WIPMC Snails and Slugs in Ornamental Production
Research Priority Setting
Portland, Oregon
March 26, 2009

Thirty-seven researchers, growers, regulatory agency representatives, and industry professionals primarily from the western U.S. and Hawai'i (Table 1) met on March 26, 2009 in Portland, Oregon to discuss research priorities, coordination of research and outreach, and future plans for managing snails and slugs in ornamentals (Table 2). Discussion and presentations focused not only on the damage caused by these pests but the economic loss of commodities due to finds in shipping products as well as impacts of potential new pests that may enter the western states and U.S. Pacific Islands.

David Robinson, Malacologist from the USDA, gave an overview of snails and slugs that he is identifying from outside the U.S. and those which are being moved interstate via unregulated (and therefore uninspected) internet sales of plants. There are also frequent interceptions of snails and slugs from Hawai'i to the mainland. Dr. Robinson pointed out that one slug, Sloan's leatherleaf slug (*Veronicella sloanii sloanii*), a serious agricultural threat from the Caribbean that may have been found in Florida and could be an enormous problem if it becomes established in the U.S. Other mollusks of note are *Cernuella virgata*, *Candidula intersecta*, *Rumina decollata* (the European decollate snail used in California as a biocontrol but is phytophagous and cannot be sold via internet now), amber snails (*Succinea* spp. found in numerous states) can be found in high numbers. All *Succinea* spp may not be phytophagous but there two groups of *Succinea* found in U.S. and these can be problems in greenhouse production. The slugs *Arion vulgaris* (= *Arion lusitanicus* of European authors) (found in tile imports, cut flowers, and other imports from Europe), *Bradybanea similaris* (may already be in California) and currently in Gulf Coast states, bore holes in citrus and secondary pests (beetles) go into the holes causing more damage. These are found mostly in subtropical and tropical fruit trees. *Veronicella cubensis* (found in Hawai'i currently) native to Caribbean is spreading across Pacific Basin and is regularly intercepted in shipments outside of mainland.

State Reports

Robin Rosetta from Oregon reported there is limited survey information about snails and slugs in the state. Slugs were found in Christmas trees imported into Hawai'i and consequently some shipments were rejected. Brown garden snail is a quarantine pest in Oregon but there are isolated populations in the landscape. Robin Rosetta is very interested in the amber snail in Oregon. Questions that need to be answered include: Are there more than one species as well as better identification tools, information about the biology of the pest (overwintering, lifecycle, time of mating, and means of dispersal, what do they feed on, where are they in the nursery production system – can there be a flow chart describing where they are found from propagation to sale), thresholds, cost of control.

Researchable Questions and Education Needs:

Thresholds – is one snail the trigger to treat? How does shipping tolerance relate to tolerance during production?

Identification – not many keys, must send to experts and there are very few (one) of them

Monitoring methods and techniques – field methods are usually not appropriate for greenhouses or container production.
Also, management information in greenhouses and nurseries is needed. For example, weed mats may be wet and dirty and snails may like that habitat; how do the baits hold up under daily irrigation?
What is the effect of the bed structure and various substrates, e.g. gravel, soil, weed mats, pot-in-pot systems, on the efficacy and residual of the control products?
Bait formulations – are they still effective when wet? Do the snails of interest even eat the baits, especially the amber snail? Do the formulations need to match the species?
Eggs are in the soil; is there a method to control eggs?
More data needed on anti-feedants and repellents – sometimes only need to keep snails off before shipping e.g. Christmas trees.
Vectors of wildlife and human diseases – should we also focus on this?

Cheryl Wilen presented information regarding snail and slug issues in California. The primary gastropod pest in California is the European brown snail or brown garden snail. Although it has previously been classified as *Cantareus aspersus, Helix aspersa, Cryptomphalus aspersus* the currently accepted Latin name is *Cornu aspersum*. There are a number of potential problems for the ornamental industry including snails *Bradybaena similaris* and *Succinea* spp. and slugs *Deroceras laeve*, *Meghimatium striatum*, and V*eronicella cubensis*, all of which have been found or intercepted in California in the last few years. The amber snail (*Succinea* spp.) shows up in shipping containers and boxes because they move from the foliage to the top of the container and are obvious when the receiver opens the box. In California, they are frequently found in crops grown under wetter conditions at the interface of the surface of the media and the container. It is not clear whether they are feeding on the plants or algae but nevertheless, they present a phytosanitary issue. Slugs do not seem to be as big an issue but it may be that they are not so obvious. Metaldehyde is the most used product, with about 4X more a.i. applied then methiocarb, and 22X more than iron phosphate.
Research areas that could be considered are potential resistance development to metaldehyde in the brown garden snail, improved scouting methods, knockdown or repellent treatments prior to shipping. Improved efficacy, whether by changing formulation or percent active ingredients, should be examined. Related to this would be research in matching rate to population size and formulation (such as size or making a sprayable) and attractant to match to species. New materials, such as soaps and plant-based products, should be examined for potential efficacy.

Robert Hollingsworth's presentation on Hawaiian snail and slug issues including the orchid snail (*Zonitoides arboreus*) which affects the $22 million orchid crop. Very hard to see but feed on roots and growers must have a regular treatment program. Probably is bigger problem in the recent years due to growers switching from lava cinder to coir (coconut husk fiber). *Deroceras laeve* and *Veronicella cubensis* also affect the orchid crops by feeding on stems and flowers. Marsh slugs (*Deroceras laeve*), even in low numbers, can cause significant damage by feeding on orchid petals.
Dracaena field stock also needs a regular mulluscicide treatments (metaldehyde 2-3X/year) and snails and slugs cause direct damage by feeding but some are also vectors of the rat-lung worm. Common species include the slugs *Meghimatium striatum*, *Veronicella cubensis*, and *Deroceras*

laeve and snail *Achatina fulica*. New arrivals include the semi-slug *Parmarion martensi*, and slug *Pallifera* sp.
Giant African snail – rat lung worm disease vector
Cuban slug –may be hard to ID as sometimes it does not always have the 2 stripes on dorsal side.
Many of the pest gastropod hide within pots during the day and emerge at night or on overcast days.
Copper screening on top of legs of greenhouse bench help protect plants on bench
Baits break down quickly or are an eyesore in pots
Smaller snails can live on benches and copper sulfate materials are not effective on these species.
Growers probably should be spraying benches with copper sulfate and latex paint mix.
Needs: Long-lasting, safe algae-killing spray-on repellent to be applied to benches and/or pots; need to identify new pests and how they are coming in and how they are spreading. We also need to research methods to protect against incursion. Population dynamics are not well understood, life history and life table studies are needed.

Regulatory

J. Scott Blackwood - USDA-APHIS
Pre-clearance program for Hawaii, Costa Rica, Spain, Italy – mainly tiles and marble from Europe. Voluntary program for tiles in Europe.
Last 2 years about 6700 interceptions?? But not all are reportable and actionable species
SITC-commerce pathways via pet stores and internet sales and tracing back to importers. Are they being smuggled in? Do they have proper documentation?
Oregon-Winkled Dune snail has been found near ports but may or may not be a pest of concern in Oregon and is so widely distributed that eradication would not be possible.
Getting the word out about the exotics – go to pest shops, conventions, going on internet and find out who is buying what. *Succinea* spp. – some are actionable by USDA. Found on bonsai plants bought from ebay which was smuggled in from China

Gary McAninch – Manages State Inspections for Nursery and Christmas tree - Oregon Department of Agriculture
Eleven states have quarantine regulations specifically for slugs and/or snails. Most other states have general phytosanitary regulations.
Oregon regulates 5 species of snails or slugs, these are brown garden snail, white garden snail (*Theba pisana*), milk snail (*Otala lactea*), giant African snail (*Achatina fulica*), and giant South American snail (*Megalobulimus oblongus*) as well as any other plant feeding snail as determined. Life stages and products that might carry the pests such as grass, potting media, etc. can also be regulated.
Last year there were two official rejections to California and two to Canada including one due to amber snails. This was the first time amber snails were the trigger to cause rejection of shipment to Canada. Five containers of Christmas were rejected by Hawai'i due to slugs. Unofficial rejections – Japan rejected 2 due to amber snail and 1 due to unidentified snail. Missouri also rejected shipments (unofficially) due to amber snail.
Research Needs:

1. Shipping – more regulatory treatment options, especially eggs. The efficacy of many of the treatments available seems to be temperature dependent and this affects how well the pests are controlled.

2. Contamination
    a. Contaminated trucks being used for shipping.
    b. Cross-contamination – clean stock mixed with infested stock causes entire load to be rejected
3. Identification – better and faster identification
4. Better and more efficient methods of inspection. Hard to see many pests in the growing media.
5. Treatments for amber snail
6. Which amber snail species are phytophagous? Seems like there are multiple species and all may not be phytophagous.
7. Development of systems approach for control
    a. ID key control points in production cycle
    b. Intervene at that control point with appropriate control
8. There is a current proposal for identification of amber snail with Oregon and Hawaii collaborating. Collect amber snails in Oregon and Hawai'i; researcher will do DNA analysis for more exact identification.

Economic loss: ~$15-25K per container (product ($10-20K/container) + shipping ($5K each container)) for Christmas trees when destroyed
In nurseries – cost of treatment to eradicate + cost of additional inspections from regulators

<u>Grower Presentations</u>
Monrovia in Oregon
Wants to know what else can be used.
Board trapping on ground are not effective because pots on the ground act like board. They scout all year and inspect all plants before going into growing areas

1. Baits
    a. Size in important
        i. distribution easier when big size is used
        ii. current smaller sizes are harder to throw
        iii. does size affect efficacy?
2. 3% of pest control budget is for snail and slug control
3. Problem pests – European red slug, milky slug
4. Metaldehyde is used except on cloudy, cool days – use iron phosphate instead under those conditions. In Visalia, trying ammonium nitrate + iron chelate but does not have any data yet to see if it is effective.

Research needs

1. Identification for *Succinea*
2. IPM Program for snails in order to reduce pesticides
3. More sprayables or increase use (cost may be an issue)

Euroamerican Propagators in California
Because Euroamerican Propagators are propagators and use reclaimed water, the sites are often moist. They are concerned that snails are coming in via irrigation and spreading throughout nursery. They apply metaldehyde every other month. Use methiocarb (sprayable) and suggest that a sprayable metaldehyde formulation would be helpful. They would also like to see more

environmentally friendly materials. Suggest that products be colored to help applicators and inspectors see the granules and smaller granule sizes to encourage feeding by smaller snails.
Research needs:

1. Attractants
2. Controlling snails e.g. *Succinea*, in or near water such as irrigation holding pond.

Crop Inspection Service (Buzz Uber)
An independent crop inspector from California reported that metaldehyde is not working well even at 20-40 lb/A and is worried that snails may be becoming resistant. Sluggo Shorts seem to work well currently. Buzz has done a small trial where brown snail was injured but not killed by metaldehyde while there was >70% control with Sluggo Shorts. Measurol is the best product when "clean-up" is needed.
Grower practices:
Nurseries which hold "snail free" certificate are making broadcast applications of baits every 3-4 weeks.
Snail Barr (copper tape) around perimeters – perimeters baited every 10-14 days or as needed
Growers often send crews in following an application to scout for survivors which is very labor intensive.
Most effective control currently is Mesurol 75W. Typical ground spray application in a container nursery varies from 200-400 GPA or $280-560 per acre. Mesurol is used primarily as spot sprays.
Current cost for snail control is $.50-.60/$ft^2$.
Snail barr (copper tape) is used on wood benches or other areas where feasible.
Current Concerns:

- Metaldehyde products not performing as they once did – resistance?
- No new effective MOA's in the pipeline – or are there?
- Growers may be unable to ship product into "uninfested" states

Research needs:

1. Methiocarb as a bait – this is a priority
2. New compounds
3. Resistance studies

<u>Industry presentations</u>

Lonza (metaldehyde)
Lonza has identified at least 3 species which are high risk for the western U.S.: white garden snail (*Theba pisana*), vineyard snail (*Cernuella virgata*) and conical snail (*Cochlicella acuta*). However, while these species may be important in the future, the main species affecting nurseries in the US have been identified as the brown garden snail (*Cornu aspersum*) along with the grey garden slug (*Deroceras reticulatum*).

These high risk species are a major pest problem in Australia and in South Africa and are mostly problems in Mediterranean or coastal areas. Large scale programs using metaldehyde baits have been successfully carried out against these pests in Australia, where they occur in large numbers in broad-acre crops such as barley and in pasture areas where they foul grazing areas. The main

method has been barrier baiting as snails tend to migrate between pasture and crops. Barriers have been able to stop the majority of these snails penetrating the crop phase of the rotation.

Highly effective programs against the brown garden snail and the grey garden slug have been carried out for decades in Europe and in the US. There is a broad knowledge of effective metaldehyde baiting usage system based on both US and European studies. So far metaldehyde has been the main molluscicide of choice against both these pest species in large scale agriculture in both the US and Europe. This is because there has been no resistance ever reported in the scientific literature against metaldehyde even after its broad and repeated usage over decades.

Another effective system for using metaldehyde is to use different formulations based on the stage of plant growth. This was to use a liquid or sand based formulation at the early seedling stage to effectively form a protective barrier around the young plants. During the mid-growth stage to use a pellet formulation to attract and neutralize slug feeding damage. Finally before taking plants from the field or at harvest, one could use a highly attractive pellet to stop any cosmetic damage and to again draw slugs away and neutralize them or to stop them in their tracks with a barrier treatment and reduce infiltration.

When developing a solution to slug and snail problems several questions should be addressed. Firstly, what are we trying to achieve, ie what is the economic impact that we are trying to address? Are we trying to reduce damage? Are we trying to eradicate? If we understand what we are trying to achieve then we can properly devise a baiting and management solution.

Therefore what solutions do we need for nurseries?
- Do we need plant protection
- Do we need eradication
- Do we need to stop infiltration into containers or in plants

Should we be looking at protection, eradication, shipping restrictions? Any or all?
These solutions will be based on the correct identification of the pest speceis, knowledge of their life history and biology, and the impact that they have on the nursery growing system

Lonza and their formulators can help develop effective solutions to the pressing mollusk problems faced by nursery growers in the Western US. We can also help to develop guidelines for use.

Metaldehyde has been the main molluscicide solution worldwide for over 50 years. It can be formulated into many delivery systems and working together with nursery growers and other stakeholders we can develop appropriate solutions for the nursery industry in the Western US.

Gowen (Mesurol 75WP)
Broad spectrum toxicant. Could be a more important product if it had other uses but constrained by regulations and product itself is owned by Bayer in Germany. Gowen has US and Bayer has rest of world. Indoor and outdoor label.

Bait (Mesurol Pro) was discontinued in 2006 due to restrictions and too expensive to import from Germany and was most effective formulation. Baits are available in Europe and widely used in wine grapes for slugs. In US, not labeled on any food crop. Longer residual than metaldehyde. 2 lb a.i. for snails and slugs.
Mesurol is a carbamate and needs to be applied in acidic (4.5-6 pH) solution. Acts as a stomach and contact poison. Very fast action. Not affected by low temperature or wet conditions. It is also a broad spectrum insecticide e.g. used for western flower thrips in greenhouses. More effective on adult slugs as opposed to juveniles. 75W not as effective as 2% bait. Most of their effort has been to try to get it into agronomic commodities in order to justify more research. IR-4 work in artichoke in California post-harvest to stubble.

Research needs: Gowen needs to justify the sales of the product or new formulations. They can formulate in Yuma if they can justify the cost – needs to expand in the turf and ornamental market and ag crops. More explorative R&D and new use ideas needed.
Attractant work should be continued. Apple bait worked well but they had a problem with getting a reliable supply.
Combination of methiocarb and metaldehyde may let the label expand because there would be less of the restrictive material in the formulation.

Nisus (borates - Niban)
Nisus manufactures and develops boric acid granular baits which are labeled for a wide range of general pests including ants, roaches, earwigs, crickets, and silverfish. Boric acid granular baits may be applied for both residential and commercial uses. There materials are generally low risk, having an Oral LD_{50} >5000 mg/kg.

Mode of action – stops metabolism at mitochondrial level.
Borates inhibit each critical step of cellular respiration including glycolysis, the Kreb's Cycle and the Electron Transport Chain and it is thought that it would be very difficult for resistance to develop.

Nisus has sponsored two studies to determine whether a boric acid granular bait would be efficacious against snails and slugs. Results indicate that it was more effective against slugs than snails.

Research needs: biology information of pests; can the product be mixed with other products? There may be an issue with contamination of attractant and labeling.

- Placement
  - Would different application rates improve efficacy?
  - What is the best placement for this bait?
- Uptake
  - Are they attracted to the bait or is it random discovery?
  - What is happening when they do find the bait?
  - Do different borates or different percentages of active ingredient change the efficacy or act as repellents?

Other issues: Would like to make sure that there is dialog among growers, researchers, and industry so that when there is a problem it can be addressed.

Cam Wilson, Neudorff (Iron phosphate – Sluggo)
Sluggo is a small uniform, natural color, pelletized bait containing 1% iron phosphate ($FePO_4$). It is applied at 24-44 lbs/ac (0.5-1 lb/1000 ft^2) evenly scattered for control of all terrestrial slug/snail pest species.

- Product must be ingested to work. Slugs/snails are highly sensitive to iron toxicity - destroys the crop and hepatopancreas. LD_{50}>5000. Once bait ingested slugs/snails stop feeding.

$FePO_4$ causes cellular damage in the slug/snail's crop and hepatopancreas causing death regardless of weather conditions
Sluggo seems to work better than metaldehyde at cooler temperatures and under humid conditions. Recovery rates of slugs exposed to Sluggo, Deadline MP, Durham 7.5 at 21, 15, 10 and 4.5C increased as temperatures decreased. Metaldehyde products decreased about 35-55% from 21 to 15C; Iron phosphate decreased about 15%. Reductions at lower temperates were not as great.
Since the pellets are not blue (cream colored) they may be more acceptable in sensitive areas. Also, Sluggo is OMRI approved, exempt from residue tolerance and is often the only mulluscicide allowed in cities where there are pesticide restrictions.
There will not be any slime trails or group of empty shells so monitoring should include evaluation of plant health.
Growers may see improved control if they use Sluggo when weather is cool or humid.
Research needs: rate vs pest density (not enough bait to go around); "tank" mixing Sluggo with other bait active ingredients as they have different modes of action and grower can avoid bait preference problems by offering multiple attractants. Liquid formulation is desirable from users.

Research Updates and Progress
Research update for Hawaii
Robert G. Hollingsworth
Research Entomologist
US Pacific Basin Agricultural Research Center
USDA-ARS, Hilo, Hawaii

Orchid snails (*Zonitoides arboreus*) (See: The Orchid Snail as a Pest of Orchids in Hawaii (Hollinsworth, http://www2.ctahr.hawaii.edu/oc/freepubs/pdf/MP-1.pdf)

This pest has world wide in distribution. They feed on roots of potted plants, especially orchids. While they are primarily a production problem quarantine rejections can occur. The orchid snail caused orchid growers declared an emergency in 1999.

In a 1999 Orchid grower survey, 44% of respondents reported that orchid snail was a pest causing $500 loss in orchids but $5700 in lost sales. By the time they notice damage it is too late to save plant. Originally thought it was root rot. Most commonly damaged species are Oncidium, Dendrobium, Cattleya, Phalaenopsis, and Vanda.

While it orchid snail probably could be found in greenhouses prior to 1999, they were not considered major pests. Many growers switched from cinder to bark with moss or coir potting

mix in the late 1990's. Growers thought it was from the potting material but that was not found to be the case. Rather, most of the population was from orchid snails in the greenhouse that increased in population when potting mix changed.

Tests: Petri dish tests conducted using baits placing lettuce as a food source, measuring mortality and behavior at 7 and 15 days. Products tested were Bug Getta Plus, Corry's 'Death', Corry's pellets, Deadline M-P, Durham 7.5% granules, Eliminator Bait, Go-West Meal, Lilly-Miller pellets, Sluggo.
Durham 7.5% worked the best, proving 60% mortality after 15 days while others ranged from 0 to 15%. Orchid snails will contact bait but don't ingest it. They can be poisoned by it if it gets on their foot.

Liquid toxicants were tested at 1X and 2X. Kocide (fungicide) was included as it contains copper, which is repellent to snails. Each treatment was applied to filter paper in Petri dish with lettuce as a food source or lettuce as dipped in a solution containing the product.
Slugfest,
Neem oil
Slugfest
Mesurol
Yucca extract (Slug-Yuc)
Had to get to 2X rate to get control due to high humidity in Petri dishes.
Metaldehyde is not too effective under moist conditions
Neem oil appears to be a feeding stimulant – can this be incorporated into pellet to increase active ingredient uptake?
Slug-yuc was very irritating to snails.
Repellents – feeding repellency and contact repellency are distinct. Some things are very offensive to snail or slug but they will still eat a treated plant as long as they did not have to be on it.
Results published in: Hollingsworth, R. G. and J. W. Armstrong. 2003. Effectiveness of products containing metaldehyde, copper or extracts of yucca or neem for control of *Zonitoides arboreus* (Say), a snail pest of orchid roots in Hawaii. Inter. J. Pest Man. 49:115-122.

Greenhouse Bait Trials

- 4 greenhouse trials
- Potted orchids in 4-inch pots holding 10 orchid snails per pot were treated with baits or liquid toxicants
- Best results were obtained with Slug-fest (liquid formulation of metaldehyde), Durham 7.5% metaldehyde granules and methiocarb
- Results with metaldehyde varied widely (20 to 98% kill) depending on whose greenhouse was used. Hot, dry conditions promoted irritant effect; snails died on surface of medium

Parmarion martensi

- Semi-slug native to SE Asia
- Discovered on Oahu in 1996; Hawaii island in 2004
- Outbreaks correlated with rat-lungworm disease; semi-slugs heavily infected with nematodes

Biological Characteristics

- Extremely abundant during winter, possibly displacing Cuban slugs
- Prone to climb, fast moving
- Loves plastic and man-made objects; seldom lays eggs in soil
- Fallen palm fronds are preferred for feeding and oviposition
- Will eat flowers, but generally not the leaves of ornamental plants. However, likes lettuce.

Field molluscicide trial in papaya for control of Giant African Snail (*Achatina fulica*), Cuban slugs (*Veronicella cubensis*), and Semi-slug (*Parmarion martensi*)

- Relatively uniform conditions, rocky soil, heavily infested with *A. fulica* and *V. cubensis*
- Main objectives were to find best baits and to compare iron phosphate with metaldehyde products

Experimental design

- RCB with four replications
- Large plots (50x60 feet)
- 20 lbs of molluscicide product per acre **(**Sluggo, Durham 7.5% metaldehyde granules, Metarex, Deadline)
- Evaluations made by counts of dead slugs and snails and by disappearance of living slugs and snails from beneath refugia
- Slugs and snails were counted under plywood board pieces (2x2 ft) and plastic sheets (1.5x1.5 ft) every week for ~9 weeks prior to bait treatment
- Numbers counted went up over time

Results

- *Parmarion* affected by molluscicides in similar manner to other species
- *Parmarion* populations declined during summer
- Sluggo (iron phosphate) killed slugs, but not snails
- Metarex (metaldehyde bait) temporarily affected snails, but many recovered

Research update in California

Rory McDonnell (with Tim D. Paine and Mike J. Gormally)
UC Riverside

Presented information about the invasive slug fauna of California. He is the lead author on a new publication: Slugs: A Guide to the Invasive and Native Fauna of California http://anrcatalog.ucdavis.edu/Items/8336.aspx which is available for free download.

He reported that there are 17 native slug species in California and 15 invasive slug species. Most of the latter were of European origin. These included *Lehmannia valentiana* (Valentia Slug), *Limacus flavus* (Cellar Slug), *Testacella haliotidea* (Shelled Slug) and *Deroceras reticulatum* (Gray Garden Slug). He also discovered the first specimen of *Veronicella cubensis* on the west coast of the U.S. This species is thought to be native to Cuba and is considered to be the seventh most potentially damaging gastropod of either agriculture or natural ecosystems if it becomes

established in the U.S.

Rory pointed out that slug identification is taxonomically challenging as external morphological features (e.g. color) tend to be unreliable. In addition, even traditionally dependable characters such as the structure of the genitalia can be unreliable (e.g. in immature specimens). This has important implications for successful pest management. In order to successfully control a group of pest organisms it is absolutely essential to be able to accurately identify them and this causes obvious problems for invasive slugs. Rory followed that with a demonstration of his novel approach to slug identification using commercially-available restriction enzymes and DNA to develop a Molecular Identification Key. This method is easy to use, highly specific and a detailed knowledge of slug morphology is not required. It can be used on immature or mature specimens and only a small amount of DNA and basic laboratory skills are needed.

Future research needs/Potential collaborations

- Invasive slug ecology
  - baseline surveys in other western states
  - population dynamics in natural and anthropogenic areas
  - field studies investigating the efficacy of control strategies

- Identification of invasive pathways
  - source locations of exotic gastropod populations using mitochondrial DNA and microsatellites

- Identification of malacophagous natural enemies with the aim of isolating a biological control agent for invasive slugs.

Research Update From Hawaii

Kenneth A. Hayes **(**with Robert H. Cowie)
Pacific Biosciences Research Center, University of Hawaii–Manoa

Introduction pathways of alien snails and slugs

Ken provided an overview of how alien snails and slugs are introduced to a region and discussed his survey of nurseries and natural areas on the Hawaiian Islands in order to establish baseline data for the distribution and spread of the non-native snails and slugs and to evaluate the role of the horticultural trade in the introduction and spread of alien terrestrial snails and slugs in the Hawaiian Islands. He reported on his survey work and results.

The initial phase of the project was a survey of 40 nurseries on 6 of the Hawaiian Islands. He found 31 species; include 5 new records for Hawaii and 21 new island records. There were 1-17 distinct species at each nursery. He noted that some species were more likely to be found outside of a greenhouse than inside and vice versa. For example, an unidentified philomycid slug, *Gulella bicolor*, and *Succinea costaricana* were only found inside, while *Allopeas gracile*, *Lamellaxis micra*, *Arion* sp., *Cecilioides aperta*, *Limax maximus*, *Milax gagates*, and *Oxychilus alliarius* were only found outside.

Ken explored the 96 natural area locations on 6 islands during the second phase of his work. He found 46 species of which 35 were non-native species and there were 1-19 species at each location. The most abundant species (> 50% of sites) were *Paropeas achatinaceum* (68%), *Subulina octona* (55%), *Euglandina rosea* (53%), and *Allopeas clavulinum* (52%).

Conclusions

- New species continue to be introduced
- Their origins are global
- Newly introduced species spread rapidly within nurseries
  - New state records widespread in nurseries, but not outside
- New island records continue to be found
  - Species introduced long ago
  - Especially on the more poorly surveyed islands
- Continued vigilance, ongoing monitoring and impact assessments are needed

Research needs:

Ongoing monitoring, eradication experiments, systematics training, basic biology

Discussion

IR-4 Western Region has allocated some money but needs researchers to develop priorities and protocols. Examples are efficacy on specific species; appropriate use patterns for eggs, neonates, and adults; use patterns related to formulations

The most import issues the group agreed on were:

- **Identification/Taxonomic support – This was identified as the major need**
  - **Training to use pictorial keys**
  - **Snail key for growers et al.**
  - **Train the trainer Cooperative Ext**
  - **FAQs, clearinghouse website**
  - **DNA**
  - **Systematist support**
    - **Dr. David Robinson as final source for non-ID'ed specimens. However, his main charge from USDA is to ID snails/slugs from foreign sources There is no one assigned to do identification of snails found domestically**
    - **We need a person who can do identification of terrestrial snails and slugs found in the U.S.**
- **National Plant Diagnostic Network lab for immediate triage. Visual guide for risky species.**
  - **First responder – needs to know what is REALLY important**

General Research Priorities

- Information about the pests and their impacts:
  - Biology/Life Cycle
  - Scouting/Monitoring/Thresholds
  - Which are really pests
  - Surveys
  - Economic impacts of snails and slugs (ag economists)
- Information about control
  - Current materials
    - Formulations/sprays/size
    - What is best bait?
    - "tank" mixes
    - Environmental differences/effect on efficacy
    - Efficacy (for each species)
  - New materials
    - Ovicides
      - Important for both shipping and control
  - Biological Control – nematode
    - Rory found a new malacopathogenic nematode species in the U.S. which caused mortality in *Arion rufus*.
    - Flies such as *Sciomyzidae*, *Phoridae* and *Sarcophagidae* could have potential as biological control agents in the U.S.
    - Bacteria
    - A potential issue w/BC is lack of specificity.

        - Biological control efforts could focus on native malacophages as conservation biological control agents. There is less risk with this approach as the natural enemies could already be present as native species in the U.S. Such an approach has been successful in the UK.
    - Repellents/Anti-feedants/Attractants
        - Orange-Guard, other limonene- based products
        - Neem
        - Use of insecticidal soap to drop the snails off prior to shipping
        - Others?
    - Exclusion in nurseries
        - Spinout (CuOH)
        - Best management practices
        - Screen out?
        - Ground covers (are mats better than gravel, weed cloth)
        - Treat reclaimed water? Heat water?

Other topics:

- Resistance issue must be clarified
- What does the grower need?
- A point person should be identified to help set priorities and develop protocols
- Shipping issues
- Where are the points of entry?

Future Meetings

- The attendees agreed that a meeting every 2 years would be optimal.
- Set goals for the meeting
    - Results of what we've done
- Could align with a North American/Pacific Islands meeting
- Could be run under the Nearctic IOBC (International Organization for Biological Control of Noxious Animals and Plants) (Marshall Johnson, UC Riverside is 2007-2008 President)

Table 1. Attendees.

Western Region Slug & Snail IPM Workgroup Meeting March 26, noon-6:00, Portland, OR		
Attendees		
Name	Association	e-mail
Amanda Hodges	Univ. of Florida	achodges@ufl.edu
Amy Dreves	Crop Science Dept., OSU/Corvallis	amy.dreves@oregonstate.edu
Arnold Hara	Univ. of HI, CTAMR	arnold@hawaii.edu
Bill Gavin	USDA-ARS Forage Seed Lab, OSU	gavinw@onid.orst.edu
Buzz Uber	Crop Inspection	buzzuber@cs.com
Cam Wilson	Neudorff	cam@neudorff.ca
Chal Landgren	OSU/NWREC	chal.landgren@oregonstate.edu
Cheryl Wilen	UC Cooperative Extension, San Diego	cawilen@ucdavis.edu
Claudia Groth	Freelance educator	claudia_groth@havenet.com
Colin Park	USDA-APHIS	colin.park@aphis.usda.gov
Dan Meier	Briggs Nursery	dmeier@briggsnursery.com
David Edwards	USDA-ARS	david.edwards@ars.usda.gov
David Hicks	Marion Ag. Service	davidh@marionag.com
David Robinson	USDA-APHIS	robinson@ansp.org
Doris Ospina	Lonza	doris.ospina@lonza.com
Fred Ceballos	EuroAmerican Propagators	fred@pweuro.com
Gary McAninch	Oregon Dept. of Agriculture	gmcaninc@oda.state.or.us
Gary Melchior	Gowan Co.	gmelchior@gowanco.com
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Jenni Cena	Washington Dept. of Agriculture	jcena@agri.wa.gov
Ken Hayes	Univ. of Hawaii	khayes@hawaii.edu
Luisa Santamaria	Botany/Plant Path. Dept., OSU/NWREC	luisa.santamaria@oregonstate.edu
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Rebecca Sisco	UC Davis-Western Region IR-4 Program	rsisco@ucdavis.edu
Robert Hollingsworth	USDA-ARS	robert.hollingsworth@ars.usda.gov
Robin Rosetta	Dept. of Horticulture, OSU/NWREC	robin.rosetta@oregonstate.edu
Ron Hammond	Ohio State University	hammond.5@osu.edu
Ron Tuckett	Monrovia Nursery	rtuckette@monrovia.com
Rory Mc Donnell	Univ. of CA, Riverside	rjmcdonnell@gmail.com
Sarah Eschmeyer	Briggs Nursery	SEschmayer@briggsnursery.com
Scott Blackwood	USDA-APHIS	jonathan.s.black@aphis.usda.gov
Steve Booth	Enovations, Inc.	boothswa@comcast.net
Suzanne Wainwright	Buglady Consulting	sw@bugladyconsulting.com
Tim Paine	Univ. of CA, Riverside	Timothy.paine@ucr.edu
Yolanda Inguanza	USDA-APHIS	Yolanda.inguanza@aphis.usda.gov

Table 2. Meeting Agenda.

1. National issues – David Robinson (15 min) (:15)
2. Current issues and research priorities by state (10 min each) (:30)
    - Oregon - Robin Rosetta
    - California - Cheryl Wilen
    - Hawai'i – Rob Hollingsworth
3. Regulatory Issues
    - Shipping
    - Quarantine
4. Growers research needs – nursery industry representatives (20 min) (:20)

BREAK (:15)

5. Industry perspective (15 min each) (1:00)
    - Lonza (meta products) - James Coupland
    - Gowan (mesurol) - Gary Melchior
    - Nisus (borates) - Janet Kintz-Early
    - Neudorff North America (iron phosphate) – Cam Wilson
6. Research updates and progress (20 min each) (1:00)
    - Rob Hollingsworth
    - Rory McDonnell
    - Ken Hayes