted tentacles and their pneumostomes are widely open. During several seconds they remain connected by the ends of spermatophores, visible as "threads" extending between the gonopores. Then the slugs separate and within 1 to 3 seconds hide the spermatophores completely (Fig. 6). The time elapsing between the resumption of movement and the full separation is 15 to 30 minutes (mean 17 min 29 sec).

Post-copulation phase – it starts at the moment of separation of the slugs and almost complete retraction of their atria and copulatory organs (Fig. 7). The process is simultaneous in both partners, or one slug bends crescent-like and retracts its organs only after several minutes. This is accompanied by a mucus secretion in the posterior part of foot, the mucus being immediately licked by the partner. After complete separation, lasting ca. 2 min, the slugs make a full circle, and then one of the partners leaves in the opposite direction. The other partner follows it, but after a moment makes a circle, returns to the place of copulation where it makes another 2–4 circles and licks the remaining mucus (Fig. 8). Sometimes also the first partner returns, though it has departed for a distance of about a dozen centimetres. The mean time spent at the place of copulation and mucus-licking is 11 minutes.

The whole courtship and copulation of *A. lusitanicus*, from finding a partner till separation and parting last from 4 to 5.5 hours (mean 4 hrs 52 min). DAVIES (1987), based on fragmentary observations, reports that the mating act lasts from 140 to 150 min. However, one of the pairs observed by that author mated for ca. 4 hours, the copulatory organs being everted during ca. 3.5 hours, and thus the time was similar to that observed in our climate conditions. For comparison – in another arionid – *Arion rufus* (Linnaeus) the whole mating takes ca. three hours (FRÖMMING 1954)

The observations demonstrated that mating of *A. lusitanicus* includes four phases. The initial phase – recognition – is similar to that in other slug species. Its purpose is to identify the species and check the partner's readiness to mate (WIKTOR 1989). The second phase – courtship dance, is aimed at stimulating the slugs to copulate. The behaviour during this phase is the most variable between slug species (WIKTOR 1989). In *A. lusitanicus*, the courtship dance lasts ca. 20 minutes and ends with a complete eversion of copulatory organs. The third phase – copulation and spermatophore transfer – starts with a prolonged motionless period (almost 4 hours) during which spermatophores are formed and inserted in the partner's spermatheca duct. At the end of this phase, the slugs resume their movements, retract their atria and exchange spermatophores. The duration of this process varies individually from 15 to 30 minutes. At the last phase – post-copulation – a complete retraction of the copulatory organs takes place, the mating being then completed.

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