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The characteristics of habitats colonized by three species of *Lymnaea* (Mollusca) in swampy meadows on acid soil : their interest for control of fasciolosis

C. Vareille-Morel[1]
G. Dreyfuss[2]
D. Rondelaud[3]

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Malacological investigations were carried out in 53 meadows on acid soil to identify the characteristics of habitats colonized by lymnaeid snails. These meadows are located in three different geographical districts (Basse-Marche, Monts d'Ambazac, Plateaux de la Vienne) in the Haute-Vienne Department (central France). *Lymnaea truncatula* lived at the distal extremity of open drainage furrows ; *L. glabra* inhabited the middle part of furrows and *L. palustris* lived in the central ditch. The mean area of *L. truncatula* habitats ranged from 2.8 to 4.8 m^2 in relation to the district studied and was smaller than those of *L. glabra* (a mean of 3.6 to 7.2 m^2) and *L. palustris* (10.3 to 19.3 m^2). Mean intervals between the sites occupied by *L. truncatula* and *L. glabra* ranged from 6.3 to 12.3 m ; they were greater between the sites occupied by *L. glabra* and *L. palustris* (11.6 to 15.4 m). Finally, the mean densities of *L. truncatula* in June ranged from 11.4 to 19.8/m^2 in relation to the district studied ; those of *L. glabra* ranged from 22.6 to 27.0 snails/m^2, whereas in *L. palustris*, they ranged from 6.3 to 8.8 snails/m^2. The mean values of these first two parameters were significantly lower in the habitats located in Monts d'Ambazac than those recorded in the two other districts. Implications of these results for fasciolosis control are discussed.

Les caractéristiques des habitats colonisés par trois espèces de *Lymnaea* (Mollusques) dans les prairies marécageuses sur sol acide : leur intérêt pour le contrôle de la fasciolose

Mots-clés : mollusques, *Lymnaea*, fasciolose, habitats, Haute-Vienne, prairie marécageuse, sol acide.

Des investigations malacologiques ont été réalisées dans 53 prairies afin de déterminer les caractéristiques des habitats colonisés par des mollusques Lymnaeidae. Ces prairies sont localisées dans trois secteurs géographiques différents du département de la Haute-Vienne (Basse-Marche, Monts d'Ambazac, Plateaux de la Vienne). *Lymnaea truncatula* vit à l'extrémité distale des rigoles de drainage superficiel ; *L. glabra* colonise la partie moyenne des mêmes rigoles et *L. palustris* vit dans le fossé central. La superficie moyenne des habitats de *L. truncatula* varie de 2,8 à 4,8 m^2 selon le secteur étudié et est plus petite que celles relevées dans les gîtes de *L. glabra* (3,6 à 7,2 m^2) ou de *L. palustris* (10,3 à 19,3m^2). Les distances moyennes entre les sites occupés par *L. truncatula* et *L. glabra.*fluctuent entre 6,3 et 12,3 m ; elles sont plus grandes entre les zones coloniées par *L. glabra* et *L. palustris* (11,6 à 15,4 m). Enfin, les densités moyennes de *L. truncatula* en juin varient de 11,4 à 19,8/m^2 selon le secteur d'étude ; celles de *L. glabra* fluctuent entre 22,6 et 27,0 mollusques/m^2 alors que chez *L. palustris*, elles se situent entre 6,3 et 8,8 mollusques/m^2. Les moyennes des deux premiers paramètres sont significativement plus faibles dans les gîtes situés dans les Monts d'Ambazac que celles enregistrées dans les deux autres secteurs. Les implications de ces résultats dans le contrôle de la fasciolose sont discutées.

1. Introduction

Prevention of fasciolosis in cattle involves a number of measures. One measure is control of the snails that act as intermediate hosts in the life cycle of the liver fluke, *Fasciole hepatica* (Linnaeus). In France, the main snail host in *Lymnaea truncatula* (O.F. Müller) which may be infected at any age. Other *Lymnaea* species such as *L. glabra* (O.F. Müller) or *L. palustris* (O.F. Müller) are also present in pastures and may assure the complete larval development of *F. hepatica* when the snails are exposed to miracidia only in the days following their hatching (Kendall 1950, Busson et al. 1982). Various methods to control these intermediate hosts have been proposed, including agronomic

1. Faculté des Sciences, Laboratoire de Malacologie Appliquée, 123 avenue Albert Thomas, F-87060 Limoges Cedex.
2. Faculté de Pharmacie, Laboratoire de Parasitologie, 2 rue du Docteur Raymond Marcland, F-87025 Limoges Cedex.
3. Faculté de Médecine, Laboratoire d'Histopathologie Parasitaire, 2 rue du Docteur Raymond Marcland, F-87025 Limoges Cedex.

techniques (drainage), the use of molluscicides (reviewed by Taylor 1965 and Euzeby 1971), or the introduction of carnivorous snails in lymnaeid habitats (Rondelaud 1975, 1981). However, except for drainage, these methods have seldom been used in *L. truncatula* habitats in French meadows.

L. truncatula is frequent in swampy meadows on acid soil. In the Haute-Vienne Department (central France), snail habitats are confined to the peripheral extremities of open drainage furrows and ditches. However, two other lymnaeid species (*L. glabra, L. palustris*) live in other isolated habitats in the lower levels of the same drainage networks (Bouix-Busson & Rondelaud 1984, Vareille et al. 1996). Colonies of each *Lymnaea* species were found to be isolated from those of other species with no overlap. In view of these findings, the question arose as to whether fasciolosis control might be affected by isolating *Lymnaea* habitats from other parts of the meadow and, subsequently, from cattle. Preliminary studies on the characteristics of the habitats of each species would be necessary to determine conditions in which this management technique could be used. The present paper gives the results of a quantitative study of 53 acid soil meadows in the Haute-Vienne Department, each with an open drainage network.

2. Stations studied

The 53 studied meadows were distributed among three geographical districts. In Basse-Marche, 15 hygro-mesophilous meadows were located within a 7 km radius around the town of Bellac (Altitude : 190-268 m). In the Monts d'Ambazac district there were 23 meadows in the communes of Compreignac, Nantiat and Thouron (Altitude : 300-420 m). The third district, Plateaux de la Vienne, included 15 meadows within a 10 km radius of the Limoges city (Altitude : 274-370 m).

The subsoil comprises crystalline or metamorphic rocks. Twenty meadows in Monts d'Ambazac have underlying two-mica granite. The substratum of the others is more variable, although migmatites underlaid 20 meadows. All soils are hydromorphous. Water is running in the furrows from mid-October to the end of June or the beginning of July, with summer drying of habitats from mid-June to the end of August. Water is oligocalcic, with a calcium ion content ranging from 3 to 26.8 mg/l and a pH from 5.5 to 7.8 (Guy et al. 1996). The habitats of *L. truncatula* and *L. glabra* contained few or no mud, but mud is more frequent in the *L. palustris* habitats and usually constitutes a layer from 1 to 3 cm.

Most meadows are in valleys and have open drainage systems.Typically, a central drainage ditch runs from a spring, emptying into a brook. From this central ditch, smaller furrows lead off, draining water from the meadow (Fig. 1). The length of the central ditch ranges from 95 to 135 m, their width 50-75 cm and their depth 20-25 cm. The length of furrows is varying from 30 to 80 m in Monts d'Ambazac meadows, and from 60 to 100 m in the meadows of the other two districts. Their width and depth are 40-45 cm and 12-15 cm, respectively.

The climate is essentially continental, but under some oceanic influence, with wet weather coming from the west. Average annual rainfall ranged from 800 to 1,100 mm, depending on altitude. Average annual temperature was 10° to 10.5° C, with a decrease of 0.55 ° C for each increasing 100 m (Vilks 1991).

Hygrophilous vegetation in the Basse-Marche meadows belongs to the *Junco-Cynosuretum cristati* association, although *Cynosurus cristatus* is rare. In the Monts d'Ambazac meadows, the vegetation belongs to the *Caro verticillati-Juncetum acutiflori* association. The plant community of the Plateaux de la Vienne meadows belongs also to the *Caro verticillati-Juncetum acutiflori* association but *Carum verticillatum* is absent. A total of 43 meadows were grazed by cattle over the year of the study, and the 10 others by sheep. Hygrophilous vegetation was mowed in August or September and the drainage furrows and ditches were cleared in October-November.

3. Methods

Two campaigns (1994-1995) were carried out to study the habitats of *Lymnaea* species in June-July because of the highest snail densities during these two months. The distributions of the three lymnaeid species were first identified in 1994 by following the open drainage systems, from the terminal extremity of each furrow until the mouth of the drainage ditch in the brook. Investigations were subsequently performed in 1995 to determine i) the length of furrow (or ditch) inhabited by each species, ii) the surface area of each snail location, including places trampled by cattle, iii) the distance between populations of different species in the same drainage system, and iv) the snail density per m^2 of habitat in June. The total surface area of every 53 meadows was also calculated to determine the percentage of the surface area occupied by each species.

The values of the parameters i), ii), and iii) were first measured in each meadow before snail count. Snails

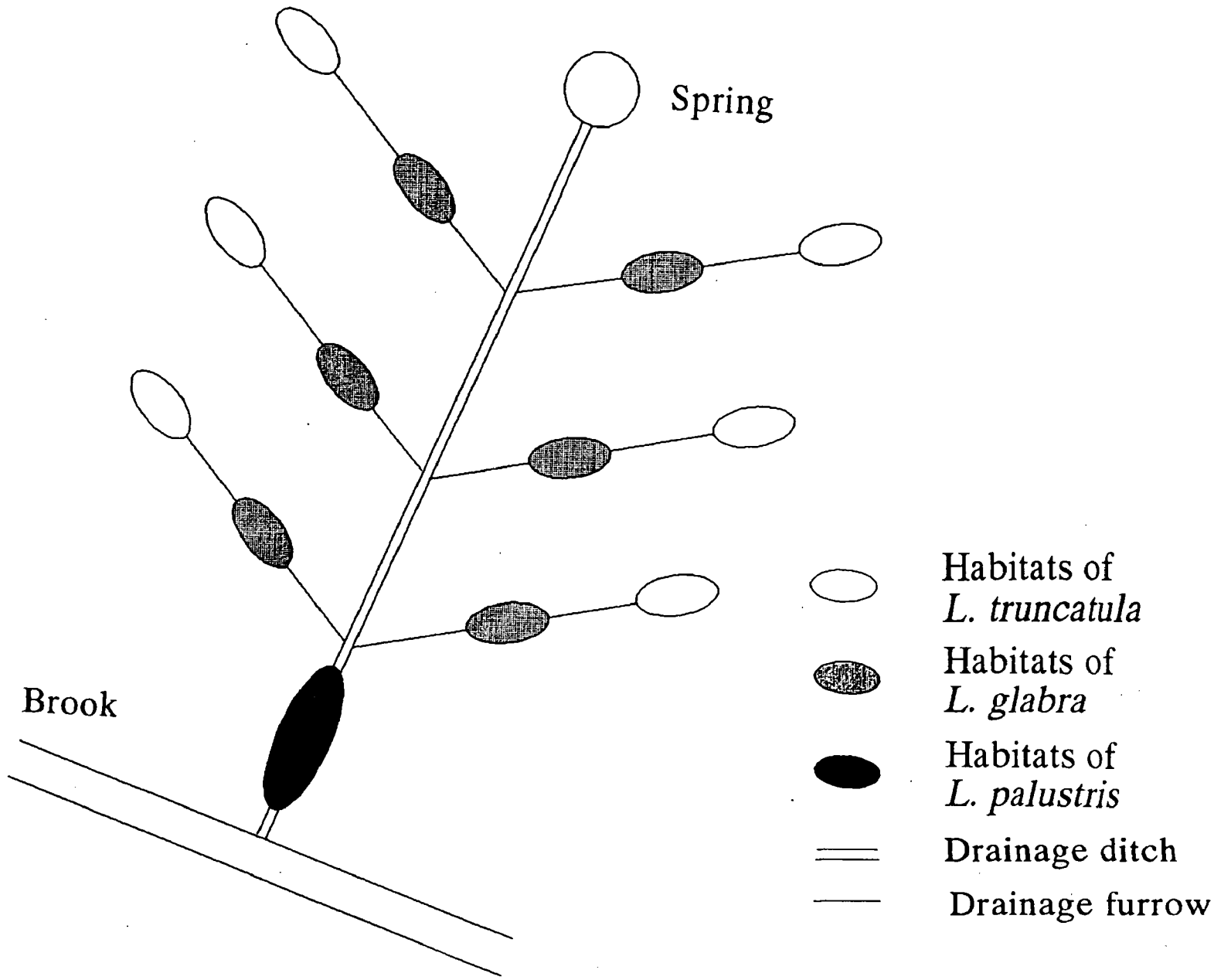

Fig. 1. Generalized location of the habitats of the three lymnaeid species in the open drainage systemps of meadows on acid soil in the Haute-Vienne Department, France.

Fig. 1. Localisation générale des habitats des trois espèces de limnées sur les réseaux de drainage superficiel dans les prairies sur sol acide dans le département de la Haute-Vienne.

were then collected in the emersed zones of each area as well as in stagnant or shallow waters (no more than 5 cm in depth during the study period). The snail search in each habitat and subsequent count were first made by one person, over 15 to 20 min. A control in each habitat was subsequently performed over 10 to 15 min by a second person to collect any snails that had escaped the first investigator. All searches and counts were made before the summer growth of hygrophilous plants, which occurred in mid-July. Lastly, the calculation of snail density was performed for each *Lymnaea* species and each habitat by dividing the total number of snails collected by the corresponding surface area.

Mean values and standard deviations were calculated from the individual meadow values for each parameter, taking into account the geographical district and snail species. These values were then analyzed by one-way analysis of variance (Stat-Itcf 1988).

4. Results

The figure 1 represents the location of habitats for each *Lymnaea* species along the drainage network. *L. truncatula* inhabited the extremity of the 231 furrows and the surrounding areas. The two other species are less frequent : *L. glabra* was found only in the middle part of 127 furrows (out of 231) and *L. palustris* in the

most downstream part of 9 central ditches and sometimes, in the lower part of the first furrows.

The mean values and standard deviations of parameters recorded in the sites occupied by *L. truncatula, L. glabra* and *L. palustris* are given in the tables 1, 2, and 3, respectively.

The mean length of the furrow inhabited by *L. truncatula* populations ranged from 3.0 to 5.0 m. The mean values were higher for the other two species : from 7.2 to 14.3 m for *L. glabra*, 5.0 to 9.9 m for *L. palustris*. For each species, the length of habitats was significantly shorter in the Monts d'Ambazac district than in the two others (*L. truncatula* : $F_{2.228} = 4.59$, $P < 0.05$; *L. glabra* : $F_{2.124} = 6.37$, $P < 0.01$; *L. palustris* : $F_{2.6} = 17.50$, $P < 0.01$). In the opposite, there was no significant difference between the values of Basse-Marche and Plateaux de la Vienne, whatever the lymnaeid species.

The surface areas of habitats inhabited by *L. truncatula* (2.8 to 4.8 m^2) and by *L. glabra* (3.6 to 7.2 m^2) were clearly lower than for *L. palustris* (10.3 to 19.3 m^2 per habitat). For each species, the areas were significantly lower in Monts d'Ambazac district than in the other two geographical zones (*L. truncatula* : $F_{2.228} = 6.37$, $P < 0.01$; *L. glabra* : $F_{2.124} = 33.40$, $P < 0.001$; *L. palustris* : $F_{2.6} = 60.54$, $P < 0.001$). This occupied area did not differ significantly in Basse-Marche and in Plateaux de la Vienne for *L. truncatula* or *L. palustris*, but did so for *L. glabra* ($F_{2.124} = 6.79$, $P < 0.01$). The total area occupied by lymnaeid snails, regardless of species, was only a tiny proportion of the overall meadow area.

The mean intervals between the sites occupied by *L. truncatula* and *L. glabra* ranged from 6.3 m (in Monts d'Ambazac) to 12.3 m (in Basse-Marche), with a significant difference between Monts d'Ambazac and each of the two other districts. Intervals between *L. glabra* and *L. palustris* were higher : 11.6 to 15.4 m, but with no significant differences between districts.

In June the snail ranged from 11.4 to 19.9 /m^2 for *L. truncatula*, from 22.6 to 27.2 /m^2 for *L. glabra*, and from 6.3 to 8.8 /m^2 for *L. palustris*. No significant differences in the mean densities of each species between the three districts were noted. The comparison of mean densities of each species was also made in relation with the nature of substratum and the altitude. There were no significant differences.

5. Discussion

In the *L. truncatula* habitats located on sedimentary soils, the snail lived in widespread habitats. For example, the surface of colonized sites was 22 ha in the region of Gembloux, Belgium (Van den Bruel 1968), whereas the four studied farms stretched over 103 ha, in which *L. truncatula* was present in 21 % of meadows. The high values were also present in the work by Pécheur (1974) : the surface of snail habitats was 1 to 4 ha, and snails colonized 5 % to 40 % of the meadow surface in the three farms studied in Belgium. Moens (1982) and Rondelaud (1988) gave clearly lower surfaces for habitats on sedimentary soil, with 99.6 m^2 per habitat for the former author and 42.5 m^2 for the latter. In contrast, the results given by Rondelaud (1977) in the department of Haute-Vienne were closer to the values we obtained. In 23 habitats colonized by *L. truncatula*, this author reported a mean surface of 9.1 m^2. A comparison of these data demonstrated that *L. truncatula* habitats had a limited surface in opposite to that recorded in snail habitats located in sedimentary soil regions.

The density of *L. truncatula* in its habitats was also dependent on the nature of the subsoil. In habitats located in sedimentary soil, most snail densities in June-July ranged from 20 to 101 *L. truncatula* /m^2 (Van den Bruel 1968, Pécheur 1974, Smith & Wilson 1980, Moens 1982). In acid soil habitats, snail densities were clearly lower, with a mean value of 25.6 snails /m^2 in the work by Rondelaud (1977), and mean densities from 11.4 to 19.8 /m^2 in the present study. From this comparison, it can be assumed that habitats on acid soil were less populated than those on sedimentary soil. The presence of the terrestrial carnivorous snail, *Zonitoides nitidus* (O.F. Müller), in the hygrophilous zones of acid soil meadows (Rondelaud 1975) may give an explanation, for *Z. nitidus* ate numerous emersed *L. truncatula* in July and therefore limited the size of *L. truncatula* populations.

Little information concerning the habitats of *L. glabra* is available and only concerned to habitats on acid soil. Bouix-Busson & Rondelaud (1984) reported a mean surface of 10 m^2 (limits : 7.7-22.8 /m^2) in the Haute-Vienne Department. Mean densities ranged from 15.9 to 19.8 snails /m^2 (Rondelaud 1982) and reached 39 snails /m^2 in the study by Bouix-Busson & Rondelaud (1984), whereas they ranged from 22.6 to 27.2 snails /m^2 in our study. Our results agree with those of these authors.

The surface area of habitats occupied by *L. palustris* was lower in the report by Dreyfuss et al. (1994) than in our study : a mean of 10.1 m^2 vs 10.3-19.3 m^2. Snail density was clearly lower in our observations than in the report of Dreyfuss et al. : 6.3-8.8 snails /m^2 vs 40.7 /m^2. These differences can be explained by the

Table 1. Characteristics of sites inhabited by *Lymnaea truncatula* and the total area of the meadows on acid soil. a (mean value). b (standard deviation.

Tableau 1. Caractéristiques des sites colonisés par *Lymnaea truncatula* et la superficie totale des prairies sur sol acide. a (moyenne). b (écart type).

Parameters	Basse-Marche	Monts d'Ambazac	Plateaux de la Vienne
Number of meadows	15	23	15
Total number of populations	68	90	73
Length of habitat : a ± b (m)	4.6 ± 1.9	3.0 ± 0.8	5.0 ± 2.1
Surface area of habitats : a ± b (m^2)	4.2 ± 1.2	2.8 ± 0.8	4.8 ± 1.4
Snail density in each habitat : a ± b	19.8 ± 8.5	11.4 ± 6.5	14.4 ± 6.8
Total area occupied (m^2)	286	252	350
Total area of meadows (ha)	36.5	28.7	20.2
Percentage of meadow occupied by snails	0.08 %	0.09 %	0.17 %

Table 2. Characteristics of sites inhabited by *Lymnaea glabra* and the total area of the meadows on acid soil. a (mean value). b (standard deviation.

Tableau 2. Caractéristiques des sites colonisés par *Lymnaea glabra* et la superficie totale des prairies sur sol acide. a (moyenne). b (écart type).

Parameters	Basse-Marche	Monts d'Ambazac	Plateaux de la Vienne
Number of meadows	15	23	15
Total number of populations	68	90	73
Length of habitat : a ± b (m)	14.3 ± 6.2	7.2 ± 2.3	12.2 ± 4.2
Surface area of habitats : a ± b (m^2)	7.2 ± 1.4	3.6 ± 0.8	5.9 ± 1.1
Distances between the sites occupied by *Lymnaea truncatula* and *L. glabra* : a ± b (m)	12.3 ± 5.2	6.3 ± 2.6	10.7 ± 4.3
Snail density in each habitat : a ± b	26.0 ± 10.7	22.6 ± 8.4	27.0 ± 9.5
Total area occupied (m^2)	274	180	232
Total area of meadows (ha)	36.5	28.7	20.2
Percentage of meadow occupied by snails	0.07 %	0.06 %	0.11 %

Table 3. Characteristics of sites inhabited by *Lymnaea palustris* and the total area of the meadows on acid soil. a (mean value). b (standard deviation.

Tableau 2. Caractéristiques des sites colonisés par *Lymnaea palustris* et la superficie totale des prairies sur sol acide. a (moyenne). b (écart type).

Parameters	Basse-Marche	Monts d'Ambazac	Plateaux de la Vienne
Number of meadows	3	3	3
Total number of populations	3	3	3
Length of habitat : a ± b (m)	8.0 ± 1.4	5.0 ± 0.8	9.9 ± 1.8
Surface area of habitats : a ± b (m^2)	17.5 ± 4.3	10.3 ± 2.3	19.3 ± 4.5
Distances between the sites occupied by *Lymnaea glabra* and *L. palustris* : a ± b (m)	15.4 ± 6.4	11.6 ± 4.2	13.7 ± 5.7
Snail density in each habitat : a ± b	7.5 ± 3.8	6.3 ± 2.3	8.8 ± 4.5
Total area occupied (m^2)	52.5	31	58
Total area of meadows (ha)	8.33	2.45	5.25
Percentage of meadow occupied by snails	0.06 %	0.12 %	0.11 %

nature of habitat : ponds for Dreyfuss et al., open drainage ditches in our study. The differences between densities may be interpreted by hypothesizing that the species richness would be greater in a pond than in an open drainage system.

From the present study, it was found that the habitats of the three species were few in number in the meadows on acid soil (for example : a mean of 4.3 per pasture for *L. truncatula*). Their size was restricted and snail densities were low. These characteristics must be considered in the control of fasciolosis and one measure may be proposed. As these *Lymnaea* species act as intermediate hosts for this trematode in the region studied, fencing snail habitats would isolate cattle or sheep from snails and subsequently, stop the life cycle of *F. hepatica*, as demonstrated by Mage et al. (1989) in a farm located in the Correze Department (France). Subsequent transformation of fenced habitats using agronomic methods would eliminate snails by suppressing moisture excess. Extension of these measure to other regions or countries of western Europe, located on acid soil, might serve to eradicate fasciolosis from local cattle and sheep.

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