Annotated Bibliography on the Ecology and Management of Invasive Species:

Black Slug (*Arion rufus*)

Prepared by Carrina Maslovat, Victoria BC
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Barone, M. and T. Frank. 1999. Effects of plant extracts on the feeding behaviour of the slug *Arion lusitanicus*. Annals of Applied Biology 134 (3): 341-345.

Authors' abstract: Methanol extracts of the plants *Geranium robertianum, Lepidium sativum, Origanum vulgare, Salvia officinalis, Salvia pratensis, Saponaria officinalis, Thymus vulgaris, Trifolium repens* and *Valerianella locusta* were produced and applied to cotyledons of 6-8 days old rape seedlings to investigate whether they can influence the feeding of the slug *Arion lusitanicus* on young rape. All plant extracts appeared to reduce slug feeding on rape to some extent, but only the extracts of *Saponaria officinalis* and *V. locusta* significantly deterred *A. lusitanicus* from feeding. The small effects of some extracts may be due to a poor extraction efficiency or an insufficient feeding inhibition capacity of these extracts.

Briner, T. and T. Frank. 1998. Egg laying activity of the slug *Arion lusitanicus* Mabille in Switzerland. Journal of Conchology 36 (3): 9-15.

Authors' abstract: 1. *Arion lusitanicus* Mabille was found to lay more than 200 eggs per clutch with an egg volume between 11 and 34 mm3. 2. The weight of adult individuals of *A. lusitanicus* varied between 3 and 27 g. 3. The body weight of the slugs correlated positively with egg volume. However, there was no correlation found between body weight and the number of eggs per clutch, or between egg volume and the number of eggs per clutch. 4. Clutch size decreased over the period of the investigation. 5. Slug density was probably responsible for the differences observed in the reproduction parameters, measured at three different locations.

Briner, T. and T. Frank. 1998. The palatability of 78 wildflower strip plants to the slug *Arion lusitanicus*. Annals of Applied Biology 133 (1): 123-133.

Authors' abstract: As *Arion lusitanicus* has been observed in high densities in wildflower strips, the palatability of the foliage of 78 species of sown and naturally occurring plants found in such strips was investigated. In the laboratory, the slugs were offered a surplus of fresh, mature leaves and, after 16 h, a consumption index was calculated to rank the plants according to their palatability to the slugs. *Arion lusitanicus* showed clear preferences for particular plant species, but more than two thirds of all plants investigated were scarcely eaten. *Brassica napus* was most eaten, followed by *Papaver rhoeas*, *Capsella bursa-pastoris* and *Lamium purpureum*. Overall, *A. lusitanicus* preferred sown species to naturally occurring ones and preferred annuals to perennials.

Bruelheide, H. and U. Scheidel. 1999. Slug herbivory as a limiting factor for the geographical range of *Arnica montana*. Journal of Ecology 87 (5): 839-848.

Authors' abstract: 1. We tested whether slug herbivory is a factor restricting the rare perennial *Arnica montana* to high elevations in the Harz mountains, Lower Saxony. 2. In one experiment we artificially increased the mollusc population density in plots containing native *Arnica montana* populations. Leaf loss and damage to *Arnica* increased significantly, whilst damage to other plant species in the same plots was unaffected by mollusc density. 3. A second experiment examined damage by molluscs of transplanted *Arnica montana* plants at three different altitudes. Whilst damage to *Arnica* was negligible at 610m a.s.l. (where natural populations occur), molluscs removed 8% of *Arnica* leaf area at 385m a.s.l. and 75% at 180m a.s.l. At the two lower sites, protective caging of *Arnica* plants significantly reduced the amount of leaf tissue consumed by molluscs. The impact of mollusc herbivory on *Arnica montana* therefore appears to increase with decreasing altitude. 4. Despite the weak relationship between leaf damage to *Arnica montana* and mollusc abundance, periods of peak mollusc activity may well coincide with those phases in *Arnica* life history that are most sensitive to tissue removal by herbivores. 5. Our results support the hypothesis that polyphagous herbivores play a major role in limiting the distribution of preferred plant species. We discuss how selective herbivory may influence the distribution of *Arnica montana* populations in these grassland communities.

Buschmann, H., P. J. Edwards and H. Dietz. 2002. Does herbivory by slugs influence the invasiveness of perennial Brassicaceae? Bulletin of the Geobotanical Institute ETH 68: 73-81.

Authors' abstract: 1 It is often assumed that invasive plants escape control by their natural herbivores and pathogens in the introduced area. The EICA-hypothesis (Evolution of Increased Competitive Ability) suggests that release from natural enemies and pathogens results in higher plant vigour or that poorly defended but rapidly growing genotypes are selectively favoured in the absence of herbivores. Alternatively or in addition, invasive plants may be either less palatable or better able to compensate for biomass losses by herbivory than related, non-invasive species in the same area. 2 The

objective of this study is to investigate whether release from slug herbivory and/or an increased ability to compensate for damage by slug herbivory is a possible reason for invasiveness. The family of the Brassicaceae has a high number of invasive species and for many of these plants slugs appear to be the main herbivores. 3 To investigate the EICA hypothesis, we compare life-history and fitness parameters of plants from native and introduced populations of four invasive Brassicaceae forbs. Plants or leaf material will be subjected to slug herbivory in controlled field and glass-house experiments using *Arion lusitanicus*, a slug that is very abundant and a real pest in Europe but has only recently been found at one location in the United States. 4 To investigate the alternative hypothesis that invasive species are less susceptible to attack, we compare life-history and fitness parameters and the susceptibility to herbivory of invasive and non-invasive species. In this experiment six Brassicaceae species are offered to two common European slug species, *Deroceras reticulatum* and *Arion lusitanicus*. 5 The results of the project will help to assess whether herbivory is a significant factor influencing the success of Brassicaceae forbs as invaders and to establish by which mechanisms herbivory interacts with species invasiveness. Additionally, the study will contribute to our understanding of variations in the effects of herbivory upon similar plant species and among different life stages within species.

Ceska, A. 2002. *Personal communication*. Botanist, Victoria, BC. October 10, 2002.

Ceska has observed black slugs at Thetis Lake in addition to other locations around Victoria, British Columbia. He did not know how black slugs have impacted Garry oak ecosystems.

Dickey, P. 2002. Slugs. Website maintained by the Green Gardening Program of King County. www.cityofseattle.net/util/proipm/docs/slug.pdf Accessed: October 23, 2002.

This two page brochure is designed to help gardeners identify and control slug pests. The document does not distinguish between *Arion ater* and *Arion rufus* but recommends general techniques that will work to control a range of slug species. Dickey also provides general life cycle information that is common to a range of species including their lifespan (1-2 years), sexuality (hermaphroditic), number of eggs (up to 400 per year usually in groups of 3-4 but can be up to 40), location of eggs (under stones, boards or mulch) and size of eggs (1/8 to 1/4 inch in diameter). Slugs feed more heavily at night and during cool, wet weather. They leave silvery mucus trails and ragged holes in vegetation. The promotion of natural predators such as snakes, birds and frogs is a biological control that may be useful in Garry oak ecosystems. Suggested cultural controls that may be applied include irrigating in the evening rather than the morning, eliminating adjacent habitat, installing barriers to exclude slugs, destroying eggs and trapping slugs with commercial or beer traps. Dickey also notes the toxicity of metaldehyde and carbaryl-based chemical controls. The recommended iron phosphate baits which are less toxic but must be regularly reapplied are most appropriate for use in Garry oak ecosystems.

Douglas, G. 2002. *Personal communication*. Conservation Data Centre Botanist,

Victoria, BC. October 30, 2002.

Douglas has not observed black slugs in Garry oak ecosystems including the deeper soiled Cowichan Garry Oak Preserve and suggests that the sites are too dry for this species. He has been growing rare species such as *Balsamorhiza deltoidea* in his backyard garden and under these conditions, the plants suffered slug damage. However, once the *B. deltoidea* seedlings were 2 years old, the slugs preferred his lettuce plants. He has never seen slug damage on *B. deltoidea* in the wild. He suggests that more research is needed to understand the impact of introduced slugs and snails in Garry oak ecosystems.

Dunwiddie, P. 2002. *Personal communication*. Restoration ecologist, The Nature Conservancy, Seattle, WA. November 13, 2002.

During his restoration work on Yellow Island, Dunwiddie started to notice black slugs after 1994. There are no native banana slugs on the island. He suspects they were brought to the island on mulch or other restoration material. The slugs spread very rapidly and within a year it was everywhere on the island. Although he has not done scientific studies on the populations, he has asked his wardens to keep track of the number of slugs they kill as they walk along the trails. The population seems to fluctuate wildly with staff killing 600 in one day one year and the next year killing the same number over a month. Dunwiddie has not done scientific studies on the effect of the slugs but has strong anecdotal evidence of their impact. He has tried using exclosures of copper edge barriers with but the slugs have managed to find their way in. Dunwiddie has noticed heavy slug browse on *Fritillaria lanceolata* and frequently browsed *Erythronium oregonum* although neither of these species appears to be negatively impacted by the herbivory. However, *Goodyera oblong folia* was very heavily impacted and would have been extirpated from the island if exclosures for the slugs had not been built. Black slugs also seem to impact rein orchids (*Platanthera sp.*) but this needs further observation. One year, the black slugs had very high herbivory on *Osmorhiza chilensis* but the plants regrew from the stubs at the base of the plant. The slugs tend to be more common in the wooded parts of the island but are in the grasslands during the wetter part of the year. Slug baits have not been effective on Yellow Island.

Erickson, W. 2002. *Personal communication*. Botanist, Ministry of Forests, Victoria, BC. October 10, 2002.

Although Erickson's research was not focussed on invertebrates, he did make notes on wildlife observations during his field work studying Garry oak plant communities. Erickson did not observe black slugs in any of his vegetation plots but has observed them in sites with full tree canopy, along moist trails and wetter sites.

Forsyth, R. 2002. Unpublished manuscript. Royal British Columbia Museum Terrestrial Gastropod Expert, Victoria, BC. October 3, 2002.

This manuscript is a preliminary document that will become a field guide to land snails of British Columbia. It includes dichotomous keys for identification in addition to species

descriptions of both adults and juveniles. The description of the species is as described in other references. Forsyth outlines the problem with determining the distribution of *Arion rufus* because it has often been misidentified as *Arion ater* and the two species can only be distinguished by their reproductive anatomy. Black slugs are native to Europe but are now common in southern British Columbia and are also found in the Queen Charlotte Islands and Yoho National Park. The habitat is described as human modified areas such as "gardens, fields and campgrounds". Black slugs mate from June to October and lay 150 or more eggs at a time. Diet consists of live and dead plants, feces and dead animals.

Forsyth, R. 2002. *Personal communication*. Royal British Columbia Museum Terrestrial Gastropod Expert, Victoria, BC. October 3, 2002.

Forsyth states that *Arion rufus* can be distinguished from *Arion ater* only by dissection of the genitalia. He has studied slugs in British Columbia and only *Arion rufus* not *Arion ater*, has been collected and dissected in the province. Forsyth has observed black slugs mating in late June through mid-October and he speculates that mating is dependent on weather and that drought and freezing conditions reduce the chances of mating. He also notes that black slugs are 1/2 cross fertilizing and 1/2 self-fertilizing so the species can reproduce without a mate. The eggs are opaque white in colour and about 2 mm in diameter. Forsyth suggests that this species is primarily introduced by people inadvertently transporting eggs or adult slugs. About 25% of the slug and snail species in British Columbia are introduced. Forsyth has not observed black slugs at Mount Tolmie in Victoria, British Columbia and at most sites where black slugs occur they are associated with people. As juveniles, black slugs can be easily confused with other *Arion* species but *A. rufus* has coarser back ridges than the other *Arion* species.

Frahm, J. P. and K. Kirchhoff. 2002. Antifeeding effects of bryophyte extracts from *Neckera crispa* and *Porella obtusata* against the slug *Arion lusitanicus*. Cryptogamie Bryologie 23 (3): 271-275.

Authors' abstract: Alcoholic extracts of one moss and one hepatic were tested for the first time for its antifeedant activity against a slug (*Arion lusitanicus*). In a preference test, the extracts of *Neckera crispa* showed low antifeedant effects in concentrations of 0.5% dry weight and more. In contrast, the extracts of *Porella obtusata* showed moderate effects at concentrations of 0.05% and absolute antifeedant activity at 0.25% dry weight.

Frank, T. 1998. Slug damage and numbers of the slug pests, *Arion lusitanicus* and *Deroceras reticulatum*, in oilseed rape grown beside sown wildflower strips. Agriculture Ecosystems & Environment 67 (1): 67-78.

Author's abstract: In 1994 and 1995, slug damage and numbers of the most abundant slugs, *Arion lusitanicus* and *Deroceras reticulatum*, were estimated in sown wildflower strips and adjacent rape fields. Slug damage was estimated using an index of defoliation, and slug numbers were measured using bait traps that did not kill the slugs. Investigations began as soon as rape seedlings appeared above ground and lasted for five weeks. In both years, slug damage to rape plants 1 m from the wildflower strips was significantly higher

than at greater distances from the strips. Within a distance up to 2 m from the wildflower strips, complete crop losses occurred. In field areas where metaldehyde pellets were used, slug damage was distinctly lower and in these areas complete crop losses near the wildflower strips never occurred. In both years, *A. lusitanicus* appeared to be responsible for the main damage near the wildflower strips because it was very abundant in the wildflower strips and at 1 m into the crop but was scarcely observed at greater distances from the strips. Results showed that the numbers of the most abundant slug species were related to the amount of slug damage and that severe damage close to the wildflower strips could be prevented by broadcasting a recommended dose of 5% metaldehyde pellets at 8 kg/ha.

Frank, T. 1998. The role of different slug species in damage to oilseed rape bordering on sown wildflower strips. Annals of Applied Biology 133 (3): 483-493.

Author's abstract: Damage caused by different slug species on above and below ground parts of young oilseed rape bordering on sown wildflower strips was studied. Slug densities and damage were recorded in the field and damage rates for each slug species were measured in the laboratory. Severe slug damage was observed in rape areas 1 m from the wildflower strips. Damage rates of slug species feeding above ground were distinctly higher than those feeding below ground. The estimated damage caused by above-ground feeding in all four study fields ranged between 72% and 89% and was always distinctly higher than damage caused by below-ground feeding (11% to 28%). The estimated damage caused by *Arion lusitanicus* above ground was between 54% and 69%, followed by *Deroceras reticulatum* (3% to 26%). Thus *A. lusitanicus* was responsible for the majority of damage in the rape crops studied.

Frank, T., K. Bieri and B. Speiser. 2002. Feeding deterrent effect of carvone, a compound from caraway seeds, on the slug *Arion lusitanicus*. Annals of Applied Biology 141 (2): 93-100.

Authors' abstract: The feeding deterrent effect of carvone on the slug *Arion lusitanicus* was investigated. Carvone, a natural compound from caraway seeds, was incorporated into mulch to reduce its inherent volatility. In a laboratory choice experiment, boxes were filled on one side with carvone-treated mulch and on the other side with untreated mulch. At carvone concentrations ranging from 0.03-0.75 ml litre-1 mulch, slugs ate significantly more lettuce on the untreated side. In a laboratory based no-choice experiment, carvone concentrations of 0.25 and 0.75 ml litre-1 mulch significantly reduced slug feeding in comparison with the untreated control. Moreover at the highest concentration of carvone (0.75 ml litre-1 mulch) 50% mortality was recorded over a period of 5 days, indicating a clear molluscicidal effect. Due to its volatility carvone did not decrease plant defoliation by *A. lusitanicus* when applied directly onto lettuce. Subsequent field evaluation showed 0.75 ml litre-1 mulch to partially reduce slug feeding damage. However, this effect was not sufficient to significantly increase lettuce yield. The incorporation of a higher carvone concentration into mulch is still to be tested to confirm whether carvone-treated mulch can be recommended as an effective alternative approach to chemical slug control.

Frank, T. and J. Friedli. 1997. Application of metaldehyde against slug damage in oilseed rape along sown wildflower strips. Mededelingen Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen Universiteit Gent 62 (2B): 547-555.

Authors' abstract: In 1994 and 1995, slug damage and number of slugs were estimated in sown wildflower strips and in adjacent rape fields comparing the effect of a recommended dose of molluscicide (5% metaldehyde at 8 kg/ha) with untreated control areas. In untreated areas, slug damage on rape plants 1 m from the wildflower strips was significantly higher than at greater distances from the strips. Within a distance up to 2 m from the wildflower strips, complete crop loss occurred. In field areas where metaldehyde pellets were used slug damage was distinctly lower and complete crop loss was never observed. Results showed that the number of the most abundant slugs corresponded to the amount of slug damage and that a severe damage close to the wildflower strips could be prevented by broadcasting a recommended dose of metaldehyde. In 1996, slug damage in rape 1 and 3 m from sown wildflower strips was investigated comparing different treatments of metaldehyde (normal concentration broadcast over the whole study area and higher concentrations of only 0.5 m width along the strips). In control plots at 1 m, complete crop loss occurred. All treatments of molluscicide protected rape from complete crop loss without significant differences among the treatments. Thus, reduced input of molluscicide in the form of 0.5 m wide barriers prevented rape from severe slug damage along wildflower strips. At 3 m, severe slug damage was never observed. The slug pest *Arion lusitanicus* was very abundant at 1 m but was rarely found at 3 m. Due to its distribution pattern *A. lusitanicus* was responsible for the main part of severe damage in control plots 1 m from the wildflower strips.

Frank, T.and J. Friedli. 1999. Laboratory food choice trials to explore the potential of common weeds to reduce slug feeding on oilseed rape. Biological Agriculture & Horticulture 17 (1): 19-29.

Authors' abstract: Food choice trials with the slug pests *Arion lusitanicus* and *Deroceras reticulatum* were carried out in the laboratory, using seedlings of rape, *Brassica napus* and several weed species. The attraction of the weeds to the slugs was compared with rape and, subsequently, the potential of the presence of weeds to reduce slug feeding on young rape was assessed. *Capsella bursa-pastoris* and *Taraxacum officinale* (only for *A. lusitanicus*) were very attractive weeds and rape was not significantly more defoliated than *C. bursa-pastoris* and *T. officinale* when tested with these two weed species. Moreover *Veronica persica* (*A. lusitanicus*) and *C. bursa-pastoris* (*D. reticulatum*) reduced the number of killed rape plants significantly. Therefore these weeds, sown in high quantities into fields of oilseed rape, could potentially prevent young rape plants from severe slug damage.

Fraser, D. 2002. *Personal communication.* Ministry of Water, Land and Air Protection, Victoria, BC.

Fraser has observed *Viola praemorsa* seedlings that are damaged and killed by black

slugs. Slugs also damage the flower structure of adult *V. praemorsa* preventing reproduction. He suspects that in smaller fragments of Garry oak ecosystems, especially those with more shade cover from exotic grasses and woody species, slug predation may be a major factor limiting plant recruitment. He has noticed the impact of black slugs in both undisturbed Garry oak ecosystems and in gardens. Fraser has observed slug impact on young *Balsamorhiza deltoidea* as well as *Lupinus rivularis* (not a Garry oak ecosystem spp.). Further research is needed to fully understand the role of introduced slugs in Garry oak ecosystems.

Friedli, J. and T. Frank. 1998. Reduced applications of metaldehyde pellets for reliable control of the slug pests Arion *lusitanicus* and *Deroceras reticulatum* in oilseed rape adjacent to sown wildflower strips. Journal of Applied Ecology 35 (4): 504-513.

Authors' abstract: 1. Slugs have been shown to cause severe damage in oilseed rape crops adjacent to sown wildflower strips. Rape can be protected from this damage by broadcasting a recommended dose of metaldehyde over the whole field area. This paper investigates whether severe slug damage can be prevented by applications of metaldehyde just along the wildflower strips thereby reducing the input of chemical molluscicide. 2. In this study, untreated control plots suffered severe crop loss at 1 m from all wildflower strips studied. However, all treatments of molluscicide protected rape from severe crop loss without significant differences among the three treatments (two different concentrations of metaldehyde applied in 50-cm wide barriers along the strips and a recommended dose of metaldehyde broadcast over the whole study area). 3. *Arion lusitanicus* and *Deroceras reticulatum* were by far the most abundant slug pests found in the studied rape fields. *Arion lusitanicus* was very abundant in the wildflower strips and up to 1 m into the field; however, it was almost entirely absent at 3 m from the strips. Since *D. reticulatum* was evenly distributed over the whole field area, *A. lusitanicus* appeared to be responsible for the majority of damage in control plots 1 m from the wildflower strips. 4. Application of metaldehyde in a 50-cm wide band has been shown to be practicable and efficient in protecting rape from severe slug damage near to wildflower strips. These reduced applications of molluscicide mean savings of time and money for farmers and can be recommended for practical application.

Fritz, R. S., C. G. Hochwender, D. A. Lewkiewicz, S. Bothwell and C. M. Orians. 2001. Seedling herbivory by slugs in a willow hybrid system: Developmental changes in damage, chemical defense, and plant performance. Oecologia 129 (1): 87-97.

Authors' abstract: We evaluated feeding preference and damage by the slug, *Arion subfuscus*, on seedlings of two willow species, *Salix sericea* and *S. eriocephala*, and their F1 interspecific hybrids. Trays of seedlings were placed in the field and excised leaves were presented to slugs in choice tests. Slugs preferred feeding on and caused the most damage to *S. eriocephala* seedlings. *S. sericea* seedlings were least preferred and least damaged. F1 hybrid seedlings were intermediate in preference and damage. Slug preference of and damage to these seedlings decreased over time, suggesting developmental changes in resistance. Seedlings were sampled for phenolic glycoside and tannin chemistry weekly to coincide with the field and laboratory experiments.

Concentrations of phenolic glycosides and tannins increased linearly with seedling age, coincident with changes in slug preference and damage, indicating a developmental change in defense. Slug deterrence was not detected at low concentrations of salicortin when painted on leaves or discs, but both salicortin and condensed tannins deterred slug feeding at concentrations between 50 and 100 mg/g, levels found in adult willows. Seedling performance was related to damage inflicted by slugs. Due to lower levels of damage when exposed to slugs in the field, *S. sericea* plants had significantly greater biomass than *S. eriocephala* plants. Biomass of F1 hybrids was equal to *S. sericea* when damaged. However, undamaged *S. eriocephala* and F1 hybrid plants had the greatest biomass. Because F1 hybrid seedlings performed as well as the most fit parent in all cases, slugs could be an important selective factor favoring introgression of defensive traits between these willow species.

Getz, L. L. and L. F. Chichester. 1971. Introduced European slugs. The biologist 53(3): 118-127.

The paper highlights the lack of published information on the distribution and ecology of introduced slugs in North America. The authors suggest that all introductions of European slugs have been accidental. Getz and Chinchester suggest that introduced slugs were first introduced to coastal sea ports on plant and horticultural material and have since been spread primarily on nursery and greenhouse material. There are inadequate records of when each species was first introduced. The authors fail to distinguish *Arion rufus* from *Arion ater* in this paper. *Arion ater* habitat is described as "roadside margins, abandoned fields and home sites, dumps, cemeteries, picnic areas, campsites, and other such sites reflecting disturbance by man". The authors note that this genus prefers sites with cover of trees and shrubs. The authors also note that the greatest impact of this genus is in cultivated areas and that it is impossible to determine its impact on native molluscs.

Grimm, B. 2002. Effect of the nematode *Phasmarhabditis hermaphrodita* on young stages of the pest slug *Arion lusitanicus*. Journal of Molluscan Studies 68 (1): 25-28.

Authors' abstract: In a soil bioassay, adult *Deroceras reticulatum* (Stylommatophora: Limacidae) and three different weight-classes of young *Arion lusitanicus* (Stylommatophora: Arionidae) were exposed to a single dosage (170 dauer larvae per g of soil) of the nematode *Phasmarhabditis hermaphrodita* monoxenically associated with the bacterium *Moraxella osloensis*. Groups of 10 slugs were continuously exposed to nematodes for 4 days, and then transferred individually to Petri-dishes containing a disc of Chinese cabbage as food. Food consumption-measured by image analysis-and slug mortality were recorded daily for 10 days. Food consumption was inhibited in both slug species tested. *D. reticulatum* stopped feeding 6 days after the start of nematode treatment, while all *A. lusitanicus* continued to feed. However, in the three weight-classes of *A. lusitanicus* (0.15 g, 0.24 g, 0.45 g), food consumption was reduced by at least 50%. The greatest reduction in feeding, nearly 90%, was noted in the smallest *A. lusitanicus*. The nematodes successfully killed *D. reticulatum* but were less efficient at killing young *A. lusitanicus*. At the end of the experiment, mortality was highest in *D. reticulatum*

(98%) and the smallest weight-class of *A. lusitanicus* (47%). There was almost no mortality in the largest weight-class of *A. lusitanicus* treated with nematodes. *P. hermaphrodita* associated with *M. osloensis* can thus be considered as a biological control agent for young stages of *A. lusitanicus* for its effect as a feeding inhibitor, rather than for its ability to kill the slugs.

Grimm, B. and W. Paill. 2001. Spatial distribution and home-range of the pest slug *Arion lusitanicus* (Mollusca: Pulmonata). Acta Oecologica 22 (4): 219-227.

Authors' abstract: The density and distribution of egg-batches, juveniles and adult *Arion lusitanicus*, as well as individual home-ranges, were investigated over two seasons. The study was performed on grassland which was mown twice a year and received no herbicides or pesticides, with neighbouring field and stream-side vegetation. Female-mature slugs preferred restricted areas closely neighbouring the taller vegetation of the stream-side vegetation and field, but less-favourable parts of the site were also inhabited in the second year when population densities increased and weather conditions were more favourable. It was postulated that slugs could have home-ranges, as homing behaviour is a well-known phenomenon. The application of a long-lasting individual marking technique enabled calculations of home-ranges (convex polygons) for slugs for the first time. Home-range size averaged 45.4 m2 when the population density was low in 1995, and was found to be negatively correlated with density, as it decreased to 12.4 m2 in 1996, when population density was high. Mating sites were found to be distinctly closer to the geometric centres of activity than the sites used for egg-deposition. Egg-batches were aggregated under the shelter traps (50 X 50 cm squares of hardboard covered with polystyrene) and the pattern of distribution of egg-batches persisted in the young hatchlings. A number of foreign *A. lusitanicus* were introduced into the unfavourable centre of the site, and by two to four weeks after release their distribution exactly resembled that of the local ones. In all the various aspects of behaviour investigated, large individual differences were found, suggesting a great plasticity in this generalist species. The importance of the species' dispersal capacity in relation to general ecological and applied aspects of control is discussed in the context of the present findings.

Grimm, B. and K. Schaumberger. 2002. Daily activity of the pest slug *Arion lusitanicus* under laboratory conditions. Annals of Applied Biology 141 (1): 35-44.

Authors' abstract: The daily activity of the slug *Arion lusitanicus* was studied using time-lapse video analysis in the laboratory. Under constant temperature (18degreeC) and 16-h photoperiod, the activity of slugs was measured in half-hourly periods as locomotor activity, feeding or resting. Track lengths were determined using image analysis. Locomotion of *A. lusitanicus* was greatest at 5:30, 1.5 h after sunrise, and at 20:30, 1 h after sunset; least locomotor activity occurred between 13:00 and 14:00. The mean distance travelled by *A. lusitanicus* in 24 h was 10.8 m. The largest slug was the most active and the smallest the least. Slugs spent 68% of 24 hours resting, mainly under artificial shelter traps, 27% in locomotion and 4% feeding. Feeding occurred mainly during the hours of darkness (76%). All categories of behaviour investigated varied greatly between individuals and also between times of day. Homing to artificial shelters

and other roost sites was regularly observed within 24 h (41%), but decreased considerably thereafter. The behavioural patterns proved to be in agreement with those found in a previous field investigation and are therefore also discussed with a view to their importance in pest control.

Hommay, G., O. Lorvelec and F. Jacky. 1998. Daily activity rhythm and use of shelter in the slugs *Deroceras reticulatum* and *Arion distinctus* under laboratory conditions. Annals of Applied Biology 132 (1): 167-185.

Authors' abstract: Daily activity of slugs, *Deroceras reticulatum* and *Arion distinctus*, was studied in the laboratory in relation to the presence of shelters so as to define optimal conditions for using traps to forecast crop damage. Under constant temperature and humidity, activity of slugs began with the lights off. Its arrest occurred after a period of activity with the lights on. Slugs rested most frequently under a shelter on bare earth and rarely used the same shelter for more than two consecutive days. When food was placed under the shelter, the number of slugs found under the shelter was more constant throughout the 24 h period, but lower during diurnal rest. The presence of 4% methiocarb pellets under the shelter led to an increased occupation by slugs, due to the poisoning of some of them. Acts of aggression were more numerous in *A. distinctus* than in *D. reticulatum*. In *D. reticulatum* the smallest slug was the least aggressive and suffered more attacks from the other slugs. In *A. distinctus* the numbers of attacks suffered or provoked varied little with the size of the slug, but the smallest slug showed less interactions with other slugs.

Iglesias J., J. Castillejo and R. Castro. 2001a. Field test using the nematode *Phasmarhabditis hermaphrodita* for biocontrol of slugs in Spain. Biocontrol Science and Technology 11 (1): 93-98.

Authors' abstract: An experiment was carried out between May and July 1999 in Galicia (North-West Spain) to test the capacity of the nematode *Phasmarhabditis hermaphrodita* to protect field grown lettuces from slug damage in our field conditions. The experiment compared a single dose of nematodes (3 X 109 ha-1) with mini-pellets containing 5% metaldehyde, applied at the recommended field rate (3 g pellets m-2), and untreated plots. Slug damage for each lettuce head was estimated on six dates during the first 4 weeks after planting. At harvest, each lettuce head was weighed, scored as marketable or not by weight and external aspect, and inspected for slugs. Metaldehyde significantly reduced slug damage to lettuce plants from the first day after planting to the third week. Nematodes significantly reduced slug damage from the second to the third week. At harvest, 6 weeks after planting, the mean weight of the lettuce heads and the number of marketable heads in the nematode plots were as good as in the metaldehyde plots, and both treatments were significantly better than the untreated plots. The number of slugs within the harvested plants was significantly reduced only with the metaldehyde treatment.

Iglesias, J., J. Castillejo and R. Castro. 2001b. Mini-plot field experiments on slug control using biological and chemical control agents. Annals of Applied Biology 139 (3):

285-292.

Authors' abstract: In three field experiments, the rhabditid nematode *Phasmarhabditis hermaphrodita* was applied one or more times at the standard rate (3 X 109 ha-1) or half the standard rate to protect crops from slug damage under experimental conditions. Expt 1 was done in a field planted with the ornamental *Polygonatum japonica*. The treatments were: infective juveniles of the nematode at the standard field rate, metaldehyde pellets at the recommended field rate, and ioxynil (a herbicide with molluscicidal properties) at 90 mg m-2. The treatments were repeated every 2 wk. *Arion ater agg.* caused most of the damage to *P. japonica*. There were no significant differences in damage between treatments during the 3 wk after first application, but plants on plots treated with metaldehyde or nematodes had significantly less damage than plants on untreated plots in the fourth and fifth weeks. Expts 2 and 3 were done on the same site, the first with leaf beet and the second with lettuce. The treatments in these experiments were: nematodes applied to the planted area at the standard field rate 3 days prior to planting, with or without previous application of cow manure; nematodes at half standard rate applied twice, 6 days apart, to the planted area or to the surrounding area; metaldehyde pellets and iron phosphate pellets, both applied at the recommended rate to the planted area immediately after planting. In both experiments, the two chemical molluscicides and nematodes applied once to the planted area at the standard field rate without previous application of cow manure, or twice at half standard rate, were able to reduce slug damage. Nematodes applied after manure did not reduce slug damage. None of the treatments reduced the numbers of slugs contaminating the harvested plants. Slug populations were assessed by means of soil sampling before and after Expts 2 and 3. Only after Expt 3 was there a significant effect of treatment on slug numbers, with significantly fewer in metaldehyde treated plots than in untreated plots.

Iglesias, J. and B. Speiser. 2001. Consumption rate and susceptibility to parasitic nematodes and chemical molluscicides of the pest slugs *Arion hortensis* s. s. and *A. distinctus*. Anzeiger fuer Schaedlingskunde 74 (6): 159-166.

Authors' abstract: The species complex *Arion hortensis* s. l. is among the most important pestiferous slugs in Europe. The species *A. distinctus* Mabille and *A. hortensis* de Ferussac have traditionally been grouped together under the denomination *A. hortensis*. Therefore, neither the feeding behaviour nor the susceptibility of the individual species to control measures are known. In the laboratory, mean daily consumption of lettuce was similar for both species. In a series of laboratory bioassays, *A. distinctus* and *A. hortensis* s. s. were exposed to the rhabditid nematode *Phasmarhabditis hermaphrodita* and to the chemical molluscicides metaldehyde and iron phosphate, and their feeding and health were measured. Both species showed a similar and low susceptibility to the biocontrol agent *P. hermaphrodita.* In field-collected slugs, the incidence of nematodes was much lower in *A. hortensis* s. l. than in *Deroceras reticulatum* or *Arion lusitanicus.* Metaldehyde and iron phosphate affected both slug species similarly. Therefore, our results do not indicate any major difference between the two slug species of agronomical relevance.

Karlin, E. J. 1961. Ecological relationships between vegetation and the distribution of land snails in Montana, Colorado and New Mexico. American Midland Naturalist 65: 60-66.

Author's abstract: Thirty-two species and subspecies of shelled land mollusks were collected. Ninety-nine per cent of the snails were associated with some form of deciduous tree, usually aspen. Food chain relationships between aspen and land snails appear likely. The amount of available calcium also is a factor noted to be related to relationships, it is proposed that snail distribution be reported in terms of associated vegetation rather than altitude. Snail distribution in burned areas is also discussed. Chance distribution appears unlikely to be the only method involved and small, permanent populations within conifers are suggested to occur. *Vertigo gouldi arizonensis, Gastrocopta pilsbryana* and *Striatura meridionalis* are reported as new records for the state of Colorado.

Keller, M., J. Kollmann and P. J. Edwards. 1999. Palatability of weeds from different European origins to the slugs *Deroceras reticulatum* Muller and *Arion lusitanicus* Mabille. Acta Oecologica 20 (2): 109-118.

Authors' abstract: As part of a study on the significance of seed provenances in schemes to enhance biodiversity in agricultural habitats, juvenile plants of *Cichorium intybus*, *Daucus carota, Leucanthemum vulgare* and *Silene alba* of different European origins were exposed to grazing by two slug species, *Deroceras reticulatum* and *Arion lusitanicus*. Living plants were offered in trays, either in a glasshouse (*Deroceras*) or outdoors (*Arion*). The amount of herbivory was origin-dependent, with higher losses for all four species from German and Hungarian provenances compared with English and Swiss plants. The main trend was similar for both slug species except in the case of *Daucus*, and there was a significant 'origin X plant species' interaction. We found strong correlations between provenance-specific herbivory and certain climatic characteristics of the corresponding regions, i.e. winter minimum temperatures, and dryness in spring and late summer, which are crucial for the development of slugs. The results can be interpreted in terms of a SW-NE European climatic gradient and may be a consequence of differences in the need for plant defences against herbivory by slugs. Additionally, the data on palatability were compared with susceptibility towards two parasites which occurred in a field experiment, a leaf miner on *Leucanthemum vulgare* and a rust fungus on *Silene alba*. While specific leaf mining frequencies on *Leucanthemum* contrasted with the palatability of the different provenances to slugs, the rust infection on *Silene* was low on local and German plants, and higher on the more distant provenances from England and Hungary.

Kerney, M. P. and R. A. D. Cameron. 1979. A field guide to the land snails of Britain and North-west Europe. William Collins Sons and Co., London, England.

This dated field guide provides descriptions of the life history and general habits of European land molluscs. Although it provides key descriptive features for identification, the reference does not describe native North American species for comparison. The guide describes *Arion rufus* as a subspecies of *Arion ater* which can only be distinguished by

dissection. The species description includes size (10-15cm), colour (black, brick-red, orange or grey with a paler and redder foot fringe), and the presence of long, coarse tubercles. When disturbed, this species contracts and rocks from side to side. Black slugs usually lay 20-50 eggs but can lay over 100 with less than 5% of the juveniles reaching adulthood. The diet of black slugs is listed as decomposing vegetation, fungi, algae and lichens. These slugs are most active during the night or on overcast days and seek refuge under moist material or under the soil in dry weather.

Kozlowski, J. 2000. Distribution and places of occurrence of the slug *Arion lusitanicus* Mabille (Gastropoda: Pulmonata: Arionidae). Bulletin of the Polish Academy of Sciences Biological Sciences 48 (4): 409-415.

Author's abstract: Abundant occurrence of the slug *Arion lusitanicus* has been found in the last few years on the territory of Podkarpackie province (foothills of the Carpathians). This species, introduced into Poland, has become a serious pest of crop plants. In connection with signals of a fast spread of this pest, observations on the places of its occurrence were carried out in the years 1997-1999. Distribution and the number of places of the slug occurrence in different habitats as well as the ways of its spread have been determined. The largest number of places of this slug occurrence was found in the UTM squares EA 84, EA 94 and EA 74.

Kozlowski, J. 2001. Daily activity of *Arion lusitanicus* Mabille, 1868 (Gastropoda: Pulmonata: Arionidae). Journal of Plant Protection Research 41 (3): 279-287.

Author's 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.

Kozlowski, J. and M. Kozlowska. 2000. Weeds as a supplementary or alternative food for *Arion lusitanicus* Mabille (Gastropoda: Stylommatophora). Journal of Conchology 37 (1): 75-79.

Authors' abstract: Susceptibility of 30 weed species to *A. lusitanicus* feeding was evaluated under natural conditions in two successive vegetation seasons (1997-1998). Observations were conducted on the number and degree of plant injuries, and as a result 13 weed species were found to be most frequently and most heavily injured. Food preference of slugs for 10 selected weed species and 8 cultivated plant species was determined under laboratory conditions. It was found that the most frequently and most

seriously damaged under field conditions was *Aegopodium podagratia* L. - this and other weeds can be an alternative food for the slug. A comparison of the number of seedlings of the studied species eaten showed a high susceptibility of *Galinsoga parviflora* Cav., *Brassica napus* L. and *Helianthus annuus* L. to slug feeding.

Melbourne, B. A., P. J. Gullan and Y. N. Su. 1997. Interpreting data from pitfall-trap surveys: Crickets and slugs in exotic and native grasslands of the Australian Capital Territory. Memoirs of the Museum of Victoria 56 (2): 361-367.

Authors' abstract: We use data from a pitfall-trap survey of 23 grassland sites to examine the effect of grassland type on the abundance of crickets and slugs and to demonstrate the problems associated with interpreting data obtained by pitfall-trapping. The data presented here are for four species of native cricket (Insecta: Orthoptera: Gryllidae: *Bobilla victoriae* Otte and Alexander, *Teleogryllus commodus* (Walker), *Buangina anemba* Otte and Alexander, *Pteronemobius arima* Otte and Alexander) and five species of introduced slug (Gastropoda: Pulmonata: Limacidae: *Deroceras reticulatum* (Mueller), *Lehmannia* (Lehmannia) *nyctelia* (Bourguignat), *Limax maximus* Linnaeus; Milacidae: *Milax gagates* (Drapamaud); Arionidae: *Arion intermedius* Normand). The survey included three types of native grassland (*Themeda*, *Stipa*, *Danthonia*), two types of exotic grassland (*Phalaris*, *Avena*), and two seasons (summer, autumn). In addition to the survey, the effect of habitat structure on the efficiency of pitfall traps was examined in a well-replicated field experiment. The experiment was carried out in *Themeda* grassland, which was manipulated to create three levels of habitat structure. Habitat structure was found to affect pitfall-trap efficiency for crickets but not for slugs. We show that it is necessary to use knowledge of the effect of habitat structure on pitfall-trap efficiency for different species to allow confident interpretation of data from field surveys. Grassland type had a significant effect on the abundance of both crickets and slugs. *Bobilla victoriae* and *T. commodus* were both found to have high abundances in *Phalaris*, an improved pasture. Slugs appear to be highly invasive of native grasslands.

Nystrand, O. and A. Granstrom. 1997. Forest floor moisture controls predator activity on juvenile seedlings of *Pinus sylvestris*. Canadian Journal of Forest Research 27 (11): 1746-1752.

Authors' abstract: Conifer seedlings are succulent and vulnerable to animal depredation in the first few weeks after germination. Several animal taxa are reported to feed on seedlings, and field observations indicate varying rates of losses in boreal vegetation. Almost nothing is known about factors regulating seedling predation levels. Here, we test the hypothesis that the risk of predation is affected by the moisture content of the forest floor. The underlying assumption is that slugs are important seedling predators and that their activity depends on the substrate moisture. In a relatively open coniferous forest in northern Sweden, 1-week-old seedlings of Scots pine (*Pinus sylvestris* L.) were placed out in plots where moisture conditions were experimentally manipulated. There was a significant effect of forest floor moisture on predation. The average predation level for the five experimental runs was over three times higher in watered than in rain-protected plots (68 versus 22%). In unmanipulated plots, average predation was intermediate (49%)

but with large variation, and more seedlings were killed during wet than dry periods. The slug *Arion subfuscus* (Drap.) was the only important seedling predator, with a population density of approximately 3 m-2. Our results show that slug predation can be a quantitatively important mortality factor, acting mainly when conditions otherwise favor seedling establishment, i.e., when the forest floor is moist.

Nystrand, O. and A. Granstrom. 2000. Predation on *Pinus sylvestris* seeds and juvenile seedlings in Swedish boreal forest in relation to stand disturbance by logging. Journal of Applied Ecology 37 (3): 449-463.

Authors' abstract: 1. Forest management involving live tree retention and natural regeneration after cutting is currently increasing in boreal areas. This calls for further analysis of the optimal conditions for seedling establishment from seed following stand disturbances due to logging. 2. We studied post-dispersal predation on seeds and juvenile seedlings of *Pinus sylvestris* over 3 years in 32 north Swedish boreal forest stands with different levels of stand disturbance by logging. The aims were to identify the most important predator species and to quantify the damage inflicted upon seeds and seedlings in relation to disturbance. 3. In most stands and years, seed predation resulted in < 20% seed mortality, although occasionally it reached 60%. Predation on juvenile seedlings ranged from 5% to 100%, with > 70% mortality in 10 cases and < 30% in 44 cases (of a total of 79 observations). 4. The most important seed predators were the carabids *Pterostichus oblongopunctatus* and *Calathus micropterus*, and seed predation was correlated with the number of seed-eating carabids caught in pitfall traps. Microtine rodents caused high damage levels only on a single occasion. 5. Logging affected both catches of carabids and seed predation levels, but the relationship between tree stand density and predation was not linear and, generally, seed predation decreased in the order shelterwood > unlogged forest clear-cut. 6. The most important predator on juvenile seedlings was the slug *Arion subfuscus*, which attacked seedlings during the first weeks after germination. Pitfall trap catches of *Hylobius abietis*, which commonly damage planted (1-3-year-old) conifer seedlings, were not related to the levels of seedling predation. 7. Seedling predation was negatively related to stand disturbance, with the highest predation levels by slugs in unlogged forests and the lowest in clear-cuts. Seedling predation was higher in wet than in dry summers, probably because slugs are moisture-limited. 8. There was a large between-site variation in both seed and seedling predation, but predation was not strongly related to forest site types. The fact that predation was strongly affected by logging operations indicates that there may be opportunities to reduce damage through modification of the silvicultural practices.

Quick, H. E. 1960 British Slugs (Pulmonata; Testacellidae; Arionidae; Limacidae). Bulletin of the British Museum (Natural History). Zoology 6(3): 103-226.

This field guide classifies *Arion rufus* as *Arion ater rufus*, a subspecies of *Arion ater*. *Arion ater rufus* is described as yellow to red-brown in colour with a red to orange foot fringe and a yellow sole. The juveniles have bands on the mantle. *Arion ater rufus* matures later than *Arion ater ater* and mates in September and October.

Ramsey, L. 2002. *Personal communication.* Program zoologist, British Columbia Conservation Data Centre, Victoria, BC.

Ramsey states that metaldehyde slug control products should be avoided in Garry oak ecosystems to prevent damage to native slugs. However, she notes that many of the native slug species are commonly found in Douglas-fir communities rather than Garry oak ecosystems. If black slugs reach high densities, they may cause damage especially to new plantings. Plants should be thoroughly checked and treated for slug eggs before they are brought into Garry oak ecosystems.

Rathcke, B. 1985. Slugs as generalist herbivores tests of 3 hypothesis on plant choices. Ecology 66 (3): 828-836.

The author presented three introduced slug species with the leaf discs of 61 plants to determine the feeding preferences of the slugs. Woody species were consumed less than herbaceous species and stem heights of over 10 cm prevented feeding. Slugs also had preferences for plants from their own habitat and had the largest impact on newly emerged seedlings. Rathcke suggests that slugs alter plant communities by selective grazing that impacts the morphology, phenology and chemical defenses of plants.

Roemer, H. 2001. *Personal communication*. Botanist, Victoria, BC.

Roemer has been trying to establish *Balsamorhiza deltoidea* (a red-listed plant) in his residential Garry oak native plant garden. The seedlings have been eaten repeatedly by slugs when the new leaves are tender and still folded buds. Slugs have also damaged his *Calypso bulbosa* plants although he was not sure which species did the damage.

Rollo, C. D. and W. G. Wellington. 1975. Terrestrial slugs in the vicinity of Vancouver, British Columbia. Nautilus 89 (4): 107-115.

Rollo and Wellington conducted surveys in 23 locations and examined the literature for previous descriptive works to determine the distribution of introduced slugs. The paper does not distinguish between *Arion rufus* and *Arion ater*. The authors note that *A. ater* had become a pest species by 1940 in Seattle and that the first introduction to western North America may have occurred in Washington. The species had become a serious threat to horticultural crops by the 1960's. The earliest record for *A. ater* in British Columbia was 1945 near New Westminster and the species was a serious pest in British Columbia by 1962. The paper is inconsistent in describing the impact of this species on the native banana slug *Ariolimax columbianus* stating in one section of the paper that it does not seem to impact the native species while in another section noting that the exotic species now dominates in sites previously dominated by *A. columbianus.*

Rollo, C. D. and W. G. Wellington. 1978. Intra- and inter-specific agonistic behavior among terrestrial slugs (Pulmonata: Stylommatophora). Canadian Journal of Zoology 57: 846-855.

Authors' abstract: Intra- and inter-specific aggression among slugs varied greatly with the species. Among pugnacious species only the mature animals displayed such behavior. Aggressiveness varied seasonally, with the most fighting occurring during summer when hot, dry weather reduced the number of shelters and availability of food. No fighting occurred in winter, when formerly aggressive conspecifics frequently aggregated. Large aggressors caused smaller conspecifics as well as other species to avoid shelters they occupied. Since slugs selected shelters closest to food, agonistic behavior improved the chances of acquiring shelter and food simultaneously.

Roth, B. and T. A. Pearce. 1984. *Vitrea contracta* (Westerlund) and other introduced land mollusks in Lynnwood, Washington. The Veliger: 27(1):90-92.

Author's abstract: The introduced land mollusk species *Vitrea contracta* (Westerlund, 1871), *Cionella lubrica* (Muller, 1774), *Oxychilus alliarius* (Miller, 1882), *Arion rufus* (Linnaeus, 1758), *Arion subfuscus* (Draparnaud, 1805), *Limax maximus* Linnaeus, 1758, and *Deroceras reticulatum* (Muller, 1774) occur in Lynnwood, a suburb of Seattle, Washington. All are natives of Europe and introduced and dispersed through human agency, probably including the use of leaves from other lots as mulch.

Royal British Columbia Museum. 2002. Terrestrial Gastropods of the Columbia Basin, British Columbia. Website: livinglandscapes.bc.ca/molluscs/arionidae.html Accessed: October 2, 2002.

The website provides comprehensive descriptions (including identification keys), habitat and distribution information for introduced and native slug species of the Columbia Basin. Black slugs are identified as *Arion rufus* and described as a large slug ranging in colour from brown to black to shades of red or yellow. The respiratory hole is in the front of the mantle and the tubercles are large and coarse. The site also describes mantle texture (granular), lack of a keel and the colouring of the foot fringe, sole of foot and mucus. The site describes the difficulty in distinguishing between the species *Arion rufus* and *A. ater* without dissection. The lack of proper identification of this species has led to incomplete distribution information; black slugs are only recorded from two locations in the province (Nakusp and Revelstoke) even though black slugs are described as being widespread in southern British Columbia.

Saucy, F., J. Studer, V. Aerni and B. Schneiter. 1999. Preference for acyanogenic white clover (*Trifolium repens*) in the vole *Arvicola terrestris*: I. Experiments with two varieties. Journal of Chemical Ecology 25 (6): 1441-1454.

Authors' abstract: We report experimental results showing that, under both laboratory conditions as well as in outdoor enclosures, the fossorial vole *Arvicola terrestris* preferentially feeds on acyanogenic white clover (*Trifolium repens*) when offered the choice between two varieties (Ladino and Aran) differing highly in their content in cyanogenic glycosides. We also observed that the voles adapted their diet and reduced their relative consumption of the cyanogenic variety during experiments conducted for two to three weeks in outdoor enclosures as compared to shorter tests conducted for 48 hr

in laboratory cages. In addition, we report a similar preference for the acyanogenic Ladino variety for the slugs *Arion ater* and *A. subfuscus*.

Scheidel, U. and H. Bruelheide. 1999. Selective slug grazing on montane meadow plants. Journal of Ecology 87 (5): 828-838.

Authors' abstract: 1. In order to test the hypothesis that the sensitivity of field populations of the rare perennial *Arnica montana* to slug attack is due to its high palatability, we compared *Arnica* leaves and seedlings with 20 other plant species in greenhouse food choice experiments. 2. When slugs were given a choice of mature plant leaf discs, *Arnica montana* was one of the food plants most preferred by all three slug species tested. *Arion lusitanicus, Arion subfuscus* and *Deroceras agreste* differed only slightly in their preference for particular plant species. Greater differences in acceptability were observed when parameters other than area consumed were evaluated. *Arnica* seedlings displayed similarly high susceptibility to slug grazing. 3. Morphological factors influence mollusc feeding behaviour, with epidermal cell wall thickness and hairiness related to acceptability. Removing the hairs by shaving the leaves increased the acceptability of one species, *Centaurea jacea*. 4. Leaves of undamaged *Arnica montana* plants were preferred to leaves of plants that had been predamaged by partial leaf removal, suggesting that there is an inducible component of chemical defence. 5. We discuss our results in comparison with other food choice experiments and attempt to extrapolate them to mollusc/plant interactions under field conditions.

Schinz. 2002. *Personal communication.* Evergro Canada Incorporated. Vancouver, BC.

The nematodes used for biological control of slugs in the United Kingdom are not native to North America and are not available commercially here. They are sold abroad by the trade name Biobest.

Simms, L. C., C. E. Mullins and M. J. Wilson. 2002. Seed dressings to control slug damage in oilseed rape. Pest Management Science58 (7): 687-694.

Authors' abstract: Slugs are major pests of oilseed rape that are poorly controlled by conventional bait pellets. A series of laboratory experiments investigated the potential of seed-dressings to control slug damage in this crop. Four compounds: metaldehyde, methiocarb, cinnamamide and 3,5-dimethoxycinnamic acid (DMCA) were tested at a range of doses for phytotoxicity and ability to reduce damage by *Deroceras reticulatum* (Muller). Metaldehyde and methiocarb were not phytotoxic at any doses, whereas all doses of cinnamamide and DMCA were. All compounds reduced slug damage, but metaldehyde and methiocarb consistently performed better than cinnamamide and DMCA. Metaldehyde and methiocarb seed-dressings were compared with baited pellets containing the same active ingredients at recommended field doses. The seed-dressings protected plants from damage by *D. reticulatum* and *Arion subfuscus* (Draparnaud) as well as, or better than, baited pellets. We therefore recommend that metaldehyde and methiocarb should be field-tested as seed dressings to control slugs in oilseed rape.

Speiser, B. 1999. Molluscicidal and slug-repellent properties of anaerobically digested organic matter. Annals of Applied Biology 135 (1): 449-455.

Author's abstract: Slug problems in arable crops and vegetables have increased drastically during the past few decades. Observations on slug damage to oilseed rape suggested that fresh, anaerobically digested organic material from a biogas production plant is molluscicidal. To find out whether digested matter can be used for the control of agricultural pest slugs, a series of experiments were carried out. The laboratory experiments demonstrated strong mollusc repellent and molluscicidal effects of digested organic matter against the three most important pest slugs of Switzerland, *Arion lusitanicus, A. distinctus* and *Deroceras reticulatum*. The effects were restricted to fresh digested matter and were rapidly lost when the material was stored, and also after application in the field. In the field experiment, fresh digested matter greatly reduced slug damage to lettuce in comparison with the untreated plots. At present, the chemical nature of the molluscicidal compound(s) in digested matter is unknown, but environmental pollutants such as heavy metals can be ruled out. Current research aims at a new formulation which is easier to apply and has a longer-lasting molluscicidal or slug-repellent effect, and at optimizing the dosage and number of applications.

Speiser, B., D. Glen, S. Piggott, A. Ester, K. Davies, J. Castillejo and J. Coupland. 2001a. Slug Damage and Control of Slugs in Horticultural Crops. European Union Funded Research Project. Website: www.slugcontrol.iacr.ac.uk/publications.html Accessed: October 24, 2002.

Speiser *et al.* categorize all pest slugs into four categories based on their habitat and ecology. Black slugs are classified as a "large roundback slug", a group which is active above the ground at temperatures warmer than 10 °C. Speiser *et al.* illustrate the damage caused by slug pests and summarize options for slug control in integrated crop management (ICM) programs and organic horticulture in Europe. Cultural practices that are listed that may be appropriate for Garry oak ecosystems include: cultivating the soil to reduce habitat thereby freezing slugs and eggs and preventing slug movement, optimizing fertilization and sowing dates to ensure vigorous seedlings and removing adjacent slug habitat. The effectiveness of metaldehyde and carbamate chemical controls is outlined but these produces should not be used in sensitive Garry oak ecosystems. Recently developed iron phosphate pellets are less toxic but must be applied at a higher does than other pellets to be effective. Iron phosphate is more appropriate for Garry oak ecosystems. Nematodes are natural slug predators that are being mass-cultured as a biological control used in organic horticulture in Europe. The species discussed is not available in North America. Beer traps and slug fences are listed as useful controls in small areas and home garden. Hand collection is labour intensive but may be useful in small areas in home gardens and other areas that can be protected by slug fences.

Speiser,B., J. G. Zaller and A. Neudecker. 2001b. Size-specific susceptibility of the pest slugs *Deroceras reticulatum* and *Arion lusitanicus* to the nematode biocontrol agent *Phasmarhabditis hermaphrodita.* BioControl 46 (3): 311-320.

Authors' abstract: The nematode *Phasmarhabditis hermaphrodita* is a commercially available biocontrol agent against slugs. This product is especially interesting for use in organic farming, where products containing metaldehyde or carbamates cannot be used for controlling pest slugs. We investigated the potential of *P. hermaphrodita* for the control of the pest slugs *Deroceras reticulatum* and *Arion lusitanicus*. These two species are the most harmful slug pests in Switzerland. At different times of the year, we collected slug specimens of different weight and assessed their susceptibility to *P. hermaphrodita* in the laboratory. Batches of five slugs were subjected to five different doses of nematodes plus an untreated control and replicated three times. During six weeks, feeding and survival of the slugs were recorded. *D. reticulatum* was strongly affected by increasing nematode doses, irrespective of the slugs' body weight. In small specimens of *A. lusitanicus*, feeding and survival were strongly affected by the nematodes, while larger specimens remained almost unaffected. Because *A. lusitanicus* has an asynchronous development in Switzerland, it seems difficult to control the entire population with a single nematode application. To what extent nematodes will be used in practice for slug control depends on their effectivity against the pest slugs of major importance, on the longevity of the molluscicidal effect and on the price of nematodes.

Symondson, W. O. C. 1997. Does *Tandonia budapestensis* (Mollusca: Pulmonata) contain toxins? Evidence from feeding trials with the slug predator *Pterostichus melanarius* (Coleoptera: Carabidae). Journal of Molluscan Studies 63 (4): 541-545.

Author's abstract: Slugs are known to be killed and consumed by a range of invertebrate and vertebrate predators in the field. Carabid beetles (Coleoptera: Carabidae) in particular are major natural enemies of slugs, and have been shown to be capable of controlling certain species in a crop environment. This paper reports experiments to investigate the effects, on the carabid *Pterostichus melanarius*, of feeding on the milacid slug *Tandonia budapestensis*. The slugs proved to be toxic, 50% of the beetles dying within two days. Mortality of beetles fed on two other species of slug, *Deroceras reticulatum* and *Arion distinctus*, was not significantly different from that for beetles fed upon a control prey (*Calliphora vomitoria*). These results represent the only known case of a European slug proving to be toxic to potential predators, and is one of a very small number of reported instances of possible toxicity amongst terrestrial gastropods. The possibility that the orange line down the dorsal keel of *T. budapestensis* may act as warning coloration to birds is discussed.

Symondson, W. O. C., D. M. Glen, C. W. Wiltshire, C. J. Langdon and J. E. Liddell. 1996. Effects of cultivation techniques and methods of straw disposal on predation by *Pterostichus melanarius* (Coleoptera: Carabidae) upon slugs (Gastropoda: Pulmonata) in an arable field. Journal of Applied Ecology 33 (4): 741-753.

Authors' abstract: 1. Interactions between the polyphagous carabid predator *Pterostichus melanarius* (Illiger) and slugs were investigated from July to September 1992, before and after harvesting a rape crop. The experimental site comprised a long-term field study of the effects of different forms of cultivation (ploughing vs. non-inversion tillage), and methods of straw disposal (baling vs. incorporation of chopped straw) upon invertebrate

populations and crop yields. Direct-drilling was also included as a no-tillage base-line. 2. Beetles (total 2078) were collected by pitfall trapping twice weekly. Each beetle was dissected, and its crop contents weighed and tested by enzyme- linked immunosorbent assay (ELISA) to determine the concentration and quantity of slug haemolymph it contained. Slugs (*Deroceras reticulatum* (Muller) and *Arion intermedius* Normand) were extracted from soil samples by gradual flooding, to estimate both numbers and biomass. 3. Significantly more *P. melanarius* were trapped in direct-drilled plots than in the tilled treatments. Within the tilled treatments, greater numbers of beetles were trapped where straw was incorporated by non-inversion tillage. 4. Crop weights were significantly greater in beetles from direct-drilled plots than in those from tilled treatments, as were both the concentrations and quantities of slug haemolymph they contained. Overall, apprxeq 84% of beetles contained slug remains. 5. Greatest concentrations and quantities of slug remains were detected prior to the disposal of rape residues at the end of July, by baling or shallow incorporation in the soil. Cultivation had both short- and long-term effects upon the proportion of the diet of the beetles that was slugs. 6. Slug biomass declined following disposal of rape residues and it was only after this time that significant treatment differences emerged. 7. Positive relationships were found between the biomass of slugs in the soil and numbers of beetles trapped, the proportion of the beetles' diet that was slugs and the quantities of slug haemolymph in beetle crops. 8. Our results strongly suggest aggregation of *P. melanarius* to areas of high slug biomass in the soil and preferential feeding in such areas upon slugs. As this carabid is probably the commonest large predatory beetle in arable crops in Britain, these results clearly identify *P. melanarius* as a potentially important slug control agent.

Theenhaus, A. and S. Scheu. 1996a. The influence of slug (*Arion rufus*) mucus and cast material addition on microbial biomass, respiration, and nutrient cycling in beech leaf litter. Biology and Fertility of Soils 23 (1): 80-85.

Authors' abstract: We investigated the effects of slug (*Arion rufus* L.) mucus and cast material on litter decomposition, nutrient mobilization, and microbial activity in two laboratory experiments: (1) Slug mucus and cast material was added to beech leaf litter (*Fagus sylvatica* L.), and leaching of N and P and CO-2 production in microcosm systems were measured during 77 days of incubation; (2) mucus was added to beech leaf litter, and basal respiration, microbial biomass (substrate-induced respiration), specific respiration (qO-2), microbial growth ability after C, CN, CP, and CNP amendment, and lag time (time between CNP addition and start of exponential increase in respiration rate) were measured during 120 days of incubation. Leaching of N and P from beech leaf litter was significantly increased in treatments with mucus or faecal material of *A. rufus*. Following day 3, slug mucus increased nitrification processes. Mucus addition to beech leaf litter also increased basal respiration and microbial biomass significantly. In contrast, specific respiration was not significantly affected by mucus addition, and generally declined until day 60 but then increased until day 120. Nutrient amendments indicated that between days 1 and 30, N was available for microbial growth in litter with mucus but not in control litter. Generally, the lag time in beech leaf litter with added mucus was shorter than in control litter. Lag times generally increased with age, indicating dominance of slow-growing microbial populations at later stages as a consequence of

depletion of easily available C resources and nutrients. We conclude that C, N, and P cycling is accelerated by slug activity.

Theenhaus, A. and S. Scheu. 1996b. Successional changes in microbial biomass, activity and nutrient status in faecal material of the slug *Arion rufus* (Gastropoda) deposited after feeding on different plant materials. Soil Biology and Biochemistry 28 (4-5): 569-577.

Authors' abstract: Microbial biomass and activity in casts of the slug *Arion rufus* L. of different ages (0 to 160 days) deposited after feeding on beech leaf litter (*Fagus sylvatica* L.) and fresh leaves of *Allium ursinum* L. and *Mercurialis perennis* L. were investigated. The following parameters were determined: basal respiration (O-2-consumption), microbial biomass (SIR, substrate-induced respiration method), microbial growth ability after C (glucose), CN, CP and CNP amendment, specific respiration (qO-2), lag time (time between CNP addition and start of exponential increase in respiration rates) and decomposition time (time required to achieve the maximum respiration rate following CNP addition). Basal respiration and microbial biomass initially increased but then decreased in ageing cast materials. The increase in basal respiration usually predated that in microbial biomass. Basal respiration in cast materials of beech leaf litter, *A. ursinum* leaves and *M. perennis* leaves was at a maximum at day 5 (521 mu-l O-2 g-1 dry wt h-1), day 1 (1420 mu-l O-2 g-1 h-1) and days 1, 2 and 5 (average 1270 mu-l O-2 g-1 dry wt h-1), respectively. Microbial biomass (C-mic) for the respective materials was at a maximum at day 5 (29.9 mg C-mic g-1 dry wt), day 2 (64.4 mg C-mic g-1) and day 1 (83.1 mg C-mic g-1). Specific respiration of cast materials deposited after feeding on beech leaf litter was exceptionally high at day 1 (43.4 mu-l O-2 mg-1 C-mic h-1) and decreased with age. Specific respiration of cast materials deposited after feeding on *A. ursinum* leaves also significantly decreased with age but no significant trend occurred in cast materials of *M. perennis* leaves. In cast materials of beech leaf litter of an age of 1 and 2 days C was the primarily limiting element and N and P were available for microbial growth. Between days 5 and 20, C-amended microorganisms were limited by N and CN-amended microorganisms were limited by P. Following day 40 P was mobilized in ageing cast materials of beech leaf litter. In cast materials deposited after feeding on *A. ursinum* and *M. perennis* leaves, microbial growth usually was limited by C. Requirement for P by microorganisms in 4- and 12-h-old C-amended cast materials was high. This P requirement decreased in ageing cast materials indicating P mobilization. In later successional stages sufficient P supply but a strong N demand by microorganisms occurred, which presumably was caused by immobilization of N in ageing cast materials. Decomposition time in cast materials deposited after feeding on beech leaf litter was shorter than in intact leaf litter. Lag time and decomposition time increased with age of casts produced after feeding on each of the food materials but remained almost constant in ageing beech leaf litter. The increase was more pronounced in *A. ursinum* and *M. perennis* casts than in casts deposited after feeding on beech leaf litter. Considering Piankas r/K-concept the prolongation of the lag and decomposition times in ageing casts and the decline in specific respiration in casts deposited after feeding on beech leaf litter and leaves of *A. ursinum* with age indicate successional replacement of r-strategists by K-strategists in ageing casts. According to Grime's theory of life strategies, the short lag and

decomposition times in early successional stages in casts indicate dominance of ruderal populations.

Theenhaus, A., S. Scheu and M. Schaefer. 1999. Contramensal interactions between two collembolan species: Effects on population development and on soil processes. Functional Ecology 13 (2): 238-246.

Authors' abstract: 1. In the laboratory, a microcosm experiment was set up to study (1) the interaction between, two collembolan species *Onychiurus furcifer* (Boerner) and *Heteromurus nitidus* (Templeton) during 24 weeks of incubation; (2) the influence of slug (*Arion rufus* L.) cast material on the outcome of this interaction; and (3) the influence of collembolan activity on microbial biomass, respiration and nutrient mobilization. 2. The CO2 production was monitored every other week and NH4+, NO3- and PO43- contents of leachates were determined every 4 weeks. After 12 and 24 weeks of incubation, the number of collembolans, basal respiration (O2 consumption), microbial biomass (substrate-induced respiration method), specific respiration (qO2) and the content of NH4+, NO3- and PO43- in soil were determined. 3. Generally, the number of collembolans in microcosms with cast material exceeded that of microcosms without cast material considerably on average by factors of 20 and 26 for *O.furcifer* and *H. nitidus*, respectively. This increase was attributed to the additional food supply provided with the cast material. Numbers of collembolans declined during the experiment. 4. At both sampling dates, the presence of *H. nitidus* led to a reduction in the number of *O. furcifer*, whereas *H. nitidus* benefited from the presence of *O. furcifer*. Either trophic or non-trophic mechanisms, or both, may have caused this interaction (contra-mensalism, sensu Arthur & Mitchell 1989). 5. Both collembola species caused a decrease in microbial respiration, decomposition rates and tentatively also microbial biomass at high densities, whereas at low densities microbial respiration was stimulated while decomposition rates and microbial biomass remained unaffected. These effects were more pronounced for *O. furcifer* than for *H. nitidus*. 6. In treatments with cast material N-mobilization was increased by collembolan activity.

Voss, M. C., B. Ulber and H. H. Hoppe. 1998. Impact of reduced and zero tillage on activity and abundance of slugs in winter oilseed rape. Zeitschrift fuer Pflanzenkrankheiten und Pflanzenschutz 105 (6):632-640.

Authors' abstract: The impact of reduced and zero tillage on activity and abundance of slugs in winter oilseed rape has been investigated in a field trial from autumn 1995 till autumn 1997. In this trial, non-inversive tillage and direct drilling were compared with conventional ploughing. Plots were split up in untreated and molluscicide-treated with two applications of metaldehyde (3 kg ha-1). Slug activity was monitored by slug mats (refuge traps), and slug abundance was assessed by fenced beer traps as well as fenced slug mats (defined area traps). Sampling commenced at drilling in late August and was carried out for 10 weeks each year. *Deroceras agreste, D. reticulatum, Arion distinctus* and *A. fasciatus* were the slug species commonly found in our field trial. Reduced and especially zero tillage increased activity and abundance of all species, however, with varying extent in different years. No long-term effect of the molluscicide could be

detected, but four of six applications were followed by a 2 to 3 week period of lower slug activity in treated plots. Therefore, growers should monitor slug activity using slug mats or comparable methods near sowing date to be aware of a potential risk of slug damage to the crop as early as possible.

Westerbergh, A. and A. B. Nyberg. 1995. Selective grazing of hairless *Silene dioica* plants by land gastropods. Oikos 73 (3):289-298.

Authors' abstract: *Silene dioica* (Caryophyllaceae) has evolved different morphotypes that vary in hairiness in different habitats in the Swedish mountains. A hairy form, var. *serpentinicola* and a hairless (glabrous) form, var. *smithii* grow on serpentine, i.e. a dry soil rich in heavy metals. Var. *lapponica* is a densely hairy morphotype on subalpine meadows. Crosses between these varieties showed that glabrousness has a simple Mendelian inheritance and that glabrousness is determined by a recessive allele. The crosses further suggested that the recessive allele has been present in the original population that invaded the mountain area. Glabrous plants have, however, never been found on subalpine meadows, even though an earlier study has shown that gene flow is relatively common among serpentine and nearby meadow populations. In addition to the genetic background of glabrousness, we studied the grazing on glabrous *smithii* and hairy *serpentinicola* and *lapponia* plants by the slugs *Arion fasciatus* and *Arion subfuscus* and the snail *Arianta arbustorum* in greenhouse and in nature. *Arion* slugs, abundant on subalpine meadows, preferred glabrous plants and, in particular, *A. fasciatus* consumed high amounts of *S. dioica*. *Arianta* snails, however, consumed irrespective of morphotype. The selective behaviour was seen both at the seedling stage and the adult plant stage, *Arion* slugs were more choosy when they were given a choice of glabrous *smithii* and densely hairy *lapponica* plants then when they were served *smithii* and the less hairy variety *serpentinicola*. This study implies that the *Arion* slugs are important agents of selection on subalpine meadows. The selective grazing seems to counteract the flow of the recessive allele that determines glabrousness, from serpentine into meadow populations. Gastropods are rare in the dry serpentine habitat. The evolution of a distinct glabrous morphotype on serpentine is therefore rather due to relaxation of selection than to adaptation to serpentine stress.

Wilson, M. J., D. M. Glen, S. K. George and L. A. Hughes. 1995. Biocontrol of slugs in protected lettuce using the rhabditid nematode *Phasmarhabditis hermaphrodita.* Biocontrol Science and Technology 5 (2): 233-242.

Authors' abstract: In two experiments, the rhabditid nematode *Phasmarhabditis hermaphrodita*, a parasite of slugs, was cultured in vitro and applied as a drench to soil at four dose rates (3 times 10-8, 1 times 10-9, 3 times 10-9 and 1 times 10-10 ha-1) 1 or 4 days before planting lettuce seedlings in a polythene tunnel. The effects of the four nematode doses on slug damage during the first 3 weeks after planting and on the numbers of slugs found within and below lettuce plants at harvest were measured. Results were then compared with untreated plots and with plots where methiocarb pellets were applied at the recommended field rate. In the first experiment, methiocarb pellets significantly reduced the percentage of plants damaged by slugs, but the nematode did

not. In the second experiment, methiocarb pellets and the second highest dose of nematodes significantly reduced the percentage of plants damaged by slugs. The different effect of the nematode in the two experiments may have resulted from differences in the timing of nematode application and/or differences in the pattern of slug damage between experiments. At the end of the first experiment, the highest two doses of nematodes and methiocarb pellets had significantly reduced the number of slugs found within lettuce plants at harvest and on the soil surface below the plants. At the end of the second experiment, analysis of variance showed no significant effects of any treatment on slug numbers or biomass, but regression analysis showed significant negative relationships between nematode dose and total slug numbers, numbers of *Arion ater agg.* and biomass of *Deroceras reticulatum*. In both experiments, increasing nematode dose significantly reduced the numbers of slugs found contaminating the harvested lettuce. At the end of the second experiment, the mean weight of individuals of *A. ater agg.* increased with rising nematode dose.

Wilson, M. and R. Gaugler. 2002 Biological control: A guide to natural enemies in North America. Website maintained by Cornell University: www.nysaes.cornell.edu/ent/biocontrol/pathogens/phasmarhabditis_h.html. Accessed: October 24, 2002.

The website documents the experimental use of *Phasmarhabditis hermaphrodita* (nematode) as a biological control for slugs in European horticultural crops. The site describes the appearance, habitat and life cycle of the nematode. The nematode is effective against several *Arion* species and is comparable to methiocarb pellets as a control. It is only available commercially in the United Kingdom.

Wilson, M. J., L. A. Hughes, D. Jefferies and D. M. Glen. 1999. Slugs (*Deroceras reticulatum* and *Arion ater agg*.) avoid soil treated with the rhabditid nematode *Phasmarhabditis hermaphrodita.* Biological Control 16 (2): 170-176.

Authors' abstract: A series of experiments was done to determine whether the pest slugs *Deroceras reticulatum* and *Arion ater agg.* (Mollusca: Gastropoda: Stylommatophora) could detect the presence of and avoid soil treated with the parasitic nematode *Phasmarhabditis hermaphrodita* (Nematoda: Rhabditidae). One-half of the surface area of moist soil in experimental boxes was treated with infective juveniles of *P. hermaphrodita* at a density of 120/cm2. The other half of each box was left untreated. Five discs of Chinese cabbage leaf were placed in each half of each box. Slugs (*D. reticulatum* or *A. ater agg*.) were added to each box and food consumption and resting sites were recorded over a 12-day period. Both slug species were more likely to rest and feed on untreated soil than on nematode-treated soil. A series of boxes was also prepared with one-half untreated and the remaining half treated with 1, 4, 12, 38, or 120 nematodes/cm2. Slugs were less likely to rest or feed in the treated half of boxes containing 38 or 120 P. hermaphrodita/cm2 but showed no preference between the untreated and the nematode-treated soil at lower nematode densities. A final experiment showed that there was little movement of *P. hermaphrodita* from the treated half to the untreated half of each box.

Winder, O., C. Friedrich, N. D. Jumbam, H. Griengl and T. Kartnig. 1996 (1997). The effects of some plant saponins on *Arion lusitanicus* (Gastropoda: Arionidae) in laboratory experiments. Zoologische Beitraege 37 (2): 185-197.

Authors' abstract: Contact to closed barriers consisting of ground seeds of *Aesculus hippocastenum* or *Koelreuteria paniculata* or ground roots of *Primula elatior* as well as single particles of these seeds and roots were avoided by *Arion lusitanicus*. Dried crude extracts of *Aesculus* seeds as well as *Koelreuteria* seeds or *Primula* roots put on glass-plates were also not crossed by these slugs. Filter paper prepared with aqueous solutions of the isolated plant saponins and sodium chloride proved to be more or less deterrent against *Arion lusitanicus*. In contact toxicity tests the lyophilization products obtained from extracts of *Koelreuteria paniculata* seeds, *Primula elatior* roots and the saponins aescin and primulic acid caused comparable mortality to *Arion lusitanicus*. The saponin mixture from *Koelreuteria paniculata* seeds was less effective than the lyophilization product, which possibly indicates the existence of one or some additional active substances in these seeds. Baits containing aescin or *Koelreuteria paniculata* saponins were partially ingested but did not damage *Arion lusitanicus*, baits with primulic acid were refused.