Montana Invasive Species Council

Panel Report
Xerolenta obvia Science Advisory Panel

A panel established to examine the existing body of knowledge about *Xerolenta obvia*, eastern heath snail, identify gaps related to its basic biology, monitoring techniques, control options, and best practices for managing pathways, and develop a containment and management strategy for populations in Belt, Montana and outlying areas.

TABLE OF CONTENTS

Montana Invasive Species Council. 2020. *Xerolenta obvia* Science Advisory Panel: A review of the existing body of knowledge about *Xerolenta obvia*, eastern heath snail, and best practices for managing pathways and containment. Helena, Montana.

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Panel Purpose and Outcomes

Purpose: To examine the existing body of knowledge about *Xerolenta obvia* (Eastern Heath Snail), identify gaps related to its basic biology, monitoring techniques, control options, and best practices for managing pathways, and develop recommendations for a containment and management strategy to address populations in Belt, Montana and the outlying areas.

Expected Panel Outcomes:

- Review the state of science about the basic biology of *X. obvia* and identify gaps in knowledge.
- Identify gaps and challenges associated with containing and managing *X. obvia*.
- Identify information and strategies to improve management of *X. obvia*.
- Acquire input and guidance regarding funding sources for research and regulatory needs.
- Develop management strategies to address survey and monitoring, control options, private landowner education and outreach, and best practices for managing movement through forage, gravel, and other material pathways.
- Identify next steps to be taken by researchers, regulators, and managers regarding the containment and management of *X. obvia*.
- Discuss including snail inspection to "weed free" certification in upcoming legislation.

Panelists

(Alphabetical)

Jennifer Birdsall, Research Associate, Montana State University
Jennie is a botanist/zoologist who has worked for several federal agencies and universities on biological control of range and forest weeds, fire effects on forest ecosystems, and whitebark pine. She has been studying the biology of the eastern heath snail for Montana State University for over two years.

Helen Brodie, Agricultural Entomologist, South *Australian* Research and Development Institute
Helen has focused on mollusc pests since 2012, and her research projects include: optimizing bait programs, testing novel molluscicides, assessing field parasitism rates, testing host-specificity of new biocontrol agents, and improving knowledge of reproductive patterns using long-term time-lapse video to monitor snails in the field. The major pest snails to the grains industry in Southern Australia are *Cernuella virgata*, *Cochlicella acuta, Prietocella barbara,* and *Theba pisana*,. Helen and her colleagues deliver learnings to growers via workshops, newsletters, the Grains Research and Development Corporation publications, conferences, updates, and social media. Besides snail research, Helen is a general and biosecurity diagnostician for the SARDI Insect Diagnostic Service, and a key diagnostician in the national project "iMapPESTS: Sentinel Surveillance for Agriculture", utilizing remotely managed 'smart' air samplers for early detection of endemic and exotic airborne invertebrate and fungal pests.

Jenni Cena, Pest Biologist 2, Washington State Department of Agriculture
Jenni has been working on agricultural research projects in the Public and Private sector of Eastern Washington and Eastern Oregon since the 1990s. She has worked at the Washington State Department of Agriculture State Survey since 2000 on pests including: Gypsy Moth, Japanese Beetle, Combine Exotic Wood Boring Insects and Exotic Terrestrial Mollusks.

Jeffrey L. Littlefield, Research Scientist and Quarantine Director, Montana State University
As Quarantine Director Jeff is responsible for the maintenance and daily operation of the Biological Containment Facility for the importation of weed feeding organisms (arthropods and pathogens) and associated duties. He develops risk assessment documents, both BAs and EAs, for field release of exotic organisms for biological control, working closely with state and regulatory personnel for maintaining the certification of the containment lab and for the importation of biological agents. Jeff's research emphasis is on the biological control of weeds, including the determination of host specificity, bionomics, and field release of potential biocontrol agents. He has recently begun evaluating the risk potential of the eastern heath snail, an introduced snail in Montana.

Nathan Luke, National Border Surveillance Coordinator (South Australia region), Department of Agriculture Water and the Environment
While Nathan's primary focus is plant health surveillance in his current position, he is considered to be the leading mollusc expert within the federal department. Prior to Nathan's current position, he worked in a senior technical role for the South Australian Research Development Institute (SARDI) on a number of invasive snail/slug projects. While at SARDI in 2001 Nathan coordinated the introduction and release of a biological control agent for the first time in Australia, against one of the highly invasive Mediterranean snails.

Rory Mc Donnell, Assistant Professor and Malacologist in the Dept. of Crop and Soil Science at Oregon State University
Rory's research and Extension program is focused on 1) understanding the ecology of invasive slugs and snails in agriculture, horticulture, urban areas, the natural environment and at the interface of these systems, and 2) developing and implementing novel strategies for the management of these pests. He and his team are currently investigating the potential for using plant extracts as novel biorational molluscicides, assessing the potential for using natural enemies as biological control agents, identifying novel attractants for use in both trapping and attract-and-kill strategies, and assessing bioactive molecules (e.g. peptides) and receptor interference as species specific management tools. He has active collaborations and projects in Oregon, Washington, California, Hawaii, Florida, Ecuador, China, U.K. and Ireland.

David Robinson, National Malacologist, USDA APHIS National Malacology Laboratory
David was appointed as the U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine, National Identification Services (USDA APHIS PPQ NIS) National Malacologist in November 1995, and his laboratory is located in the Malacology Department of the Academy of Natural Sciences, in Philadelphia, PA. One of his chief interests has been capacity-building in malacology, including in most countries in the West Indies, Central and South America, as well as Hawaii, Micronesia, Guam, the Northern Mariana Islands, Samoa, American Samoa and China. Much of his focus has been on the giant African snail, veronicellid slugs and Cerebral angiostrongyliasis (Rat lungworm disease), as well as other invasive snails and slugs.

Amy L. Roda, Entomologist, USDA APHIS-PPQ Center for Plant Health Science and Technology
Amy serves as a project leader with USDA, Animal Plant Health Inspection Service, Plant Protection and Quarantine Science and Technology, in Miami, Florida, where she has developed and evaluated survey and mitigation strategies for key invasive pests primarily in the southeastern U.S. and Greater Caribbean Basin for the past 16 years. Her work has focused on pests of high consequence including the Giant African Snail (*Lissachatina fulica*), the tomato leafminer (*Tuta absoluta*), the melon fruit fly (*Anastrepha grandis*), the passionvine mealybug (*Planococcus minor*), and the red palm weevil (*Rhynchophorus ferrugineus*). The results of the efforts have also led to the development of survey and mitigation options to manage invasive pests.

Brian Sullivan Plant Safeguarding Specialist, USDA APHIS PPQ
Brian has worked as a USDA APHIS PPQ Plant Health Safeguarding Specialist since 1998. In 2001 he discovered first US population *Xerolenta obvia* and has been working directly with this species ever since as the Wayne County Michigan Eradication Project Coordinator (2005 - 2011) and Michigan Exotic Snail Lead. His is a member of National The Mollusk Action Plan Working Group that drafted *New Pest Response Guidelines: Temperate Terrestrial Gastropods (2008).*

Summary

Challenges

- *Xerolenta obvia* (Eastern Heath Snail) is established in Belt, Montana
    - Introduced as early as 1910, possibly with mining operations
    - At least one producer currently impacted (hay)
    - Residents resistant to control efforts as risk of chemical treatments seen as higher risk than the snail
    - Population density reaches high levels within the Belt Valley
    - Resources are limited to mitigate existing snail populations and potential spread
    - There are currently no local cooperative agreements to manage this species or rules prohibiting their transport
- *Xerolenta obvia* is spreading in Montana, Michigan and Ontario, Canada
    - Climate does not appear to be a barrier to the spread of *Xerolenta obvia*
    - Millions of acres are located in production areas within the likely range of this species
    - The species is regulated at the international border; not all states regulate interstate movement
    - Populations in Michigan expanded once control efforts discontinued and snails spread along rail lines and through intermodal transport
    - Transport of materials (gravel) and vehicles have established at least three additional Montana populations 18-28 miles from Belt
    - Construction (electrical, internet cables) and road work can potentially spread snails
    - Vehicles, garbage cans, propane tanks, bee hives, and any structures left in the field can amass snails providing the potential to move them to other sites
- *Xerolenta obvia* is not currently identified as a high-risk species due to the following:
    - The Canadian Food Inspection Agency's 2004 Pest Risk Assessment
    - It is considered a generalist feeder with low direct impacts
    - Lower densities in native range do not have the impacts observed in the introduced range
    - Very high densities have not significantly impacted producers by contaminating equipment or crops
- Research on the biology of *Xerolenta obvia* and gastropods in general is limited and underfunded
- Management requires substantial time, consistent access to funds, staffing, effective molluscicides, and community support for long-term control efforts.
- The most effective molluscicide (e.g. metaldehyde) is not being used due to cost and mitigation requirements
- Sustainable long-term funding for outreach and management for mollusk pests is limited and a low priority

Recommendations

- Initiate a robust research program to investigate and better understand the biology of *Xerolenta obvia* to improve management decisions and options in the future
    - Identify if *Xerolenta obvia* is capable of transmitting vertebrate parasites in North America or the spores of plant diseases
    - Identify where the North American populations of *Xerolenta obvia* originated from to improve efforts to predict their spread and introduction

  - Identify and prioritize other research needs
- Redevelop and modify the 2012 Environmental Review for *Xerolenta obvia* based on the larger area now occupied, including different treatments recommended for landowners, roadsides and different cropping systems, and the impact of integrated pest management (IPM) measures that include increased till and burning to reduce populations in hay fields
- Develop a cooperative management plan for *Xerolenta obvia* in Montana based on the recommendations in the USDA New Pest Guidelines – Temperate Terrestrial Gastropods, other local response plans for gastropod species, and local priorities to include the following recommendations:
  - Boost survey efforts to identify locations of established populations
  - Develop tools to manage pathways and reduce the movement of snails
  - Utilize metaldehyde products, wherever possible, and reduce the use of iron phosphate for control. Incorporate vegetation management into control work
  - Use the full suite of management tools to keep snails from reaching densities that make harvesting impossible and to ensure that there is uniform use to eliminate refugia populations
- Conduct an economic impact analysis of the spread of this and related species in Montana
- Develop targeted outreach materials for the public and those that recreate near infested areas; the public; residents; producers; and industry to build awareness of invasive gastropods
  - Develop identification and reporting tools
  - Raise awareness about the need to check for and remove hitchhiking snails, e.g. install signage at access points to local recreation areas in infested areas indicating the presence of *Xerolenta obvia*
  - Identify impacted industries, processors, and growers and improve understanding of the impacts of expanding snail populations on operations and exports
  - Create a liaison officer position modeled after the South Australia Grains Biosecurity Officer to support impacted industries in adopting the control practices and equipment modifications needed to continue producing crops on heavily infested sites
- Include snails to the gravel section being developed for the Montana weed seed free forage program (MDA bill 2021 leg. Session)
- Secure long-term and sustainable funding and capacity for management efforts
- Support the continued availability of chemical control tools to contain spreading invasive species
- Address non-insect pests at a national level

Conclusion

The MISC *Xerolenta obvia* Science Advisory Panel provided a platform to review the efforts taken since the official discovery of this species in Montana in 2012 and discuss the best globally practiced management practices for pest gastropods. An advantage in managing this newly expanding threat is the ability of U.S. managers and producers to build on decades of experience developed in Australia. A complex of terrestrial snails similar to the Eastern heath snail [i.e. the Mediterranean snails: *Cernuella virgata*, *Cochlicella acuta*, *Cochlicella (Prietocella) barbara* (Geomitridae), and *Theba pisana* (Helicidae)] have impacted grain and pulse growers in South Australia and surrounding regions.

The economic impact in areas with these high-density aggregating snails has led to the development of a suite of management tools and practices that can be adapted to U.S. grain, pulse, and canola production. The estimated cost to producers to manage the four established Mediterranean snail species is an additional $50/hectare ($20.23/acre/year). Costs include reducing snail presence in fields of grain, pulses, and hay in addition to costs due to crop losses. For Montana, the 2019 State Agricultural Review for Montana (USDA) indications predict productions to be:

- 5,450,000 acres wheat
- 3,000,000 acres hay
- 950,000 acres barley
- 1,024,000 acres pulses (lentils, peas, chickpeas)
- 244,800 acres brassica (canola, sugar beets)

Applying Australian estimates, additional costs to Montana growers using the predicted total acreage of crop production could exceed $215 million per year in additional costs to producers to manage snails. Australia's experience provides information that Montana can use to mitigate the impacts of *Xerolenta obvia* and also amplifies a sense of urgency regarding the importance to develop a local and regional approach for containment and management of *Xerolenta obvia* to avoid potential economic impacts.

Next Steps

MISC has identified the following steps to utilize the information from the panel:

- Distribute information generated from the scientific advisory panel to all interested parties including outreach networks, neighboring states, and impacted industries
- Engage regional coordinating bodies for both impacted industries and invasive species coordinating bodies to assist in the promotion/implementation of the next steps identified by the panelists
- Support research on both the biology of this pest and possible control strategies
- Conduct an economic impact analysis and develop education and outreach materials
- Encourage and support the development of funding and regulations for invasive gastropods (slugs and snails)

Review

Review: Table of Contents

Basic Biology and Potential Risk of the Eastern Heath Snail

1. What is known about the basic biology of the Eastern Heath Snail?

X. obvia is a medium-sized (≤ 20 mm shell width) xerophilous (adapted to dry, hot habitat), thermophilous (warm loving) and heliophilous (attracted to sunlight) snail species. Its native range is Asia Minor through central Europe. It is primarily a calciphile (thrives in lime-rich soils) and tends to live in dry, open grassy areas where massing behavior is common. Snails are also found on dry grassy slopes, dunes, vineyards, sunny walls of ruins, railway dams, road margins, and are often found estivating in large numbers on vegetation.

A characteristic of most populations is the co-occurrence of large numbers of living snails and dead shells with populations sometimes covering several hectares. This phenomenon does not appear to be a result of a population explosion as is often typical for an invasive species but is normal for *X. obvia* and also occurs in its native range (Pfeiffer 1841; Welter-Schultes 2012). In older literature this species is referred to by its synonym *Helicella obvia.*

In Montana, studies have been ongoing for the past 18 months. At this time, it is it is difficult to make generalities about the biology of the snail in Montana due to the high degree of plasticity observed among individuals and in the population through time.

Life Cycle Varies by Climate

Lazaridou & Chatziioannou (2005) showed that in an inland mountainous area of Greece where the climate is classed as temperate, snails hatch in autumn, become adults the following July, but do not lay eggs until October, and then the adults die i.e. the species displays an annual lifecycle. Clutch size is small, but eggs and neonate snails are large. Laying larger eggs increases the chances of juveniles reaching adult size before the short growing season ends. Growth is fast in spring and continues until the end of July. In a coastal area in Greece where the climate is classed as Mediterranean (milder winters and longer hotter dry periods) eggs are also oviposited (laid) in October, and young snails emerge from hibernation in March, but maturation does not take place until April of the following year. They thus have a 2-year life cycle, and adults die during their second autumn. Clutches are ~3 times the size of clutches in the mountainous area, but eggs and neonates are significantly smaller. A small amount of growth occurs in winter, but the growth rate is typically slower than at the mountain site. At the two study sites, the population density of *X. obvia* fluctuated during both study years, but it was always higher at the site with the Mediterranean climate (Lazaridou and Chatziioannou 2005).

Marzec *et al.* (2020) showed that in a temperate area of Poland *X. obvia* is an annual species. Most snails hatch in Fall, they overwinter as juveniles, continue growth in spring and summer and finally they reproduce in Fall. In an area of the country with a milder climate, the snail population was more plastic with some individuals capable of living and reproducing longer. The authors also found that the length of the growing season and temperature were additional factors impacting growth and population dynamics of *X. obvia*. Growth rate was negatively correlated with the initial size of the neonate snail shells. They suggest that larger shells in regions with warmer and drier conditions may constitute responses to selection by environmental factors i.e. larger individuals are likely to be more resistant to desiccation because of the lower ratio of surface area to volume (Marzec, Kuźnik-Kowalska, and Proćków 2020).

In a temperate region in Belarus, the breeding season for *X. obvia* was during the autumn and the species displayed an annual life cycle (Zemoglyadchuk 2019).

These studies indicate that length of growing season and temperature variability are factors determining differences in *X. obvia* growth and population dynamics. This would imply a greater invasive potential in warmer environments. So, it may be inferred that the life cycle of the species potentially could be different in both Montana and Michigan, and life cycle studies need to be conducted in both states due to differences in the climates of the two states.

Life history studies in Montana indicate snails in the field are variable in size and may take two or more years to mature. In laboratory tests, some individuals mature faster than others with some snails living more than two years. Eggs were collected from the field in the autumn of 2018 and in the spring and autumn of 2019, but none were found in the spring of 2020. However, groups of adult snails collected in the spring of 2020 laid eggs when brought into the laboratory.

There are many years of experience in working to improve management of *Theba pisana, Cernuella virgata, Prietocella barbara* and *Cochlicella acuta* in broad acre crops throughout southern Australia. The southeastern corner of Australia has a climate comparable to Montana and is thoroughly infested with these snails. *Cernuella virgata* (vineyard snail) is probably the closest to *X. obvia*, in terms of ecology, adaptability and habitat (though often combinations of all four species cohabit).

Reproduction

In Europe, adult snails laid single clutches of between 17 and 95 eggs, buried at an average depth of 2 cm (Heller 2001; Lazaridou and Chatziioannou 2005). Heller's studies indicate that *X. obvia* is normally an outcrossing species (breeding between different breeds with no common ancestors) but may self-reproduce (parthenogenetic reproduction with no mating) under certain circumstances, especially when kept in isolation. *X. obvia* was thought to be semelparous in egg laying (eggs laid in one event) but, in laboratory studies, *X. obvia* was also iteroparous (clutches of eggs laid in multiple events). The number of eggs laid per clutch varied but ranged from one to 80 eggs. Egg viability also varied but averaged about 51% for field collected eggs.

In Australia in the cooler month of March (beginning of Autumn in Australia), 80 percent relative humidity or 1-2 mm of rain is enough for *T. pisana* and *C. virgata* to begin moving and feeding. The lighter rain events that occur before a main rain event, the more snails will have a chance to prepare for egg lay as soon as the soil stays sufficiently moist. If the topsoil remains moist, egg laying will occur as early as two weeks after the first serious rains and for as long as conditions remain favorable. *Theba pisana* and *C. virgata* can lay about 400 eggs per season with eggs hatching approx. two weeks after laying. Juvenile *T. pisana* and *C. virgata* (hatched early in the growing season) feed over winter but are not sexually mature until the following autumn. Snails will continue to lay egg clusters as long as moist conditions persist. As the season begins to dry out, it has been observed that the albumen glands of the round snails (*T. pisana* and *C. virgata*) begin to shrink prior to snails shifting into survival mode to wait out the dry summer ahead. Some snails will remain reproductive longer than others, so we see a staggered "shut-down" of the breeding phase.

In Michigan, mating occurs late summer to early fall when fall rains occur. Hatchlings emergence has been witnessed in fall, but some may occur in the spring. It has been stated that after egg laying adults die but this has not been locally confirmed to see if multiple clutches are laid during their lifespan.

Population Density

Cehanoviča & Stalažs (2020) conducted a population dynamics study of *X. obvia* at an infested railway site in Latvia. Their data showed that the snail can move up to 29.7 m over 28 days i.e. 1.07 m per day. However, the total distance moved by the snail is probably greater as distances were measured as the crow flies. In addition, the authors calculated population density estimates ranging from 170.5 to 2004.7 m^{-2}. The study also demonstrated that mowing resulted in a significant decrease in the population size likely because it takes away critical aerial microhabitat that the snails use to prevent thermal death (Cehanoviča and Stalažs 2020; Schweizer, Triebskorn, and Köhler 2019).

In at least six areas in Montana, the density of snails was estimated at a million per acre or more i.e. $\geq$247 m^{-2} (Foley and Eiring 2013).

According to Lazaridou & Chatziioannou (2005) population density of this species varied from 2.5 – 79.3 m^{-2} at a temperate location and 3.8 to 145.8 m^{-2} at a location with a Mediterranean climate in Greece. Lastly, White-McLean (2011) cited population densities of 70 to 100 snails per square foot (6.5 to 9.3 m^{-2}) (Lazaridou and Chatziioannou 2005; White-Mclean 2012).

Feeding Habits

X. obvia has been shown to feed on a wide range of plant species of minimal economic importance (Hatziioannou, Eleutheriadis, and Lazaridou-Dimitriadou 1994) but is also reported as a pest of fodder crops. Feeds on faded and rotting parts of plants (Welter-Schultes 2012). It has caused feeding damage to alfalfa, clover, lupine, sanfoin, and seradella in southern Germany and is considered a serious pest in Italy and Bulgaria, where it is a contaminant of fruits and vegetables exported to other European countries.

In the field in Montana, *X. obvia* has been recorded on 35 plant species belonging to 15 plant families (did not observe snails actively feeding on all 35 species but observed possible feeding on some of these species). As a juvenile, *X. obvia* probably feeds predominately on plant detritus and soil debris, adding more live plant material to its diet as it matures. Preliminary laboratory feeding tests on 18 key economic crops in Montana indicate that *X. obvia* can feed on all 18 crops but prefers certain legumes such as sweet clover and peas to small grains such as barley or wheat. Currently examining long-term survival on several crop species.

Environmental Limitations

Research in Montana has been initiated to determine the conditions under which *X. obvia* can survive. Snails, when grown at three different temperatures (12, 20, and 28º C), generally develop faster at 20º C (68 º F) than at the other temperatures (although there is variability among individuals). Only the snails at the 20º C temperature have laid eggs. Snail mortality increased with increasing temperatures, with the coolest snails generally living the longest. Activity and long-term survival of *X. obvia* at temperatures close to freezing has been observed.

Some individuals survive through the Montana winter, probably by producing multiple epiphragms (clear or white calcified seals) and hibernating, although this may be facultative. *X. obvia* also tolerates hot, dry conditions by producing epiphragm(s) and estivating (suspending movement for a shorter time than during a hibernation). Live snails floating in the Belt River has been observed, however examination of their ability to survive through time in water or the distances they might be transported downstream has yet to be determined.

X. obvia displays negative geotrophic behavior during unfavorable conditions. These snails estivate to survive the hot, dry summers by climbing up off the ground (e.g. fence posts, tall stubble/weeds, standing crops, nursery stock, firewood, vehicles, shipping containers, etc.) or they go down deep into the base of plants with complex stem/leaf structures that provide cool, moist refuge (especially the conical snails). The intensity of their aestivation state varies among individuals, some will react and move/rehydrate/feed with light showers or dew events, others will stay "locked up" until damp conditions persist. Smaller snails seem to be more reactive. The goal of such behavior is to avoid higher temperatures on the ground surface thereby helping to prevent thermal death (Schweizer, Triebskorn, and Köhler 2019). For example, McQuaid *et al.* (1979) recorded a temperature difference of 8°C at the soil surface compared to 1 m off the ground in a sunny, open habitat in South Africa (McQuad, Branch, and Frost 1979).

With cooler (approx. below 22°C) and moist conditions, snails will be active most nights. Although they can and are active during daylight (especially during rain events), activity is greatest at night. Due to the need for soil moisture and depending on when the main season opening rains begin, egg lay may coincide with broad acre crop sowing. This means that growers must balance the need to apply bait prior to egg lay and sow crops at the ideal time.

In Europe, the growth and longevity of the snails is impacted by environmental stresses (heat, drought, winter) and the snails exhibit plasticity in growth and longevity based on yearly differences in these environmental stress factors (Lazaridou and Chatziioannou 2005; Marzec, Kuźnik-Kowalska, and Proćków 2020). Overwintering stages vary: eggs (possible), juveniles (most common) and few adults (milder climates). Mating can be seasonal (annual populations) or more plastic in milder climates. *X. obvia* has been observed up to 2000 m in the Alps, 1900 m in Bulgaria.

Natural Enemies

In Montana, three species of nematodes have been identified that appear to cause *X. obvia* mortality. Nibbled *X. obvia* shells indicate that various rodents feed on *X. obvia*; birds have been observed feeding on these snails; and ground beetles and other insects may also feed on *X. obvia*. One parasitic fly was reported as having emerged from a *X. obvia* individual, although none have emerged from multiple samples collected and maintained in our laboratory.

Shell Polymorphism

X. obvia displays significant variation in the color of bands on the shell and this may be linked to the fitness of different phenotypes in particular climatic conditions (Jones, Leith, and Rawlings 1977). Shells with faint or no bands likely heat up less than the darker banded shells when exposed to the sun and thus these snails may be able to remain active for longer periods during hot summers (Lazaridou and Chatziioannou 2005). Conversely, having shells with dark bands may enable snails to be active at lower temperatures as they likely absorb solar radiation more quickly than unbanded shells. In addition, there is evidence with other gastropods e.g. *Cepaea* (Cowie and Jones 1985) to suggest that climatic selection favors pale color in hot environments but other authors (Schweizer, Triebskorn, and Köhler 2019) suggest more research is required to confirm such an hypothesis.

2. What information is unknown about the basic biology of *X. obvia* and necessary to determine the best control methods or strategies?

Feeding Preferences

As a potential plant pest, additional information is needed on its actual food preferences and plant utilization under field conditions to supplement our continuing laboratory experiments, e.g. direct feeding on various seedlings of plants of agricultural and environmental importance. Determining whether neonates, immatures, and adults have different feeding preferences will improve understanding of risk and susceptibility to control tools at all life stages. Behavior patterns such the timing of massing behavior relative to the harvesting time of all crops in each area need to be documented. With this information, we could further predict what crops may be at risk.

Disease Transmission

The assumption is that *X. obvia* can be pestiferous (harboring infection and disease). Little is known about the potential of *X. obvia* to transmit parasites to wildlife, domesticated animals and pets, or humans in Montana. Little information is known as to the parasitic species *X. obvia* carries or is susceptible to in North America and if they can effectively serve as intermediate hosts of lung worms, tapeworms, etc. here. Similarly, do the snails spread propagules of plant diseases?

Life Cycle

Understanding the life history of the target pest is a key initial step in developing effective management plans as it can help identify optimum times for using different IPM tools such as molluscicides and tillage/grading. Life cycle studies need to be made at both Montana and Michigan sites, in order to determine the reproductive characteristics such as whether it display an annual or two-year life cycle. Does this vary by location? Do the annual populations have a mating season (e.g. Oct-Nov in Europe)? If control resources are limited, perhaps they could be targeted mating season to reduce oviposition and thereby the next generation.

What is the peak egg-laying season? What is the time to reach sexual maturity? Do adults live long enough to lay more than one clutch in any given period? Can different cohorts live together simultaneously? What life cycle stage does the snail overwinter in?

As noted above more information is needed to understand if there is multiple clutches of eggs or single clutches before adults perish. Does the emergence of hatchings occur only in fall or is there additional emergence in the spring as well? The reason this information is critical, the neonates or immatures do not have mature mouth parts to feed on molluscicide baits. The immatures may also have different feeding behaviors than the adults at this stage. In Michigan, baiting is halted in the late summer/early fall once mating has been observed as bait is not as effective on the entire population.

Plasticity

The variability of *X. obvia's* life cycle needs to be better defined to further determine how this correlates with seasonal environmental conditions and habitats. This information would be useful in determining the potential range of *X. obvia* and in making management recommendations (such as timing of chemical treatment or baiting). Do predictions of potential range consider current observations in the introduced range of the snails and do range predictions respond significantly to predicted climate change?

Community Ecology

We need to learn more about the various factors that regulate *X. obvia* populations. For example, what are the role of native natural enemies in snail mortality? Are the nematodes found in Montana associated with *X. obvia* resulting in significant mortality and could they be utilized as potential biocontrol agents? Are additional nematodes/natural enemies (e.g. parasitic flies) present in Montana and might they be utilized as potential biocontrol agents? How is it interacting with other snails (native or introduced)? Competition? Repellency? (Australian observations where *C. virgata* and *T. pisana* cohabit are that the two species tend to have distinct patches on the ground or on estivating sites that are dominated by one species.)

Activity and Movement

When do the snails become active in Montana? This is important for surveys and control. The snails need to be active to go to traps or ingest/metabolize the molluscicides. What are the lowest (highest) temperatures that the snails are active? What are the lowest humidity snails are found active? What is the relationship between air humidity and ground humidity to predict activity? Are their ways to induce activity? Can an area that will be treated watered prior to applying the molluscicides?

What are the environmental conditions that cause the snails to climb? Can these conditions be altered in a crop to prevent their climbing and contaminating a crop? (e.g. watered?) Do estivating snails become active after they climb such as at night when humidity increases and temperature decreases? Or do they 'commit' and stay inactive despite more favorable conditions? Does this vary with age? Time of year? Do all snails always climb when they are estivating (e.g. is there a time when they don't climb/a population relationship/a proportion of the population that does not climb/do all age classes climb?) Estivating snails may be more apparent, timing surveys to likely times/conditions of snail estivation may help in surveying (more likely noticed, better time if resources are limited).

Where do they go in the winter in Montana? Does this location vary between urban areas, open fields and near stream beds? Can these areas be managed while the snails are inactive (steam treatments?)

Dispersal and Spread

In Montana, field experiments have begun on the dispersal of *X. obvia* under field conditions through time. This information is needed to determine the rate of spread of a population. Has the population in MT spread since its detection? What were the conditions of these new areas of spread? This may help target surveys and identify areas to focus management areas (e.g. establish 'pest free areas') particularly if a population is small or recent and near commodities likely to be exported (intra/inter State and internationally).

How long do the snails survive in soil attached to tractors/highway equipment?

Control

What is the toxicity of available pesticides? Does this toxicity vary among the different stages? The 'softer' pesticides were found to be not as effective against giant African snail and may have caused the snail to disperse from treated areas (eradication team observations).

3. In the 2009 Cowie et al. risk assessment, *X. obvia* ranked 12 on the simple scale and 16 on the proportional scale. What do these risk ratings mean and how does the rating for *X. obvia* compare with snails that are established elsewhere and whose biologies and impacts are better known?

Cowie et al. (2009) conducted a preliminary regulatory assessment of 46 taxa (species or species-groups) in 18 gastropod families of regulatory concern. *X. obvia* had a middle score (or a little above) at 5.5 (Simple scale). In comparison, the Australian round snails *Cernuella* and *Theba pisana* scored 9.5 & 9.0 (1 & 3 ranks) respectively, while the conical snails (*Cochlicella*) scored 9.0 (3 rank). *Prietocella* was not included. However, as Cowie et al. pointed out, there is uncertainty in the ratings due to lack of knowledge, etc. (Cowie et al. 2009).

For each species or group the scores were summed to obtain S, a simple measure of the pest potential of each species or group. This measure, however, downplays a species' pest potential when fewer attributes can be scored (i.e., when less knowledge was available). Therefore, each value was also divided of S by the total number of attributes scored, to obtain P, a proportional measure of pest potential not influenced by the number of scores, and ranging from 0 to 1, least to greatest concern. The species/groups were then ranked from highest to lowest based on the values of S and P. For each species, a simple ranking represented its suspected pest potential, but this did not consider 12 attributes (different parameters such as distribution, feeding preferences, egg clutch sizes, overall size, etc. that would contribute to its potential pest status). The proportional ranking incorporated those attributes but could not accurately predict pest status if few attributes were known. The ranking was a relative measure rating the different species, not an absolute value. It is likely that the ranking for *X. obvia* would increase due to its apparent taxonomic affinity to related geomitrids such as *Cernuella virgata* and *Cochlicella* spp. that are causing such devastation on crops in Australia (a taxonomic relationship that was not fully understood when the 2009 study was conducted).

The proportional scale rankings appear to have less deviation in the upper third of the taxa and may indicate elevated concern for some of the species ranked, including *X. obvia*. The rankings probably serve as an acceptable approximation of the potential of these taxa to be problematic and an initial tool to help prioritize their regulatory significance. Since *X. obvia* appears to be a highly variable species, actual risk may be dependent upon a multitude of factors including the genetic plasticity of the introduced population combined with the climate, habitat, and land management practices (among other factors) in the area of introduction.

Based on the Australian experience, we acknowledge that there is limited bionomic information on *X. obvia* and agree with the approach of grouping higher taxonomic groups (families) of snails and slugs when considering them as pests. As a potential broad acre pest in Montana, we would consider *X. obvia* to be of similar ranking to *Theba* and *Cernuella*. Given the similarities between *X. obvia* and *C. virgata* both in biology and ecology, the experiences of growers in Australia with *C. virgata* would likely be identical to those that may develop with *X. obvia* in Montana. Given the impact of Australian pest snails on export markets, have the impacts of *X. obvia* on access to export markets (both interstate and overseas) been estimated and taken into consideration? Economic impact is more than just lost plants and cost of control.

It seems that the risk ratings justify either releasing or withholding funding required for eradiation, containment and control activities. Australian biosecurity agencies have similar documents and prioritized pest lists. Such lists can be helpful but often they are a hindrance since pests are labelled and categorized before their true impact has been observed or accurately predicted. It can be very hard to convince authorities of the need to fund a control program if that pest has already been designated a low ranking, even in the face of evidence to suggest otherwise.

It is known that *X. obvia* is established in North America, has the potential to further spread, is beyond eradication, and difficult to control. This may make it a more critical species than higher ranked snails that are not yet here.

Questions

Would it be beneficial to adjust the rankings for specific states to consider the significance of potential damaged crops/industries to each state's gross product? Will a low raking help remove any intra/inter State or International regulations on commodities? Would a higher-ranking help obtain resources and support regulatory measures?

4. Does the ranking of the *X. obvia* (Question 3) merit a different risk assessment based on research conducted since 2009?

As pointed out by Cowie et al. – "In addition to the uncertainty in an analysis of this kind resulting from a lack of adequate basic knowledge of the attributes scored, subjectivity in scoring some of them, and choice of ranking algorithm, one could arguably include other attributes or weight the attributes differentially, as certain ones may be more important than others in determining potential invasiveness." The rating of the *X. obvia* may differ depending upon risk rating models and the attributes that these models utilize (Cowie et al. 2009).

Past pest risk assessments (PRAs) have indicated that this species is low to medium risk but the evidence from Australia demonstrates that there is substantial economic impact and impact to established producers based on the density and behavior of similar snails. A better understanding of the *X. obvia's* biology and potential economic impact could affect its ranking if a new PRA was conducted and different attributes were evaluated.

It is also important to note that a ranking of this pest relative to threats other than other snails may be a more meaningful PRA. Threats include the pest as a hitchhiker, the potential to reduce exports, and the potential for these snails to be vectors of animal pathogens.

5. Are there potential human health, livestock, and wildlife risks associated with this species?

X. obvia probably poses risk of parasite transmission to wildlife and birds and to livestock such as sheep and cattle. Transmission risk to pets such as dogs and cats is unknown and human transmission (at this time) appears incidental. Potential human health risks are documented in Dr. Robinson's Pest Alert (Michalak and Price 2012).

In Europe, *X. obvia* is thought to be a vector of disease to many species. Examples include: *Protostrongylus rufescens* (a lungworm of sheep and goats), *Davainea proglottina* (a cestode of poultry), and *Dicrocoelium dendriticum* a trematode of ruminants (Godan 1983). There are North American counterparts to these parasites. For example, *Protostrongylus stilesi* is known from bighorn sheep in Montana and other western states and snails serve as intermediate hosts (Becklund and Senger 1967).

In Australia, the four pest species of snails are intermediate hosts of several nematodes of veterinary importance as well as intermediate hosts for a fluke worm, (*Brachylaima* sp.). There have been reported cases of severe stomach disorders in South Australia due to children consuming infected snails. Where high populations of Australia's pest snails infest pasture, livestock are known to avoid feeding due to the high level of snails and fecal/mucus contamination. There is strong evidence, they have invaded the natural systems in (i.e. York Peninsula coastal dunes) where they have disrupted native snail species.

Questions

Detailed information is lacking on the transmission success of *X. obvia* as an intermediary host of parasitic worms in Europe and for novel parasitic species found in its introduced range. Ecological interactions between *X. obvia* and other snail species have not been studied or documented.

6. What habitat or habitat limitations determines the snail's potential distribution and establishment elsewhere in Montana, in the U.S and North America?

The native distribution of this snail species is Asia Minor to eastern Europe including the Ukraine, and along the northern Mediterranean coast as far west as southeastern France. Climatically it thrives from warm Mediterranean environments to cooler mountain regions such as the Carpathian Mountains and the Alps. Therefore, potentially, *X. obvia* could thrive in much of the continental United States (including parts of Alaska), excepting the Gulf Coast area that is warmer and more humid. The snail appears to avoid wetland and heavily forested habitats. Habitats where the snail species has been reported are as follows:

<u>Montana</u>: Additional habitat and microhabitat limitations in Montana are under investigation. *X. obvia* is found in a variety of habitats, especially in open vacant land, roadsides, grasslands,

hayfields, and moist open draws. It is also found in transportation corridors, residential areas, and on a wide variety of plant material, e.g., grasses, ornamentals, trees (including fruit), shrubs and weeds (Foley and Eiring 2013). It is less prevalent in cultivated fields (e.g. wheat), irrigated lawns, and heavily shaded areas. It is also reported in grazed pastures and gravel pits. The snail is consistently reported from open/grassland areas and roadsides, the snail is not reported from forested areas, and not urban/highly managed yards. This is based on observations made Oct 2014 in Great Falls where snails were seen in Great Falls only in relatively unmanaged open areas vs lawns/fields regularly mowed. Perhaps suggesting the snail does not persist in highly disturbed areas. Other relevant environmental constrains to population growth include dry conditions (that cause estivation/reduce activity), cold (limits/slows growth) and very high altitudes. There must be enough warm/humid days to allow complete development to a sage the snail overwinters.

Michigan: The snail has been found in freight (rail and road) yards (Robinson and Slapcinsky 2005; Sullivan and Dehn 2006).

Canada: Based on Grimm & Wiggins (1974) and Forsyth *et al.* (2015) specific sites in Ontario, Canada, where the snail has been found include 1) an area of rubble from a demolished light-industrial building surrounded by old-field and shrubby growth. The site (within about 100 m of an active railway line and 175 m from the nearest road) has a history of being highly disturbed, and was transitioning to a weedy old-field type plant community; 2) a curving grassy strip with snails mostly on tall dead *Melilotus albus*; 3) along rail tracks; 4) in the playground of a school house that had a rich growth of grasses and herbaceous vegetation mowed to a length of 4-5"; 5) on disturbed waste ground with sparse plant growth and abundant bare ground; 5) quarry; 6) pasture; 7) roadsides; and 8) along a rough track. Snails were occasionally found on dry grass stems, but favored stronger dried plants such as *M. albus*, *Centaurea* sp., *Daucus carota*, and *Cichorium intybus*. In Ontario Province, Canada, *X. obvia* is expanding in distribution since first being recorded in 1969, although it may have been present 75 years prior (F.W. Grimm and Wiggins 1974; Forsyth et al. 2015). From more recent surveys, populations are present in three separate areas of the province but are still limited to specific geographic areas.

Europe: The snail has colonized dry, steppe-like habitats that have been created because of human activities in many countries outside its native range (Cehanovica & Stalazs, 2020). Thus, a range of anthropogenic habitats appear to be suitable for the species including industrial areas, abandoned quarries, gravel pits, factory and mine dumps, the ruins of abandoned buildings (including castles), roadsides, railways and vineyards (see citations in Cehanovica & Stalazs, 2020). In several countries such as Belarus, Latvia, Lithuania, and Poland, *X. obvia* has been found on railways (see Cehanoviča and Stalažs 2020). In central Europe, it is found in vineyards, around ruins, in dunes, and on walls (Kerney, Cameron, and Jungbluth 1983; Welter-Schultes 2012). The species appears to survive cold temperatures and high altitudes (2000 m in Germany) but extremes would likely limit populations.

According to Wiktor (2004), in Poland *X. obvia* lives on dry grassy slopes, fallows, gravel pits, railway embankments and road margins, often estivating in large numbers in the low vegetation. In Poland, *X. obvia* is not considered native but has significantly expanded its distribution since introduction. It is now widely distributed in lowlands in western Poland with a more maritime climate and in continental climates in eastern Poland (Marzec, Kuźnik-Kowalska, and Proćków 2020).

In Latvia the snail has started to spread from rail-associated areas into sand dunes (Cehanoviča and Stalažs 2020). The latter authors suggest that the possibility for spread may also exist in places where relatively dry habitats (e.g. open pine forests on inland sandy dunes and dry meadows) are found near railways.

In Lithuania, the species inhabits grass communities such as those dominated by *Poetum compressae* (Skujienë and Vaivilavièius 2001).

Australia: Most of the four snail pests of Australian grain are found throughout the agricultural districts of South Australia, New South Wales, Victoria and Western Australia and eastern Tasmania sourcing food from dead organic material, weeds and from emerging cereal, canola and pulse crops. Australian pest snails have not established in arid areas. Extreme long dry summers is a limiter of their spread inland. It took these species 50-70+ years following their introduction to emerge as significant grain pests but now they are one of the most economically damaging of all invertebrate pests of Australia grain.

Soil: There are mixed observations for the impact of soil type on the distribution of *X. obvia*. One is that this species must have access to calcareous soil/rocks with the caveat that Australian pest snails only became an issue in areas after lime/calcium was applied to the soil. Although the snail can be prolific in high calcium carbonate environments, it can still do well in more acidic environments where certain plant species actively store calcium carbonate (sometimes referred as "calcium pumps"). One such species is Spotted knapweed.

Climate: The USFWS conduced climate matching for *X. obvia* see the "Eastern Heath Snail (*X. obvia*) Ecological Risk Screening Summary U.S. Fish & Wildlife Service, July 2015" (Revised, December 2016, Web Version, 4/2/2018) (currently not posted). The climate match (Sanders, Castiglione, and Hoff 2014; 16 environmental variables; Euclidean distance, referenced in risk analysis document) is high in the northern Interior West, southern California, the Mid-Atlantic region, and the eastern Midwest. Medium match extends over much of the remainder of the continental U.S. The climate match is low in parts of the Pacific Northwest, the Southwest, and in peninsular Florida.

Questions

How grazing rates affect *X. obvia* densities has not been examined.
Would the duration of winter hibernation reduce the population growth of *X. obvia* in Montana?

7. What economic crops and cropping practices (i.e. no-till) might most be impacted by *X. obvia* if it were to establish?

X. obvia in Montana seems less numerous in heavily cultivated crops such as wheat and more numerous in forage crops (grass & alfalfa fields). No-till situations are probably more conducive to the snail. In hayfields, *X. obvia* has survived plowing, reseeding, spring-toothing, rolling, and cutting.

Legume forages and pulse crops may be more heavily impacted based on European data and our initial laboratory feeding trials. Although *X. obvia* may feed on these species we have not seen much defoliation to mature green plants. Grimm and Wiggins, 1974 reported similar observations. At our field sites in Montana, we have observed possible snail feeding on green plants (e.g. alfalfa, Canada thistle, smooth brome) but it is difficult to separate from possible insect feeding.

There is some contradictory information in the published literature about the likely impact of *X. obvia* on crops. According to Grimm & Wiggins (1974) and Grimm et al., 2009 *X. obvia* feeds on dead vegetation. Grimm & Wiggins (1974) also suggested that the snail consumes soil likely for its algal content. They conclude that the snail does not feed on green vegetation and consequently poses no threat to agriculture. However, Godan (1983) identifies fodder crops (sainfoin, alfalfa and clover), and forestry crops (conifer seedlings, juniper berries) as being subject to feeding damage by the snail, and she also suggested that it is problematic in storehouses. Regardless, a species can be an important pest even if it does not feed on a crop.

Snail numbers have rapidly increased in southern Australia. The adoption of conservation farming where there is stubble retention, minimal burning and no tillage are factors which may have resulted in increased snail populations, especially in the calcareous and highly alkaline soils. Consecutive seasons of above average winter and spring rainfall may also have contributed.

In some cases, Australian growers adopt an "occasional till" or "occasional burn" to achieve a serious reduction of snails, however this comes at the cost of lost soil organic matter, soil damage and air pollution. Rolling of stubble to flatten and reduce refuge away from hot dry surface is a good management practice but growers may be reluctant to use this since it can mess up their precision inter-row sowing the next season and the laying stubble can clog the sowing equipment. Rolling or bashing requires temperatures >35°C to be effective.

Some farmers used to have both crops and livestock, but many (for a variety of reasons) have moved to cropping only. This means that there is no snail population build-up in pastures, however they report that neighboring pastures and roadside vegetation are sources of new snails each year.

Legume crops are more heavily impacted. This includes a crop rotation with legume-based pastures that encourages snail numbers. In some regions of Australia, growers no longer grow peas since the issues with snails at harvest (machine damage and grain cleaning) are not worth the effort. Harvesting a crop with high snail numbers, causes much damage to machinery and the grain itself. Snails crush in to a glue-like substance that if not cleaned regularly from harvest machinery can clog up inlets and sets like concrete inside the machinery. Snails that are crushed during harvest also often cause sticky clumps of grain to form in the header and the snail "mush" contaminates even the free grains. Post-harvest grain cleaning causes lost grain, extra processing and labour costs, and may not be very effective depending on the grain type and the shape and size of the problem snail.

Australian crops negatively impacted:

- Wheat and Barley – direct feeding, harvest and post-harvest issues
- Canola – crop damage by direct feeding, harvest and post-harvest issues
- Peas – direct feeding, harvest and post-harvest issues. In some regions of Australia, growers no longer grow peas since the issues with snails at harvest (machine damage and grain cleaning) are not worth the effort.
- Beans – harvest issues
- Vetch – direct feeding and harvest issues
- Legume based pastures (medics, Lucerne and clovers) – direct feeding

- Livestock reject pasture and hay that are heavily contaminated with snails, due to the mucus
- Grapevines - reports of *T. pisana* and *C. virgata* contaminating grapes during harvest in Australia

X. obvia is already established; 5 counties in Michigan, 2 counties in Montana, and as of 2015, 6 counties in southern Ontario (Forsyth et al. 2015). As has been recorded in the continental United States and Australia, no-till cropping practices greatly increase the populations of both pest snails and slugs, and in South Australia, tilling has been resumed on some farms to decrease the population of snails. This is obviously detrimental to soil conservation and hard choices would have to be made to balance the pest potential versus soil erosion. Also, organic production would decrease as farmers would likely need to utilize all control options available to them including those not approved for organic farming (e.g. metaldehyde baits). Some growers may also change the crops they grow with less susceptible crops grown at the expense of more susceptible crops such as barley.

As seen in closely related geomitrid snails in Australia, *X. obvia* is likely to reach extremely high numbers and mass on crops including wheat and other grains as well as legumes, inhibiting the harvest of such crops. This massing behavior has already been observed in Montana and Michigan. The proposed development of rape (canola) production in central Montana could also be directly affected. *X. obvia* is known to infest fodder crops including alfalfa, clover, lupine, sainfoin, seradella, and is often found as a contaminant on other agricultural products in countries where it is established. Export of any agricultural product infested or contaminated with snails could be impacted.

One of the primary reasons *X. obvia* is considered a pest is its behavior of climbing up on plants and other objects during the summer. Snails climb onto forage wheat, and other crops resulting in contamination of the commodity. As a result, products may be downgraded (e.g. malting barley to feed barley) or may be unacceptable to grain handling authorities. The combination of climbing and large numbers may also result in damage to seed and grain harvesting equipment ("Oregon Pest Alert: Eastern Heath Snail" 2014). In fact, it poses a threat to many mechanically harvested crops, but especially small grains where machinery is most vulnerable to damage. The snail can also act as a contaminant of fruits and vegetables, and it is thought to transmit spores of the plant pathogens, *Alternaria* sp., *Fusarium* sp., and P*hytophthora* sp.

Some harvesting practices including moving equipment such as harvesters between farms will spread snails to new areas. Leased and seasonal equipment placed into and removed from infested fields such as bee hives will also spread snails and quarantines and decontamination requirements may change use patterns.

Survey and Monitoring for the Eastern Heath Snail

8. What early detection tools are available for monitoring of the Eastern heath snail and/or similar species of snail? What survey methods are available to monitor established populations?

Attractants

Unlike insects, there are no widely used early detection tools (e.g. pheromone – baited traps) for invasive gastropods. Recent work on the development of novel attractants demonstrated that chopped fresh cucumber (*Cucumis sativus*) was highly attractive to *X. obvia* in infested sites in

Montana (Cordoba et al. 2020). Cucumber was also highly attractive to other invasive gastropods i.e. *Cornu aspersum* and *Deroceras reticulatum* in the laboratory (Cordoba, Millar, and Mc Donnell 2018). Thus, in combination with an effective trap, chopped cucumber could constitute a cheap and simple lure for early detection of *X. obvia* in high-risk areas (e.g. rail yards) and for monitoring established populations. Subsequent research underway has highlighted for *X. obvia* and a range of other invasive gastropods. This work is currently being prepared for publication.

Based on Australian observations *X. obvia* could be attracted to Brassica plants and lime (limestone/calcium carbonate) based on field observations of *T. pisana* and *C. virgata* in South Australia.

Traps with metaldehyde work much more effectively than traps without it as the snails (particularly the immatures) can easily leave. It would be useful to explore other options to retain snails in traps other than metaldehyde. Note that snails may avoid traps with salt (this was found with giant African snail) and the use of water may provide mosquito breeding site if not regularly monitored. The use of baited traps such as beer traps did not provide any results in tests in Michigan early in the program.

Cardboard refugia (location which supports an isolated or relict population of a once more widespread species) baited with calcium carbonate have been used in Australia to target temperate exotic snails. Non-target snails including *T. pisana, Caracollina lenticula* and *C. virgata* seem to be attracted to the trap. Refuges work best where they provide a better option that existing environment. E.g. damper, darker, more food. Staff at SARDI have used roof tiles, bathroom tiles and slug monitoring mats (60x60cm underlay felt matting with top foil and bottom black plastic perforated for presoaking). This works well for slugs and *P. barbara*. The use of survey boards that provide diurnal hiding spots do not work as well for this species (dry loving) is not known to seek such spots as other species do.

Detection Tools

Specially trained dogs have been used by USDA to survey for other high-priority invasive gastropods (e.g. *Lissachatina fulica* in Florida) and such an approach may also be an option for *X. obvia* in Montana. The use of snail detection dogs is helpful in early detection of snails at high risk locations, e.g. transportation hubs, granaries, recreation areas, and has been effectively used in the field after an exotic snail has been detected to help determine distribution. However, snail detection dogs require extensive training and are not always readily available. The use of K9 teams was tried in Michigan with mixed results.

If dogs are used, it is important to confirm that the dog is alerting to *X. obvia* and maintaining research colonies may be necessary. In the case of *Lissachatina fulica* (the giant African snail) in Florida, "sniffer" dogs have been successfully used to detect that snail hidden in the underbrush, being able to distinguish it from all other snail and slug species. Use of these snails with the dogs requires that precaution if the snails are placed in non-infested areas (e.g. Giant African Snails program in Florida uses mesh bags to transport live snails). Detector dogs may not be effective when snails are estivating/hibernating and may be best used in areas with low or undetectable populations.

Drones could be used for early detection/monitoring purposes. Robust, easy to operate drones with high-quality digital cameras are now readily available for <$500. Drones have been used to scan >100 ac grass seed fields in Oregon for areas of slug damage. This approach has provided a more rapid approach than simply walking through fields searching for damage. In addition, the massing behavior of *X. obvia* would make it easier to spot with drones than other invasive gastropods.

Molecular tools and eDNA have been used in some terrestrial settings. Researchers in Canberra and Victoria are doing work where they non-destructively analyze samples for target sequences. Staff with CSIRO were taking samples of leaf material, stubble, soil, *C. acuta* shells or live *C. acuta* and shaking them in fluid prior to testing the fluid to detect the presence of the introduced parasitic fly in different locations on the Yorke Peninsula, SA. The Agriculture Victoria team are doing similar with processing of air suction samples into fluid and analyzing the clear fluid to determine if a target flying insect is in the sample. Perhaps a similar technique could be deployed in Montana to sample environments (e.g. mulch, soil, etc.) thereby minimizing searching time (and ID training) and increase the number of samples and area assessed.

Detection Methods

Monitoring of established populations are dependent upon the objectives of the monitoring program. The USDA-APHIS manual "New Pest Response Guidelines: Temperate Terrestrial Gastropods" (2012) is a good reference for the early detection and monitoring of invasive snails and slugs. The manual is to be used "as a guide when designing a program to detect, monitor, control, contain, or eradicate an infestation of temperate climate pest snails and slugs in the United States."

Active searching by hand is the most effective for collecting live specimens and traditionally detection of *X. obvia* and related geomitrids is by visual surveys, particularly in the summer and fall when the larger adults start to estivate in large numbers on upright surfaces, such as the stems of grain crops, hay, fence posts, walls of buildings and on trees. In spring, smaller subadults and juveniles are more difficult to detect as they live at the bases of plants and in the leaf litter. A substantial challenge is the ability to recognize potentially invasive snails or slugs. Taxonomic support is critical. As noted in Michigan program reports, giving new surveyors the opportunity to train at a known infestation allows them to develop a good search image of the snail.

Visual surveys monitoring presence/absence are probably adequate for delineating distributions but can result in under detection if distribution is patchy and at low population levels. For the determination of population levels (e.g. for establishing treatment thresholds for baiting) the use of quadrats is useful. At well-established *X. obvia* populations, a 0.25 m^2 quadrat seems adequate for counting snails at specific sites when small numbers of samples are needed. Quadrats can be reduced to 0.1 m^2 when *X. obvia* populations are high or if numerous samples are required. The amount of time that is required to count snails is dependent upon the time of day, temperature, humidity, and season. Snails can be on or under vegetation or on the ground surface. Eggs, babies, and smaller snails are often located in the soil litter or even the top few centimeters of soil and can easily be overlooked.

A significant problem in field counting *X. obvia* densities is in determining live versus dead snails. Even with detailed inspection, it can be impossible to determine if a shell contains a withdrawn estivating or hibernating snail or if it is empty, particularly in colder seasons. All shells within a transect are collected except the obviously decaying ones and brought back to the lab to check for movement. Estivating/hibernating snails can take over a month to resume movement.

Quadrat placement can be problematic at low population levels or for patchy snail populations (e.g. smaller infestations). In these cases, we have used a 10 m transect to count snails. The observer walks with both arms stretched out (~ 1.5 m total arm width x 10 m = ~15 m^2 transect area) to delineate the outer sampling boundaries and counts visible *X. obvia* shells along the length of the transect. Transects are easy to utilize, relatively fast, and good when snails are patchy or in low numbers because one can quickly sample a larger area. They are not effective for counting smaller individuals or for separating live from dead snails (a similar issue with quadrats) and at higher snail densities observer variability in counts increases.

Nighttime or evening surveys when snails are active are a very effective tool. Regarding detection of the giant African snail, a 'second' shift was used (2 p.m.-10 p.m.). These surveys allowed new locations to be discovered and targeted application of pesticides to where snails were located. Observations in Oct 2014 indicated that the snails became active around sunset and increased activity was related to relative humidity (RH). RH increases over the course of the night and snails became actively later if the RH was initially low. RH recorded on the ground was different than RH in the air. Similarly, WA State Dept. of Agriculture primarily conducts visual mollusk surveys that targets debris or items that slugs, and snails could use as shelter, food, and calcium sources after a good rain with cool weather when the animals are likely to be more active.

A seasonal approach to the Montana field season could be as follows:

- June/July- assess options for stubble management
- August/September- assess options for baiting or burning?
- October/November- assess options for baiting particularly along fence lines
- Shortly before harvest- assess need for header modifications

For post-treatment work include monitoring for reinvasion. Observe habitats and snail numbers outside the treatment paddock. Adjacent roadside verges, pasture paddocks, and heavily infested crops are often the source of invading snails.

9. Are there any classifications for various densities of snail and the associated impact?

Original *X. obvia* survey(s) in Montana (2012-2013) determined presence/absence and classified densities at established sites as none, low, medium or high. These were likely estimates of relative abundance rather than based on exact snail numbers. Quadrat population counts are variable but range up to 1,200/m^2. With higher densities there is greater dispersal to new areas (natural spread) and climbing on various articles that can move snails (artificial spread).

Information on the economic/environmental injury level or threshold (at what population level impact occurs or treatment is needed) is lacking for *X. obvia*. Currently, *X. obvia* is considered more of a nuisance problem than an economic crop problem. The main concern may be with export commodities such as small grain, hay or forage, gravel, etc. Since *X. obvia* can self-reproduce, it potentially requires only a single individual to establish a new infestation. Because *X. obvia* can survive inclement conditions by estivating, can have a multiyear life cycle, can lay eggs without mating and for several months after mating, and can lay multiple viable eggs and clutches, one or a few snails can quickly produce a significant population. Because of this, tolerance levels for *X. obvia* may be low or none. Australia Department of Agriculture biosecurity officers recently turned away nine hundred Mercedes-Benz cars because more than 30 *X. obvia* were found in the car shipments (Zhou 2019).

Both a classification used to describe snail densities and measurement of pest impact are similarly ill-defined for related species. For example, in the case of the four snail species in that are currently devastating Australian crops, only two are considered "plant pests", i.e. that actually feed on crops. However, all four are agricultural pests, exhibiting massing behavior, estivating in vast numbers on the stalks and grains of, for example wheat, prior to harvesting. An attempt to harvest the crop (where the biomass of the snails may exceed the biomass of the grain) can result in the combine harvesters grinding to a halt after perhaps a hundred meters, completely incapacitated by snail bodies, shells and slime. In such instances, the crop is designated as a 100% loss. Although the impact of a snail pest has been described in relative terms, a complete inability to harvest a crop is absolute.

Australian pest snail economic thresholds (see Smith 2019; Leonard 2003; Grains Research & Development Corporation 2012):

- *C. acuta* or *P. barbara* in canola and pulses: 20/m^2
- *C. acuta* or *P. barbara* in cereals: 40/m^2
- *P. barbara* in pastures: 100/m^2
- *C. virgata* and *T. pisana* in canola and pulses: 5/m^2
- *C. virgata* and *T. pisana* in cereals: 20/m^2
- *C. virgata* and *T. pisana* in pastures: 80/m^2

Density related impact is relative to the commodity (e.g. if exporting, one snail being found may result in regulatory action). However, for *X. obvia,* information is lacking on the economic/environmental injury level or threshold (at what population level impact occurs or treatment is needed). Fewer snails that are carrying a pathogen may require a management response even if populations are low, particularly if the snail vector and animal/plant host are near (e.g. foraging livestock/wildlife in field with infected snails).

It is important to always record the size categories of the snails. Smaller snails may not be well controlled with bait (harder for snails to access bait before larger ones eat it, ground surface obstacles are relatively larger and harder to overcome to reach bait, smaller snails move slower than larger snails). As the shells of these snails do not degrade quickly and the snails may have an annual lifecycle an area with many shells does not necessarily mean that there are many live snails, more likely the population was there longer.

In Australia, the following was offered as a lighter take which is included here as it is painfully familiar to those working with establishing invasive species and is a reminder that management directly impacts livelihoods. Farmer snail density categories:

- "not too many"
- "a fair few"
- "need to do something about them"
- "s**t-loads"

- "why do I even bother trying to grow crops?"

10. What are the major obstacles to effectively monitoring movement of this species across the landscape?

Survey Effort and Expertise

Conducting surveys across large landscapes requires significant resources (personnel, time, travel funds, etc.), as well as the cooperation of private landowners. There is no effective trap, so active surveys require labor and skilled workers. It takes time to gain detection skills and know what to look for both in terms of suspect habitat and snails (especially juveniles). Snails with a similar appearance in the same landscape can lead to assumption of innocence and "false negatives" or lead to "false positives." If surveillance staff reports every snail detected without distinguishing between species it would slow down the confirmation process. Given the prevalence of *C. virgata* in Australia and its similar appearance to *X. obvia* distinguishing between these species could be a surveillance and diagnostic nightmare.

The use of drones and citizen scientists could help mitigate some of these obstacles. Forsyth *et al.* (2015) suggested that *X. obvia* would be a prime candidate for citizen science-based monitoring given the usually dense populations, persisting dead shells, its relatively large body, and the tendency of snails to estivate well off the ground en masse on the stems of plants. Existing citizen science platforms could be used for such an undertaking e.g. iNaturalist. Citizen science programs however are not without their disadvantages and for difficult to identify taxa erroneous records can be commonplace.

Habitat suitability mapping (such as the maps developed by the Montana Nature Heritage Program for invasive weeds) may help delineate and prioritize survey areas. The key habitats and environmental factors for *X. obvia* need further definition.

Montana's populations have been locally established for some time, complacency is a concern for efforts to suppress the populations and to contain their spread. The snails have not caused negative impacts in many areas, so there is a perception that survey and management efforts are not warranted.

Accessibility

Obstacles to effective survey efforts include site access and timing. In Montana, the original survey results indicated that large areas were not road accessible and that additional resources, time, and surveyors would have been necessary to survey these areas by foot. These initial roadside surveys did provide a reasonable estimation of population distribution and density (Foley and Eiring 2013). Snails have been recorded at several sites where they were missed in the original surveys (shell densities indicate that these populations would have been established at the time of initial survey).

Rough terrain limits the ability of survey staff to safely access the likely area occupied by the population and tall vegetation makes leading edge or delimiting surveys more difficult within these areas. Staff availability might not correspond to the best time to survey (when snails are active or when they are estivating).

The cooperation of private landowners is critical to efforts to identify areas and provide ongoing monitoring of suppression and containment actions. Survey personnel may not be able to access areas if property owners prevent egress.

Transport

There is a need to identify and document the key modes of *X. obvia* dispersal to help prioritize future survey areas and to monitor current movement/spread. Transportation is considered a major pathway for the introduction and spread of snails. The movement of containers by truck and rail in domestic commerce provides an ideal pathway for snails to rapidly spread throughout the United States.

The small size of the snails, especially the juveniles and neonates can make it difficult to monitor the movement, particularly if they are hitch-hiking on vehicles. For this reason, vehicles should be excluded from any infested areas.

Roadway management equipment is a likely vector for moving live snails. Expanding monitoring to include equipment storage or garage areas and conducing outreach with maintenance staff should be initiated. Similarly, landscape and lawn equipment and other materials sitting in areas with infestations from private residences can move snails. Equipment can become a long-distance transport vector when it is moved to a new residence or job site.
Montana has no restrictions on moving vehicles and equipment into and out of the infestation area.

It is also possible for people to notice the striking color pattern on the shell and intentionally transport the snail elsewhere.

Questions

The key habitats and environmental factors for *X. obvia* need further definition to populate models of their potential range.

11. When and how often should monitoring take place?

Delineation

The frequency, timing, and type of monitoring is related to project objectives. In surveys to delineate the distribution of *X. obvia*, presence/absence and visual estimates of densities are probably adequate. For delineation surveys, 5 to 10-year intervals may be an adequate sampling period. A partial resurvey conducted in 2019 of the original 2012 survey points detected *X. obvia* populations 8 to 10 miles distant from the known 2012 observations. This may reflect a combination of actual *X. obvia* movement and the buildup of outlying populations to detectable numbers.

Late summer monitoring on dry days in Montana has some advantages because *X. obvia* are more visible while massed on foliage and plant stems. Washington visual snail surveys are conducted in the spring and fall during the cooler wet weather on both sides of the mountains. Fall visual survey for *C. virgata* in the Port of Tacoma tends to be the easiest time of year to detect *C. virgata*. The fall most of *C. virgata* are late stage juvenile or adults both life stages are actively feeding and adults seeking other *C. virgata*. In August, detected *C. virgata* was found estivating underneath rocks or at the base of plants. The edges of properties that contain refuse, weed barrier or other material like rock walls with vegetation have been promising areas to find slugs and snails. Fields with high vegetation like uncut grass tends to be challenging for visual surveys. Mixed success was achieved with laying out cardboard, boards or other shelter to detect slugs and snails over time.

Surveys should also occur later in the day as morning surveys the snails can be observed closer and, on the ground, making them difficult to detect if vegetation is thick. In Oregon even during summer when snails and slugs are typically inactive, small populations of active snails have been found due to decreased temperatures and increased humidity. Thus, it may also be worthwhile scouting infested sites after sunset during the summer. Consider including sentinel sites if there are sensitive natural areas or high-traffic commercial areas near established populations.

12. What is the best way to distribute this information and to train the public and land managers to identify and report invasive snails?

Multiple approaches to engage and support both resource and infrastructure managers, landowners with infestations, and the public should be carried out.

Public Engagement & Citizen Science

Common to many of these projects is a need to determine project goals, identify potential partners and how to motivate them, provide a mechanism to share and disseminate information (e.g. web site), provide resources such as training materials and data sheets, etc., and identify data gaps (Niemiec et al. 2017). For Montana such programs may utilize existing models or programs, e.g. weed education projects. There appears to be significant interest in *X. obvia* in Montana, so it is probably a good candidate for a citizen science-based monitoring program and for youth and school groups.

The Wisconsin Department of Natural Resources has a web site listing various citizen-based monitoring projects within their state (Lewandowski 2004). One mollusk example is a survey to determine which slug and snail species are present in UK gardens. Another project is SLIME: Snails and Slugs Living in Metropolitan Environments, based in southern California (Vendetti 2015).

Broadly informing the public as well as land managers not included in specific efforts centered around the known infestation could rely on more traditional methods such as: newspaper articles, county extension talks and materials, and web sites (such as MISC). Montana AG Live is one of the most highly watched shows on Montana PBS. There have been several shows where people have called in questions about *X. obvia* and garden slugs. A local media campaign (e.g. newspapers, local radio, local television news) would be an effective way to increase the awareness of the snail among the general public.

The "giant African snail" (*Lissachatina fulica*) control and eradication programs in Florida, Barbados, Dominica, Puerto Rico, the Galapagos Islands and elsewhere in the West Indies and South America, has been a successful coordinated approach using ongoing public education, posters and flyers, regular radio and television coverage (the news and scientific programming), and most effectively, involving local schools. At schools, children are more likely to come across the snails when they play outside. All methods of public awareness-raising should include photographs of the snail with a detailed description and provide a toll-free phone number to a central phone bank, so the agricultural authorities can immediately respond and investigate any sightings. In Miami, a Junior Detective program was successfully used to detect many of the populations of *L. fulica*.

Land Owners & Local Managers

In Michigan impacted property owners were given information directly. Currently concern citizens can report *X. obvia* on an invasive species website.

Workshops to train land managers and stakeholders involved in high risk pathways (e.g. rail companies, freight companies) on how to identify *X. obvia*, its preferred habitats, damage it can cause, effective molluscicide application strategies, and how to report occurrences would be an effective approach. Offering pesticide credits for continuing education is a good strategy for increasing the appeal of such workshops.

Articles in trade magazines (e.g. Trains Magazine - https://trn.trains.com/) and commodity magazines (e.g. publications associated with Montana Wheat and Barley) could be an effective way to target specific stakeholders. Articles on the websites and social media of these magazines and their associated organizations would also help with information dissemination, as would a presence at trade shows, state fairs, county fairs, and other relevant meetings.

Other education and outreach tools:

- Community engagement through social media platforms, guidebooks, apps for farmers, citizen science.
- Management field days for land managers/growers with a demo search in an infested area
- Distribution of materials to University/Extension/Master Gardeners/Environmental groups (trout fishing groups)/(Science) teachers
- Provide sampling/postal kits for residents/farmers to place suspect snails into appropriate containers and send to correct labs for testing/confirmation
- Targeted training to road management crews and growers in know infested areas
- Utilize iNaturalist by checking for reports of the snail (and other pests)
- WSDA has found social platforms, media and location based adds to be invaluable in many of the programs like gypsy moth and Asian giant hornet

Control Methods for the Eastern Heath Snail

13. What is the recommended control method for landowners to use when controlling invasive snails on their property?

Invasive gastropod management encompasses three main areas chemical, cultural, and biological.

Chemical Control

Chemical molluscicides are the mainstay of invasive gastropod control globally. Metaldehyde, iron phosphate, and sodium ferric EDTA are the most widely used. Methiocarb (e.g. Mesurol) is also highly toxic to gastropods but it is a restricted use material and only authorized for use as a rescue treatment in ornamental nurseries. Metaldehyde (e.g. Deadline® M-Ps™, Metarex®) is the most widely used and has been shown to be the most effective in Montana, but it is very toxic to pets, particularly dogs and cats. Baits with iron phosphate (e.g. Sluggo®) and sodium ferric EDTA products (e.g. Ferroxx®) are generally regarded as less toxic to non-targets, and iron phosphate can be used in organic production but can be less effective. The key to successful bait use is timing of application. For example, best results with metaldehyde will be achieved if the bait is applied when sunny, dry conditions develop shortly after a wet period.

The Montana Department of Agriculture has chemical recommendations and restrictions for use.

In Australia, it has been observed that *C. virgata* are more likely to die from metaldehyde baits when they are reproductive active (i.e. have enlarged albumen glands) (Brodie et al. 2020). It is suspected that metabolic processing of active ingredients is variable depending on the physiological state of snail.

Cultural Control

The most widely used cultural control method for pest gastropod management is tillage but with the current drive towards no till and conservation tillage for soil management purposes many growers are reluctant to employ it as part of their pest management plans. Hand collecting, and sanitation can also be effective (Roda et al. 2016) but for massing species such as *X. obvia* hand collecting might be excessively time and labor intensive in large infested areas. Other cultural control options include the use of barriers, traps, crop rotation, grading, surface mulching, solarization, steaming, controlled burns, weed removal, trap plants, and refuge or banker plants to promote populations of native natural enemies e.g. ground beetles.

Biological Control

An effective biological control for *X. obvia* has not been identified and biological control of snails is currently limited. Foreign snail parasitoids such as parasitic flies in the family Sarcophagidae would require extensive host specificity screening to meet NAPPO and APHIS guidelines (probably similar to arthropod parasitoids) prior to approval for release. No recent introductions of a classical biological control agent for snail or slug control have occurred in the continental United States. While the snail predator the rosy wolfsnail (*Euglandina rosea*) has been used as a biocontrol agent to control other snail pest species; its use has also resulted in predation-caused extinction of native snails. It is now considered an invasive species.

Birdsall *et al.* (2019) reported nematodes belonging to three genera, *Panagrolaimus, Plectus,* and *Rhabditia* that are associated with *X. obvia* mortality in Montana. However, nematodes in these taxa are commensals/necromenics and hence do not have potential to be used as biological control agents. Other nematodes have been utilized and are commercially available (at least in the UK and Europe). Nematodes are considered microorganisms and might therefore not be regulated by the EPA but might fall under the jurisdiction of APHIS and other federal agencies. The recent discovery of *Phasmarhabditis hermaphrodita* in California (Tandingan De Ley et al. 2017) changes the regulatory framework, but certain federal and state approvals would nevertheless be required. Not all land and freshwater snails are susceptible to Phasmarhabditis, but the broad taxonomic and ecological range of species known to be vulnerable to it shows that *P. hermaphrodita* is not narrowly host-specific, thus raising legitimate doubts as to its supposed benign nature.

For small landowners the use of domesticated fowl (such as ducks, geese, or chickens) has been known to help manage snails with ducks being the most enthusiastic snail predator. Since *X. obvia* is known as an intermediate host of the tape worm, *Davainea proglottina*, whose final host is birds, the use of domesticated fowl could be a concern depending on the prevalence of *Davainea* in Montana.

Rumina decollata has been used to control *Cornu aspersum* primarily in citrus in southern California (Fresno, Imperial, Kern, Los Angeles, Madera, Orange, Riverside, Santa Barbara, San Bernardino, San Diego, Ventura, and Tulare counties only). Mc Donnell *et al.* (2016) presented data that questioned strongly the widely held assumption that *R. decollata* is an effective biological control agent. Based on this data *R. decollata* would not be an appropriate biological control agent of *X. obvia* because its generalist feeding behavior would represent a risk to native gastropod species. In Europe, the malacopathogenic nematode *Phasmarhabditis hermaphrodita* and its bacterial symbiont, *Moraxella osloensis* are currently being used to manage gastropods in crops. Although this nematode has recently been discovered in the western US (Oregon: Mc Donnell, De Ley, and Paine 2018; California: Tandingan De Ley et al. 2017) there is insufficient information on the biology, distribution and infectivity of the US strain to make an informed decision on whether it can be used as a safe biological control agent (Mc Donnell et al. 2020).

Integrated Pest Management

For alternative management practices, the Australian publications "Bash'Em Burn'Em Bait'Em: Integrated Snail Management in Crops and Pastures" (Leonard 2003) or "Mitigating Snails, Slugs and Slaters in Southern Western Australia" (Smith 2019) are good resources. These publications provide information on numerous snail management options such as burning, stubble management, tilling, grazing, mechanical control, baiting, and chemicals that are briefly summarized here. Control strategies differ by land use such as cropland versus residential, presence of pets or other animals, and other factors.

Washington State Department of Agriculture found that a multifaceted approach to be essential in reducing the population from 11 properties to 2. WSDA, Port of Tacoma and stakeholders have reduced populations or eradicated *C. virgata* by reducing vegetation, trash removal (always double bagging) from properties along with baiting in the spring and fall. Multiple years in a row, WSDA did outreach and visual surveys of infested properties until *C. virgata* was eradicated from property. Equipment and footwear was always inspected and cleaned before leaving or removing from properties. Currently, WSDA is working with WSU to steam treatment in a wetland area that is the last areas that contain *C. virgata*.

Year-round management of snails is required for control of large populations on a property (Leonard 2003).

Recommended Mechanical Control

Integrated pest management is important in managing a snail population; pesticides alone are not sufficient. Removal of debris, trash, litter, and other forms of waste increases the effectiveness of pesticide application to areas where the snails are active because these materials provide snails with a pathway for hitchhiking, as well as daytime hiding places or harborage. To mitigate risks, ensure waste is free of snails, place waste in regular waste bags and seal prior to normal proper disposal.

Seasonal Best Practice Recommendations from Australia

<u>Summer season:</u>

- Stubble management- can you burn? Can you cable (>35°C)? Rolling could be an option.
- Weed control over summer will reduce snail numbers
- Slashing- remove all tall stubble and effectively crushes snails
- Grazing- knock snails from stubble. Less effective than other methods
- Post-harvest cleaning?

- Harvest "cleanest" paddocks first and leave infested fields until last to avoid transferring to clean paddocks.

Autumn/Winter season:

- Baiting when rain/moisture triggers snail activity in autumn and before significant egg laying
- Target fence line posts and roadside vegetation with baits during autumn rains
- Ensure you get thorough bait application, even spread and that you hit the right dosage. In Australia, we recommend minimum 30 bait points per m^2, and do a second application in really high populations or get closer to $60/m^2$ (Brodie et al. 2020). Some products may require a second application to reach the $30/m^2$ guideline (that is, to avoid making an application that is off-label or above registered rates).
- If using an agricultural spreader, ensure that the machine is calibrated and set for the specific product being applied. SARDI/GRDC trials found that many spreaders are effectively spreading only 60-70% of the expected spread width, leading to overdosed and underdosed strips.

Year-round:

- Implement good farm hygiene and biosecurity measures (e.g. no outsiders vehicles to drive through paddocks - use farm ute/truck only, thorough clean down of harvest machinery if likely to move between farms)
- Notification at all property entrances
- Vegetation/rubbish removal and clean up

Questions

What work can be conducted on understanding the impact of molluscicidal baits on *X. obvia* individuals and populations?

14. Can *X. obvia* and/or similar snail species be eradicated in small outlier populations? If so, what is the recommended eradication method for small outlier populations?

There is general agreement that small populations can be eradicated with dedicated, long-term effort. Vegetation management in concert with treatment is key to achieve this.

For small populations, repeated chemical control would probably be most successful (either by spraying or possibly baiting), although supplementing chemical control with vegetation and land management practices and/or hand collecting may increase chances for eradication. Treatment and environmental modification combined with quarantining to exclude all vehicles, people or livestock from the defined boundaries of a population improve efficacy.

It is very difficult to eradicate the *X. obvia* due to variation in life stages, overlapping generations, the presence of snails and eggs in the soil, the potential of individuals to lay multiple eggs without a mate (selfing), and the ability of snails to actively disperse.

Examples of small snail populations that have been successfully controlled include the 2013 Australian response to Chocolate banded snail (*Massylaea vermiculata*). Small outlier populations of *Lissachatina fulica* in certain sites in Florida were eradicated but this was a time consuming and costly process.

15. Are there regulatory obstacles or restrictions to the use of any molluscicides or biological controls for the treatment of this species in Montana?

Yes. For example, the product label for Durham Metaldehyde Granules states: "This product is intended solely for use on agricultural crops grown for commercial or research purposes and in State and/or Federal invasive mollusk eradication operations. This product may not be applied to residential sites (i.e., in yards, gardens, around homes and apartments) and other sites such as the exterior areas around schools and daycare facilities, and athletic fields, playgrounds, parks, recreation areas, etc. Broadcast applications and applications of this product directed to plant parts are prohibited except to grass grown for seed and as specified for use in State and/or Federal invasive mollusk eradication operations." And, "This product may be used only on the following use sites in response to State and/or Federal invasive mollusk eradication operations. Broadcast applications of this product may be made to the following use-sites for State and/or Federal invasive mollusk eradication operations: fallow land; barrier strips; uncultivated non-agricultural areas; recreational areas; non-food or non-feed brush; weed or dense vegetative areas; railroad, pipeline, highway, power and telephone rights of way and roadsides; guardrails and fences; lumberyards; storage areas; seaports; industrial facility sites, including yards and walkways around industrial buildings, parking areas, parks, golf courses, other public areas; and airport and similar industrial non-crop areas. This product may be applied for State and/or Federal invasive mollusk eradication operations at an individual application rate of no more than 2 lbs. ai/A, and at no more than 6 applications/year."

In Michigan, the labels for baits have been amended as requested by the State to include the various environs where these snails occur. Metaldehdye has been reviewed by EPA several times and during this review USDA has been involved to ensure it can still be available for local control operations. Categorical Exclusions are used to meet EPA requirements. If an endangered or threatened species occur in the area/s of treatment an impact statement would be needed
Molluscicides can also be non-specific and affect native molluscs. We have found several species of native snails and slugs in our research sites, although these are generally found at low levels. Certain molluscicides still approved in the United States are currently being banned in Europe.

16. What are the best options if the *X. obvia* population expands onto new landscapes and has new impacts? How do we prepare for that possibility?

The spread of *X. obvia* depends on the level of control that can be achieved. Eradicating existing populations in order to prevent *X. obvia* from spreading would eliminate future harm to Montana as well as adjacent states.

If eradication or containment are not achieved the snail will move or be moved to new areas. Spread has happened in Michigan where new populations were found in several different counties. The population and size of these pockets are too large to contain or maintain.

X. obvia is expanding its range in Montana and has moved out of the Belt River drainage and into adjacent wheat producing areas and other habitats. The impacts are still speculative. Currently, *X. obvia* seems to be perceived mostly as a curiosity or a nuisance species and people seem more reactive than proactive. A large unknown is whether and how extensively *X. obvia* is being transported and subsequently establishing outside the Belt area by commodities such as gravel and hay. There are currently examples of new infestations in surrounding communities that have been attributed to movement of such materials. Currently, since *X. obvia* remains relatively unregulated within the U.S., the best method we have for early detection and subsequent treatment is to provide resources and education to producers, consumers, and people in areas that have the possibility of being infested. Keeping people informed and encouraging them to reduce the spread of *X. obvia* and to report problems associated with snails might reduce or slow spread and establishment. Should *X. obvia* continue to expand into territory within and/or outside Montana, it may become necessary to consider regulations. Surveying locations where commodities have been transported in the past could provide needed information on risk.

For areas with at risk commodities early detection and rapid response will be critical as these actions will increase the likelihood of containment and eradication of new populations. Thus, 1) on going surveys (these could be funded through the Plant Protection Act/CAPS), and 2) training, information dissemination, and promoting reporting among stakeholders and the general public will be key steps. In addition, developing action plans now will be advantageous, as it will save time after detection and enable management and site delineation to begin immediately. For example these plans should have guidance on strategies to prevent further population expansion, a communication strategy to disseminate information to land owners and other impacted stakeholders, guidance on molluscicide use (e.g. when to use iron-based baits and when to use metaldehyde baits), and assessing the proximity of vulnerable crops (e.g. wheat) and vectors (e.g. freight). Mathematical modeling could be utilized to map potential new landscapes and locations in Montana that are vulnerable to invasion by *X. obvia*. This is a rapidly growing field with a wealth of new approaches including artificial neural networks, cellular automata (CA) coupled with fuzzy logic (FL), fractal, multi-fractal, percolation, synchronization and individual/agent-based approaches. If resources are limited such distribution and risk mapping could help highlight high priority areas for surveys.

Suggested Action Summary (not prioritized)

- An all year-round integrated snail management program to be in place
- Proactive measures – monitor, monitor, monitor
- Buffer zones in active “fronts”. Monitoring, and/or site modifying (e.g. resurfacing)
- Pre-emptive citizen science, community awareness programs/workshop in areas not yet invaded.
- Look ahead to those areas that might be invaded and have a good understanding of dispersal pathway from that point (e.g. river courses, vegetation corridors, regular transport of fodder, crops, vegetables etc.).
- Have best management practices outlined and available for different groups (homeowners, parks, farmers, road crews, etc.)
- Have a to date website where the public can easily find the best management practices
- Extensive and intensive outreach with a consistent message, where to find resources and who to contact for more information (staffing resources so there is a point of contact that responds promptly to requests)
- Have a (Fed/State/local agreed upon) regulatory response established that will prevent movement from new area.
- Have compliance agreements (that outline approved management options) for different industries in the new area of infestation (e.g. landscaping companies, non-host commodities that might have hitchhikers, nursery growers, farmers, road maintenance companies, etc.)
- Have the regulatory authority to survey and manage the snail on private/federal properties

Managing Pathways

17. What are the key pathways for the introduction of *X. obvia* and other invasive land snails?

Multiple pathways have been identified for *X. obvia* and related land snails. APHIS PPQ interception data from 1995 to the present indicate the most important pathway for the snail is hitchhiking on commercial container exteriors, particularly being transported by ship and then by rail. It has also been intercepted on ceramic tiles, steel, and on and in military containers. The population in Detroit may have been on containers being transported by rail from the Ontario Peninsula. The pathways for other invasive land snails are discussed below, but shipping containers (inside and out) are particularly important.

The 2012 and 2013 containment and mitigation survey sites (Foley and Eiring 2013) included high-risk transportation areas, recreational areas, and nurseries. Transportation is considered a major pathway of introduction and spread of snails. Areas identified for USDA canine surveys in 2013 included - "grain/seed terminals, storage, production, and processing facilities and co-operatives; pea production areas; an apiary; soil and gravel source areas; staging areas for materials and equipment for construction; transportation corridors and rest areas; an oil company; ARCO Smelter Works, and Ports of Entry at Wildhorse and Sweetgrass in and between Great Falls, Shelby, and Havre."

Intrastate dispersal of *X. obvia* is probably through several means. Dispersal along primary and secondary roads could be through various types of vehicles or road equipment such as mowers, graders, etc. Transport through agricultural equipment, e.g. tractors, swathers, or balers, or contaminated commodities, such as hay. It is possible that in drought years, contaminated hay will be donated to farmers in other states. As with the dispersal of noxious weeds there are concerns that the *X. obvia* is being spread through contaminated gravel or by recreational vehicles campers, four wheelers, etc. Eastern Heath Snails were observed crawling up onto vehicles or being picked up in muddy boot soles or car tires (and possibly undercarriages was well). Montana Department of Agriculture staff have also observed snails floating in Belt River. It is undetermined what role water transport plays in dispersal.

Melilotus (sweet clover) is listed as an important host plant for *X. obvia* being imported to the US from Europe and Canada via the Agricultural Quarantine Activity System (AQAS, 2009). Gurskas (1997) listed imported vegetables as a minor pathway in Lithuania. Godan (1983) stated that *X. obvia* is often transported with dry seed from clover, alfalfa, and sainfoin in Mediterranean areas; and from Italy to other countries in Europe on fruit and vegetable exports. Godan (1983) also stated that the species has been intercepted in the US on peaches from Norway, and specimens of *X. obvia* in storehouses in the US originated from Turkey. However, she did not provide a primary reference for this information.

Pathway Summary

APHIS PPQ interception data indicates the most important pathway for the snail is hitchhiking on commercial container exteriors, particularly being transported by ship and then by rail. Other pathways include:

- Vehicles, roadways, transportation corridors
- Plant materials—horticultural plants, cut flowers, aquarium plants

- Non-plant materials-- Ceramic tiles, marble and stone products
- Military cargo
- Recreational areas and recreational vehicles
- Nurseries
- Agricultural production and equipment (e.g. grain/seed terminals, storage, production, and processing facilities and co-operatives, tractors, swathers)
- Soil and gravel source areas
- Staging areas for materials and equipment for construction
- Pet trade and heliciculture (snail farming)

18. Are there proven regulatory actions to prevent the spread of invasive snails through commodities such as gravel, forage, etc.? Are there proven education and outreach methods and or messages to educate this sector?

There are regulatory actions, compliance agreements (e.g. with landowners), and education and outreach protocols that can and have been effectively used for various pests. Effectiveness is entirely dependent on the extent that authorities apply/implement those regulations and protocols, how strictly and consistently they are applied, and for how long they are maintained. Not being fully implemented for the appropriate amount of time, lack of funding, lack of political will, incompetence, and the inability of authorities to carry out the program to its fullest extent (e.g. a change in government) also impede effectiveness. Local municipalities/permitting agencies should be informed about any agreements and/or regulations and be provided with a contact/source for questions.

In Florida, compliance agreements with landscapers and growers have been effective means to control pests. They establish best management practices and outline what is necessary to allow movement of commodities safely and the repercussions if the agreement is not followed.

In Michigan early on in the control and eradication phase of *X. obvia* , intermodal containers were getting infested from local populations. An emergency Action Notice were used to hold and inspect containers before they could be moved. Yard workers were provided education to perform inspections and remove snails in the yard.

The state of Oregon enacted a rule restricting the importation of all life stages of *X. obvia* tic phytophagous snails or commodities originating from the entire states of Arizona, California, Hawaii, Michigan, New Mexico, Texas, Utah, Washington, and any other state or territory where exotic phytophagous snails are established (*Quarantine; Against Exotic Phytophagous Snails* 2014). Oregon also has research and outreach programs on economic snails and slugs.

The North American Invasive Species Management Association's Weed Free Forage and Gravel program, Montana's Noxious Weed Seed Free Forage program, and Washington's weed free certifications for gravel could serve as a model for an *X. obvia* program. There are education and outreach components associated with these programs.

In Australia, the green snail (*Cornu apertus*) is a declared and present pest in metropolitan Western Australia (WA). It was a local issue beginning in the 1980s until 2011, when it was detected in the town of Cobram in Victoria (the other side of Australia). The state of South Australia (SA) sits between WA and Victoria, and as such SA is on high alert for this pest which is expected to impact multiple agricultural industries. New regulations were introduced very rapidly to prevent the transport of hay/fodder, leafy material, soil, plants, cut flowers and farm machinery out of metro WA or Cobram into SA and other areas. These restrictions are still in place and, to date, green snail has not been detected in SA. Although these are WA state regulations to contain an outbreak, they are enacted by SA officers, and this demonstrates a collaborative approach between state officers.

South Australia's Primary Industries and Regions SA (PIRSA) includes a Biosecurity SA Division that employs a SA Grains Biosecurity Officer. This position is funded partly by government and partly by the grains industry to reach growers through direct contact (farm visits), workshops (often tacked onto a larger event or training day) and social media/technology programs. The officer raises awareness of exotic pests and best management of current pests to avoid resistance issues (e.g. storage pests in silos). They are also key to liaising with growers when an incursion is detected and maintain a grower-managed surveillance program. In our experience, growers need to develop a rapport with growers and individuals in the biosecurity space before they take notice of information provided to them.

Suggestion

Provide extension agents with pesticide application credits associated with training on proper treatments for snails.

19. What non-regulatory actions can be taken to address the movement of invasive land snails?

Education and outreach to landowners, industry groups (e.g. Montana Grain Growers Association), the community, and the public-at-large. Potential education activities could include:

- Citizen science
- Signage at recreational areas
- Education to government officials, e.g. extension agents, road crews
- Development of best management practices for specific groups (homeowners, growers, park managers, gravel pits, etc).
- Targeted outreach to landowners about mitigation to avoid regulatory action. Landowner signage that identifies property boundaries to avoid inadvertent introductions

20. What agricultural commodities (wheat, barley, hay, sugar beets, dry peas) would be at risk for exporting if the *X. obvia* or similar snail species are present? How could we best mitigate this risk?

Any crop containing *X. obvia* is at risk for exporting. Crops such as wheat, barley, forage, hay and others that are known to support large populations of *X. obvia* are particularly vulnerable for export restrictions.

In Montana, most dryland crops could be at risk but there is no data to support actual risks.

In Australia, the following crops have experienced issues with snails and exportation: wheat, barley, peas, canola, beans, vetch, malting barley, lentils, table grapes, citrus

In Washington, cereal crops were at risk for export with the detection of *C. virgata* in the Port of Tacoma. Washington State Dept. of Agriculture. chose eradication to mitigate the risk.

In western Europe, *X. obvia* is a pest of fodder crops such as alfalfa or lucerne (*Medicago sativa* L.), clover (*Melilotus* spp. and *Trifolium* spp.), lupine (*Lupinus* spp.), sanfoin or sainfoin (*Onobrychis viciifolia* Scop.), and seradella or birdsfoot (*Ornithopus sativus* Brot.) in southern Germany, a contaminant pest of fruits and vegetables in Italy and Bulgaria, and passes spores of Alternaria sp., Fusarium sp., and Phytophthora sp. in its feces, and vectors *Protostrongylus rufescens, Davainea proglottina,* and *Dicrocoelium dendriticum* (Godan, 1983).

Mitigation

Preventing introduction, preventing expansion of current populations, and eradication (where possible) are the best mitigation strategies. Early detection via frequent surveying of high-risk crops and areas (potentially identified through modelling) is essential, and ensuring stakeholders remain vigilant and informed through outreach and education activities should also be employed.

Other tactics include establishing strict harvesting, processing, and commodity inspection processes, establishing buffer zones around agricultural crops in snail impacted areas, and creating criteria to declare an area free of snails.

Other

21. Considering the Montana Department of Agriculture has unfunded authority for invasive snails, what funding opportunities are available for research, monitoring, control, and regulatory management of the *X. obvia*?

- PPA 7721 (Farm Bill) for research and survey (CAPS) has been the major funding source complimented by the Montana Agricultural Research Stations
- Western SARE (Sustainable Agriculture Research and Education) grants program
- Scientific grants through universities and research institutions
- Potential sources for exploration—Burlington Northern, Montana Wheat and Barley Association, Montana Grant Growers Association

22. What would "trigger" a quarantine or regulatory action by either the State or the Federal Government?

Generally, a phytosanitary incident where snails where found on exported goods would trigger a quarantine.

The Montana Quarantine and Pest Management Act allows for the adoption of intra- and interstate quarantines to prevent the introduction and spread of plant pests, as well as setting procedures to investigate and enforce quarantines, develop pest management standards and procedures for surveying and controlling plant pests, and develop procedures for the recovery of expenses and imposition of penalties (*Montana Quarantine and Pest Management Act* 1997).

By departmental rule Montana could impose a quarantine to prevent the importation of commodities, etc. from other states that may contain invasive gastropods. It could also impose a quarantine on a specific county or geographic area to prevent the spread of an invasive species. Internal quarantines tend to be a rarity in Montana.

Trade restrictions with other states or international partners that would impact Montana as a whole, or specific commodities such as wheat would trigger regulatory action(s) by the state to limit potential economic impacts associated with these restrictions.

Federal agencies could impose regulations as to the use of snail-free hay or gravel, similar to that of weed free hay or gravel, however, it is unlikely that USDA-APHIS-PPQ will change the regulatory status of *X. obvia* in the near future since it has limited distribution in the U.S.

Discussion

X. obvia Science Advisory Panel notes from facilitated discussions, held on-line (using Zoom as the platform) December 7-10, 2020.

DAY 1 December 7, 2020

Background on the efforts since 2012, population status and biology of *X. obvia*, and current research in Montana.

Welcome introduction, Bryce Christiaens, Chair Montana Invasive Species Council.

- Panelist Introductions.
- Video premier: Current status of *Xerolenta obvia* in Montana and field site visuals.

Ian Foley, Montana Department of Agriculture (MDA), Presentation
Overview of history and impacts, current status

- *Xerolenta obvia* (Eastern Heath Snail) considered invasive.
- USDA-APHIS and MDA have joint jurisdiction
- Started meetings in 2012—Stories indicate establishment is not recent:
    - Wife played in Belt Creek 30 years ago
    - Resident made necklaces with snail shells 70 years ago
- Timeline:
    - 2009 risk assessment, this species was one of the top 15 worst in world terrestrial snails to agriculture
    - 2012 EHS detected and reported to USDA-APHIS
        - One of 3 known populations in North America, others are in Detroit, MI and Ontario, Canada.
        - Have gotten into hay fields here but not in pulse crops
        - Control work in Detroit different in Belt (Railyard vs. cropland)
    - David Robinson, USDA-APHIS, National malacologist has been to Belt 3 times
    - MDA does surveys for non-infested areas
    - Have used USDA detector dogs to survey many sites across Montana
    - Only found snails in Belt Valley, Highwood, Monarch, Great Falls
    - 80% Montana grain exported. USDA-APHIS working to make that market safe. Have never found them in a grain field
        - No regulations in place currently. Continue surveys to protect trade market and ensure grain has no snails
    - There may be an environmental trigger (like Australia) that could change snail abundance—wet falls (similar to 2019)
- Background *X. obvia*:
    - From eastern Europe including alpine areas
    - Population genetically diverse
    - Montana is in the suitability range
    - Massing behavior—snails climb up and collect on plants and other structures (best time to survey for them)
    - Snails don't seem to thrive out of Belt Valley
    - Snails don't seem to cause harm to animals, however slime trails can be off-putting to horses and cattle

- Need calcium to exist in soil. Local limestone outcroppings provide calcium source and are somewhat unique to the area.
  - Cool, wet falls in Australia are when they get a spike the following growing season
- Impacts:
  - Feed on alfalfa and pulse crops, contamination is biggest risk/impact to agriculture
  - Primary damage to agriculture is contamination, feed on skin of fruits, crops and contaminate
    - Vector for other plant diseases
    - Alternate host to livestock pathogens (most do not occur in MT other than Bighorn Sheep)
- Vectors:
  - Inspected equipment
    - Snails popping up on roadside equipment—verified they do move this way
  - Gavel is a vector—no regulations. Education and outreach and best management practices are best ways to deal with gravel companies.
  - Belt Valley floods and snails may be moved with water.
  - People are another vector through intentional movement, vehicles, equipment, gravel/fill, hay
  - Native snails do not crawl up on plants and structures
- Treatment and control:
  - MDA has good relationship with city
  - MDA has provided baits to landowners, about 50% responded to a card sent with a utility bill and agreed to treatment.
    - Landowners see the treatments as higher risk than the snail
  - Have used 2 products
    - Iron phosphate (40 lbs./acre, $175/acre),
    - Metaldehyde (44 lbs./acre, $125/lb.) (bait that has to be consumed by snail—not that effective for landscape level control)
  - Liquid products best way to more effective but a lot more expensive
  - Handpicking—laborious process, needs to be repeated yearly
  - Ducks may consume, chickens less effective
  - Have evaluated mechanical treatments (mowing and rolling)—provides some control
  - Australia uses mechanical bashing and burning and have done a proof of concept with the DOT .
    - Equipment works on flat ground
    - Rolling and mowing do damage/crush snails
    - Have also tried spraying water—didn't really work
  - Tried 22% salt solution that is used on roads. Works but not cost or control effective
  - Snail roundup—local school kids collected snails, MDA disposed, kids received prizes—525 lbs. of snails collected in one week, 625,000 individual snails
    - Outreach tool
- Planning:
  - Original introduction may have been coal industry in 1810
  - MDA main focus surveys to make sure populations isolated so can write export certificates
  - Support research on biology so can make recommendations to landowners
  - Private landowners, DEQ, MDT are landowners where infestations are

    - Actions are voluntary, no quarantines or regulations currently in place
    - Nationally, only funded snail program is Giant African large snail in Florida—human health risk
    - Need to redo environmental review for larger scale control
    - Response to new detection—based on trade and impact
        - Export certification side-if grain produced in area, would take action if going to another state
        - Preventing movement side—much larger regulatory discussion with leadership at MDA and USDA-APHIS
        - Would not be significant regulatory response unless impacts trade
        - Industry drives regulation
- All funding for actions has come through USDA-APHIS. MDA does not have funding for snail control.
- Can counties designate snail for regulatory action? Yes, county pest districts have authority through Pest Act. County commissioners could develop regulations to limit spread.

Jeff Littlefield, Montana State University - Department of Land Resources and Environmental Sciences (MSU-LRES), Presentation

- Have been studying local biology of *X. obvia* for approximately two years
- Spreading across Europe and becoming invasive there
- Vector lung flukes, rat lungworm, tapeworm and plant pathogens
- Main objective—to understand best management tools
    - Basic biology
    - Feeding habits and preferences
    - Relative importance of habitat & environmental limitations
- Reproduction and egg laying:
    - Males and females have harpoons (love darts) that they exchange for reproduction
    - If mate upwards of 190 baby snails/pair
    - They are able to reproduce without mating but 12% viability
    - Have found 4-80 eggs /clutch
    - In lab seeing multiple groups of eggs per snail. Adults do not die after laying eggs
    - ~50% of eggs hatch
    - Lay eggs in soil up to about 2 cm deep
    - Currently determining when they are laying eggs
        - Snails lay eggs in fall, winter, and spring when soil is moist.
        - Eggs found in January, March, April, May, October, November in field. Haven't checked in December or February yet.
        - No eggs in field when soil is generally dry (June-September).
        - Eggs hatch within a month.
- Population development:
    - Found throughout areas but sometimes clustered in more dense groups
    - Not sure why
    - Trying to figure out best methods to sample and how to accurately count
    - Jennie counted over 1,200 in square meter
- Temperature development studies at 3 (12c, 20c, 28c) different temperatures. Has been going on for 2 years.

    - Appear to be cool weather species
    - Currently evaluating growth and development (weight, width) in lab at different temperatures
    - Very variable at all temps (Developing at different rates)
- Life cycle:
    - Multiple size classes present throughout year
    - Life span 1-2 years—possibly longer
    - Factors—genetics (high genetic diversity) and environment (environmental conditions) impact size classes
    - Fairly long lived—maybe up to 5 years.
- Natural enemies:
    - Nematodes
    - Mice, birds, ducks, other insects perhaps
- Food preferences (mostly laboratory work):
    - Recorded on a large range of plants in field (not sure what plants they are feeding on though)
    - Have tested at pulse crops and grains and other plant species in lab
        - Able to feed on most plant species including pulse crops and grains
        - Prefer younger succulent plant material vs. older
- Field activity
    - Set-up game cameras with time lapse to see activity
    - Early summer move up to 12m and only about 1m by August
    - In lab travel 0.01-0.03 mph
- Dispersal:
    - Human movement
    - Have seen in Belt creek (probably transported by water)
    - In Australia finding them imported on vehicles from Europe
- Habitats and environmental limitations:
    - Future research
    - In lab, have stayed in estivation/hibernation for up to 5 years.
- Continuing research:
    - Continue field monitoring
    - Continue lab development study through at least one generation
    - Host plant suitability—determine which plants are key hosts
    - Habitat studies
    - Future (dependent on funding—snail work not well funded)
        - Natural enemies
        - Monitoring guidelines for management
        - Alternative mitigation strategies
- Take-home messages:
    - Snails are highly variable and viable in Montana
    - Little apparent feeding damage in field (for now), but….
    - Snails are found in soil & litter and have the potential to be moved
    - The Eastern heath snail is here to stay—beyond eradication

Panel Discussion

- McDonnell—Control using iron phosphate vs. metaldehyde
    - Better results if switch to metaldehyde
    - Discourage use of iron phosphate, not very effective
    - Grazing considerations can be managed by excluding animals
- What are landowners doing to manage snails?
    - Some iron phosphate treatments
    - Landowners largely avoiding chemical controls
    - Have not tried crush and burn in fields
- Roda: Summary of iron phosphate vs. metaldehyde on Giant African Snail in Miami
    - Initially used iron phosphate, switched to metaldehyde
    - Snails actually spread when iron phosphate used
    - Using metaldehyde was a game changer. Very effective.
        - Used in urban areas where kids, dogs, etc. are present
        - Needed to do some management adaptations for species
        - Was thought eradication wasn't possible, now they are close to eradication.
        - Need to be careful. Moved pets, including dogs and donkeys when treating
        - Education to landowners was critical using personal visits and contacts
        - Don't give up on eradication
        - Look at how climate change may impact populations. Will they explode
        - Look at attractants in bait. Liquid formulation would likely be most effective tool in rangelands
        - Juvenile snails don't feed on bait pellets as much. Liquid better.
        - Liquid needs to be applied when snails are active
        - McDonnell - mini pellets are most effective
        - Sullivan-has tried different formulations—Metarex has been most effective.
        - Cena—has been using steam treatments. WSU has machine connected to hoses. Might be effective in small areas, does kill everything.
- There have been some impacts to hay production
    - Tillage and disturbance has kept them out of fields
    - Combination of reasons why snails haven't spread to grain growing areas
    - Dryland hay fields are above limestone formations
    - Brodie—Australia is pretty much no-till at this point, which is one of the reasons snails increased. Can't let up on management
        - Montana moving to no-till but still a limited practice
        - Growers use tillage to manage weeds
    - Pulse crops one of Montana's main concerns
        - Growers manage for moisture: long rotations and fallow cropping
- Sullivan: Have there been surveys on the Missouri River?
    - Creek is pathway for movement
    - Floaters and recreationists vehicles are another pathway

- How many growers have snail issues?
    - One main wheat grower. Looking for alternative crop to see what may be suitable. Landowner is concerned about human health. Believes snails are in water well.
    - More of nuisance. Haven't seen economic impacts yet.
- Have snails been tested for pathogens? Not yet.
    - Recommended testing snails and local vertebrate hosts for transmissible pathogens.
    - Michigan did not do any of these studies.
    - *Dicrocoelium dendriticum* was introduced into the Cypress Hills region of southern Alberta (approximately 120 miles north of the *X. obvia* infestation in Montana) and was found within populations of mule and white-tail deer, elk. Could be vectored by snails.
    - Methods:
        - Would look at droppings from deer and other animals
        - DNA extraction and targeted PCR for parasites of interest
    - Snails may transmit spores of the plant pathogens, *Alternaria* sp., *Fusarium* sp., and P*hytophthora* sp.
- Role of railways
    - Direct correlations of rail movement and snails
    - Detroit population was introduced by intermodal. Spread by railway equipment, staging areas.
    - Sullivan—Electric companies move snails through equipment
    - Foley—did outreach to electric company when they were doing work. Snails are also attracted to propane tanks creating another pathway
    - Montana Department of Transportation demonstrated they could use their equipment to crush snails. Has not been implemented as management strategy.
    - High-speed internet companies laying cables may also be transporting snails
        - Is there a protocol in place for these businesses to voluntarily comply with abatement of snails? Nothing specific for snails. MDT uses same protocols used for noxious weeds.
        - Recommended to capitalize on noxious weed protocols since companies in MT are familiar
    - Brodie—trained companies to bait roadways. Pre-empted movement.

Day 1 takeaways:

Utilize metaldehyde products for control, discontinue use of iron phosphate.

Shifting chemical control in areas where suppression and potentially eradication is the goal from iron phosphate to metaldehyde is recommended. Iron phosphate is not as effective. Control of *Achatina fulica* in **Florida using iron phosphate formulations led to the dispersal of snails from the treated area exacerbating the problem.** Both small pellet formulations containing metaldehyde for use on adult snails and liquid formulations for juvenile snails that may not successfully feed on the baits were recommended. Specific Categorical Exclusions to use these formulations may be required for the duration of a limited duration, area specific control action, as well as management adaptations to avoid exposure (e.g. moving donkeys (livestock, children, dogs). **Control work in Australia relies on metaldehyde.**

Snails reach densities in Montana high enough to impact hay harvesting and will require management.
The snails are currently a nuisance species in the urban areas where they are established but the impact to producers may prove similar to that observed in Australia. Snail abundance in a hay field was high enough that they filled the swather deck with their shells and fouled the machinery. While the movement of snails in hay is a concern as is the possible impact on hay quality, the establishment of *X. obvia* in pulse (pea, bean, lentil, chick pea) fields where the snails and the harvested seeds are approximately the same size would add a new management burden to producers who are currently managing for mollusk pests. Developing the tools and outreach to producers to protect Montana's crops for export will be necessary if this species spreads into pulse production areas. The high densities of snails in Australia led to support for research and the development of a suite of management tools can be adopted for growers.

It is currently unknown if Xerolenta obvia is capable of transmitting vertebrate parasites in North America. A number of possible parasites were identified in the literature but the presence of this species in wells and gardens is currently a nuisance but may be problematic if the snails are an intermediate host. It is recommended to test for pathogens as resources allow.
"In Europe, Xo is known to vector *Protostrongylus rufescens* (sheep lungworm), *Davainea proglottina* (cestode), and *Dicrocoelium dendriticum* (trematode). There are North American counterparts to these internal parasites. *Protostrongylus stilesi* is known from bighorn sheep in Montana and other western states and snails serve as intermediate hosts (Becklund and Senger 1967). *Davainea proglottina* is widespread and chicken, turkey, guineafowl, grouse, and other domestic and wild gallinaceous birds including pigeons serve as final hosts ("*Davainea proglottina* the Minute Tapeworm, Parasite of Poultry and Other Birds. Biology, Prevention and Control" n.d.). *Dicrocoelium dendriticum* was introduced into the Cypress Hills region of southern Alberta (approximately 120 miles north of the Xo infestation in Montana) prior to the 1980s. Ten to twenty years later, it was found within populations of mule and white-tail deer, elk (*Cervus canadensis*), and beef cattle (van Paridon et al. 2017, Goater and Colwell 2007)."

The movement of snails can occur with any materials moved out of areas with established populations.
Any item left in areas with snails can create a surface for these animals to climb onto and adhere to. Their massing behavior and ability to estivate allows them to survive transport for under adverse conditions for long periods. Cars and trucks parked in sites with snails on the ground or vegetation are a risk, items left in the area for longer times can accumulate more snails and snails have been observed on bee hives, propane tanks, and trash cans all of which are occasionally moved out of the infested areas. Work in the infested areas creates a pathway for snails to be moved on equipment used in maintaining electric lines, installing communications cables and other infrastructure. Following Noxious Weed protocols can reduce the risk posed by equipment and materials moved out of sites with snail populations but there is no regulation specifically addressing this species or any other slug or snail pest (gastropods).

DAY 2 December 8, 2020

Control Tools & Integrated Management

Welcome, review of day 1
Helen Brodie, Agricultural Entomologist, South Australian Research and Development Institute, Presentation
Integrated Pest Management of Mediterranean Snails in Australia

- Snails are hard shells to crack! Lessons to be Learned from Australian agriculture
    - Climate in Australia similar to Montana, crops similar.
    - Snails in Australia similar to *X. obvia* and some are closely related (Hygromiidae)
    - Above average rainfall events in Southern Australia produces higher numbers of snails in paddocks.
- Impacts
    - Snails and slugs cause extensive damage to Australian crops.
        - Field management costs, crop loss, grain value loss, harvest losses/costs
    - Nash estimated the opportunity costs for growing canola at upwards of $270 million annually. A five per cent production loss by slug and snail activity would represent >$82 million loss to the Australian canola industry (2012 values)(Nash n.d.).
    - Export impact—rejection of barley by quarantine authorities led to attention by industry and growers
    - On farm impacts
        - Harvesting costs increased—estimated $50/hectare/year per farm
        - Snail concrete clogs harvesting equipment, livestock reject pasture with high snail densities, blocking of irrigation conveyances, damage to crops
    - Other impacts—off-target effects from bait ingredients, native vegetation removal near boundaries of fields to reduce refugia for snails and slugs reduces habitat, intermediate hosts for a fluke worm (*Brachylaima* sp.) which infects people.
- **What we could have done differently**
    - **Strengthen biosecurity checks**
    - **Increase awareness of potential damage and spread early**
    - **Implement farming practices that do not support snails**
    - **Ramp up research!! (in Australia, research didn't start until snails were major problem)**
- Tools
    - IPM needed, consistency in management, community approach most effective, the Bash'em, Burn'em, Bait'em publication is being updated this year.
    - Burning does kill snails but reduces air quality and soil carbon
    - Bashing—has transitioned to crushing (w/out high heat), compacts soil reduces snail refuge. Mostly rolling is current practice in Australia.
    - Baiting—it's all about the number of bait sites on the ground (30-60 baits per square meter) and even distribution

    - Harvest options—modification to harvesters, timing, segregate highly infested fields, post-harvest cleaning (expensive)
    - Grazing/slashing stubble, removing overgrown vegetation
    - Weed control (preventing snails from having a cooler place to estivate)
    - Biocontrol research is ongoing. Nematodes require more water than is practical and parasitic flies are being evaluated.
- Monitoring research 2015-2020 to better understand bait application, climate impacts

Panel Discussion

- Have growers recorded reduced efficacy of bait over time? Anecdotal evidence, it's possible.
    - McDonnell: suggested the idea of switching out bait over time as a precaution
- Is there a difference for control strategies between snail species that are annual and those that are multi-generational?
    - Hasn't been studied.
- Does Australia use liquid metaldehyde?
    - No, not registered for use, can be used on exotic snails at ports
- Post-harvest treatments possible in China?
    - Import requirements change constantly. Currently, part of a snail is enough for rejecting shipments if more than one per 2.5 liters
    - Fumigation not guaranteed effective so not an alternative
- Baiting strategies:
    - Oregon uses 6 lbs./acre, recommended is 20 lbs./acre
    - Educate growers about optimal time, appropriate amount
    - Non-target feeding bait removal should be addressed
        - Ants may remove baits by carrying them away or underground
        - Worms may drag baits underground reducing the available baits by 20%
        - Mice plagues may result in snail baits being consumed, applying baits for mice may reduce take of baits by mollusks. Timing is difficult.
- Sluggo + spinosad being tested for efficacy?
    - Not yet.
- Lines of research that have paid off in Australia:
    - Baiting
    - Harvest cleaning options that separate snails from grain
    - Work like Dr. Littlefield's on biology hasn't been done on Australia snails. Details would be useful.
- Any incentives to get tools adopted by producers. How were they promoted?
    - Workshops and meetings in beginning—findings from IPM manual
    - Contacts initiated from growers needing to address problems being experienced so no need to seek out growers
    - Full time IPM support staff hired to meet demand for technical transfer
    - Sustained interest by ag engineering firms and corporations
- Vegetation management important in MT. Add protective border around fields. Extra baiting along fence lines.

- When did growers begin widespread control? What was the tipping point for management?
  - Rejection of barley by Chile 1984 led to Jeff Baker's field studies being initiated. Further rejections by China in the late 1990s
- Bait being developed for specific climates to resist weathering
- Rain through summer lead to higher numbers surviving (La Niña cycle)
- Retaining nutrients and moisture in soil gains better crops but also more snails
- More "residential pests" including earwigs (Dermaptera) than before so difficult to distinguish which pest is causing damage. But overall, not seeing any changes in snail feeding or behaviors
- In Australia, snails not a problem with chickpeas. Also low on Littlefield's palatability tests. Hairy stems may confer protection.
- Is there continuing range expansion in Australia? What human actions have led to expansion that could be addressed? What has worked to slow/stop spread between jurisdictions?
  - The Mediterranean snail species are not restricted, only regulations for green snail (*Cornu apertus)*
  - Mediterranean snails are managed through compliance agreements with growers (clean machinery)
  - They occupy 80-90% of their predicted range. Remaining areas are where they can't get a real foothold
  - Goal is management not eradication unless some miracle biocontrol is identified
    - Nematodes are water-intensive and have not established, could be reframed as a bio-pesticide
    - Research on other nematodes as snail control has been problematic and indicates that they may not be host specific.
    - French biocontrol fly may have additional habitat requirements and work is ongoing to boost resources for the fly including wildflowers near control sites
    - Testing a new collection of the fly from Morocco which will require re-testing 30-40 species of native snails.
- Biocontrol for snails and slugs not popular with malacologists given the history of introduced generalist predators contributing to the extinction of endemic species
- New tools are needed for mollusk control and McDonnell and Roda organized a workshop on new frontiers in control including RNAi, neuropeptides, and biocontrol
- Have the Mediterranean snail populations demonstrated explosions and crashes?
  - See shifts in dominant species over patches, not landscapes. No evidence of extremes.
- What detection tools or traps for mollusks and slugs are available?
  - McDonnell: Working on attractants (gastropods love cucumbers). Combine with liquid metaldehyde for a trap
  - A good trap for snails has not been developed as they are reluctant to enter structures that they can't get out of
  - Discussion of use of port detection tools including attractants and detection blankets (refugia)

        - Mixing attractants like cucumber with metaldehyde has potential
    - Detection in Montana uses visual surveys only when snails are estivating
        - Detector dogs—grain elevators
        - Recreation areas
        - Rail areas
    - Need to better understand metaldehyde and maintain use as a tool as other options are not currently effective
        - Research requires partnering with companies that have technology, expertise in mixing metaldehyde
    - Have stripper headers been used in Australia?
        - Yes
    - Management of eggs vs. snail. Not a lot done with eggs. March/April egg laying in Australia but varies with when rainfall occurs
    - Are there promising snail-based attractants?
        - Evidence is strong that Giant African Snails emit pheromones, nothing definitive but past work on aquatic snails in Canada suggested mollusks use pheromones
        - Roda: Working on a project to develop odor profiles…will lead to pheromones.

Day 2 takeaways:

Identify impacted industries, processors, and growers. Develop an education campaign to improve understanding of the impact of expanding snail populations on operations and exports.
The impacts from *X. obvia* to producers of grains, brassica crops for oil, pulses, and hay will include direct feeding on seedlings and crops, and the overwhelming impact of the aggregating snails at the time of harvest on the harvesting equipment and the quality of the commodities through contamination with crushed snails. The impact of gastropod pests to Montana crops is currently extremely limited and the spread of this species represents an entirely new class of pest for most growers. Because the impacts will almost entirely fall on producers, informing these industries now both in Montana and regionally on the threat posed by the will improve management decisions that will impact their industries for decades.

Create a liaison officer modeled after the South Australia Grains Biosecurity Officer.
This position could be funded cooperatively by both the grain growers' association and the government. Their role would be farm visits, education, resource and outreach. Building trust and increasing the likelihood of reporting new pests would be the goal. The need for this position will become urgent as snails spread into grain and pulse production areas.
Possible funding: Western SARE (Sustainable Agriculture Research and Education) grants program.

Share Montana's recommendation in a format that can inform neighboring states and impacted industries.
The spread of *Xerolenta obvia* throughout the predicted range in North America has substantial overlap with grain and pulse growing areas. While these recommendations are specific to the partners working in Montana, sharing the recommendations along with the concern that the continued spread of this species will substantially impact farming in the West is important to the council. The recommendations should be shared both with invasive species coordinating groups and

with journals including the American Malacological Society to raise awareness among specialists working in the region.

Support continued availability of metaldehyde products until good alternatives are identified
The use of metaldehyde is currently supported by labeling for crop areas but may need to be used for control in areas not currently listed on the label or with other formulations. Maintaining this chemical tool for control of invasive mollusk populations is important in managing new invasions before the need for widespread control. Tracking restrictions on the use of this chemical globally and continuing to support responsible domestic use will benefit control efforts.

Using the four established Mediterranean snail species established in Australia, the estimated cost to producers is an additional $50/hectare to reduce snail presence in fields and grain, pulses, and hay.

Mollusks in Australia result in a broad economic impact). Losses specific to the canola industry were higher $270 million(Nash n.d.). The tipping point for producers was the rejection of a load of barley by Chile in 1984. China has maintained focus by imposing strict hygiene standards as low as 1 snail or parts of a snail per 2.25 m.

The use of the full suite of tools is required to keep snails from reaching densities that make harvesting impossible and to make sure there is uniform use practices, eliminating refugia properties.
The Australian publications "Bash'Em Burn'Em Bait'Em: Integrated Snail Management in Crops and Pastures"(Leonard 2003) or "Mitigating Snails, Slugs and Slaters in Southern Western Australia"(Smith 2019) are good resources and can largely be adopted. As farming practices have changed since 2003, a revised version of the integrated snail management publication will be released soon, and the recommendations should be incorporated into training and outreach for local extension and industry education.

Vegetation management is necessary when using baits for control work.
If there are other options for feeding, the baits will have reduced effect on the population. Removing refugia, baiting when snails are physiologically active (typically when staring to reproduce), and ensuring careful spacing with calibrated equipment improves the likelihood that the baiting effort will succeed.

Starting a robust research program to investigate the control and biology of Xerolenta obvia now will improve management.
The one advantage the US has over Australia in managing new snail species is that for the Mediterranean species, they were widely established in Australia prior to the initiation of research programs. As production practices shifted from till, deep mixing to bring up clay, and burning to soil conserving practices of no-till and reduced burning, snails increased their population densities. Identifying effective and economical tools with support producers when this species establishes in grain production areas.

DAY 3 December 9, 2020

Response Considerations

Welcome, day 1 and 2 review
Clarifications:

- Pheromone attractants: this work is at the beginning stage. There is evidence for snails responding to pheromones but have not found the compounds responsible.
- Cucumber and mystery substance (when published) aren't being used anywhere yet for detection. Some people using in gardens as well as port detections. More widespread use is encouraged especially at high risk sites.
- Metaldehyde containing baits do have a bittering compound added to discourage consumption by non-target animals.

Brian Sullivan, Plant Safeguarding Specialist, USDA-APHIS-PPQ, Presentation
Regulatory status and population control experience of *Xerolenta obvia* in Detroit population

- Detected in 2001 in Detroit (in 1970s estimated had been there for 50 years) occupying an estimated 17 acres
- Treatments started at 2002
- 2004-2005 population core area survey and non-port of entry sites (100 sites)
  - Other species identified
  - 8 sites in Wayne County, Michigan
  - Resulted in pest risk assessment
- Applied containment treatments
- **Developed exotic snail strategic plan**
  - **Reduce or eliminate artificial spread by controlling snails' access to parked equipment**
  - **Reduce natural spread by treating at boundaries**
  - **Eradicate where possible**
  - **Continue surveying and mapping**
  - **Vegetation management is a key to success**
- **Worked cooperatively with landowners**
- Observation: Control burns were not possible at the urban area but an incidental burn covering 1 acre in a treatment area did remove snails.
- 2008 5-year eradication workplan approved (approval of funding was year-by-year)
- Two other detected snail species, *Xeroplexa intersecta* (was *Candidula*) and *Hygromia cinctella* were eradicated
- Reduced infestation from 100 acre to 20 acres
- Funding reductions resulted in work being taken over by staff rather than contractors No work after 2012.
  - Result--treatments became very selective, e.g. isolated pockets, strongholds
- In 2015 started to receive new detections via retired pest specialist, likely source was railyard materials
- A population discovered in 2007 in Kent County was identified through the Midwest Invasive Species Network, with no obvious introduction pathway
- Currently 4 counties have snails, expect it is in other counties
- Control tools initially not available, labeling for use was central to ability to plan a control effort.

- Molluscicide bait—formulation and registration main issues. Some treatments achieved a 80-90% kill rate
  - Had good results with Sluggo (iron phosphate) but control took longer. Sites were prepped (mowed) and so they couldn't pull in nutrients.
  - Application tools
    - Hand spreaders
    - Backpack blower (for hard to reach areas, calibration difficult)
    - ATV spreaders
- Artificial spread prevention
  - Mud flaps terrible for artificial movement, remove ladder vegetation near parking
  - Salt barriers to reduce entry into parking or storage areas
- Habitat and site alteration—crushed asphalt grading, rock substrate sufficient
- Vegetation control, caution as snails can move through brush hogging
- K-9 snail detectors effective

Panel Discussion

- Questions and panel discussion
  - What was the role of Michigan Department of Agriculture?
    - They got hit with Emerald Ash Borer and that took precedent. MI MDA did add snails to the prohibited species list, helped with survey work
  - Are the snails from the same source?
    - Foley: Genetic barcoding gene CO1 of a sample of snails from native and introduced ranges
      - Montana snails are diverse and do not cluster together, MI is a subset, but samples are limited
    - Sullivan noted that the snails look different and the MI snails may be related to the 1975 Ontario population of this species.
  - Suggestion: McDonnell willing to do DNA sequencing (Robinson has data set from Europe for comparison)
  - Management observation: To manage artificial movement only in railyards, would be full-time job.
  - In Michigan, the snails are prolific movers year around
    - Most activity at night with favorable dew points. Rain events are triggers for movement.
    - Relative humidity in MT is much lower, so may be reason Belt population hasn't expanded much.
    - Climate comparisons—MI and MT similar winters (snails survive fine in Ontario, Canada).
  - In Michigan don't shade so not as common in forests, they do cluster on knapweed (from native range and calcium source)
  - Size of populations able to eradicate—under 5 acres. Success due to vegetation control and other modifications in addition to chemical control.
  - **Satellite populations-possible to eradicate? Consider Great Falls and Monarch sites.** Highway to Monarch is via a limestone corridor. Irrigation near Great Falls population may encourage more movement/survival that rural sites.

- Sullivan: No limiting factors related to calcium, especially in urban areas where concrete is a source.
- Burn em Bash em techniques helpful in MI.
  - Grading, crushing asphalt—aggressive mechanical control was successful especially as the snails were found between rocks in aggregate road base.
  - Cleaning equipment critical
  - MI success in handpicking to eradicate (might be possible method for urban areas where residents do not prefer baiting).
  - Buy-in difficult if control efforts start and stop.
- Cena: Cleaning equipment is key to controlling spread, mowing equipment was a source of transmission.
- Can we implement sanitation best practices at a federal level?
  - No, there are no regulations on domestic movement of this species.
  - National Plant Board has movement checklists (best practices), e.g. gypsy moth which are federally regulated. Not one specific for mollusks.
- Robinson notes that both interstate and intrastate movement are concerning but there is no regulation or enforcement. OR, CA state exotic snail quarantines at state level.
  - MDA goal to limit movement between states—e.g. commercial beekeepers in infested areas. Snail climb on hives and end up in California. Because of CA quarantine, MDA inspects to protect other states.
  - Cooperative agreements with other states are a method for limiting spread, e.g. Japanese Beetle agreements in Washington.
- Could MDA have enforceable agreements in high-risk areas?
  - Yes, authority is broad and driven by industry partners and stakeholders.
  - Driven by stakeholders.
- Montana law delegates authority to counties for management areas.
  - Counties don't utilize authority.
  - Authority doesn't currently cover gastropods only arthropods.
  - **Add authority for gastropods, other pests?**
- Specific to gravel, MDA has bill to include gravel in noxious weed seed free forage program. Could establish, through rule, a voluntary program for snail-free gravel.
  - Look to other states to see where local authority has been used as model, e.g. Japanese Beetle
- Very little sampling in MT except roadways, and concrete structures on damns along Missouri.
  - **Recommending increasing/enhancing surveys**
  - Judith Basin area, others
- It <u>is</u> worth containing outlier populations to protect other areas. No funding or authority to implement.
- Model for response plan: USDA New Pest Response Guidelines for Temperate Terrestrial Gastropods
  - USDA has guidelines for containment and limitation for gastropods
  - Can be modified specific to MT populations
    - Melinda Sullivan, USDA: No dedicated funds for planning. Projects led by USDA get funds when needed—typically after the fact.

Recommend discussion with Andrew Wilds about getting emergency funding for snail outbreaks.

- Western IPM funding source

- Where infestation occurs is factor in addressing, urban vs. rural

- What is the status of the populations in Ontario, Canada?
    - Widespread, won't be doing much.
    - CFIA 2004 PRA did not recommend action due to belief that *X. obvia* would not persist that far north, lack of information on damage to crops (Garland 2004).
    - No money or interest in control
- US snail management funding
    - Need dedicated funding source, not currently the practice
    - Snails take a long time to control
- **Need a local Cooperative Management Plan**
    - City, landowners, state (MDT, DEQ), possibly USFS
    - Need to know resources going into plan
    - Need to stick with plan once you start
    - Look at both USDA plan and local plans. Identify successes.
    - Once you start, you can't stop, have to stick with it
- Compliance agreements--Port of Tacoma-rental compliance agreements
- Sullivan: If snails are rafting downstream, search along stream.
    - Go to known population, follow the debris (depositional path—bends in river) to see if/how far they go.
    - They don't drown if their epiphragm remains intact

Draft Recommendations

Build a cooperative management plan for Xerolenta obvia in Montana based on the recommendations in the USDA New Pest Guidelines – Temperate Terrestrial Gastropods, other local response plans for gastropod species, and local priorities.

The lessons learned in the effort to control *Xerolenta obvia* in the freight yards and industrial areas around Detroit, MI in part were generalized into a set of USDA recommendations on managing temperate terrestrial gastropods. The general USDA guidelines combined with the recent experience of other snail management efforts can be used to create a specific and current strategy to meet Montana's management goals. The partners for a Montana specific plan would include the city, county, landowner, and state agencies responsible for land management in the affected areas. Funding for planning documents may be available through the Western IPM center.

Control efforts must include a long-term funding source and stable control resources.

The results of the work in Detroit were promising. Additional species of pest snails were discovered and three were eradicated. Several small populations of *Xerolenta obvia* were removed but once control stopped as funding became limited or site modification failed to be maintained, the populations rebounded. Additional populations of this species have been found in surrounding areas, likely associated with the rail lines and cargo moving out of infested rail yards.

Building a better model of where the North American populations of Xerolenta obvia originated will improve efforts to contain their spread and reintroduction.
Initial work conducted by Ian Foley, MT DOA on the genetic barcoding gene CO1 indicated that the Montana population of *X. obvia* is diverse and that the Canadian and Michigan individuals cluster within the local collections. Further sequencing in cooperation Rory McDonnell at Oregon State University using Bernard Hausdorf's European collection may identify markers for identifying source populations and allow containment efforts to become more targeted.

Climate is not a barrier to the spread of Xerolenta obvia in Montana.
The climate matching model previously produced by the USFWS demonstrated that the central Montana region was a close climate match for *X. obvia*. The continued expansion of this species in both Ontario and in Michigan where minimum winter temperatures are substantially colder indicates that the adaptations to surviving harsh conditions allow this species to tolerate winter freezing.

DAY 4 December 10, 2020

Welcome, day 1, 2 and 3 review
Panel Discussion

- Concern about withdrawing metaldehyde on US control efforts
    - UK has plan to withdraw this chemical because it's showing up in waterways and impacting aquatic ecosystem, far above what is allowed
    - No current discussion to withdraw from the North American market, however what happens in Europe trickles to U.S.
- What would an outreach strategy look like to gain engagement and have locals help with detection?
    - Cena: WA hired an Outreach & Education Specialist for gypsy moth and Asian giant hornet
        - Pulled together resources, postcard mailers, social media. Hires greased wheels for public engagement
    - Roda: In FL work on engaging residents with giant African snail control was face-to-face! Know your audience and outreach needs to be consistent and is ongoing. Florida has hotline that has been successful. Need to respond to reports. Most snails were detected by public. Keep it fresh and re-advertise.
        - Jr. Detective Program was used to engage kids (safely) in looking for snails. Kids get a badge for learning about snail and get to go look for them.
    - CAP surveys funded by USDA PPA funding
    - MDA doesn't have capacity for outreach—**MISC can help**! E.g. Squeal on Pigs
    - Snails and slugs Living in Metropolitan Environments SLIME-L.A. citizen science program is led by someone with malacology experience
    - *X. obvia* is easy to identify. No native that look similar. Massing behavior is unique.
- Is it possible to see peaks and valleys (crashes) with Xo populations similar to what happened with Australia's invasive snails?
    - Robinson: Thinks populations will remain relatively at same levels and spread.
    - Has never seen abundance of snails in Europe like he's seen in Belt
    - No natural predators in the introduced range

- How invasive is this snail in Europe? Is the range expanding?
  - Yes, *X. obvia* is spreading to Poland, Germany, etc. – outside of native range. Not considered a serious pest currently.
  - McDonnell: reached out to European snail experts. They said *X. obvia* is not a significant agricultural pest to areas it has spread. Not a high-priority pest in Europe but does contaminate crops including orchard products.
- Robinson: Pest Risk Assessment-Snail rankings would likely change with the new information available including spread
  - Foley: **If new risk assessment is done, it should include soil types, data on population explosions after rains, dispersal due to transport/flooding.**
- The Montana Natural Heritage Program has done habitat suitability modeling and matching for *X. obvia* based on temperature and moisture.

- **Key management recommendations**
  - Preferential use of metaldehyde . Timing of control efforts
    - Snails are a higher risk to Montana than the toxicity risks of chemical control. Haven't reached the tipping point with locals to gain agreement on control around homes.
    - From Melinda Sullivan to All Panelists: 02:43 PM
      - For wide-scale use of metaldehyde in MT, APHIS would need to complete a full Environmental Assessment for widespread use of metaldehyde. Right now, MT is working under a categorical exclusion from my understanding.
      - The EA is required if APHIS is involved in any manner, including providing funding.
  - Initiate an outreach campaign about metaldehyde to manage snails
    - African giant snail success as example
    - Challenge - haven't been able to find a local champion
    - Foley: Have sent *X. obvia* information and an offer for no-cost control with utility bills to locals. About 50% acceptance.
    - Grain industry will need to weigh in based on their assessment of the risk.
    - Canola and camelina growers—reach out to see if they will engage? Study to see if *X. obvia* has an impact on those crops? Is it a threat to new markets? In Australia, snails are pests of Brassicaceae seedlings
  - Pathway recommendations based on spread (about 10 miles of spread from original boundaries—road associated in the past 8 years)
    - Dispersal studies show they can move 30 meters in a few of weeks
  - Brodie: Do concrete walls and structures encourage movement?
    - Unclear, but if so, roads may be a vector.
  - Preventing spread at the current population:
    - Regulations to prevent cars from parking in infested areas are unlikely to help given dispersed use of the public lands in the area.
    - Equipment protocols for utilities would be a possibility
    - Signage at parking areas is encouraged
    - Pave gravel areas with heavy infestations?

        - Sullivan: Snails were associated with gravel in parking areas in Detroit, this may not deter them.
        - Cost to pave fairgrounds was beyond the local municipality
    - Capitalize on Clean.Drain.Dry success
    - Noxious weed best management practices, USDA fire ants best management practices as models to reduce spread
    - Incorporate snails into noxious weed education efforts. Currently no authority to add non-plant species to noxious weed—add as recommendation.
    - Identify and monitor pathways

Via Attendees on Zoom:

- From RM to All Panelists: 03:08 PM

  Has the group thought about working with MSU Extension Agents since their main mission is to educate?
- From RM to All Panelists: 03:38 PM

  I have noticed that producers reach out to Extension more than government agencies.
- From Bryce Christiaens to All Panelists: 03:09 PM

  What about the ability to designate a "management area" that consists of concerted education efforts on BMP's, then a managed/treated edge and EDRR efforts for outlying infestations?
- Have there been any studies of how quickly invasive snails spread on their own, that is without human intervention? Do they have any biological traits that allow long-distance dispersal? I'm thinking of parallels from the plant world with a pappus that allows wind dispersal or buoyancy that allows dispersal via water.
- Are producers near Belt seeing any impacts to production? If not, then is control motivated solely by contamination of ag products and/or prevention of movement to new areas?
- Are there any known predators (native to MT) of the snails? Clearly, they don't achieve control, but does anything eat them?
    - Answer: Yes, birds and rodents eat them. Ducks like them.
- Are there examples of pathogens keeping a snail population in check (Xerolenta species or other)? Just thinking about how long the snails have been in the Belt area but they don't appear to have spread very far.
- One of the things I would like to add from yesterday is that the Highwood bench averages 18 inches of rainfall per year which is quite high for montana. As a result, the majority of the farmland is crop on crop, which may increase eastern heath snail populations and concerns from producers. Tyler Lane, MSU Extension Chouteau County

Draft Recommendations

Re-do the North American risk assessment of Xerolenta obvia based on observations.

The distribution models previously based on temperature and humidity should be refined using data on soil type to reflect the role of calcium in regulating the growth of this organism. This species has now been introduced to several areas and observing the response of each population to moisture, soil type, and other differences between sites will improve management.

Control efforts must include a long-term funding source and stable control resources.
The results of the work in Detroit were promising. Additional species of pest snails were discovered and three were eradicated. Several small populations of *Xerolenta obvia* were removed but once control stopped as funding became limited or site modification failed to be maintained, the populations rebounded. Additional populations of this species have been found in surrounding areas, likely associated with the rail lines and cargo moving out of infested rail yards. The annual operating budget for the Giant African Snail control in Florida is around $4m/year. Funding sources include Specialty Crop Block grants, USDA 7721 and state match. Advocating for funding to control this species is an area where MISC can assist partner agencies.

Advocate for building up funding for non-insect pests nationally.
Insect pests of crops are the focus of emergency control funds. As gastropod pests do not have a dedicated funding source but are associated with substantial damage, advocating for their inclusion in national funding to control emerging pests is critical for multiple industries and the protection of native species from new introductions of slugs and snails. Building the case for increased attention to non-arthropod pests will also require attention to the economic damage caused by the increasing number of gastropod pests in North America.

Work with existing outreach networks and resources to build awareness of the threats posed by this species.
Outreach specific funding is limited so using partners through the Montana Invasive Species Council and experts who work with the affected industries including Extension services to build awareness and motivation for detecting *X. obvia* and taking actions to prevent its spread are needed. Regionally, the Tri-State Commissions for pulse and wheat represent growers who will bear the costs of management should this species become widespread. Generally, the Western Governors' Biosecurity and Invasive Species Initiative along with PNWER and the National Plant Board should be included in the efforts to increase awareness of this species.

Local actions including adding signs indicating the presence of Xerolenta at access points to recreation areas in infested areas should be done to raise awareness of the need to check for and remove hitchhiking individuals.
The experience in the rail yards in Detroit indicated that gravel or paved areas reduce but do not eliminate snail movement. While paving high risk areas may not be feasible for a small municipality like Belt, adding signs to encourage the public to exercise caution and to not move the snails from the areas would be beneficial in raising awareness.

Snails should be added to the gravel section being developed for the Montana weed seed free forage program (MDA bill 2021 leg. Session).
Outreach and awareness of public lands users in infested areas is critical but the bulk movement of gravel, road building and maintenance equipment, and materials transport has already been identified as the source for satellite populations of *X. obvia* outside of Belt, MT. Adding snails to the regulations being developed for weed seed free gravel will add a critical tool for managing this pathway.

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