Management of the invasive alien snail *Cantareus aspersus* on conservation land

DOC SCIENCE INTERNAL SERIES 31

Gary M. Barker and Corinne Watts

Published by
Department of Conservation
P.O. Box 10-420
Wellington, New Zealand

DOC Science Internal Series is a published record of scientific research carried out, or advice given, by Department of Conservation staff, or external contractors funded by DOC. It comprises progress reports and short communications that are generally peer-reviewed within DOC, but not always externally refereed. Fully refereed contract reports funded from the Conservation Services Levy are also included.

Individual contributions to the series are first released on the departmental intranet in pdf form. Hardcopy is printed, bound, and distributed at regular intervals. Titles are listed in the DOC Science Publishing catalogue on the departmental website http://www.doc.govt.nz and electronic copies of CSL papers can be downloaded from http://csl.doc.govt.nz

ISSN 1175-6519

ISBN 0-478-22206-8

This is a client report commissioned by Northland Conservancy and funded from the Unprogrammed Science Advice fund. It was prepared for publication by DOC Science Publishing, Science & Research Unit; editing and layout by Geoff Gregory. Publication was approved by the Manager, Science & Research Unit, Science Technology and Information Services, Department of Conservation, Wellington.

CONTENTS

Management of the invasive alien snail *Cantareus aspersus* on conservation land

Gary M. Barker and Corinne Watts

Landcare Research, Private Bag 3127, Hamilton

ABSTRACT

There is concern about the possible adverse effects of the invasive European brown garden snail *Cantareus aspersus* (Müller) on indigenous biodiversity, particularly in the coastal environments of Northland, where the species is particularly prevalent. This report sets out the strategic options and methodologies for possible management of *C. aspersus* on conservation land. It draws on published information relating to the biology of *C. aspersus*, briefly reviews mollusc pest management and, in particular, control with molluscicides, and gives consideration to possible non-target effects of control treatments on the special indigenous fauna of the region. Conclusions are derived about development and implementation of suitable management procedures for *C. aspersus* in island and mainland ecosystems in Northland. Opportunities for improvement of current molluscicide bait technologies and research needs, with specific reference to control of *C. aspersus* in these ecosystems, are identified.

Keywords: *Cantareus aspersus*, brown garden snail, molluscs, invasive species, pest control, molluscicides, environmental impacts, coastal biodiversity, Northland, New Zealand.

This paper may be cited as:
Barker, G.M.; Watts, C. 2002. Management of the invasive alien snail *Cantareus aspersus* on conservation land. *DOC Science Internal Series 31*. Department of Conservation, Wellington. 30 p.

1. Introduction

The alien terrestrial mollusc fauna of New Zealand currently comprises 30 species, representing 15 families. These species originate in Europe, North America, or the Pacific, although some might have been introduced secondarily from populations first naturalised elsewhere. The species established in New Zealand are those associated with human development of crops in their native range, those with great propensity for passive dispersal, and those that have been widely distributed through human commerce.

A number of these introduced molluscs occur widely in New Zealand indigenous ecosystems and constitute a range of threats to our indigenous biodiversity. *Cantareus aspersus* (Müller) (formerly *Helix aspersa*) (brown garden snail) (Mollusca: Gastropoda: Stylommatophora: Helicidae) is among the most conspicuous and abundant of these. It is particularly common in coastal scrubland and dune systems of northern New Zealand, both on the mainland and on many islands (Barker 1999; Brook 2000). Many of these systems include sites of high conservation value due to their low representation in the protected natural areas network and/or the presence of locally endemic species in the flora and fauna. There is growing concern about the adverse effect of *C. aspersus* on the indigenous flora and fauna in these systems. The potential effects are multiple.

Herbivory

Through selective feeding on foliage of herbaceous plants and the seedlings of a range of species, *C. aspersus* represents a significant threat to natural processes of vegetation regeneration. This herbivory has already been shown to be a particularly important threat to *Clianthus puniceus* (G. Don) Sol. Ex Lindl. (Shaw & Burns 1997) and may be significant for several other rare/threatened coastal species. Research in progress (J. Iglesias & G.M. Barker, unpubl.) indicates that seedlings of *Arthropodium cirrhatum* (Forst.) Br., *Sophora* spp., *Pseudopanax arboreus* (Murray) Philipson, *Cordyline* spp., *Dysoxylum spectabile* (Forst.) Hook, *Hedycarya arborea* Forst. & Forst., *Rhopalostylis sapida* Wendl. & Drude, and *Phormium* spp. are particularly susceptible to *C. aspersus* herbivory. *Cantareus aspersus* has been shown to feed on a wide range of vascular plants (e.g. Iglesias & Castillejo 1999) and to have importance in structuring plant communities (e.g. Oliveira Silva 1992).

Resource competition

By virtue of its abundance and biomass, *C. aspersus* may monopolise the plant litter and understorey herbaceous food resources critical to some sympatric indigenous mollusc species. Information on this competitive interaction is at present lacking. While there are species differences in niche due to microclimatic preferences, behavioural repertoires and functional morphologies (e.g. shell shape, radular dentition), there is likely to be strong dietary overlap with both detritivorous (primarily Charopidae and Punctidae) and herbivorous (primarily bulimulid *Placostylus*) indigenous species. Sherley et al.

(1998) discuss the possible competition between sympatric *C. aspersus* and *Placostylus ambagiosus* Suter.

Fouling of the habitat

By virtue of its abundance and biomass, *C. aspersus* deposits substantial quantities of mucus and faecal material in occupied habitats. Faeces and mucus carry chemicals that can modify the behaviour of both conspecifics and other species. Information on this type of interaction is at present lacking for *C. aspersus* in New Zealand ecosystems, but has been demonstrated as important in the population dynamics of co-occurring species elsewhere (e.g. Cameron & Carter 1979; Dan & Bailey 1982).

Parasite and disease transmission

Many of the introduced terrestrial molluscs brought with them to New Zealand a range of parasites, including mites, ciliate protozoa, microsporidia, and nematodes (Barker 1993; G.M. Barker in prep.). With increasing contact between the alien and indigenous species, there is potential for transmission of these parasites and pathogens to our indigenous fauna. This transmission has already occurred in the case of the parasitic mite *Riccardoella limacum* (Schrank) in urban areas (Barker & Ramsay 1978) and in Egmont National Park (G.M. Barker, unpubl.). *Cantareus aspersus* provides a reservoir of *Riccardoella* that is likely to infest sympatric indigenous species.

Predation pressure

Cantareus aspersus may constitute a significant food resource for mammalian and avian predators, promoting high local abundance of these predators and increasing probability of their feeding on sympatric indigenous molluscs. There is ample evidence of the inclusion of *C. aspersus* and indigenous molluscs in the diet of introduced mammalian and avian predators operating in natural ecosystems (Ogle 1979; Anderson et al. 1984; Sherley et al. 1998; Parrish et al. 1995), although at present there are no demonstrated links between predation on *C. aspersus* and increased vulnerability in indigenous species.

While there is habitat overlap with a wide range of indigenous mollusc species, of greatest concern is the interaction with locally endemic species, and in particular, with those considered endangered (e.g. *Placostylus ambagiosus*; *Succinea archeyi* Powell (Succineidae)).

1.1 OBJECTIVES

This report sets out the strategic options and methodologies for possible management of *C. aspersus* on conservation land. It draws on published information relating to the biology of the species, mollusc pest management and in particular control with molluscicides, and gives consideration to possible non-target effects on the special indigenous fauna of the Northland region.

The objectives of this report are to:

- provide details of control methodology that would enable eradication of *C. aspersus* from islands of up to 35 ha;

- provide details of control methodology that would enable sustained control of *C. aspersus* to low levels at mainland sites;
- describe any known measures that should be taken to minimise impact of poisoning on native herbivorous snails.

2. Principles of mollusc pest management

Herbivorous molluscs are significant pests of cultivated plant species in many regions of the world, affecting ornamental, horticultural, arable, pastoral and silvicultural crop species. Reflecting their economic status, there has been substantial research and development effort on terrestrial mollusc control. Furthermore, several species have proved to be highly invasive and disruptive in areas of conservation interest. Consequently, molluscs represent some of the most thoroughly studied pest species, with a substantive body of literature relating to population and behavioural ecology, and control. Yet molluscs are also among the most intractable of pests.

There is a vast literature specifically relating to *C. aspersus*, essentially because this species is one of the helicids favoured as an edible snail in Europe and has been harvested from natural populations and 'farmed' in captivity for centuries. It has been introduced to most temperate regions of the world and is now widely recognised as a pest in gardens and plantation crops such as vineyards and citrus.

2.1 CONTROL OPTIONS

2.1.1 Biological control

There has been much interest in biological control approaches to pest mollusc management. A large number of natural enemies of molluscs are known, with a voluminous, albeit widely dispersed, literature. Recorded enemies include: pathogenic bacteria, fungi, and viruses; parasitic protozoa and microsporidia; parasitoid and predatory Sciomyzidae; predatory molluscs, flatworms and arthropods; and predatory vertebrates, including amphibians, reptiles, birds, and mammals. Some of these records relate to *C. aspersus*. Most natural enemies of molluscs have proved not to be host-specific and therefore are not amenable to use in control programmes where effects on non-target species are of concern. To date, no natural enemy specific to *C. aspersus* is known.

There have been relatively few classical biological control programmes for pest mollusc species. The most publicised refers to attempts to control the giant African snail *Achatina fulica* Bowdich (Achatinidae) in Asia and the islands of the Pacific and Indian Oceans. A large range of predatory invertebrates has been employed, including molluscs, planarians, insects and crustaceans. In the main, these control programmes have not controlled *A. fulica* but in many cases have resulted in substantive adverse effects on indigenous mollusc faunas. The most widely publicised of these non-target effects relates to the predatory snail *Euglandina rosea* (de Férussac) (Oleacinidae) (Civeyrel & Simberloff 1996; Cowie 2000; Barker & Efford 2002).

There has been recent interest in inundative biological control approaches. These procedures have primarily focused on the rhabiditid nematode *Phasmarhabditis hermaphrodita* (Schneider) (Morand et al. 2002). This species is native to Europe, but its use in agriculture there is at present constrained by the high cost. The lack of host-specificity negates the potential use of *P. hermaphrodita* outside its native European range, but the development of a commercial product has stimulated renewed search for nematode parasites in faunas elsewhere (e.g. Morand & Barker 1994a, 1994b; Charwat & Davies 1999; Charwat et al. 2000).

2.1.2 Manual control

Hand collection with subsequent destruction of animals is the oldest method of control of pest molluscs (Godan 1983), and has been used effectively in conjunction with chemical methods for management of infestations in agricultural areas (e.g. *Bradybaena ravida* Benson in arable crops in China: Deniu et al. 1996, 2001) and in eradication of incipient infestations of invasive species (e.g. *A. fulica* eradication in Queensland, California, Arizona, and Florida: summarised by Mead 1979; *Cernuella virgata* (da Costa) (Hygromiidae) in Palmerston North and Auckland: J. Richmond, MAF pers. comm.).

Manual removal as a control method has two primary constraints: the high labour costs, and the physical disturbance of the habitat. Both constraints are highest where the species being controlled is small and individuals are therefore difficult to detect in infested habitat. Nonetheless, *C. aspersus* may be efficiently harvested (high proportion located and removed) from some habitats during the summer aestivation period, when the snails occur above the ground, affixed to low vegetation and other rigid structures such as rocks.

2.1.3 Chemical control

Application of pesticides (molluscicides) is today regarded as the most pragmatic approach to control of terrestrial mollusc pests, and there has been extensive research and development of these, although there is renewed interest in non-chemical approaches in response to concerns over adverse environmental effects. In general, screening of chemicals for molluscicidal activity has ‘piggy-backed’ on the development of herbicides and insecticides, core foci of the agrichemicals industry. Delivery of molluscicidal chemicals to target pest populations has primarily focused on bait formulations, and there has been substantial investment in bait technologies by government and commercial agencies in many parts of the world, including New Zealand. In general, other molluscicide formulations, such as sprays and dusts, have proved ineffective in control of field infestations. There are considerable biological imperatives for this, not least the demonstrated remarkably difficult delivery of pesticides to the target molluscan tissues when applied as spray and dust formulations. The mucus extruded on the body surface provides a significant barrier to uptake of pesticides of large molecular weight by molluscs active in treated environments. Both means of control depend on high application rates of active ingredient and they are more indiscriminate in their effects on fauna than bait formulations. Some of the research of molluscicide screening and formulation has been directed specifically to *C. aspersus* or has included this species among a suite of pests evaluated (e.g. Pappas & Carman 1955, 1961; Crowell 1967, 1977; Stringer & Morgan 1969; Morse & Sakovich 1986; del Rivero 1990; Young 1996).

There are three major classes of compounds presently used in control of terrestrial mollusc pests, namely metaldehyde, carbamates, and metal chelates. These classes are represented in the molluscicidal bait formulations registered for use in New Zealand (Table 1).

The molluscicidal effect of metaldehyde is based primarily on its effect on the mucous cells; it causes major disruption of the water balance physiology of the molluscs, resulting in their desiccation (Triebskorn & Ebert 1989). Metaldehyde has a secondary neurotoxic effect, contributing to loss of motor activity (Coloso et al. 1998). This molluscicidal activity is effected both through ingestion and dermal contact (Godan 1983).

The molluscicidal activity of carbamates relates to their disruption of the neurotransmitter cholinesterase (Frain 1982). In molluscs the toxicant causes rapid paralysis and loss of muscle tone (Godan 1983). The principal carbamates used to control terrestrial mollusc pests are carbaryl, isolan, mexacarbate, cloethocarb, methiocarb, and thiodicarb—only the last two are at present registered for use in New Zealand.

The mode of toxicity of metal-containing chelates in molluscs is poorly known at present (Clark et al. 1995), but that of iron EDTA principally involves ferric ion interference with the oxygen uptake by haemocyanin, the respiratory pigment of haemolymph in molluscs. Ingestion of iron chelate does not cause paralysis in molluscs but arrests feeding and kills within 24 hours. Chelates offer advantages over metaldehyde and carbamate products in that the level of mortality is independent of the water relations of the molluscs and thus not

TABLE 1. MOLLUSCICIDAL BAIT PRODUCTS REGISTERED FOR USE IN NEW ZEALAND.*

REG. NO.	PRODUCT NAME	ACTIVE INGREDIENT AND CONC.	PROPRIETOR
P000624	Slug Slam	Metaldehyde 15.0 g/kg	Yates NZ Ltd
P001685	Mesurol Snail & Slug Bait	Methiocarb 20.0 g/kg	Bayer New Zealand Ltd
P003847	Yates Blitzem Granules	Metaldehyde 27.0 g/kg	Yates NZ Ltd
P004161	Slugout	Metaldehyde 18.0 g/kg	Crop Care Holdings Ltd
P004377	Larbait	Thiodicarb 40.0 g/kg	Aventis Cropscience Pty Ltd
P004611	Defender Pellets Snail & Slug Killer	Metaldehyde 15.0 g/kg	Defender (NZ) Ltd
P004833	Dismissal	Thiodicarb 40.0 g/kg	Wrightson Nutrition
P005001	Multicrop Multiguard Snail & Slug Killer	Iron EDTA 90.0 g/kg	Multicrop (NZ) Ltd/ Tui Garden Products Ltd
P005337	McGregor's Snail & Slug Pellets	Metaldehyde 15.0 g/kg	Amalgamated Hardware Merchants

*Information from MAF Agricultural Compounds & Veterinary Medicines Database at www.maf.govt.nz dependent on prevailing environmental moisture conditions (Henderson et al. 1989).

2.2 CONTROL STRATEGIES

Eradication of alien species such as *C. aspersus* is clearly the desired outcome where there is concern about negative impacts on the indigenous biota and ecosystem processes.

Eradication of molluscs is generally not attempted, mainly because most pest-infested areas are surrounded by habitat occupied by pest species and therefore subject to recolonisation by immigration. It is also very difficult to achieve 100% mortality due to differential susceptibility of individuals in populations and, in the case of chemical or manual controls, there are no barriers to rapid population resurgence from survivors, hatch from eggs, and recolonisation by immigration. Thirdly, most plant protection control operations are concerned only with short-term release of plants (usually seedlings) from herbivory. Finally, current biological and chemical molluscicides affect both target and sympatric non-target mollusc species

In mainland systems, eradication of *C. aspersus* will be impossible unless the populations are naturally isolated and barriers to recolonisation (re-invasion) are established as part of the management regime. In isolated populations, eradication is theoretically possible by repeated molluscicide application over several years (reproductive seasons). Experience with other mollusc pest species clearly demonstrates that it is feasible to eradicate incipient infestations (see above), but to date there have been no successful attempts to eradicate long-established populations of invasive mollusc species.

In most situations, management of *C. aspersus* to a predetermined population level is the only pragmatic strategy. A series of molluscicide bait applications over a single season could be used to reduce *C. aspersus* below some predetermined baseline population density, at which the population is subsequently maintained by periodic re-treatment of the site. The frequency of the maintenance treatments is obviously dependent on the projected rates of population increase, which in turn will be a function of population density and age structure after treatment, the intrinsic rate of increase, and immigration. Timing of the maintenance treatments should coincide with the period in which the population comprises only one, uniformly-aged, susceptible cohort—namely that of pre-reproductive adult snails.

2.3 CONTROL SUCCESS WITH MOLLUSCICIDAL BAITS

Under the relatively uniform conditions of agricultural fields, the level of control with a single baiting operation is rarely above 70%, and typically 10–60% (e.g. Frömming & Plate 1952; Godan 1983; Barker et al. 1991). The level of control in more complex, spatially varied ecosystems can be expected to be substantially less. A number of factors influence the efficacy of molluscicide bait treatments.

Susceptibility varies among species

It has been well established that susceptibility to molluscicidal compounds varies among terrestrial mollusc species (i.e. lethal dose varies with species), although comparisons to date have generally been between pest (herbivorous) species (for examples see Godan 1966, 1983; Coupland 1996; Hata et al. 1997; Hussein et al. 1999) and many of the data are confounded by formulation effects. However, a general conclusion would be that *C. aspersus* is highly susceptible to the active ingredients metaldehyde, methiocarb, and thiodicarb, if the bait formulation provides for ingestion of a lethal dose. Young (1996) provides the only published data on the susceptibility of *C. aspersus* to chelates.

Susceptibility varies within species with age, size, and reproductive condition

Age, size and reproductive condition have been demonstrated to have important effects on the susceptibility of individuals within a species (Godan 1983). In some species of terrestrial molluscs, juveniles have been found to be less susceptible to molluscicidal compounds than sexually mature animals (Godan 1983). This effect has been shown for *C. aspersus* exposed to methiocarb (Crowell 1977).

Furthermore, juvenile and adult animals often have different feeding behaviours (demonstrated in *C. aspersus* by Iglesias & Castillejo 1999). In general, adult molluscs are more likely to feed on molluscicidal baits than juveniles.

This differential susceptibility amongst individuals has important implications for effectiveness of control when pulsed applications of molluscicides are made in age-structured populations.

Effectiveness varies with bait formulation

It is generally recognised that bait formulation is as important as the active ingredient in determining the effectiveness of control. Current bait technology relies heavily on plant material, primarily bran, both as the carrier for the active ingredient and as the principal attractant (Frain 1982). However, there is considerable variation among commercial products in the type(s) of plant material and how it is formulated into a pellet. Most products are based on an extruded matrix primarily of wheat bran. The result is considerable variation in product effectiveness against particular mollusc species, even when the baits contain similar concentrations of a particular active ingredient.

Most herbivorous species accept bran-based baits, although there are some species differences (Godan 1983). Wheat bran is at best only slightly attractive to *C. aspersus* (Crowell 1967), and thus control of this species may be sub-optimal with most current molluscicidal bait formulations. Non-herbivorous species are known to exhibit differences in their acceptance of bran-based baits (e.g. Coupland 1996).

It has long been recognised that baits are attractive to molluscs over relatively short distances (c. 5 mm; Hunter & Symonds 1970), and level of control is strongly influenced by the number of bait pellets per unit area. A trade-off therefore exists between bait pellet size and application rate (and associated cost). In recent years there has been a trend towards the development of bait formulations based on small pellet size, increasing bait numbers per unit area while maintaining the amount of active ingredient applied per unit area. Where applications are directed at a relatively large-bodied species, control with small-pellet products may be compromised by the amount of active ingredient per bait pellet; a sublethal dose might be ingested but the onset of toxicity can prevent the further feeding on the bait needed for a lethal dose. This sublethal-dose effect has been shown to contribute to the reduced efficacy of baits applied against *C. aspersus* (Barker et al. 1991; G.M. Barker, unpubl.).

Toxicity depends on dose and environment

Generally palatability of baits declines with increasing concentration of the active ingredient (e.g. Wright & Williams 1980; Wedgwood & Bailey 1988; Bailey et al. 1989). Therefore, there is a balance between active ingredient concentration and bait acceptance, resulting in variation in the quantities of active ingredient ingested before the onset of toxicity. Under suboptimal conditions, the quantity of active ingredient ingested is sublethal. This 'active ingredient concentration/bait acceptance' trade-off varies among active ingredients (variation in deterrency and quantity required for outset of toxicity), mollusc species (inherent variation in feeding aversion and susceptibility to toxicity), and prevailing environmental conditions (rate of toxicity onset is temperature-dependent). In general, mortality is less at high concentrations of the molluscicide than at lower concentrations.

Furthermore, for a given quantity of active ingredient ingested, the likelihood of mortality is strongly influenced by the prevailing environmental conditions. Metaldehyde is most effective when low humidity/high temperature conditions follow ingestion of bait (Godan 1983), reflecting the primary role of excess mucus production and desiccation as the mode of action of this molluscicide. However, it is now recognised that many early studies underestimated the level of control effected by metaldehyde bait treatments because those individuals moving away from the baits before death were not included in mortality estimates. Due to its mode of action in the nervous system, the level of mortality effected by methiocarb is less dependent on the prevailing environmental conditions (Godan 1983).

Considerable advances have been made in development of formulations that prolong the effective life of baits in the field. Nonetheless, both attractiveness and toxicity of baits decline rapidly on exposure to moist conditions. Furthermore, extreme environmental conditions can reduce or arrest mollusc activity (Godan 1983). Bait application should therefore coincide with periods of high mollusc activity, under moist but not excessively wet weather.

Placement of baits at sites of mollusc activity maximises control

As a general principle, the placement of baits within the foraging range of the molluscs will maximise levels of control. As noted earlier, the range over which molluscs are able to detect baits is relatively short, and most bait 'discoveries' are little more than random events in the normal foraging activity. In areas where the land surface is replete with crevices, a proportion of the bait pellets will lodge at micro-sites inaccessible to foraging molluscs. Furthermore, in densely vegetated sites the reduced mobility of the molluscs can lead to reduced rates of 'bait discovery'. Under both conditions, application rates will need to be increased accordingly.

Control of *C. aspersus* with ground-applied baits may be compromised in some habitat types by the fact that a high proportion of the population may occupy sites above the ground, and may not descend for foraging. This effect is well known in vineyards and citrus orchards, where *C. aspersus* can remain in the canopy for considerable periods of the year.

Food availability has little influence on bait effectiveness

Habitat effects are generally a manifestation of microclimatic conditions. There is at present little evidence that availability of alternative foods strongly influences the acceptance of baits by herbivorous molluscs. The foraging behaviour of herbivorous species evidently provides for feeding on a variety of plant material and ready 'sampling' of novel foods found during the course of foraging bouts.

One bait, one mollusc

Molluscs produce a suite of pheromones in their mucus as a vehicle for communicating information about environmental and physiological conditions. There is unpublished evidence (G.M. Barker, unpubl.) for release of alarm pheromones in the mucus at the onset of molluscicidal toxicity. These pheromones tend to be deposited at sites immediately adjacent to the bait on which the intoxicated mollusc had fed. The effect is repellancy against approach and feeding by other molluscs that reside in the vicinity, and reductions in the levels of pest control.

For products based on small pellet sizes there is often only sufficient material for a meal for one individual, especially for large-bodied species (see above). Indeed, given the alarm pheromone phenomenon, the use of large pellets that carry more than one-meal-equivalent can be viewed as wasteful.

Application rates in bait pellets per unit area should in general exceed the estimated numbers of pest molluscs, but should not be so sparsely distributed that rate of 'discovery' is low. In experimental plots, Hunter & Symonds (1970) found that 25–100 bait pellets/m^2 were optimal for control of the agriolimacid slug *Deroceras reticulatum* (Müller) using broadcast applications of an extruded bait formulation. Because the activity may be less in some mollusc species and be reduced by weather and microtopographic conditions, Hunter & Symonds recommended increasing the number of baits per unit area for field use, either by higher quantities of bait per hectare or by smaller bait pellet size. At recommended rates, many current extruded bait products achieve pellet distributions of 10–30/m^2, which may be suboptimal under some use conditions (Barker et al. 1991). As noted above, there has been a trend towards the manufacture of bait products with smaller mean bait pellet size. This development is most evident in Slugout®, which at the application rate of 20 kg/ha provides for c. 260 pellets/m^2 (Barker et al. 1991).

3. Management of environmental effects

In most agricultural and plant protection situations, non-pest molluscs are rare (due to habitat disturbance). Therefore, effects on non-target molluscs are not generally at issue in these systems. The main concern has been with effects on other fauna, primarily those of importance in the maintenance of soil processes (such as earthworms) and generalist invertebrate predators with perceived roles in regulation of pest numbers (e.g. Carabidae: Purvis & Bannon 1992; Purvis 1996; Staphylinidae: Kross & Schaefer 1998). There is increasing concern over possible effects on other components of biodiversity and in particular adverse effects on populations of insectivorous and granivorous vertebrates such as rodents and birds.

The potential for more extensive and pervasive environmental effects is greater where molluscicide baits are applied in natural ecosystems, as would be the case for control of *C. aspersus* in a conservation area. Clearly, the objective of any control programme would be to reduce the abundance of *C. aspersus* while minimising adverse impacts on indigenous fauna. Greatest concern would be the adverse effects on populations of locally endemic species.

The potential for adverse impact of molluscicide baits on indigenous molluscs is high where two conditions are met: there is habitat overlap between *C. aspersus* and the indigenous species, and the indigenous species feed on the baits. At present, there are no data on the relative susceptibility of species in the New Zealand indigenous fauna to molluscicidal compounds. Indeed, no data are available on susceptibility for any member of the families Bulimulidae, Charopidae, Punctidae, Athoracophoridae, Succineidae, Achatinellidae, Assimineidae, Hydrocenidae, Liareidae and Rhytididae, as these families are not generally recognised as including pest species. Nonetheless, all species in the indigenous terrestrial mollusc fauna should be regarded as susceptible to metaldehyde, carbamates, and chelates until such time that data indicate otherwise. Furthermore, it is highly probable that *Placostylus* in Bulimulidae, *Succinea archeyi* in Succineidae, and at least some members of Charopidae and Punctidae would forage on baits. Our current understanding of the feeding ecology of terrestrial molluscs strongly suggests that members of Athoracophoridae, Achatinellidae, Assimineidae, Hydrocenidae, Liareidae and Rhytididae are unlikely to feed on baits to any significant extent.

Overlap in size and niche between *Placostylus* species and *C. aspersus* negates any opportunity to provide differential (pest-only) access to baits, such as the bait station approach used in mammal control. Temporary removal of *Placostylus* from areas to be treated, analogous to the temporary removal of weka (*Gallirallus australis* (Sparrman)) from Kapiti I. before possum control, might be an appropriate strategy where eradication of *C. aspersus* is the objective. However, in developing control strategies, consideration must be given to the relative cost effectiveness of manual removal and captive maintenance/rearing of *Placostylus* as a component of molluscicide treatment compared with manual removal of *C. aspersus*.

Molluscicides vary in their toxicity to non-molluscan invertebrates and to vertebrates. The available information on the ecotoxicology of metaldehyde, methiocarb and iron EDTA is summarised in Table 2. Use of baits containing metaldehyde as the active ingredient are preferred over those containing carbamates due to reduced effects on non-target invertebrate species. Metaldehyde reputedly has no effect on invertebrates other than molluscs (Godan 1983), but there are occasional reports of non-target effects such as mortality in the diplopod *Cylindroiulus britannicus* Verh. (Plate & Frömming 1952) and the carabid *Carabus granulatus* Linnaeus (Büchs et al. 1989).

The undesirable effects of carbamates are much more marked than those of metaldehyde, reflecting the mode of action. There are numerous studies and observations of adverse effects on earthworms and various insects that feed on the baits (e.g. Aspöck & An der Laan 1963; Symonds 1975; Stringer & Wright 1980; Barker 1982; Bieri et al. 1989; Büchs et al. 1989; Purvis & Bannon 1992; Purvis 1996). Methiocarb and thiodicarb were principally developed as pesticides because of their insecticidal activity.

The limited published information on metal chelates indicates that those compounds with molluscicidal activity have limited significant insecticidal

TABLE 2. ECOTOXICOLOGICAL DATA FOR THE MOLLUSCICIDAL CHEMICALS USED IN BAIT PRODUCTS AVAILABLE IN NEW ZEALAND.*

Iron EDTA ferric sodium ethylenediamine tetraacetic acid	
Acute oral toxicity	LD50 rats and mice > 5000 mg/kg
Metaldehyde 2,4,6,8-tetramethyl-1,3,5,7-tetroxocane	
Acute mammalian oral toxicity	LD_{50} rats 283–750 mg/kg
	LD_{50} dogs 60–1000 mg/kg
	LD_{50} cats 630–690 mg/kg
Acute avian oral toxicity	LD_{50} Japanese quail 170–181 mg/kg
	LD_{50} mallard 1030 mg/kg
Acute fish toxicity	LC_{50} rainbow trout 75 mg/L
Acute soil biota toxicity	LC_{50} earthworms > 50 000 mg/kg soil
Acute mammalian dermal toxicity	LD_{50} rats 5000 mg/kg
Methiocarb 3,5-dimethyl-4-methylmercapto-phenyl-N-methylcarbamate	
Acute mammalian oral toxicity	LD_{50} rats 20–135 mg/kg
Acute avian oral toxicity	LD_{50} Japanese quail 5.0 mg/kg
	LD_{50} mallard 7.1 mg/kg
Acute fish toxicity	LC_{50} rainbow trout 0.44 mg/L
Acute soil biota toxicity	LC_{50} earthworms 200 mg/kg soil
Acute mammalian dermal toxicity	LD_{50} rats 300–700 mg/kg
Thiodicarb 3,7,9,13-tetramethyl-5,11-dioxa-2,8,14-trithia-4,7,9,12-tetra-azapentadeca-3,12-diene-6,10-dione	
Acute mammalian oral toxicity	LD_{50} rats 1000–1290 mg/kg
Acute mammalian dermal toxicity	LD_{50} rats > 2000 mg/kg

*Compiled from various sources.

activity (Henderson et al. 1989). The iron chelate compound used in commercial products at present available in New Zealand is evidently appropriate for those invertebrates with haemocyanin as the respiratory pigment in the haemolymph, which includes the greater majority of gastropod molluscs, malacostracan Crustacea, and Arachnida. Mortality as a result of feeding on iron chelate-containing baits is at present known for gastropod molluscs, the primary targets, and isopods (Olivia Riddell, Tui Garden Products Ltd, pers. comm.).

Metaldehyde and carbamates are toxic to vertebrates. Consumption of the molluscicide by vertebrates can either be direct via ingestion of baits or indirect via ingestion of poisoned molluscs. Mortality in birds feeding on metaldehyde baits became evident during the early years of molluscicide bait development (e.g. Oldcorn 1938) and poisoning in pets such as dogs and cats has long been an issue for the molluscicide industry. The effects of metaldehyde baits on other vertebrate wildlife are less well documented, although there are reports of mortality in lagomorphs (Godan 1983). Most contemporary commercial formulations are coloured blue to reduce bird take and often include a mammal repellent, though neither is entirely effective.

Barnes & Weil (1942) reported toxicity in hedgehogs (*Erinaceus europaeus* Linnaeus) following their feeding of slugs killed by metaldehyde, confirming the need to be aware of the potential for secondary poisoning.

While methiocarb has repellent action in birds, there have been numerous reports of bird mortality following broadcast applications of methiocarb baits. Indeed, bird mortality has been the principal reason for the withdrawal of methiocarb baits from the agrichemicals market in many US states (Hammond & Byers 2001). Baits containing methiocarb have been reported to cause significant mortality in various small mammal populations (e.g. murids *Mus domesticus* Rutty and *Apodemus sylvaticus* Linnaeus: Shore et al. 1997; Mutze & Hubbard 2000). As with metaldehyde products, most commercial bait formulations are coloured to reduce bird intake, and include a mammal repellent.

Iron EDTA has low mammalian toxicity.

The risks to reptiles posed by molluscicidal baits are at present not known.

4. Biology of *Cantareus aspersus* in New Zealand

In any pest management programme, effectiveness is largely dependent on a good understanding of the biology of the pest and on working to the strengths and weaknesses of the available control methodologies.

Cantareus aspersus is a native of Western Europe to the borders of the Mediterranean and Black Seas. However, it has been introduced to numerous other European countries, Africa, North America, South America, Australia, New Zealand, and Pacific islands. Introductions were often unintentional through garden plants and freight, but not infrequently they were deliberately introduced as an edible species.

The species is believed to have been first introduced into New Zealand by the French in the 1860s, and is now among the most widespread and abundant of the naturalised terrestrial molluscs. While present in both North and South Islands, it is more common in the north. Generally, it is most abundant in coastal areas, and becomes scarcer with increasing altitude and/or distance from the coast; nonetheless, *C. aspersus* is abundant in some inland North Island districts. It is absent from closed-canopy native forest, but may occur in disturbed native forest or scrub on the coast and inland on limestone outcrops.

Cantareus aspersus is highly prized by Europeans as an edible snail. It continues to be collected in vast numbers for human consumption in the Mediterrenean area but, as wild stocks are declining, there is increasing emphasis on importation from North Africa (especially Morocco) and farming (heliciculture). The current centre of commercial production is France, but significant quantities are produced in other Mediterranean countries such as Italy, Spain, and Greece. *Cantareus aspersus* is also farmed for both local consumption and export in other parts of the world, including New Zealand. Heliciculture methods vary from simple outdoor pens to a largely automated indoor battery pen system. Information on commercial culture of *C. aspersus* can be found in Avagnina (1983), Chevallier (1983, 1985), Daguzan (1983, 1989), Elmslie (1982, 1989), Runham (1989), de Grisse (1991), and the Associazione Nazionale Elicicoltori (1986–90). A consequence of this interest in heliciculture, and the importance of the species as a laboratory animal, bioindicator of environmental metal contamination and as a pest in several crops, is the considerable information available on the biology of *C. aspersus*.

The species has a very well developed homing instinct, and most individuals return regularly to the same retreat each morning after their nightly forays. Feeding is selective, but nonetheless a large variety of living and dead plant tissues are consumed. A fundamental prerequisite of intensive heliciculture is the availability of suitable feed stock. It has been demonstrated that snails will grow at an acceptable rate on dry feed diets with high ash and relatively low protein content, provided that they have access to water (Daguzan 1981). Studies on the performance of *C. aspersus* fed on commercially available animal feedstuffs demonstrated their preference for diets based on vegetable rather than animal protein (Stephanou 1986a, Jess & Marks 1989). The selection of raw materials, particularly the cereal component, is also known to be an important factor in the palatability of snail diets (Bittante 1984). *Cantareus aspersus* consumes significant quantities of soil as part of its normal diet. In heliciculture, the provision of a soil substrate has demonstrated significant beneficial effects on growth rates (Gomot et al. 1986, 1989a; Jess & Marks 1989; Albuquerque de Matos 1990).

Cantareus aspersus exhibits determinant growth, i.e. growth is arrested when the animals approach reproductive maturity. At maturity a reflected lip is produced at the shell aperture and no further increase in shell size is possible. Herzberg & Herzberg (1962), Cowie (1980), Giusti & Lepri (1980), Chung (1987), and Pos (1994a, 1994b) have noted precocious mating in young

C. aspersus lacking a deflected lip on the shell. These snails produce fertile eggs. For a South Auckland population, Pos (1994a) noted that over 30% of snails mated and 23% laid eggs before cessation of shell growth.

Populations are able to establish from a single gravid individual, or from two similarly aged, reproductively functional individuals. However, *C. aspersus* is an obligate out-crossing species (Frömming 1954; Albuquerque de Matos 1989) and is highly sensitive to degeneracy effects of inbreeding. These are manifested first in reduced fecundity and fertility, then in reduced size and survivorship, until finally, within three or four generations of sib matings, the lines become wholly infertile (Albuquerque de Matos & Serra 1984, 1988; Albuquerque de Matos 1989).

While courtship behaviour varies little in this species, the reproductive output of *C. aspersus* varies greatly between individuals and populations. Studies of natural populations (Millar, 1978), experiments in the laboratory (Herzberg 1965; Dan & Bailey 1982), and experience in heliciculture (Lucarz 1984; Daguzan 1985, 1989; Marciano 1986; Stephanou 1986b, 1986c; Elmslie 1989) show that crowding effects at high population densities result in reduced growth rate, increased mortality, and reduced and more variable adult snail weight, all of which contribute to reduced fecundity. Albuquerque de Matos (1989, 1990) found high heritability values for adult size, but diet has an overriding effect on snail growth rates and size at maturity. The season of the year in which snails are reproductive in the wild varies between populations and even among individuals within a population; this variation is largely governed by environmental conditions, but there is apparently a genetic component that long days stimulate growth rates and egg laying whereas short days inhibit them (Albuquerque de Matos 1989, 1990; Elmslie 1989). It has been well established (Bailey 1981; Enée et al. 1982; Le Guhennec & Daguzan 1983; Laurent et al. 1984; Gomot & Gomot 1985; Aupinel & Daguzan 1989; Gomot et al. 1989b; Lazaridou-Dimitriadou & Bailey 1991) that long ays stimulate growth rates an egg laying, whereas short days inhibit them. While the first oviposition of the season is indifferent to photoperiod, long days are needed to induce more egg-layings (Enée et al. 1982).

A period of hibernation (or artificially imposed quiescence) has been shown to increase the reproductive activity and fecundity of *C. aspersus* (Bonnefoy-Claudet & Deray 1984). Hibernation in *C. aspersus* is controlled primarily by photoperiod, although temperature may determine its duration (Bailey 1981, 1983; Aupinel 1987); this hibernation condition is more correctly termed diapause. Reproduction becomes non-seasonal within several generations when the snails are maintained under optimum conditions (Albuquerque de Matos 1990); three or four generations can be produced each year.

Like most Mediterranean snails, *C. aspersus* can survive in a dormant aestivatory state for many months during dry weather. Under New Zealand conditions, the majority of mature snails begin mating in spring (October/November) and oviposition continues throughout the late spring, summer and autumn, provided that activity is not arrested by aestivation during dry weather (Pos 1990, 1994a, 1994b; G.M. Barker, unpubl. data). Millar (1978) found that *C. aspersus* populations increased following the seeding of lupin (*Lupinus arboreus* Linnaeus) into Manawatu coastal dunes. Under these conditions of actively expanding populations, snails reached maturity in about 12 months. High snail numbers were maintained for as little as 3 years, however, as lupin growth and survival was adversely affected. In declining populations, Millar found that the snails required 2–3 years to reach maturity.

Each mature snail will mate several times in a single season, with an interval between matings of as little as 3 days (Basinger 1931). Observations on mating behaviour in *C. aspersus* have been summarised by Barker (1999). Egg laying starts 3–6 days after first mating, but can occur within hours of subsequent matings. Under unfavourable conditions, egg laying in fertilised snails may be delayed by a period of aestivation (Basinger 1931). *Cantareus aspersus* deposit their eggs into pockets in moist soil. These pockets are usually excavated by the snails themselves through movement of the head and anterior foot, though occasionally natural cavities will be used (Basinger 1931; Herzberg & Herzberg 1962; Pos 1990). Not all nest excavations initiated will be successfully filled with eggs; many are apparently abandoned before one is finally considered suitable. After oviposition the nests are covered with soil and abandoned. The number of eggs in each clutch varies from 10 to 176 (e.g. Basinger 1931; Ingram 1947; Herzberg & Herzberg 1962; Daguzan 1989; Pos 1990, 1994a, 1994b) and deposition of a single clutch may take as long as 36 hours (Pos 1990). Under optimum conditions in indoor farms, individual snails can produce 2500 eggs in a year (Runham 1989).

The eggs are spherical to oval, varying in greater diameter from 3 to 4.9 mm. The egg shell is partly calcified, with discrete crystals of calcium carbonate dispersed in the inner of two flexible jelly matrix layers. The snail embryo dissolves and absorbs calcium from the egg shell (Tompa 1984). Guéméné & Daguzan (1983) observed that eggs produced by different snails varied from translucent to opaque, according to the quantity of calcium carbonate crystals in the egg shell. They were able to demonstrate that embryo development and hatching success were higher in those with high calcium provisions. Reproductive snails have a high calcium requirement (Tompa 1984), and egg production by snails exposed to calcium-poor soil was approximately doubled when $CaCO_3$ was supplied (Crowell 1973).

The incubation period of the eggs has been shown by Guéméné & Daguzan (1983) to vary according to the relative humidity of the incubation environment. In one experiment at 20.0°C, for example, they recorded that the incubation period increased from 13.8 + 1.9 days to 40.0 + 9.9 days as relative humidity declined from 100% to 70%. Egg survivorship similarly declined from 91.5% to 14% with decreasing humidity. The young hatchling snails remain in the nest for 1–16 days (Basinger 1931; Ingram 1947; Herzberg & Herzberg 1962). During this time, cannibalism on sib eggs can occur (Elmslie 1988).

Cantareus aspersus is gregarious, and very high numbers of snails can occur in favourable habitats such as garden shrubbery, coastal dunes and cliffs, and scrub on limestone outcrops. The gregarious behaviour is particularly apparent over the winter months, when the diapausing snails aggregate in protected sites. During this diapause hibernation the shell aperture is sealed with an epiphragm or several epiphragms. In the Manawatu dunes, Millar (1978) observed hibernation to begin in May and to reach a peak in July. The snails became active again in mid-August. According to Taylor (1906–14), juvenile snails are less sensitive to the cold and thus less inclined to diapause. There are few reported estimates of population size, but from an average of 40 snails per lupin plant Brockie (1957) estimated 20 000 snails per hectare in the Paekakariki dunes north of Wellington.

Giusti et al. (1995) and Barker (1999) discussed the taxonomy and systematic relationships of *C. aspersus*. Numerous varieties of *C. aspersus*, founded on shell variation, are recorded in the literature. Shell polymorphism in size, shape, markings, and colour has been extensively studied, with recognition of several endemic forms in North Africa (Taylor 1906–14; Chevallier 1977). Recent work on the genetic variability of allozymic characters (Crook 1981; Bleakney et al. 1989; Madec 1991) and life-history traits (Madec & Daguzan 1993) has suggested that the more distinct morphs, *C. aspersus aspersus* and *C. aspersus maximus* Taylor, can be recognised as subspecies. Guiller et al. (1994) found that the morphological heterogenic Moroccan populations could not, however, be distinguished by allozymic variation, thus again calling into question the subspecific status of *C. aspersus maximus*. They raise the possibility that *C. aspersus maximus* is an 'artificial' morph, associated with early selective breeding in cultivation, rather than a natural morphotype. Material from New Zealand (Auckland, Hokitika) was included in the allozyme study of Bleakney et al. (1989).

5. Conclusions and recommendations

Ecological thresholds for *C. aspersus* in New Zealand natural environments are not known at present. These can be established by comparing key ecological parameters in replicated paired plots, one plot in the pair with *C. aspersus* infestation and the other plot where *C. aspersus* is eliminated or substantially reduced by molluscicide bait treatments. Ecological parameters of interest may include vegetation cover condition, plant recruitment, and abundance of indigenous mollusc species. These plot comparisons also provide an opportunity to refine the bait treatment methods appropriate to the environment being restored. Where the ecological threshold is zero, eradication would become the suggested management goal. Where the ecological threshold allows for the continued presence of *C. aspersus*, controls could be applied when the pest reached some predetermined population level (action threshold), which might be lower than the ecological threshold.

Appropriate methodologies need to be established for monitoring changes in: abundance of *C. aspersus*, including those changes brought about by management; and key population parameters of indigenous species at sites subjected to *C. aspersus* management.

The principal route for *C. aspersus* into isolated habitats is that of accidental transport of snails in or attached to potted plant material and packaged freight. In most mainland situations, the principal route for *C. aspersus* colonisation is immigration of snails from adjacent habitat. Operational procedures need to be instituted to reduce or eliminate routes for re-colonisation.

It is desirable that the bait formulation that offers greatest effectiveness against *C. aspersus* and ease of application at the sites of interest is selected. The key formulation parameters to consider include: the size of the bait pellets and the amount of active ingredient carried in relation to the LD_{90} dose for *C. aspersus*; the aerodynamic characteristics in relation to equipment used to distribute the baits (from fixed-wing aircraft, helicopter, ground travel machinery, or by hand) and the ability to penetrate vegetation to reach target microsites; and the desired level of bait persistence in relation to likely periodicity in *C. aspersus* activity and the ability to make repeat applications.

The selected bait formulation should also preferably offer the least potential for impact on indigenous species. The key formulation parameters to consider include the ecotoxicology of the active ingredient, and the relative attractiveness and palatability of the baits to the non-target species.

The need for temporary removal of 'at risk' indigenous species from sites to be treated with the molluscicide baits could be considered. However, such removal requires an ability to maintain populations of the indigenous species in 'captivity' in sufficient numbers to constitute the nucleus of a viable population on return to the site.

A series of molluscicide bait applications over a single season could be used to provide initial reduction in *C. aspersus* numbers, and repeated in subsequent seasons to reduce *C. aspersus* to below the ecological threshold or until eradication is achieved. Timing of the initial 'knock-down' treatments and the subsequent 'maintenance' treatments should coincide with the period in which the population comprises only one, uniformly aged, susceptible cohort—namely that of pre-reproductive adult snails. It is this period that could be regarded as the control season. Two or three treatments within a season, at approximately monthly intervals, would maximise the level of *C. aspersus* control in ensuring that toxic baits are available throughout the pre-reproductive activity season of the pest, and thus accommodate the variation in activity among *C. aspersus* individuals. (It is not appropriate to apply molluscicidal baits when the greater part of the *C. aspersus* population is in either diapause or aestivation.)

It is anticipated that treatment would initially be required in two or more consecutive seasons before *C. aspersus* abundance is reduced to below the ecological threshold. The frequency of subsequent maintenance treatments is obviously dependent on the rates of population increase, which in turn will be a function of population density and age structure after treatment and intrinsic rate of increase. It is probable that a pulsed treatment regime can be introduced, with molluscicidal baits applied when the action threshold is reached.

5.1 POTENTIAL IMPROVEMENTS IN CONTROL TECHNOLOGIES

Current bait formulations seek to offer effectiveness against a range of pestiferous mollusc species. For pest management on conservation land, there is considerable scope to refine current bait formulations, or to develop new formulations, to maximise effectiveness against *C. aspersus.* Options include: optimising bait size and concentration of active ingredient to ensure sufficient toxicant is available in a single 'meal' to effect a lethal dose; and optimising bait formulation to maximise attractiveness and palatability to *C. aspersus*. It might be possible to optimise bait formulation for *Cantareus* control while providing low attractiveness and palatability to *Placostylus* or other at-risk indigenous mollusc species. Evaluation of variations in molluscicide bait formulation can be readily achieved in laboratory assays with *C. aspersus* collected from feral populations.

In some habitat types, management of *C. aspersus* might be enhanced by supplementing chemical control with manual removal of survivors from aestivation sites.

5.2 RESEARCH NEEDS

There are significant information gaps in the following areas, and these need to be addressed before any control of *Cantareus* occurs:

- The acceptance of baits by *Placostylus* and other fauna (e.g. reptiles). This could be tested using non-toxic baits in laboratory assays.
- The degree of habitat overlap between *Cantareus* and any other susceptible fauna (e.g. *Placostylus*, minute native land snails, Carabidae, etc.) and therefore the degree of risk associated with molluscicide bait applications.
- Procedures for captive rearing of *Placostylus* species. Captive rearing would provide for the possibility of removing *Placostylus* from habitats before molluscicide treatments and then returning individuals after degradation of the applied baits.

6. Acknowledgements

The authors thank the Ministry of Agriculture and Forestry for providing information on molluscicide bait products registered for use in New Zealand (as at December 2000), and Tui Garden Products Ltd for supply toxicological data about Quash Slug & Snail Killer™. John Innes (Landcare Research) and Javier Iglesias (University of Santiago de Compostela) assisted by critical review of an early draft of this report.

7. References

Albuquerque de Matos, R.M. 1989: Contributions of genetics to snail farming and conservation. Pp. 11–18 *in*: Henderson, I.F. (ed.) Slugs and snails in world agriculture. *British Crop Protection Council Monograph 41.*

Albuquerque de Matos, R.M. 1990: Genetic and adaptive characteristics in *Helix aspersa* of direct interest in snail farming. *Snail Farming Research 3*: 33–43.

Albuquerque de Matos, R.M.; Serra, J.A. 1984: Taxonomic polymorphism and intrinsic factors in *Helix aspersa. Brotéria-Genética 5*: 181–220.

Albuquerque de Matos, R.M.; Serra, J.A. 1988: Ce que la génétique a fait et peut faire pour l'héliciculture. *Brotéria-Genética 9*: 25–81.

Anderson, R.; Hogarth, I.; Pickard, R.; Ogle, C. 1984. Loss of wildlife habitat in Northland, 1978–83, with notes on recently identified wildlife values. *New Zealand Wildlife Service Technical Report 6.*

Aspöck, H.; An der Laan, H.1963: Ökologische Auswirkungen und physiologische Besonderheiten des Pflanzenschutzmittels Sevin (1-naphthyl-N-methylcarbamat). *Zeitschrift für Angewandte Zoologie 50*: 343–380.

Associazione Nazionale Elicicoltori 1986–90: Snail farming research. Cherasco, Italy. Vol. 1 (1986), viii + 92 p.; Vol. 2 (1988), v + 74 p.; Vol. 3 (1990), vii + 64 p.

Aupinel, P. 1987: Étude préliminaire du rôle de la photopéroide sur l'hibernation de jeunes escargots petits gris (*Helix aspersa* Müller) (Mollusques Gastéropode, Pulmoné Stylommatophore). *Haliotis 16*: 47–55.

Aupinel, P.; Daguzan, J. 1989: Étude du rôle de la photopéroide sur l'activité metabolique de jeunes escargots petits gris (*Helix aspersa* Müller) et mise en evidence d'une phase photosensible. *Haliotis 19*: 47–55.

Avagnina, G. 1983: Principi di Elicicoltura. Edagricole, Bologna.

Bailey, S.E.R. 1981: Circannual and circadian rhythms in the snail *Helix aspersa* Müller and the photoperiodic control of annual activity and reproduction. *Journal of Comparative Physiology 142*: 89–94.

Bailey, S.E.R. 1983: The photoperiodic control of hibernation and reproduction in the landsnail *Helix aspersa* Müller. *Journal of Molluscan Studies 12, Supplement*: 2–5.

Bailey, S.E.R.; Cordon, S.; Hutchinson, S. 1989: Why don't slugs eat more bait? A behavioural study of early meal termination produced by methiocarb and metaldehyde baits in *Deroceras caruanae*. Pp. 385–390 *in*: Henderson, I.F. (ed.) Slugs and snails in world agriculture. *British Crop Protection Council Monograph 41*.

Barker, G.M. 1982: Short-term effects of methiocarb formulations on pasture earthworms (Oligochaeta: Lumbricidae). *New Zealand Journal of Experimental Agriculture 10*: 309–311.

Barker, G.M. 1993: Population regulation of *Deroceras* slugs (Agriolimacidae) in northern New Zealand pastures with particular reference to the role of *Tetrahymena rostrata* (Kahl) (Ciliata) and *Microsporidium novacastriensis* (Jones & Selman) (Microspora). Proceedings of the 3rd International Congress of Medical and Applied Malacology, Camden, Australia.

Barker, G.M. 1999: Naturalised terrestrial Stylommatophora (Mollusca, Gastropoda). *Fauna of New Zealand 38.* 253 p.

Barker, G.M.; Efford, M. 2002: Predatory gastropods as natural enemies of terrestrial gastropods and other invertebrates. *In*: Barker, G.M. (ed.) Natural Enemies of Terrestrial Molluscs. CAB International, Wallingford.

Barker, G.M.; Pottinger, R.P.; Lloyd, J.M.; Addison, P.J.; Firth, A.C.; Stewart, A.P. 1991: A novel bait formulation for slug and snail control. *Proceedings of the New Zealand Weed and Pest Control Conference 44*: 195–200.

Barker, G.M.; Ramsay, G.W. 1978: The slug mite *Riccardoella limacum* (Acari: Ereynetidae) in New Zealand. *New Zealand Entomologist 6*: 441–442.

Barnes, H.F.; Weil, J.W. 1942: Baiting slugs using metaldehyde mixed with various substances. *Annals of Applied Biology* 29: 56–58.

Basinger, A.J. 1931: The European brown snail in California. *University of California Agricultural Experimental Station bulletin 515*. 20 p.

Bieri, M.; Schweizer, H.; Christensen, K.; Daniel, O. 1989: The effect of metaldehyde and methiocarb slug pellets on *Lumbricus terrestris* Linne. Pp. 237–244 *in*: Henderson, I.F. (ed.) Slugs and snails in world agriculture. *British Crop Protection Council Monograph 41*.

Bittante, G. 1984: Voluntary intake and digestibility of barley and wheat bran by *Helix pomatia* and *Helix aspersa. Zootecnica e Nutrizione Animale 10*: 449–462.

Bleakney, M.M.; Fleming, C.C.; Marks, R.J. 1989: Genetic and phenotypic variation in allopatric populations of *Helix aspersa* (Müller): a preliminary report. Pp. 319–326 *in*: Henderson, I.F. (ed.) Slugs and snails in world agriculture. *British Crop Protection Council Monograph 41*.

Bonnefoy-Claudet, R.; Deray, A. 1984: Influence de la durée d'hibernation sur l'activité reproductrice de l'escargot *Helix aspersa* Müller. *Comptes Rendus de la Société de Biologie 178*: 442–449.

Brockie, R.E. 1957: The hedgehog population and invertebrate fauna of the west coast sand dunes. *Proceedings of the New Zealand Ecological Society 5*: 27–29.

Brook, F.J. 2000: Holocene distribution, ecology and local extinction of the endemic New Zealand dune snail *Succinea archeyi* Powell (Stylommatophora: Succineidae). *Journal of the Royal Society of New Zealand 30*: 209–225.

Büchs, W.; Heimbach, U.; Czarnecki, E. 1989: Effects of snail baits on non-target carabid beetles. Pp. 245–252 *in*: Henderson, I.F. (ed.) Slugs and snails in world agriculture. *British Crop Protection Council Monograph 41*.

Cameron, R.A.D.; Carter, M.A. 1979: Intra- and interspecific effects of population density on growth and activity in some helicid snails (Gastropoda: Pulmonata). *Journal of Animal Ecology 48*: 237–246.

Charwat, S.M.; Davies, K.A. 1999. Laboratory screening of nematodes isolated from South Australia for potential as biocontrol agents of helicid snails. *Journal of Invertebrate Pathology 74*: 55–61.

Charwat, S.M., Davies, K.A.; Hunt, C.H. 2000. Impact of a rhabditid nematode on survival and fecundity of *Cernuella virgata* (Mollusca: Helicidae). *Biocontrol Science and Technology 10*: 147–155.

Chevallier, H. 1977: La variabilité de l'escargot petit-gris *Helix aspersa* Müller. *Bulletin du Museum National d'Histoire Naturelle (ser. 3) 448, Zoologie 311*: 425–442.

Chevallier, H. 1983: Recherches appliquées pour l'élevage des escargots du genre *Helix. Journal of Molluscan Studies, Supplement 12A (Proceedings of the 2nd Franco-British Symposium on Molluscs)*: 27–30.

Chevallier, H. 1985: L'élevage des escargots. Production et preparation du petit gris. Maisons Alfort, Editions du Point Veterinaire. 127 p.

Chung, D.J.D. 1987: Courtship and dart shooting behavior of the land snail *Helix aspersa. The Veliger 30*: 24–39.

Civeyrel, L.; Simberloff, D. 1996: A tale of two snails: Is the cure worse than the disease? *Biodiversity and Conservation 5*: 1231–1252.

Clark, S.J.; Coward, N.P.; Dawson, G.W.; Henderson, I.F.; Martin, A.P. 1995: Metal chelate molluscicides: the redistribution of iron diazaalkanolates from the gut lumen of the slug, *Deroceras reticulatum* (Müller) (Pulmonata: Limacidae). *Pesticide Science 44*: 381–388.

Coloso, R.M.; Borlongan, I.G.; Blum, R.A. 1998: Use of metaldehyde as a molluscicide in semi-commercial and commercial milkfish ponds. *Crop Protection 17*: 669–674.

Coupland, J.B. 1996: The efficacy of metaldehyde formulations against helicid snails: the effects of concentration, formulation and species. Pp. 151–156 *in:* Henderson, I.F. (ed.). Slug and snail pests in agriculture. *British Crop Protection Council Symposium Proceedings 66.*

Cowie, R.H. 1980: Precocious breeding of *Theba pisana* (Müller) (Pulmonata: Helicidae). *Journal of Conchology 30*: 238.

Cowie, R.H. 2000: Non-indigenous land and freshwater molluscs in the islands of the Pacific: conservation impacts and threats. Pp. 115–143 *in:* Sherley, G. Invasive species in the Pacific: A technical review and draft regional strategy. South Pacific Regional Environmental Programme, Apia.

Crook, S.J. 1981: Genetic studies of allozyme variation in leucine aminopeptidase in the landsnail *Helix aspersa* Müller. *Journal of Molluscan Studies 48*: 362–365.

Crowell, H.H. 1967: Slug and snail control with experimental poison baits. *Journal of Economic Entomology 60*: 1048–1050.

Crowell, H.H. 1973: Laboratory study of calcium requirements of the brown garden snail, *Helix aspersa* Müller. *Proceedings of the Malacological Society of London 40*: 491–503.

Crowell, H.H. 1977: Chemical control of terrestrial slugs and snails. *Bulletin 628, Agricultural Experiment Station, Oregon State University, Corvallis.* 69 p.

Daguzan, J. 1981: Contribution a l'élevage de l'éscargot Petit Gris: *Helix aspersa* Müller (Mollusque Gastéropode Pulmoné Stylommatophore). I. Reproducion et éclosion des jeunes en bâtiment et en conditions thermohygrométriques controlées. *Annales de Zootechie 30*: 249–272.

Daguzan, J. 1983: L'Escargot et l'Héliciculture. Paris, Informations Techniques des Services Vétérinaires. 207 p.

Daguzan, J. 1985: Contribution a l'élevage de l'éscargot Petit Gris: *Helix aspersa* Müller (Mollusque Gastéropode Pulmoné Stylommatophore). III. Elevage mixte (reproduction en bâtiment contrôlé et engraissement en parc exterieur): activité des individus et évolution de la population juvenile selon la charge biotique du parc. *Annales de Zootechie 34*: 127–148.

Daguzan, J. 1989: Snail rearing or heliciculture of *Helix aspersa* Müller. Pp. 3–10 *in:* Henderson, I.F. (ed.) Slugs and snails in world agriculture. *British Crop Protection Council Monograph 41.*

Dan, N.; Bailey, S.E.R. 1982: Growth, mortality, and feeding rates of the snail *Helix aspersa* at different population densities in the laboratory, and the depression of activity of helicid snails by other individuals, or their mucus. *Journal of Molluscan Studies 48*: 257–265.

de Grisse, A. 1991: Automatisatie van de vetmesting van escargots. *Mededelingen Faculteit Landbouwwetenschappen Rijksuniversiteit Gent 56*: 83–96.

del Rivero, J.M. 1990: Investigacion sobre otros efectos plaguicidas potenciales diferentes de varios herbicidas; especialmente bipiridilos y organo arsenicales. *Boletin de Sanidad Vegetal Plagas 16*: 605–611.

De-niu, C.; Guo-qing, Z.; Wenxian, X.; Man-sheng W.; Yanhong, L.; Xingmin, C.; Jiqing, W. 2001: *Bradybaena ravida* (Benson) in cereal-cotton rotations of Jingyang County, Shaanxi Province, China. *In:* Barker, G.M. (ed.) Molluscs as Crop Pests*.* CAB International, Wallingford.

De-niu, C.; Zhang, G.Q.; Wenxian, X.; Yanhong, L.; Man-sheng, W.; Yonggan, Y. 1996: A study of outbreaks of *Bradybaena ravida* in China. Pp. 405–410 *in:* Henderson, I.F. (ed.) Slug and snail pests in agriculture. *British Crop Protection Council Symposium 66.*

Elmslie, L.J. 1982: Snails and snail farming. *World Animal Review 41*: 20–26.

Elmslie, L.J. 1988: Studies on the feeding of newly hatched *Helix aspersa. Snail Farming Research 2*: 45–48.

Elmslie, L.J. 1989: Snail farming in field pens in Italy. Pp. 19–25 *in*: Henderson, I.F. (ed.) Slugs and snails in world agriculture. *British Crop Protection Council Monograph 41.*

Enée, J.; Bonnefoy-Claudet, R.; Gomot, L. 1982: Effet de la photopériode artificielle sur la reproduction de l'escargot *Helix aspersa* Müller. *Comptes Rendus de l'Académie des Sciences (ser. III) 294*: 357–360.

Frain, J. 1982. Chemical control of molluscs using metaldehyde. *International Pest Control November/December 1982*: 150–151.

Frömming, E. 1954: Biologie der Mitteleuropäischen Landgastropoden. Duncker & Humbolt, Berlin. 404 p.

Frömming, E.; Plate, H.-P. 1952: Sind die metaldehydköder zuverlässige Schneckenbekämpfungsmittel? *Schädlingsbekämpfung 44*: 130–131.

Giusti, F.; Lepri, A. 1980: Aspetti morphologici ed etologici dell'accoppiamento in alcune specie della famiglia Helicidae (Gastropoda, Pulmonata). *Atti Accademia della Scienze di Siena della dei Fisiocritici (1980)*: 11–71.

Giusti, F.; Manganelli, G.; Schembri, P.J. 1995: The non-marine molluscs of the Maltese Islands. *Museo Regionale di Scienze Naturali, Torino, Monografie 15*: 10–167.

Godan, D. 1966: Untersuchungen über die molluskizide Wirkung der carbamate. II. Abhängigkeit von Art, Größe und Ernährung der Schnecke. *Zeitschrift für Angewandte Zoologie 53*: 417–430.

Godan, D. 1983: Pest slugs and snails: Biology and control. 2nd edn. Springer-Verlag, Berlin, Heidelberg, NewYork.

Gomot, P.; Bruckert, S.; Gomot, L.; Combe, J.C. 1986: A contribution to the study of the beneficial effects of soil on the growth of *Helix aspersa. Snail Farming Research 1*: 76–83.

Gomot, P.; Gomot, L. 1985: Action de la photopéroide sur la multiplication spermatogoniale et la reproduction de l'escargot *Helix aspersa. Bulletin de la Société Zoologique de France 110*: 445–459.

Gomot, P.; Gomot, L.; Boukraa, S.; Bruckert, S. 1989a: Influence of soil on the growth of the land snail *Helix aspersa. Journal of Molluscan Studies 55*: 1–7.

Gomot, P.; Gomot, L.; Giffond, B. 1989b: Evidence for light compensation of the inhibition of reproduction by low temperatures in the snail *Helix aspersa.* Ovotestis and albumen gland responsiveness to different conditions of photoperiods and temperatures. *Biology of Reproduction 40*: 1237–1245.

Guéméné, D.; Daguzan, J. 1983: Variations des capacités reproctrices de l'escargot petit-gris, *Helix aspersa* Müller (Mollusques Gastéropodes Pulmoné Stylommatophore), selon son origine géographique. II. Incubation des oeufs et éclosion des jeunes. *Annales de Zootechnie 32*: 525–538.

Guiller, A.; Madec, L.; Daguzan, J. 1994: Geographic patterns of genetic differentiation in the landsnail *Helix aspersa* Müller (Gastropoda: Pulmonata). *Journal of Molluscan Studies 60*: 205–221.

Hammond, R.B.; Byers, R.A. 2001: Agriolimacidae and Arionidae as pests in conservation tillage soybean and corn cropping in North America. *In:* Barker, G.M. (ed.) Molluscs as Crop Pests. CAB International, Wallingford.

Hata, T.Y.; Hara, A.H.; Hu, B.K.S. 1997: Molluscicides and mechanical barriers against slugs, *Vaginula plebeia* Fischer and *Veronicella cubensis* (Pfeiffer) (Stylommatophora Veronicellidae). *Crop Protection 16*: 501–506.

Henderson, I.F.; Briggs, G.G.; Coward, N.P.; Dawson, G.W.; Pickett, J.A. 1989: A new group of molluscicidal compounds. Pp. 289–294 *in:* Henderson, I.F. (ed.) Slugs and snails in world agriculture. *British Crop Protection Council Monograph 41*.

Herzberg, F. 1965: Crowding as a factor in growth and reproduction of *Helix aspersa*. *American Society of Zoologists 5*: 234.

Herzberg, F.; Herzberg, A. 1962: Observations on reproduction in *Helix aspersa*. *American Midland Naturalist 68*: 297–306.

Hunter, P.J.; Symonds, B.V. 1970: The distribution of bait pellets for slug control. *Annals of Applied Biology 65*: 1–7.

Hussein, H.I.; Al-Rajhy, D.; El-Shahawi, F.I.; Hashem, S.M. 1999: Molluscicidal acivity of *Pergularia tomentosa* (L.), methomyl and methiocarb, against land snails. *International Journal of Pest Managament 45*: 211–213.

Iglesias, J.; Castillejo, J. 1999: Field observations on feeding of the land snail *Helix aspersa* Müller. *Journal of Molluscan Studies 65*: 411–423.

Ingram, W.M. 1947: Egg laying of the European brown snail in terraria. *Bulletin of the Southern Californian Academy of Science 46*: 55–56.

Jess, S.; Marks, R.J. 1989: The interaction of diet and substrate on the growth of *Helix aspersa* (Müller) var. *maxima*. Pp. 311–317 *in:* Henderson, I.F. (ed.) Slugs and snails in world agriculture. *British Crop Protection Council Monograph 41*.

Kross, S.; Schaefer, M. 1998: The effect of different farming systems on epigeic arthropods—a five-year study on the rove beetle fauna (Coleoptera, Staphylinidae) of winter wheat. *Agriculture Ecosystems and Environment 69*: 121–133.

Laurent, J.; Deray, A.; Grimmard, A.-M. 1984: Influence de la photopériode, du degré d'hétérogénéité de la population sur la dynamique de croissance et la maturation sexualle de l'Escargot *Helix aspersa*. *Comptes Rendus de la Société de Biologie 178*: 421-441.

Lazaridou-Dimitriadou, M.; Bailey, S.E.R. 1991: Growth, reproduction and activity rhythms in two species of edible snails, *Helix aspersa* and *Helix lucorum*, in non 24-hour light cycles. *Journal of Zoology 225*: 381–391.

Le Guhennec, M.F.; Daguzan, J. 1983: Rôle de la lumière sur la reproduction de l'Escargot Petit Gris, *Helix aspersa* Müller. *Comptes Rendus de l'Académie des Sciences, Paris 297*: 141–144.

Lucarz, A. 1984: Etude experimentale de l'effet du groupement sur la ponte d'*Helix aspersa* Müller. *International Journal of Invertebrate Reproduction and Development* 7: 185–192.

Madec, L. 1991: Genetic divergences in natural populations of the landsnail *Helix aspersa* Müller, 1774. *Journal of Molluscan Studies 57*: 483–487.

Madec, L.; Daguzan, J. 1993: Geographic variation in reproductive traits of *Helix aspersa* Müller studied under laboratory conditions. *Malacologia 35*: 99–117.

Marciano, P. 1986: Growth of *Helix aspersa* in the presence or absence of adults of the same species or of another species (*Helix pomatia*). *Snail Farming Research 1*: 67–75.

Mead, A.R. 1979: Economic malacology with particular reference to *Achatina fulica*. Pp. 1–150 *in*: Fretter, V.; Peake, J. (eds) Pulmonates, Volume 2B. Academic Press, London.

Millar, I.R. 1978: Ecology of the common snail *Helix aspersa* Muller in a disturbed dune environment. MSc thesis, Massey University, Palmerston North.

Morand, S.; Barker, G.M. 1994a: *Angiostoma schizoglossae* n. sp. (Nematoda: Angiostomatidae) from the New Zealand endemic slug, *Schizoglossa novoseelandica* (Gastropoda: Rhytididae). *Journal of Parasitology 81*: 94–98.

Morand, S.; Barker, G.M. 1994b: *Hugotdiplogaster neozelandia* n. gen., n. sp. (Nematoda: Diplogasteridae), a parasite of the New Zealand endemic slug, *Athoracophorus bitentaculatus* (Quoy and Gaimard, 1832) (Gastropoda: Athoracophoridae). *New Zealand Journal of Zoology 22*: 109–113.

Morand, S.; Wilson, M.; Glen, D.M. 2002: Nematodes parasitic in terrestrial gastropods. *In*: Barker, G.M. (ed.) Natural Enemies of Terrestrial Molluscs. CAB International, Wallingford.

Morse, J.G.; Sakovich, N.J. 1986: Control of *Helix aspersa* on citrus and avocado. *Journal of Agricultural Entomology 3:* 342–349.

Mutze, G.J.; Hubbard, D.J. 2000: Effects of molluscicide baits on field populations of house mice. *Agriculture, Ecosystems and Environment 80*: 205–211.

Ogle, C.C. 1979: Critical status of *Placostylus* and *Paryphanta* land snails in the far north. *New Zealand Wildlife Service Fauna Survey Unit Report 14*.

Oliveira Silva, M.T. 1992: Effects of mollusc grazing on the development of grassland species. *Journal of Vegetation Science 3*: 267–270.

Oldcorn, R.A. 1938: Meta-bran and birds. *Gardener's Chronicle 103*: 32.

Pappas, J.L.; Carman, G.E. 1955: Field screening tests with various materials against the European brown snail on citrus in California. *Journal of Economic Entomology 48*: 689–700.

Pappas, J.L.; Carman, G.E. 1961: Field screening tests with various materials against the European brown snail on citrus in California. *Journal of Economic Entomology 54*: 152–156.

Parrish, G.R.; Sherley, G.H.; Aviss, M. 1995: Giant land snail recovery plan *Placostylus* spp., *Paryphanta* sp. *Threatened species recovery plan 13*. Department of Conservation, Wellington.

Plate, H.-P.; Frömming, E. 1952: Quantitative Untersuchungen über die Wirksamkeit einiger metaldehydpräparate gegenüber Landlungenschnecken. *Anzeiger Schädlingskunde 25*: 133–136.

Pos, H.G. 1990: Production of clean snail eggs of *Helix aspersa* (Müller). *Snail Farming Research 3*: 1–5.

Pos, H.G. 1994a: Some observations on lip formation and reproduction in *Helix aspersa. Snail Farming Research* 5: 32–36.

Pos, H.G. 1994b: The effect of temperature on the sexual activity of *Helix aspersa. Snail Farming Research 5*: 37-42.

Purvis, G. 1996: The hazard posed by methiocarb slug pellets to Carabid beetles: Understanding population effects in the field. Pp. 189–196 *in:* Henderson, I.F. (ed). Slug and snail pests in agriculture. *British Crop Protection Council Symposium Proceedings 66*.

Purvis, G.; Bannon, J.W. 1992: Non-target effects of repeated methiocarb slug pellet application on carabid beetle (Coleoptera: Carabidae) activity in winter-sown cereals. *Annals of Applied Biology 121*: 401–422.

Runham, N.W. 1989: Snail farming in the United Kingdom. Pp. 49–55 *in:* Henderson, I.F. (ed.) Slugs and snails in world agriculture. *British Crop Protection Council Monograph 41*.

Shaw, W.B.; Burns, B.R. 1997: The ecology and conservation of the endangered endemic shrub, kowhai ngutukaka *Clianthus puniceus* in New Zealand. *Biological Conservation 81*: 233–245.

Sherley, G.H.; Stringer, I.A.N.; Parrish, G.R.; Flux, I. 1998: Demography of two landsnail populations (*Placostylus ambigiosus*, Pulmonata: Bulimulidae) in relation to predator control in the far north of New Zealand. *Biological Conservation 84*: 83–88.

Shore, R.F.; Feber, R.E.; Firbank, L.G.; Fishwick, S.K.; MacDonald, D.W.; Norum, U. 1997: The impacts of molluscicide pellets on spring and autumn populations of wood mice *Apodemus sylvaticus*. *Agriculture Ecosystems and Environment 64*: 211–217.

Stephanou, D. 1986a: Experiments on the nutrition of *Helix cincta* (Kobelt) and *Helix aspersa* (Müller). *Snail Farming Research 1*: 42–49.

Stephanou, D. 1986b: Contribution to the study of the effect of stocking density in the culture of *Helix aspersa* (Müller). *Snail Farming Research 1*: 27–33.

Stephanou, D. 1986c: Some aspects of the reproduction of *Helix aspersa* (Müller). *Snail Farming Research 1*: 34–41.

Stringer, A.; Morgan, N.G. 1969: Population and control of snails in blackcurrant plantations. Proceedings of the 5th British Insecticides and Fungicides Conference (1969): 453–457.

Stringer, A.; Wright, M.A. 1980: Ecology of earthworms. The toxicity of methiocarb and its breakdown products to earthworms. Long Ashton Research Station report for 1979: 120–121.

Symonds, B.V. 1975: Evaluation of potential molluscicides for the control of the field slug, *Agriolimax reticulatus* (Mull.). *Plant Pathology 24*: 1–9.

Taylor, J.W. 1906-14: Monograph of the land and freshwater Mollusca of the British Isles. 3. Zonitidae, Endodontidae, Helicidae. Taylor Brothers, Leeds. 498 p.

Tompa, A. 1984: Land snails (Stylommatophora). Pp. 47–140 *in:* Tompa, A.; Verdonk, N.H.; van den Biggelaar, J.A.M. (eds) The Mollusca, Vol. 7. Reproduction. Academic Press, New York.

Triebskorn, R.; Ebert, D. 1989: The importance of mucus production in slugs' reaction to molluscicides and the impact of molluscicides on the mucus producing system. Pp. 373–378 *in:* Henderson, I.F. (ed.) Slugs and snails in world agriculture. *British Crop Protection Council Monograph 41*.

Wedgwood, M.A.; Bailey, S.E.R. 1988: The inhibitory effects of the molluscicide metaldehyde on feeding, locomotion and faecal elimination of three pest species of terrestrial slug. *Annals of Applied Biology 112*: 439–457.

Wright, A.A.; Williams, R. 1980: The effect of molluscicides on the consumption of bait by slugs. *Journal of Molluscan Studies 46*: 265–281.

Young, C. 1996: Metal chelates as stomach poison molluscicides for introduced pests, *Helix aspersa*, *Theba pisana*, *Cernuella virgata* and *Deroceras reticulatum* in Australia. Pp. 237–243 *in:* Henderson, I.F. (ed.) Slug and snail pests in agriculture. *British Crop Protection Council Symposium Proceedings 66*.