Section 3 – Monitoring

Overview

Regular monitoring of snail populations is essential for successful snail management. It is important to identify the species (round or conical), density, and size of snails present at key times to determine appropriate management options. The rapid sampling method is often adequate for decision-making. More detailed sampling can be performed to guide baiting application rates, assess the efficacy of control or monitor populations over time.

How to monitor

The four key times of year to monitor snail populations and assess the options for management are as follows (Table 3.1; Figure 1.1):

- early summer;
- late summer and early autumn;
- early winter; and
- three to four weeks before harvest.

The different monitoring methods are listed below and described in more detail later in this section:

- **Rapid sampling** – to assess management options at key times of year
- **Quadrat sampling** – to count snail densities before and after control, or monitor over time
- **Monitoring snail movement** – in late summer and autumn, to detect the onset of snail feeding and guide the timing of early bait applications.

Snail behaviour and distribution affect monitoring (Box 3.1). Assessing snail risk and knowing the higher risk areas on the farm allow targeting of monitoring and management. Only live snails need to be counted. Live snails retract into their shell when prodded and are moist if squashed.

BOX 3.1: SNAIL BEHAVIOUR, DISTRIBUTION AND MONITORING

- Changes in snail behaviour throughout the year can affect snail distribution and sampling results.
- In **late spring and summer**, snails are mostly in a dormant state (aestivation) and their distribution becomes extremely aggregated. Aestivating snails commonly cluster together on fence posts or stubble, or in sheltered positions, such as around weeds (Figure 3A), under rocks, logs and surface litter, or inside soil cracks[1,2] (Figures 3.1–3.3).
- Monitoring in summer is useful as snails attached to objects above ground level are visible. However, overall numbers are easily underestimated as many snails shelter in refuges. Conical snails prefer refuges over elevated positions[1]. They often shelter in the root zone and inside the stalks of canola stubble (Figure 3.2).
- Random quadrat sampling can be unsuitable in areas with patchy habitat, such as weedy fencelines or roadsides, when snail distribution is highly aggregated. In summer, checking in refuges such as under rocks or inside plants can reveal many snails (Figures 3.2, 3.3).
- In **autumn to early spring** and when moisture is present, snails are often active and distributed more evenly on the soil surface than in dry summer conditions.
- Snail numbers per metre squared (m^2) can be estimated using quadrat sampling.

Figure 3A. Small conical snails sheltering under green vegetation over summer.

Image: Stirlings to Coast Farmers

GRDC

Table 3.1: Key monitoring times and recommended methods.			
What to monitor	**Purpose**	**Method**	**Management action**
1. Early summer (soon after harvest)			
• Snail species • Snail density	Assess options for managing snails in stubble	• Rapid sampling • Quadrat sampling (to assess control success)	Summer controls: • weed control • cabling • rolling • grazing stubbles with snails
2. Late summer to early autumn (before crop sowing)			
• Snail species • Snail density • Snail movement	Assess areas and timing for baiting Assess options for burning	• Rapid sampling • Monitor movement • Quadrat sampling (to assess bait rates or control success)	• Bait as soon as snails commence feeding and before egg laying • Burn stubble if warranted
3. Autumn to early winter (crop establishment)			
• Snail species • Snail density • Crop damage	Assess the need to re-apply bait	• Rapid sampling • Quadrat sampling (to assess bait rates or control success)	• Re-apply bait as needed
4. Early spring (three to four weeks before harvest)			
• Snail species • Snail density and size class	Assess the risk of snail contamination and options to minimise the risk	• Rapid sampling	• Plan harvest to minimise snail intake and maximise snail/grain separation

Figure 3B. Conical snails at the base of a wooden fence post.

Image: Kym Perry

Figure 3.1: Round and conical snails aggregating on *Brassica* weeds in summer.

Image: Nicole Fechner

Image: Kym Perry

Figure 3.2: Conical snails *(C. acuta)* sheltering inside and on canola stubble.

Image: Kym Perry

Image: Kate Muirhead

Figure 3.3: Snails rest on objects above the ground and shelter in refuges.

Image: Helen Brodie

Image: Nicole Fechner

Image: Nicole Fechner

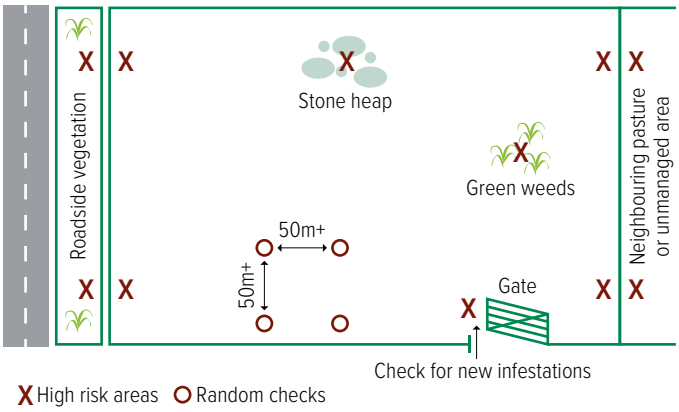
Rapid sampling

Rapid sampling aims to quickly gauge snail populations across the farm to determine options for management. Cover as much ground as quickly as possible, sampling only until a management decision can be made in each paddock. If sampling all paddocks is impractical, sample at least several higher risk and several lower risk paddocks to assess whether snail populations are restricted or widespread.

A suggested strategy for rapid sampling is illustrated below (Figure 3.4). Within each paddock, check higher risk areas. Sample two to several locations along fencelines (for example, adjacent to pastures, roadsides or infested crops). Check outside the paddock to assess the potential for snail reinvasion. Also sample several randomly chosen locations both near the fenceline and farther away (at least 50m).

At each sampling point, turn over any rocks or other refuges, check under weeds and look in surface trash for sheltering snails (Figure 3.3). Visually estimate and record the average numbers of snails (round and conical) per m^2 at each sampling point. Approximate counts are adequate. If desired, also estimate the relative percentage of adult and juvenile snails. As a guide, snails with shells greater than 7mm length or diameter may be adults, or sub-adults that can grow quickly to an adult size, which are capable of reproduction. The minimum reproductive size varies between snail species (page 14). Note any hotspots of higher snail density for targeted management.

Figure 3.4: Recommended rapid sampling points.



Quadrat sampling

Quadrat sampling can be used to estimate the number of live snails per m^2. It is a detailed form of sampling and best used when calculating baiting application rates, to estimate the snail density after a control (for example, baiting or cabling) has been applied, or to monitor populations over time.

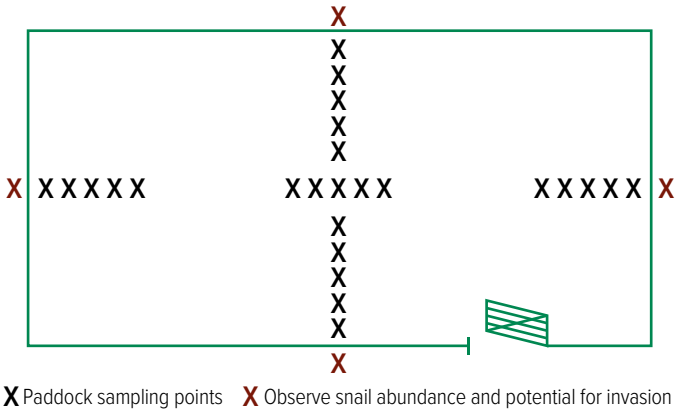
To sample, place a $0.1m^2$ quadrat (32cm x 32cm) randomly on the ground and count all live snails within it (Figure 3.5). Record the numbers of round and conical snails separately. It is useful to distinguish two size classes: 1) adult or sub-adult snails that will soon be capable of reproduction, with shell diameter (round snails) or length (conical snails) greater than 7mm; and 2) juvenile snails with shell diameter or length less than 7mm. An example monitoring sheet is provided in Figure 3.6.

Figure 3.5: A 32cm x 32cm quadrat used to count snails.

Image: Kym Perry

To sample a whole paddock, sample five transects (straight lines along which multiple samples will be taken), one at 90° to each fenceline and the fifth across the paddock centre (Figure 3.7). Take five samples (quadrat counts) 10m apart along each transect. For each transect, average the quadrat counts and multiply this figure by 10 to calculate the number of snails per m^2 in that paddock area. Observe habitats and snail numbers outside paddocks to determine the potential for reinvasion. To estimate the efficacy of a control method, sample the whole paddock before and then seven days after application and calculate the percentage mortality.

Figure 3.7: Quadrat sampling points across a paddock.



Monitoring over time

Monitoring snail populations over time in selected areas on the farm has several benefits. Comparing snail populations across years helps to define the level of management effort required each season based on past experience. The data can also reveal the longer term effectiveness of snail management strategies applied on the farm.

For accurate monitoring over time, detailed sampling and record-keeping are required. A suggested sampling strategy is to select two or more cropping paddocks to be sampled. Sample these same paddocks each year in autumn and spring around the same dates. Sample the paddock using the quadrat sampling method, taking five transects and five quadrats per transect. Count all live snails on the ground surface and vegetation within quadrats.

Figure 3.6

Snail Monitoring Sheet

Paddock name:	Date:	Crop:	Temperature:
Name of sampler:	Time:	Count: before / after treatment	Rain (mm) in last 7 days:

	Round Snails		Conical Snails	
	Circle species present: *Cernuella virgata* / *Theba pisana*		Circle species present: *Cochlicella acuta* / *Cochlicella barbara*	
Transect 1	< 7mm diameter	> 7mm diameter	< 7mm diameter	> 7mm diameter
1				
2				
3				
4				
5				
Total				
Average				
Snails/m²				
Transect 2	< 7mm diameter	> 7mm diameter	< 7mm diameter	> 7mm diameter
1				
2				
3				
4				
5				
Total				
Average				
Snails/m²				
Transect 3	< 7mm diameter	> 7mm diameter	< 7mm diameter	> 7mm diameter
1				
2				
3				
4				
5				
Total				
Average				
Snails/m²				
Transect 4	< 7mm diameter	> 7mm diameter	< 7mm diameter	> 7mm diameter
1				
2				
3				
4				
5				
Total				
Average				
Snails/m²				
Transect 5	< 7mm diameter	> 7mm diameter	< 7mm diameter	> 7mm diameter
1				
2				
3				
4				
5				
Total				
Average				
Snails/m²				
All Transects	**< 7mm diameter**	**> 7mm diameter**	**< 7mm diameter**	**> 7mm diameter**
Av. Snails/m²				

Relative percentage of round snails:			**Relative percentage of conical snails:**		
	Cernuella virgata	eg. 80%		***Cochlicella acuta***	eg. 100%
	Theba pisana	eg. 20%		***Cochlicella barbara***	eg. 0%

In autumn, sample in March or April at the end of the snails' summer dormancy, soon after they have commenced activity on the ground (Box 3.1). Even better, sampling these paddocks both before and seven days after the first bait application each year could give an overall indication of baiting success. In spring, sample before harvest, around October or November. Record the weather conditions during sampling and keep consistent records of sampling data.

Sampling at these times measures the population both before (early autumn) and after (spring) the peak breeding season, to help guide management.

Monitoring snail movement

The critical time to monitor snail movement is in late summer and early autumn, to guide the timing of bait applications. Bait should be applied as soon as snails commence movement and feeding activity, at the end of their summer dormancy (Section 4). Accurate timing of bait application is essential for control. Snails must be moving and feeding to encounter and consume a lethal dose of pellets (Figure 3.8 and Box 4.1).

Snail movement is dependent on weather (Box 3.2). Movement can be monitored using a time-lapse camera placed along a fenceline with high snail numbers (Figure 3.9). Alternatively, check the ground for snail trails in the morning. Feeding can be detected by placing small areas of bait in infested areas and checking after a few days. The presence of dead snails around baits indicates that they are feeding, and widespread bait application may be warranted.

BOX 3.2: SNAIL MOVEMENT AND WEATHER

- Snail movement is dependent on weather. Most movement occurs overnight or in the early morning when moisture is present [5].
- In summer, snails are mostly inactive when conditions are hot and dry. Summer rainfall can trigger short periods of snail movement but there is no breeding at this time.
- In late summer and early autumn, snails become more active in response to moisture. At this time, they commence feeding and maturing their sexual organs in preparation for reproduction. This is the ideal time to apply bait (Section 4).
- Snail movement is greatest when relative humidity at ground level exceeds 90–95% in summer and 80–95% in autumn (Table 2.1).

Figure 3.8: Round snail moving.

Image: Kym Perry

Figure 3.9: Time-lapse camera and weather station for monitoring snails.

Image: Helen Brodie

Figure 3.10: Snail feeding damage to canola seedlings (left and middle) and vegetative cereals (right).

Image: Kym Perry

Image: Kym Perry

Image: Martyn Chandler

Feeding damage

Snails have rasping mouthparts that they use to graze on the surface of plant tissues and other foods. Feeding creates irregular holes or ragged edges in leaves (Figure 3.10). In canola, whole cotyledons, leaves or seedlings can be lopped. Maturing cereal crops can be surface grazed, creating leaf striping. Surface grazing of pods in maturing pea crops can cause some grain shattering. Monitoring for snail damage symptoms during crop establishment can inform the need to re-apply bait (Table 3.1).

Assessing snail risk

Areas at risk of higher snail densities include those with previously high snail densities, calcareous soils or acid soils with lime applied, summer weeds and paddock margins (Table 3.2). Adjacent roadside verges, stone heaps, pasture paddocks and heavily infested crops are often sources of invading snails. Noting areas with high snail contamination the previous harvest can identify snail hotspots. Weather also affects seasonal snail risk. Good growing conditions and wet summers generally favour snail populations. Retained stubble and trash provide a favourable environment for snails.

Table 3.2: General and seasonal risk factors for snails.

Risk factor	Lower risk	Higher risk	Explanatory notes
General risk factors			
Cropping region	• Low snail abundance in the region	• High snail abundance in the region	• Snails are more abundant in some coastal regions
Soil type	• Acid soils not limed	• Calcareous soils	• Available calcium benefits snail populations [6, 7]
Liming	• No liming	• Lime applied	• Liming can increase snail populations and shell strength[7]
Previous history of snail populations in the paddock/area	• Low previous snail populations	• Recurring high snail populations • Presence of juvenile snails • Snail contamination during prior harvest	• Snails recur in the same areas • Presence of juvenile snails indicates breeding areas
Vehicle traffic	• Low vehicle traffic	• Vehicle entry points, high traffic areas, parking areas	• Snails hitchhike on vehicles
Seasonal risk factors			
Summer weather	• Relatively hot, dry summer weather • Heatwave events	• Relatively cool and/or wet summer	• Hot weather kills many snails[8]
Summer weeds	• Few green weeds, or weeds controlled	• Green weeds not controlled	• Green weeds increase snail survival[9,10]
Amount of stubble and trash in summer	• Light stubble or trash	• Heavy stubble or trash following high yields	• Residue provides cool, moist refuge
Summer management	• Paddock effectively cabled, rolled or grazed	• Ineffective summer management, or lack of suitable weather (hot days for cabling)	• Snails not suppressed
Crop or pasture rotation in paddock last year	• Paddock continuously cropped	• Pasture phase • Canola rotation	• Conical snails may increase following canola rotations • Snails can breed more in pasture phases[3]

References

1. Muirhead, K.A. and Perry, K.D., 2021. Biocontrol of invasive conical snails by the parasitoid fly *Sarcophaga villeneuveana* in South Australia 20 years after release. *Insects*, 12(10), p.865. https://doi.org/10.3390/insects12100865

2. Hanache, P., Thomann, T., Caron, V. and Desurmont, G.A., 2021. Can estivation preferences be used to develop novel management tools against invasive mediterranean snails? *Insects*, 12(12), p.1118. https://doi.org/10.3390/insects12121118

3. Baker, G.H., 2008. The population dynamics of the Mediterranean snails *Cernuella virgata, Cochlicella acuta* (Hygromiidae) and *Theba pisana* (Helicidae) in pasture–cereal rotations in South Australia: a 20-year study. *Australian Journal of Experimental Agriculture*, 48(12), pp.1514-1522. https://doi.org/10.1071/ea08031

4. Baker, G.H., 2012. The population dynamics of the Mediterranean snail, *Cernuella virgata* (da Costa, 1778) (Hygromiidae), in continuous-cropping rotations in South Australia. *Journal of Molluscan Studies*, 78(3), pp.290-296. https://doi.org/10.1093/mollus/eys015

5. Perry, K.D., Brodie, H., Muirhead, K.A., Fechner, N.K., Baker, G.J., Nash, M.A., Micic S., Ruggiero K., et al., 2020. Biology and management of snails and slugs in grains crops (DAS00160). Final report for GRDC. South Australian Research and Development Institute.

6. Carne-Cavagnaro, V.L., Keller, M.A. and Baker, G.H., 2006. Soil moisture and soil type influence the breeding behavior of the pest snail *Cernuella virgata* (da Costa). *Applied Soil Ecology*, 33(3), pp.235-242. https://doi.org/10.1016/j.apsoil.2005.10.005

7. Micic, S., Skinner, G., Dore, T., Babativa-Rodriguez, C., 2020. Determining effect of lime on small pointed (conical) snail fecundity and shell strength. *GRDC Updates Proceedings, 10 February 2020*. Department of Primary Industries and Regional Development. URL: https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2020/02/determining-the-effect-of-lime-on-small-pointed-conical-snail-fecundity-and-shell-strength

8. Perry, K.D., Brodie, H., Muirhead, K.A., 2020. New methods for snail control (UOA1903-014BLX). Final report for GRDC. South Australian Research and Development Institute.

9. Baker, G.H. and Vogelzang, B.K., 1988. Life history, population dynamics and polymorphism of *Theba pisana* (Mollusca: Helicidae) in Australia. *Journal of Applied Ecology*, pp.867-887. https://doi.org/10.2307/2403752

10. Baker, G.H., 1988. The life history, population dynamics and polymorphism of *Cernuella virgata* (Mollusca, Helicidae). *Australian Journal of Zoology*, 36(5), pp.497-512. https://doi.org/10.1071/zo9880497