Integrated Pest Management Plan and Curriculum Overview

Angiostrongylus cantonensis the rat lungworm parasite presents challenging issues for both the health of Hawai'i's residents, and for Hawai'i's agriculture. The existing network of school garden projects in the state can aid in addressing this important issue. This outline describes the integrated pest management plan for control of slugs and snails in school gardens, and important, related concepts that are available as lesson plans for school garden and classroom teachers. The management plan is based on best methods for slug and snail control from the University of California at Davis, one of the leading agriculture schools in the nation. The lessons are designed to support place-based education and integrated curriculum. Place-based education allows students and teachers to investigate real-life issues that are important to their communities. School gardens provide unique opportunities for on-campus, place-based education.

These lessons are aligned with the Hawai'i State Academic Standards, Next Generation Science, and Common Core Math. These lessons have been trialed in schools with teachers and students from the grade 5 through grade 8 and could be used for high school grade levels as well. The lessons are intended to provide deep learning and encourage critical thinking. Through the series of lessons, students are provided with sufficient information and activities to become well-informed educators for their families and communities. As citizen scientists, students and their teachers make observations and collect data, including long-term data, that can be used by state agencies and researchers who are working to control hosts of the rat lungworm parasite and reduce rat lungworm disease infection rates. This information is crucial to better understand patterns and cycles of our invasive slug and snail populations. The project also provides the opportunity for much-needed support for early detection of invasive slug and snail species. Collaboration with this network allows the more than 200 school and youth garden projects located throughout the state and on every island to act as sentinels to prevent the further spread of invasive slug and snail species. Early detection of a new, effective slug or snail host of the rat lungworm parasite is crucial for successful control or eradication, and for predicting the potential for an increase in rat lungworm disease incidence.

The information in these lessons is supported by the latest research on rat lungworm disease from the Hawai'i Island Rat Lungworm Working Group, which is housed at the University of Hawai'i

at Hilo, Daniel K. Inouye College of Pharmacy under the directorship of Dr. Susan Jarvi. The Jarvi lab has a national and international reputation as leaders in the field of research and education on the issue of rat lungworm disease on Hawai'i Island. In addition to the school garden teacher, this curriculum is intended for use by the classroom teacher. It is designed to aid in student achievement of the grade-level specific benchmarks and general learner outcomes required. We encourage teachers to aid in the continued development of learning activities and assessments of student mastery of the lessons.

1). *Angiostrongylus cantonensis* the rat lungworm in a global context

Rat lungworm disease, or angiostrongyliasis, the medical term for the disease, is described as an emerging tropical disease and is currently described as found in 30 countries. While considered a tropical disease, the parasite has been found established as far south as Sydney Australia, which has a humid subtropical climate. In the United States the parasites' range has and is expected to continue to expand. *Angiostrongylus cantonensis* is established in Hawai'i, the Gulf Coast States including Florida, Georgia, Mississippi, Louisiana, and Texas, and it has been found in Oklahoma, and Tennessee. The parasite was first discovered in Canton, China (now called Gaungzhou) in 1938 by a scientist named Chen. The species name, *cantonensis*, is derived from the location where it was first identified, Canton. The parasite spread during World War II with ships transporting military equipment and personnel throughout the Pacific and Southeast Asia.

2). Integrated Pest Management

Integrated pest management (IPM) incorporates the employment of the least toxic methods available for control of unwanted pests. It requires the careful consideration of available pest control methods including biological, chemical, and cultural practices. These management practices are dynamic and must involve the development of monitoring systems to continuously evaluate population levels for decision making and adaptive management. The IPM plan described here was adopted from the University of California Statewide Integrated Pest Management Program guidelines for snails and slugs, which recommends the use of cultural practices (removing materials where they can hide), traps (providing specific shelters for them to hide under), hand picking, barriers (copper, Bordeaux mixture, ashes or other abrasives), natural enemies (predacious snails and domesticated fowl such as ducks, chickens), and baits. Safety is stressed. Students are educated as to the proper handling of slugs and snails found under shelters or when conducting searches.

3). The rat lungworm lifecycle

It is important that the general public understand the lifecycle, be able to identify where the infective stage larvae would be harbored, and understand why control of hosts is crucial to prevention. The rat lungworm lifecycle is complex, requires two very different hosts and can be challenging to understand. If students are to be educators for their families and communities they

must have enough familiarity with the lifecycle so they can explain it correctly to others. The lifecycle lesson provides a clear description of the movement of *A. cantonensis* between hosts.

4). Classification

Student basic understanding of taxonomy and the classification of organisms will aid in proper and consistent methods of data collection across schools. Students understand the levels of the Linnaean hierarchical system of classification of biological organisms. Students understand gastropods, more commonly known as slugs and snails, are a toxemic class within the phylum Mollusca, the third most successful animal group after arthropods and vertebrates.

5). Slug and snail biology

Students will be educated about basic gastropod biology including morphology, reproduction, and feeding and behavior. Identification of some species can be difficult. Often identification requires dissection and examination of reproductive organs by microscopy. Experts can be sought for help with species identification by properly photographing the species in question. The specimen should be photographed from the right side, showing the position of the pneumostome in relation to the body, and the length of the mantle covering the body. It is also good to photograph the specimen from above to distinguish if the specimen has a keel, a ridge-like protrusion such as that on the semi-slug *Parmarion martensi.* An object of recognizable size, such as a coin, pencil, ruler, etc. should be placed in the photo view as a reference to the specimen's size. An identification guide of species commonly found is important for proper data collection, but we are still learning what species will be found on the various islands. Schools can help build this guide over time.

6). Data collection

Data collection on a regular basis is essential to be able to evaluate control efforts and includes name(s) of students collecting the data, the date, the current weather (sunny, cloudy, etc.), rainfall, species found and number of each species, and shelter or area where the slug/snail was found. Data is collected for later analysis of species variation and frequencies, shelter-type capture rate, and hand-collection capture rate. A rain gauge should be kept at each school to record rainfall data. When examining shelters and recording data, slugs, snails, and flatworms are identified by their scientific name using a three-letter abbreviation format (e.g. *Parmarion martensi* = PAR MAR). Students can transfer the information collected on data sheets in the garden to an electronic file on Google Drive using Google Sheets. We recommend that fifth/sixth grade students collect the data in the garden and give it to the seventh/eighth grade students to enter into a Google Sheet for later analysis. Students made bar graphs and pie charts to analyze and visually describe the information collected in the garden.

7). Paratenic and accidental hosts

There are other organisms, termed paratenic hosts, which can harbor *A. cantonensis* and can serve as pathways of infection. These include shrimp, prawns, land crabs, frogs, water monitor lizards, and predacious flatworms. Particular emphasis is placed on flatworms, in particular *Platydemous manokwari.*as this flatworm preys on slugs and snails and can harbor the rat lungworm parasite.

8). Native snails of Hawai'i and the story of failed bio-control

Students will be introduced to Hawai'i's beautiful native snails, many of which are now extinct or endangered. Students will learn what impact the introduction of non-native snails, slugs and predacious flatworms, along with human collection of native species, had on Hawaii's endemic snail species. Students will also understand what impact non-native gastropods have on native plant species and forest regeneration.

9). Reporting

Photography can be used for reporting on various IPM and educational activities. The photographs taken can be when making the ArcGIS online story map for reporting, or for educational purposes at the school. We recommend all schools or classrooms involved with this project apply for the free ArcGIS online software. The ESRI, ArcGIS software is available to all K-12 schools in the State of Hawaii and allows users to create and share maps, scenes data, and applications, which can be edited and published. Participating schools will use this story mapping technology to report on the outcome of their control and education efforts.

10). Rat lungworm disease symptoms and treatment

Students are informed of the various known routes of infection; ingestion on raw or undercooked food, paratenic hosts, water, as well as potential transmission through skin, eyes, and mucosal tissue. As rainwater catchment is common in many communities served by the partner schools, catchment design and maintenance is discussed as are other diseases that can be transmitted through water in catchment tanks such as mosquito, lizard, rat, and bird-borne diseases.

11). Rat lungworm disease prevention

Students learn the measures that need to be taken to prevent rat lungworm disease. These include steps that need to be taken in food preparation and food storage, especially foods and beverages that might be taken and consumed outdoors. Students also learn other ways people have been infected and how to best prevent infection from sources such as rainwater catchment tanks and garden hoses. As animals can contract the disease, we touch on preventative measures to keep our pets safe.

12). Master Data Sheet

This is the master data sheet all schools will use for recording information control efforts in the garden. The sheet can be downloaded and printed.

13). Invasive gastropod ID photos

Photographs of some of the most common gastropods we encounter are depicted with their scientific name and common name, if they have one. With the help of students, teachers, and experts, we aim to build this identification file as schools report various species from around the state.

This material is written by Kathleen Howe and produced by the Hawaii Island Rat Lungworm Working Group with funding from the Hawaii Invasive Species Council and support from the Daniel K. Inouye College of Pharmacy. Photo credits of snails: The Jarvi lab.