

# Surface swimming behavior of the curculionid *Ochetina uniformis* Pascoe (Eirrhinae, Stenopelmini) and *Ludovix fasciatus* (Gyllenhal) (Curculioninae, Erodiscini)<sup>1</sup>

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**ABSTRACT.** Surface swimming behavior of the curculionid *Ochetina uniformis* Pascoe (Eirrhinae, Stenopelmini) and *Ludovix fasciatus* (Gyllenhal) (Curculioninae, Erodiscini). The swimming behavior exhibited by specimens of *L. fasciatus* and *O. uniformis* was analyzed frame-by-frame with video observation recorded with a digital camera, attached to a stereomicroscope. Adults of *O. uniformis*, an aquatic insect, swim with all three pairs of legs. During the process of swimming the majority of the abdomen and rostrum remain submerged, part of the fore and hind tibiae remain above the surface, while the mid tibiae remain submerged. The mesothoracic legs, during the power-stroke stage, provide the greatest thrust while the metathoracic legs provide the least forward propulsion. The prothoracic legs, extended forward, help to direct the swimming. The semi-aquatic specie *L. fasciatus* shows the same swimming style as *O. uniformis*, that is, with movement of all the three pairs of legs; the mesothoracic legs are responsible for the main propulsion. The insect body remains on the water surface during the process of swimming, while the legs remain submerged. Both species complete a swimming cycle in 0.33 and 0.32 seconds, respectively, with an average speed of 1.38 cm/s and a maximum and minimum swimming duration time of 11.15 and 5.05 minutes, respectively, for *L. fasciatus*. The swimming behavior exhibited by *O. uniformis* and *L. fasciatus* corresponds to the style known as a breast stroke-like maneuver. This is the first record of this kind of swimming for both species here observed and increases to seven the number of genera of Curculionidae exhibiting this behavior.

**KEYWORDS.** Aquatic/semi-aquatic weevils; behavioral adaptation; Central Amazonia; Pantanal Mato-grossense.

**RESUMO.** Comportamento de nado superficial exibido pelos Curculionidae *Ochetina uniformis* Pascoe (Eirrhinae, Stenopelmini) e *Ludovix fasciatus* (Gyllenhal) (Curculioninae, Erodiscini). O comportamento de nado exibido por indivíduos de *L. fasciatus* e *O. uniformis* foi analisado quadro a quadro através de imagens obtidas com o auxílio de uma câmera fotográfica digital com opção de vídeo, acoplada a um estereomicroscópio. Foi demonstrado que *O. uniformis*, espécie aquática, nada com o auxílio dos três pares de pernas. Durante este processo a maior parte do abdome e rostrum localizam-se abaixo da superfície da água, parte das tíbias anteriores e posteriores acima da superfície, enquanto as médias permanecem submersas durante o nado. As pernas metatorácicas, durante a “braçada”, impulsionam fracamente o inseto para frente, enquanto que as mesotorácicas são as responsáveis por uma maior propulsão. As pernas protorácicas, estendidas anteriormente, ajudam na orientação do nado. A espécie *L. fasciatus*, de hábito semi-aquático, apresenta o mesmo estilo de nado como em *O. uniformis*, também realizado com auxílio dos três pares de pernas, sendo as mesotorácicas, responsáveis pela maior propulsão. O corpo do inseto permanece na superfície da água durante todo o processo, porém as pernas encontram-se mergulhadas. Ambas as espécies, *O. uniformis* e *L. fasciatus*, completam um ciclo do nado em cerca de 0,33 e 0,32 segundos, respectivamente, com uma velocidade média de 1,38 cm/s e tempo máximo e mínimo de permanência de nado 11,15 e 5,05 minutos, respectivamente, para *L. fasciatus*. O comportamento de nado exibido por *O. uniformis* e *L. fasciatus* corresponde ao estilo de nado conhecido como manobra semelhante ao nado peito (breast stroke-like maneuver). Trata-se do primeiro registro para ambas as espécies elevando para sete o número de gêneros de Curculionidae conhecidos com tal comportamento.

**PALAVRAS-CHAVE:** Adaptação comportamental; Amazônia Central; gorgulhos aquáticos/semi-aquáticos; Pantanal Mato-grossense.

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The aquatic environment establishes a series of limitations to the insect's survival, which often demand adaptations on these organisms. The adaptations presented by the insects to survive in the aquatic environment can be observed mainly through the form of locomotion and the breathing system (Anderson & Wallace 1984; Norris 1970, 1991; Williams & Feltmate 1992). Within the Coleoptera there are at least ten

separate evolutionary lineages which led several groups to occupy aquatic environments throughout their entire lifetime (Crowson 1981). Few groups are exclusively aquatic in any one phase of development, having individuals in an aquatic larval phase and a terrestrial adult or vice versa, and many others have sporadic aquatic phases. Features such as a strong exoskeleton and the presence of elytrons, have probably

helped as a pre-adaptation to this kind of environment (Crowson 1981; Jäch & Ji 1998).

The immense spreading of adaptation made the representatives of the Curculionidae family occupy the most varied kinds of habitats where vascular plants occur and because of this it is unsurprising to find groups associated to plants that develop in aquatic environments (Crowson 1981). Aquatic and semi-aquatic species (in the *sensu* of Morrone & O'Brien, 1999) are found in at least six groups, mainly in Eirrhiniinae, normally restricted to lentic habitats, feeding on varied species of aquatic plants belonging to different genera (Spangler 1981; Morrone & O'Brien 1999).

The aquatic and semi-aquatic curculionids can swim, walk on water and plants, as well as on the substratum under the water, breathing the stored air in the air chambers located under the elytra, or by means of plastron breathing (Langer & Messner 1984; Splanger 1981). The pattern of movements presented by the legs during swimming differs from the coordinated movements during walking. Contrary to what happens with terrestrial insects, the legs located on a same thoracic segment move in synchronicity during swimming (Chapman 1998).

At least four kinds of free swimming are mentioned for the adult weevils that differ from the kinds generally described for Coleoptera. Adaptations related to swimming behavior are already known for five genera belonging to three families and five subfamilies within the Curculionoidea (Hix *et al.* 2000; Cline *et al.* 2002). O'Brien & Marshall (1979) described the behavior shown by *Bagous cavifrons* LeConte, 1876 and *B. americanus* LeConte, 1876, two curculionid species that swim just under the surface in a "dog-paddle" style, stating that this behavior is typical of the *Bagous* genus. This type of swimming is also presented by *B. limosus* (Gyllenhal, 1827) (Angus 1966; Meiner 1970). *Lissorhoptrus oryzophilus* Kuschel, 1952, when submerged, propels itself using the mesothoracic legs which move in synchronicity during extension and retraction (Hix *et al.* 2000). Surface swimming is recognized for *Phytobius leucogaster* (Marshall, 1802) (Buckingham & Bennett 1981), *Phytobius comari* (Herbst, 1795) (Read 1985), *Eubrychius velutus* (Beck, 1817) (Ruter 1978; Morris 1976), *Hypera rumicis* (Linnaeus, 1758) (Read 1982) and *H. eximia* (LeConte, 1876) (Cline *et al.* 2002). Morphometrical analysis among *H. eximia*, *H. postica* (Gyllenhal, 1813) and *H. nigrirostris* (Fabricius, 1775), has demonstrated differences in the morphology of the legs that support the swimming behavior exhibited only by *H. eximia* (Cline *et al.* 2002).

Considering the importance of the behavioral studies related to ecological characteristics, this work aims to describe the swimming behavior shown by two curculionid species which are phylogenetically distant (Marvaldi *et al.* 2002), *Ochetina uniformis* (Eirrhiniinae) and *Ludovix fasciatus* (Curculioninae), in order to assist future phylogenetic pattern studies, as well as to compare the movement patterns of these two species with those found in other studies that deal with swimming in Curculionidae.

## MATERIAL AND METHODS

**Field collections.** For the description of swimming, samples of *O. uniformis* and *L. fasciatus* collected from aquatic macrophyte banks distributed in the varzea area of the Solimões river, Marchantaria Island (03°15'S and 59°58'W), Iranduba Municipality, Amazonas State, Brazil, from 28/VI/05 to 05/VII/05 for *Ochetina uniformis* (n=16) and 08/II/05 to 28/VI/05 for *L. fasciatus* (n=09); four males and one *L. fasciatus* female, used in the experiment to calculate the speed and maximum swimming duration, were collected on 04/II/2006, in *Eichhornia crassipes* (Mart.) Solms banks distributed in Piuval bay (16°15'S and 56°22'W), located in Ipiranga farm, Pantanal mato-grossense, Poconé, Mato Grosso State Brazil.

**Video observations.** The swimming behavior shown by the individuals of these species was observed through a stereomicroscope, from a dorsal view, on Petri dish containing water, with three *L. fasciatus* and eleven *O. uniformis* individuals analyzed in real time and frame by frame, through the images obtained with the use of a digital camera with optional video, attached to a WILD M3B stereomicroscope.

**Terminology.** The swimming description is presented based on the three stages recognized by Cline *et al.* (2002) and considered as: "resting", "power-stroke" and "recovery-stroke" and compared to studies that deal with the swimming of other curculionid species such as O'Brien & Marshall (1979), Hix *et al.* (2000) and Cline *et al.* (2002). The name of the family, subfamily and tribe of the species here studied is in accordance with the recent proposal of Marvaldi & Lanteri (2005) for the South American weevils. The terms "aquatic and semi-aquatic" are used in the same sense of that Morrone & O'Brien (1999).

**Speed experiments.** The time calculation used for each movement was made based on the total number of frames per second. In order to measure the swimming speed the samples were tested individually three consecutive times in an aquarium of 20x40 cm, containing 3 liters of water at a temperature of 22°C, with subsequent recording of the time and distance traveled during swimming. In the experiment carried out to measure the maximum swimming duration time the samples were individually placed in the aquarium and monitored during the whole process. This test was carried out 24 hours after the speed calculation test and done only for *L. fasciatus*.

**Illustration.** A sample of each species was analyzed and drawn under a WILD M3C stereomicroscope with a light camera attached, using twelve and twenty five times magnification for *L. fasciatus* and *O. uniformis*, respectively. The position of the legs during each movement was defined based upon the images obtained from a digital photographic camera. The magnitude of the drawings was recorded using the scales that accompany them.

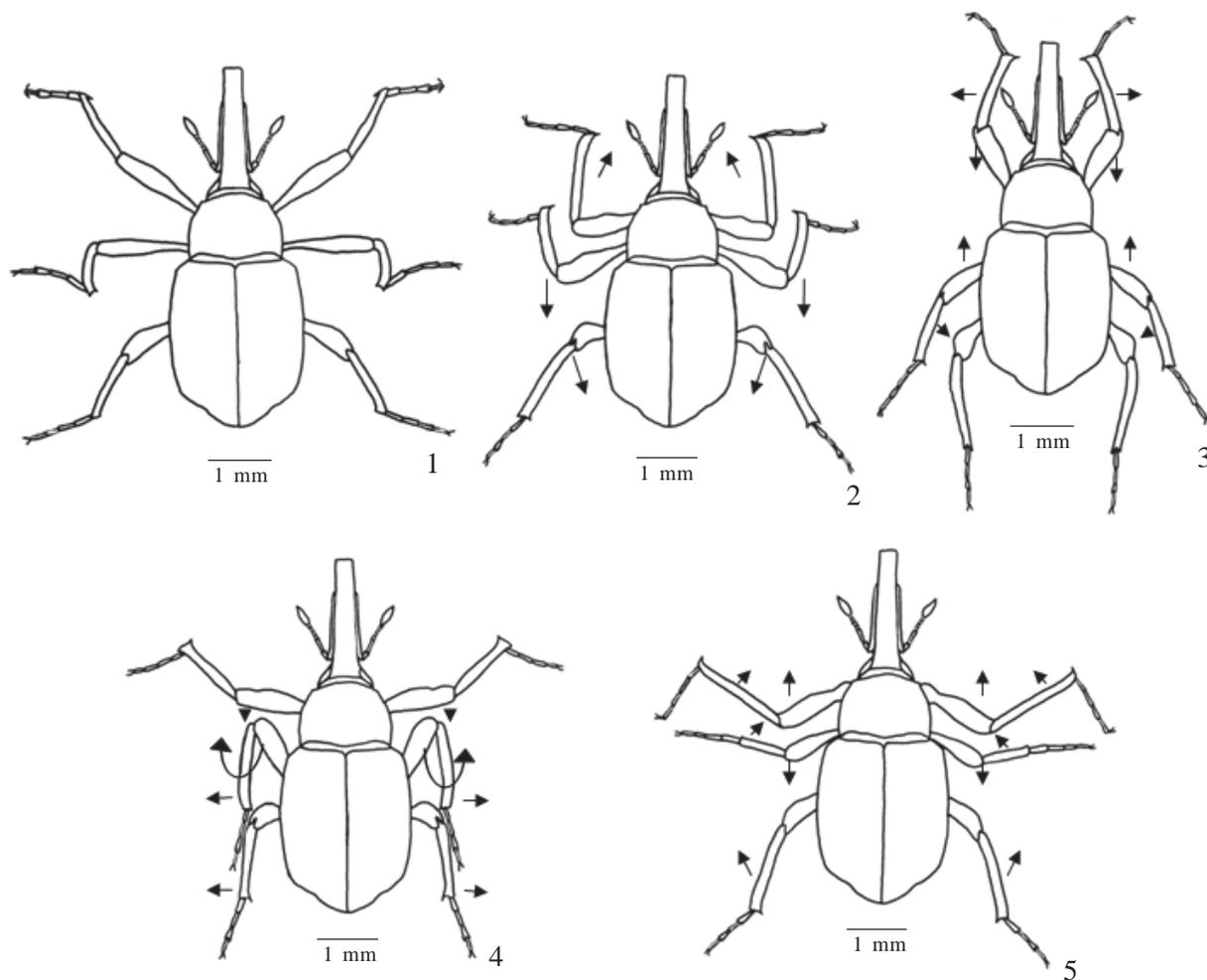


Fig. 1-5. Movements of the legs during swimming of *Ochetina uniformis*: 1, resting; 2-3, stroke; 4-5, recovery.

## RESULTS

In *O. uniformis* swimming occurs with the help of the three pairs of legs. During the process, the majority of the abdomen and rostrum remain under the surface, part of the fore and hind tibiae are above the surface, while the middle ones remain submerged during the whole process. The resting stage (Fig. 1), intermediary between the other stages, is characterized by the position of each pair of fore and hind legs, stretched away from the median region of the body, with the mesothoracic femora perpendicularly placed and the pro- and metathoracic obliquely placed in relation to the longitudinal axis of the body. The fore tibiae are turned forwards and the middle ones downward, creating an angle larger or equal to  $90^\circ$  with the femur, respectively, the hind legs placed backwards in relation to the longitudinal axis of the body. The stroke (Figs. 2-3), responsible for the propulsion of the insect in the water, is described in two simultaneous actions: a) one in which the movements of the femora and tibiae are responsible for the metathoracic leg beats. The femora are positioned and moved lightly and obliquely forward and then backwards, ending in a position more or less parallel to the longitudinal axis of the body. The tibiae move obliquely when extending and retract

in parallel to the longitudinal axis of the body. These combined movements provide for weak forward propulsion of the insect; b) in the second action the use of the mesothoracic legs is observed, with the femora obliquely positioned, projected and perpendicularly rotated forwards and backwards, until they reach an adjacent position to the body, forming a  $90^\circ$  angle with the tibiae. The tibiae move forwards in parallel, perpendicularly downwards and backwards in parallel in relation to the longitudinal axis of the body. The mesothoracic legs are responsible for the main swimming propulsion. During this process the prothoracic legs are projected backwards coming close to the median region of the body, and afterwards retract to the resting position. Just as in the stroke stage, the recovery stage (Figs. 4-5) occurs simultaneously and is described in two distinct stages: extension and retraction of the prothoracic legs making a femur-tibial angle of about  $180^\circ$  which is gradually reduced to  $90^\circ$ , at the same time that they are projected backwards and forwards. Meanwhile, the meso- and metathoracic legs are extended sideways followed by the mesothoracics in a rotational movement returning to the position of the first stroke movement. The total time spent in all the stages, that is, in each cycle, is about 0.33 seconds, 0.16s taken in the stroke, 0.12s for the recovery and 0.05s

spent in the resting stage. Maximum and minimum swimming duration time was not measured for *O. uniformis*.

*Ludovix fasciatus* presents the same swimming style mentioned before, realized with the help of the three pairs of legs. The insect's body remains on the surface during the whole process, except for the legs which remain submerged. In the resting stage (Fig.7) the legs remain stretched away from the median region of the body, the femora are positioned along the longitudinal axis of the body, the prothoracics obliquely forward, the mesothoracics obliquely perpendicular and the metathoracics obliquely backwards. The fore and middle tibiae form an angle of about 90° with the femur, respectively, forward and backwards, and the hind legs turned backwards, in parallel to the longitudinal axis of the body. The stroke (Figs. 8-9), described in two actions, occurs through simultaneous movements of the three pairs of legs. In the first action, femora, tibiae and metathoracic tarsus remain stretched, projected sideways, extending and retracting in relation to the median region of the body. The combined movements of these structures provide weak forward propulsion of the insect. The main propulsion is obtained from the mesothoracic legs during the second action, with the femora projected obliquely forwards and then backwards, reaching an adjacent position to the body, forming an angle of 90° with the tibiae which increases as it propels itself forwards. The tibiae move forward in parallel, perpendicularly downwards and backwards in parallel in relation to the longitudinal axis of the body. Concomitantly to these movements there is a forward projection of the prothoracic legs, which subsequently come closer to the median region of the body, forming a tibia-tarsal angle of 90°. Just as in the stroke stage, the recovery stage (Figs.10-11) occurs simultaneously and is described in two distinct stages: extension of the prothoracic legs when projected backwards, making a femur-tibial angle of about 180° which decreases to 90° as they are projected forwards and go

Table I. Values obtained in the test for speed calculation of the swimming of *L. fasciatus*. (M=male, F=female); T/s=time in seconds; cm=distance in centimeters.

Replication	Sex/number	T/s	cm	Speed
1	M1	7.61	10	1.314060447
	M2	8.9	11	1.235955056
	M4	7.9	11	1.392405063
	F1	4.26	10	2.347417840
	M3	6.32	11	1.740506329
2	M1	15.34	19	1.238591917
	M2	51.42	39	0.758459743
	M3	43.95	39	0.887372014
	M4	33.12	39	1.177536232
	F1	18.69	41	2.193686463
3	M1	31.84	38	1.193467337
	M2	53.48	39	0.729244577
	M4	21.79	39	1.789811840
	F1	19.98	40	2.002002002
	M3	47.56	39	0.820016821
mean				1.388035579



Fig. 6. Arrows indicate the air bubble attached to the ventral surface of the insect body.

into the resting stage position. Meanwhile, the meso- and metathoracic legs are extended. The total time spent in all the stages, that is, in each cycle, is of about 0.32 seconds, of which 0.13 seconds is the stroke, 0.13s is for the recovery and 0.06s is spent in the resting stage. *L. fasciatus* swims at an average speed of 1.38 cm/s, whereas the female presents higher values if compared to the males (Table I). The maximum and minimum swimming duration time was 11.15 and 5.05 minutes, respectively.

## DISCUSSION

The swimming behavior exhibited by *O. uniformis* and *L. fasciatus* corresponds to the swimming style mentioned by Cline *et al.* (2002) for *H. eximia* as a maneuver similar to the breast stroke. The description of surface swimming represents the first record for both species, increasing to seven the number of genera Curculionidae with individuals which represent this kind of adaptation. The swimming style quoted previously was first mentioned by Putter *et al.* (1973) referring to the swimming activity of the species *H. compta* (Say, 1831), *H. paludicola* Warner, 1973, and *H. eximia*. Later, Read (1982) defined the same swimming style in a note about *Hypera rumicis*.

During the resting stage the pro- and metathoracic legs of the *O. uniformis* and *L. fasciatus* take on a stretched position in relation to the body, increasing the contact area of the insect body with the water, and that, according to Hix *et al.* (2000) and Cline *et al.* (2002), helps the stability of the insect on the water surface. Apart from this, the formation of an air bubble with hydrophobic properties attached to the scales (Fig.6) in *O. uniformis* located in the ventral region of the pro- and mesothorax, also helps the insect to float.

In order to overcome the problems related to the physical strength required in the water to move forward, *O. uniformis* and *L. fasciatus* produce propulsion by extension and retraction of the three pairs of legs in surface swimming, with

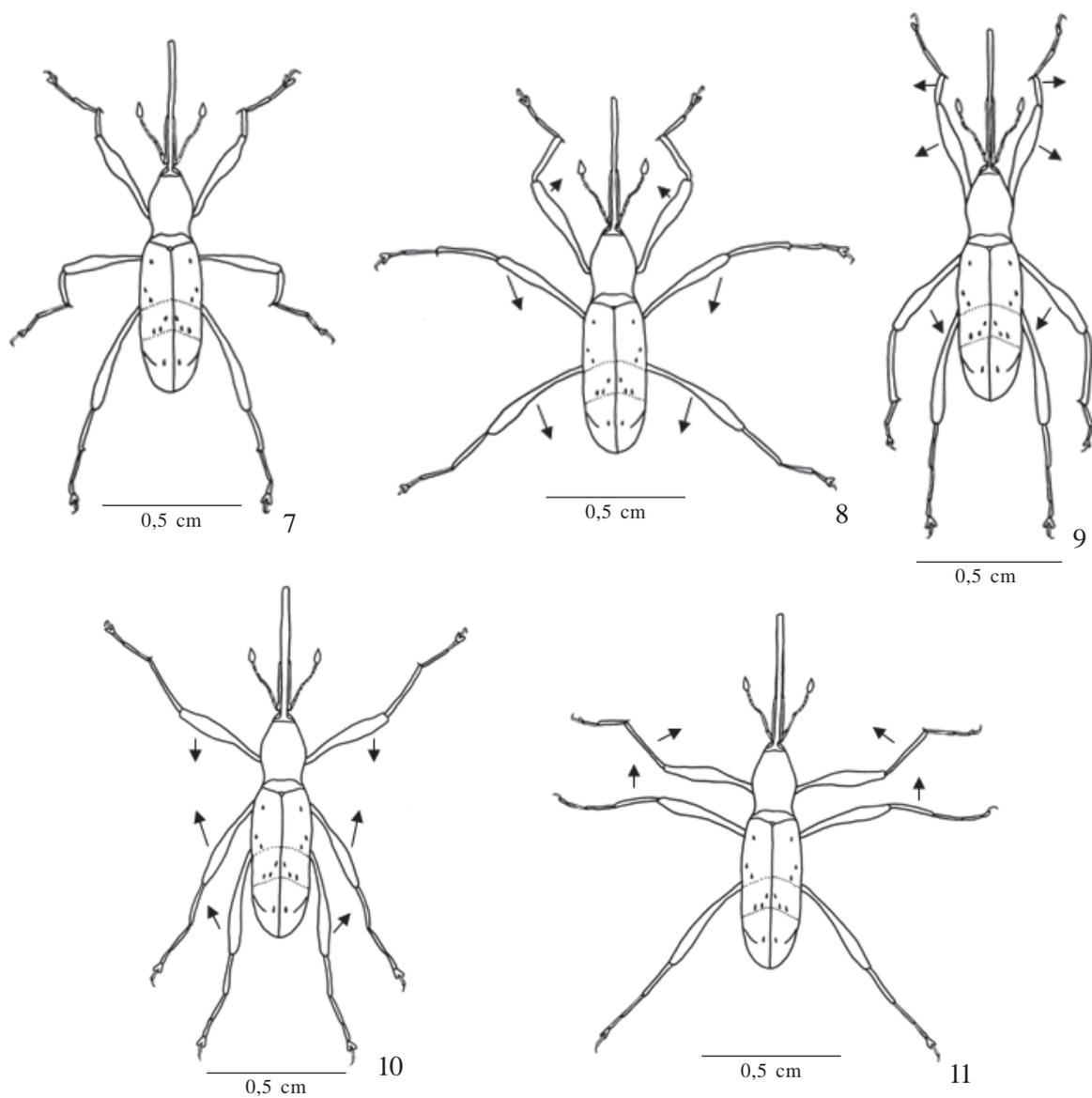


Fig. 7-11. Movements of the legs during swimming of *Ludovix fasciatus*: 7, resting; 8-9, stroke; 10-11, recovery.

part of the body in contact with the air, so reducing the problems related to the density of water (Crowson 1981; Cline *et al.* 2002).

The movements of the legs in surface swimming of the *O. uniformis* present a greater rotation of the mesothoracic femora during the stroke as compared to those of *L. fasciatus*. The pattern of movements of both species is similar to those found for the other curculionids such as in *Phytobius leucogaster*, which swims on the water surface using the three pairs of legs for propulsion, and the prothoracic legs are kept retracted while the meso- and metathoracics are extended forward (Buckingham & Bennett 1981).

Cline *et al.* (2002) have attributed the functions of orientation and stability during swimming to the pro- and mesothoracic legs, respectively, and of propulsion to the metathoracic legs of *H. eximia*. However, we believe that for

*O. uniformis* and *L. fasciatus* the propulsion is obtained through the mesothoracic legs. Also, the position of the prothoracic legs in *H. eximia* during swimming differs from that described here for both species as they take on a similar form to that of the praying mantis.

The swimming cycle of the *O. uniformis* and *L. fasciatus* is shorter than the one described for the other curculionids such as *H. eximia*, which takes about 0.76 seconds (Cline *et al.* 2002). The swimming speed of the curculionids is very slow, with an average of 2-3 cm/s (Crowson 1981). The estimated average for *L. fasciatus* (1.38cm/s), as well as for the other species like *L. oryzophilus* (1.53cm/s) is much lower than previously stated. The propulsion obtained during swimming is proportional to the area of the legs and the square of the velocity rate with which it moves, that is, to produce more efficient forward movements it is necessary for the legs to

move fast and to have a larger surface area (Crowson 1981). So the slow velocity presented by some species can be explained by the variations and differences in the length and width of the femur, tibiae and tarsus, as these reveal patterns related to the coordinated movements and efficiency of the legs during swimming (Cline *et al.* 2002).

Some researchers have mentioned swimming in several species without presenting a behavior description, like Ruter (1978) and Morris (1991) for *Eubrychius velutus*; Solarz & Newman (1996) for *Euhrychiopsis lecontei* (Dietz, 1896); O'Brien (personal information, in Hix *et al.* 2002) for the genera *Helodytes* Kuschel, *Hydrotimetes* Kolbe, *Ilyodytes* Kuschel, *Lissorhoptrus* and *Oryzophagus* Kuschel. The swimming behavior known as a maneuver similar to the breast stroke, and the other types, is diverse among the Curculionoidea, as well as in certain groups such as Hyperinae, which presents congenerically similar species with this kind of behavior, whereas others are not able to swim (Hix *et al.* 2000; Cline *et al.* 2002).

Studies related to the several types of swimming behavior associated with morphometric analyses, as well as those indicated by Hix *et al.* (2000) and Cline *et al.* (2002), are necessary to understand the evolution of this kind of behavior in the different allocated groups in Curculionidae.

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