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A Hawaii public education programme for rat lungworm disease prevention

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Research Article

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Abstract

Education is essential for lowering cases of *Angiostrongyliasis* in Hawaii. A professional development course on rat lungworm disease (RLWD) prevention was offered to Hawaii K-12 teachers during the 2018–2019 school year. Fourteen teachers, 11 from Hawaii Island and three from Maui, representing grades K, 2, 6–8, and 10−12, completed workshops and activities and received course credit. Teachers reached 652 students and educated 86 teachers and staff and approximately 900 community members including parents. A pre-course survey showed 55% of teachers agreed to a basic understanding of rat lungworm and its impact on Hawaii; this increased to 100% post-course. A sixth-grade class was the first to document the arrival of a highly competent intermediate host of the rat lungworm in a new location, an important discovery that initiated community awareness and control efforts. Six, 1-day workshops were held in 2018–2019, each on one of the main Hawaiian Islands. These were attended by 106 participants including teachers, community educators, and interested individuals from agencies, non-profits, businesses and the private sector. Of participants surveyed, 100% responded the workshop improved their overall understanding of RLWD. Efforts are being made to continue these programmes.

Introduction

The parasite *Angiostrongylus cantonensis* or rat lungworm (RLW), which causes rat lungworm disease (RLWD), has been known to be endemic in Hawaii for almost 60 years (Alicata, 1964; Wallace and Rosen, 1969). A trend in rising numbers of RLWD cases statewide is now observed, with Hawaii Island reporting the greatest number of incidences (Hochberg *et al.*, 2007, 2011; Howe, 2013; Howe and Jarvi, 2017; Kwon *et al.*, 2013; Johnston *et al.*, 2019). The 2nd International Rat Lungworm Workshop was held in Honolulu, Hawaii in 2011 to 'develop a rigorous and concerted research agenda to address rat lungworm disease at a global scale…'. A list of prioritized objectives identifying areas of need was developed by workshop participants (Cowie, 2013). One priority identified was to introduce RLWD prevention education into K-12 schools as science, technology, engineering, and math (STEM) education (Cowie, 2013).

In 2012, the Jarvi Lab at the University of Hawaii, Hilo (UHH) Daniel K. Inouye College of Pharmacy (DKICP) began developing educational materials to be used in K-12 classrooms. An activity book developed for lower grades (K-5) was published in 2013 (https://pharmacy.uhh.hawaii.edu/rat-lung-worm-activity-book). In 2013–2016 a pilot project was initiated for the intermediate grades. The project enlisted five partner schools on Hawaii Island with the objective of developing an integrated pest management (IPM) plan for the control of intermediate, non-native/invasive gastropod hosts and to design standards-aligned STEAM (science, technology, engineering, arts, agriculture, math) curriculum related to the RLW and RLWD prevention (Howe *et al.*, 2018). The partner schools were affiliated with the Hawaii Island School Garden Network, part of the Hawaii Farm to School Hui, which supports a statewide network of over 200 school garden and agriculture projects. The curriculum and IPM plan developed from the pilot project were made available online at the UHH DKICP Jarvi RLW education website in 2017 (https://pharmacy.uhh.hawaii.edu/rat-lungworm/lesson-plans-teachers). The curriculum includes an overview of educational pedagogies incorporated and lessons that cover a global review of RLW, the RLW lifecycle, slug/snail taxonomy and biology, data collection, paratenic hosts, native Hawaiian snails, RLWD and RLWD prevention and reporting with ArcGIS Story Mapping. Supplementary materials include a master data sheet and an evolving file of common non-native/invasive slugs and snails found in Hawaii.

A collaborative effort between the UHH DKICP Jarvi lab, 'Iolani School, the Hawaii Farm to School Hui, and the Big Island Invasive Species Committee (BIISC) allowed for an expansion of the education outreach in 2018–2019. Funding was secured through a Career Track Learning Grant and from the Hawaii Department of Health (HDOH) and was used to (1) conduct 1-day workshops on all of the main Hawaiian islands and (2) for the development, organization and execution of a for-credit Professional Development Education (PDE3) course for Hawaii Department of Education (HDOE) teachers to be held during the 2018–2019 school

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year. The objective of these activities was to train teachers, students and community members as educators to prevent disease and to integrate IPM activities to reduce populations of intermediate hosts of the RLW.

Methods and materials

Professional development education course (PDE3)

Discussions were begun in Spring 2018 between UHH DKICP Jarvi Lab and members of the Hawaii Farm to School Hui, herein known as the Hui, a programme of the Hawaii Public Health Institute, to further training of K-12 educators in the use of the developed IPM plan and curriculum. The Hui is a statewide network comprised of five island-level networks, community organizations and representatives of the Hawaii Departments of Agriculture, Education, and Health, and the University of Hawaii. A proposal for the PDE3 course was collaboratively developed by personnel from Iolani School, the Hui, the Jarvi Lab, BIISC and the STEM Educational Specialist at the Hawaii Department of Education (HDOE). A focus on teacher professional development in the Design-Thinking process (Stanford Design School Model; https://dschool.stanford.edu/about) was to be implemented in the course as an HDOE priority. Design-Thinking is an educational pedagogical process meant to unlock creative potential through unique learning experiences (Scheer *et al.*, 2012). It is very similar to the Human-Centred Design process that was successfully used in Zanzibar for urogenital schistosomiasis control interventions for school age children (Person *et al.*, 2016). Human-Centred Design assumes that community members are experts and can develop workable solutions for their community problems. In Zanzibar, researchers and community members co-designed and developed innovative solutions and co-designed and developed innovative solutions and products to reduce the incidence of urogenital schistosomiasis by providing affordable and socio-culturally acceptable solutions for accessing and encouraging the use of safe water rather than contaminated, natural, open bodies of fresh water for bathing, washing and latrine use. The PDE3 course in Hawaii brought together RLW researchers, educational professionals and K-12 teachers and students to co-design solutions for control of RLW and prevention of RLWD. In addition to Design-thinking, PDE3 course educational pedagogies include the FAIR features of STEM learning experiences (framework, authentic assessment, cross-discipline integration and real-world connections) and place-based education, which uses the local setting as a context for learning. Teachers and students are introduced to citizen science and collaborate with scientists in data collection for conservation efforts (Haywood *et al.*, 2016), in this case data pertaining to invasive species removal.

The course was approved as a hybrid course consisting of both in-person and online instruction. The course was to be conducted by an instructor with experience in RLW research and K-12 education, and a co-instructor with experience in invasive species control and K-12 education. The PDE3 course was aligned with the HDOE General Learner Outcomes and the Vision for Success of the State's Strategic Plan.

Timeline

The course was open to HDOE K-12 teachers statewide. Locations were secured through communication with school administers. Three sessions of 2-day workshops were held on Hawaii Island in the Autumn 2018 semester, and the online-workshops and final presentations were conducted in the Spring 2019 semester. Teacher portfolios were submitted for review to course instructors and sent to HDOE for approval and credit before the end of the 2018–19 school year.

Specific course objectives

The PDE3 course objectives were as follows:

Course participants develop content knowledge relating to human/environment interactions and the role of IPM and community engagement for RLWD prevention. Participants explore the UHH RLW curriculum and apply knowledge of their content standards to the lessons. Participants design and implement classroom-appropriate lessons, learning activities and assessments using the curriculum and incorporating connections with state standards. Participants engage with students to conduct investigations, solve problems and create opportunities for discussions that lead to a deeper understanding of IPM, the RLW life cycle and community education for RLWD prevention. Participants and their students integrate community connections into the classroom for further discussion on the impacts of RLW and RLWD and connect with professionals to help gain deeper understanding of RLW/RLWD and to expose students to career-connected pathways. Finally, participants analyse student learning of specific content standards as they relate to human/environment interactions, IPM and disease prevention.

Course requirements

Participants were required to complete the following:

Attend a 2-day, in-person workshop and two online workshops; participate in weekly email discussions and keep a journal of their experiences; attend an online presentation session at the end of the course to report on their project and to hear reports from their cohorts. With their students, teachers collect, record and analyse data and produce a report using ArcGIS Online Story Mapping software (ArcGIS online is a software offered free of charge to K-12 schools and allows students to make connections between their communities and what they learn in school. Story mapping is used to describe and share experiences and results using software-provided base maps, photos and writing.) (Esri, 380 New York Street, Redlands, CA 92373). Participants choose two lessons from the curriculum in the Teacher Manual, adapt the lessons to their grade-level and subject area, and include activities and assessments. Two examples of student work and an explanation as to whether the student met proficiency are to be provided. All teachers give a presentation to a community group and all teachers produce a portfolio with specified contents and evidence of work, to be reviewed by course instructors and the HDOE at the course end.

Course activities

At the in-person, 2-day workshop participants received a copy of the Teacher Manual containing the UHH RLW curriculum, a copy of the second-grade activity book for themselves and copies of the activity book for each student in their classroom. The workshops were formatted to include lectures using PowerPoint, demonstrations, hands-on activities and collaborative discussions. Lectures covered course requirements, the global spread of the RLW, the RLW life cycle, paratenic hosts, IPM and RLWD and prevention. Hands-on activities were interspersed with the lectures and included slug/snail hunts (Fig. 1a and b), and clay modelling of the RLW life cycle (Fig. 2a). Demonstrations covered safety measures, shelter fabrication from materials such as cardboard, plastic and tarps, and proper disposal of slugs/snails. Observations were made of slugs and snails captured in the hunt, and morphology, identification and biology were discussed (Fig. 2b). The impact of invasive gastropods on native Hawaiian snail species was also covered. Outside resources that could be used as contacts for RLW/RLWD classroom discussions and visits

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Fig. 1. (a) A teacher uses chopsticks to safely pick up slugs. (b) A jar full of Cuban slugs is captured during a slug hunt in a school garden.

Fig. 2. (a) Teachers recreate the RLW life cycle using modelling clay. (b) PDE3 course instructor identifies slugs and snails captured during the hunt with course participants.

were identified. Teachers collaborated on a lesson development activity and wrote reflections at the end of each workshop day.

After the workshop and to the end of the Autumn 2018 semester, teachers shared information learned with their students. Teachers and students worked with maintenance staff to identify a location on school grounds to set out the slug/snail shelters and teachers acquired the ArcGIS online Story Mapping software for their school. Weekly email discussions between teachers and course instructors and journaling and reflection writing continued through the autumn semester. Teachers photographed activities with their students for use in their Story Maps.

Two online-workshops and the final presentations were conducted during the Spring 2019 semester using Blackboard Collaborate (Blackboard Collaborate is a collaboration and web conferencing software and a tool for online teaching and virtual classroom visits. All HDOE teachers have access to the software.) (https://www.blackboard.com). The first workshop introduced teachers to the ArcGIS Story Mapping process with a Powerpoint presentation of the step-by-step process for creating a story map. Teachers were able to access the PowerPoint guide after the workshop. The second workshop covered data entry from IPM efforts. Using the master data sheet in the field, teachers and students recorded findings from the slug/snail shelter checks. Data recorded included dates, species types, numbers captured and shelter-type capture rates. Field data were to be entered into Google Sheets in the classroom and the data were to be displayed using graphs and charts. A step-by-step PowerPoint guide for use of Google Sheets was provided to teachers. The final online-session featured the teacher presentations, where each course participant shared their experiences with their cohorts. These online sessions provided opportunities for participant discussions, questions and connection building.

One-day workshops

One-day workshops were held on all of the main Hawaiian Islands. Workshops were organized and conducted by those involved with the PDE3 course design with the exception of BIISC personnel and the HDOE STEM specialist. Two workshops were held in July (Oahu) and September (Hawaii Island) 2018. One-day workshops for Maui, Kauai, Molokai, plus a second workshop on Oahu, were held in June 2019. Workshops were open to teachers, community educators and residents interested in gaining a deeper understanding of RLW and RLWD. Two individuals from each island were identified to be a co-instructor and workshop assistant; these then became the lead RLW contact persons for their island and provide follow-up support to residents. Teacher Manuals and a copy of the second-grade activity book were provided to all participants. The workshops introduced the materials presented in the PDE3 course with the exception of

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Fig. 3. (a) High school graphic arts students create RLWD prevention stickers and T-shirts with their 'Jug the Slug' logo. (b) High school graphics art teacher and PDE3 course participant presents Hawaii Senator Mike Gabbard with a t-shirt created by students (Photos: Courtesy D. McDowell).

data collection and ArcGIS story mapping. Hands-on activities, demonstrations, observations, collaborations and discussions similar to those described for the PDE3 course were conducted in a more condensed format.

Results

PDE3 course

Twenty-three teachers initially signed up for the course. Five of these audited the course and three dropped from the course. Fifteen teachers from grade levels K, 2, 6–8 and 10−12 completed workshops and activities; 12 were from Hawaii Island and three were from Maui. Fourteen participants submitted portfolios and received HDOE credits. Teachers reached 652 students, educated 86 teachers and staff members, and reached approximately 900 community members including parents. A pre-course survey showed 5% of participants were strongly confident, and 45% were confident in their familiarity with and basic understanding RLW and its impacts on Hawaii. The post-course survey showed 100% of participants feeling strongly confident in their familiarity with and basic understanding of RLW and its impacts on Hawaii.

All teachers set out shelters for controlling slugs and snails. Shelters were checked regularly with students over a 2-month period and data were collected. Teachers at lower-grades (K, 2) adapted the master data sheet to accommodate their students and intermediate-level (6–8) teachers and students entered and analysed the data in Google Sheets. A pre-course survey showed 50% of teachers had not taken their students into the school garden and only 20% regularly had students visit the garden. A post-course survey showed 60% of teachers visited the garden more than three times, and 30% visited one to two times. All teachers reported that students enjoyed the hunts and shelter checks to find slugs and snails, and they became adept at identifying species.

Of the 14 teachers who completed the PDE3 course, 13 used the ArcGIS online software to share their story and data. Participants teaching at the same school teamed up for some activities and to make the story maps. Some of the story maps were published and can be viewed online.

Story Map Links:

https://kishawks.maps.arcgis.com/apps/MapJournal/index.html?appid=0c81fb06e1884f53bd2a85d5094d6440

https://mhsstem.maps.arcgis.com/apps/MapJournal/index.html?appid=c6279f9436874b1fb232409ca5b3792f

http://hhis.maps.arcgis.com/apps/MapJournal/index.html?appid=2a266b35fdc84caab5020f1c260de896

Workbooks and posters were made by students to take home to educate family or to display in their schools. Sixth grade students and their teacher hosted a table to provide RLWD education at a community jamboree. Seventh and eighth-grade students and their teachers attended the West Hawaii Educational Summit and gave a presentation. High school students designed and printed T-shirts and stickers with the message to 'Jug the Slug' and handed them out to community members (Fig. 3a). These students also gave hands-on demonstrations in IPM slug/snail control to an educational farm in their community. Teachers gave presentations to parents at parent nights and to teachers at faculty meetings and Teacher Institute Day.

All teachers took two lessons from the Teacher Manual curriculum and adapted the lessons to fit their grade level. All teachers became proficient in the use of the Blackboard Collaborate software to attend the online sessions. Two teachers requested either online or in-person classroom visits from course instructors using the Blackboard software. One teacher invited the HDOE IPM specialist at their school to visit their classroom.

A pre-post course survey showed improvement in teaching abilities using the educational pedagogies embedded in the course. All teachers confirmed that the implementation of place-based education to address a real-world problem resulted in a high level of student enthusiasm and engagement. Students expressed a desire to continue the activities even after their teacher completed the PDE3 course. All teachers stated that although the course was challenging, they felt empowered and understood they played important roles to prevent cases of RLWD in their community. These individuals and their students have now become resources for their communities to provide accurate, research-based information.

One-day workshops

A total of 106 individuals attended the 1-day workshops. Participants came from diverse occupations which included but were not limited to Hawaii public and private K-12 schools and school garden support organizations including the Kokua Hawaii Foundation, the Hawaii Farm to School Hui and the Maui and Oahu Farm to School Networks. Also attending were members of state agencies and higher education from HDOE, HDOH, the Department of Land and Natural Resources, and the University of Hawaii, College of Tropical Agriculture and Human Resources. Additionally, representatives from the Oahu, Big Island (Hawaii), Maui, and Kauai Invasive Species Committees, the Hawaii Farmers Union United/Hana Chapter, and local agriculture producers and their representatives including Pu'u o Hoku Ranch and Anahola Farm, and a commercial pest control company, attended the 1-day workshops. An electronic evaluation form was sent to workshop participants.

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Table 1. Participants from 1-day workshop survey responses ($n = 10$)

How much did your overall understanding of RLWD change due to your participation in the workshop?			
20%	**80%**		
4	5		
How much did your understanding of the rat lungworm lifecycle change due to the workshop?			
30%	**70%**		
4	5		
How much did your ability to identify slugs and snails change due to the workshop?			
10%	**20%**	**30%**	**40%**
1	4	3	5
How much did your knowledge of the impact of RLWD on humans change due to the workshop?			
30%	**70%**		
4	5		
How important are school gardens to the work you do with students?			
10%	**20%**	**30%**	**40%**
1	3	4	5
After the workshop, how confident do you feel sharing what you learned about RLWD with your students?			
10%	**20%**	**70%**	
2	4	5	
How likely are you to implement lessons learned at the workshop relating to RLWD with your students?			
20%	**40%**	**40%**	
3	4	5	
Please rate your overall experience in this professional development workshop.			
20%	**80%**		
4	5		
How likely are you to recommend this workshop to another educator?			
20%	**80%**		
4	5		

Ranking is on a scale of 1–5 with 1 representing the least and 5 representing the greatest (only rankings with responses are shown).

Questions were ranked 1–5 with 1 representing the least and 5 representing the greatest (Table 1). Overall, the response to the 1-day workshops was positive.

Discussion

The integration of these activities into K-12 classrooms can be useful to increase public awareness of RLWD, prevent disease, enlist community participation in host control efforts, provide teacher professional development in STEAM subjects and introduce students to career connections. Using technology to cross distances allows teachers and professionals to collaborate, educate and inspire each other. Participants gained experience and proficiency in the use of online video conferencing, data collection and implementing design thinking, citizen science and place-based education to increase student enthusiasm for learning. Teachers and students engaged in leadership roles, applied critical thinking and worked in teams to address an important health issue for Hawaii. All participants, including those at the 1-day workshops, were highly engaged in the study of the parasite, the disease and disease prevention.

Several events occurred that offered opportunities for students to engage with career professionals or were recognized as newsworthy. Third-grade students and their teacher were filmed conducting a slug hunt and were interviewed by a tropical medicine, global health and infectious disease specialist from the UCLA School of Medicine, Division of Infectious Disease, who is producing a medical documentary on RLWD. High school graphic arts students met with a Hawaii State senator to share information about RLW, RLWD and community education efforts. Their teacher presented the senator with a T-shirt that students had printed, featuring the logo they had designed (Fig. 3b).

In January 2019, a sixth-grade teacher and her students on the north end of Hawaii Island in the North Kohala District were the first to report the arrival of the semi-slug *Parmarion martensi*, a very effective host of the RLW (Hollingsworth *et al.*, 2007). Their identification of this slug resulted in a press release and news stories in Hawaii (https://www.biisc.org/semi-slug-found-in-kohala/; https://www.kitv.com/story/39935249/invasive-semi-slug-recently-discovered-in-north-kohala#:~:text=The%20invasive%20semislug%2C%20a%20known%20carrier%20of%20rat,4%20On%20Now%3A%20Watch%20Island%20News%20Live%20Stream). In Hawaii, the presence of this slug correlates with an increase in cases of RLWD due to its high infection potential (Hollingsworth *et al.*, 2007; Cowie *et al.*, 2018). Shortly after the presence of this slug in North Kohala was made public, a case of RLWD originating in the North Kohala area was reported by HDOH (https://health.hawaii.gov/news/files/2019/04/19-022-DOH_RLWD-N.-Kohala-Info-Meeting-NR-FINAL-041719.pdf). Though control efforts were initiated within the community when the news was made public, the semi-slug is now likely established in north Hawaii Island. This incident shows the importance of training teachers, students and community members to identify gastropod species common to their area so they can recognize the arrival of new species and report it. This will aid communities and state agencies in focusing efforts on vector control and disease prevention.

The educational efforts described here are an attempt to initiate a coordinated, statewide IPM plan for the control of slug/snail agricultural pests and disease vectors. K-12 schools can be the starting point for this effort. A statewide project that includes identification, monitoring and record maintaining is crucial. Only data can determine if control measures can effectively interrupt the life cycle of the RLW, drop high infection rates and reduce cases of RLWD in Hawaii. Continuation of these efforts is important for the health of Hawaii's residents, for Hawaii's agriculture and for tourism. With the increased interest in the workshops and PDE3 course, it will be important to continue these RLW/RLWD education efforts.

Although the data on control efforts for slug/snail intermediate hosts are important, equally important is the collection of data on the effectiveness of RLW/RLWD education to raise community awareness and encourage prevention interventions. Although some data pertaining to these components were collected for this project, all participants did not respond to survey questions. A more rigorous survey and collection of complete sets of participant responses must be designed into future educational outreach efforts.

Conclusion

The emphasis on food security in Hawaii and the rise in popularity of school gardens provides an excellent opportunity for an educational focus on RLWD. A broader focus to include other food-borne disease-causing organisms, such as *Listeria*, *Salmonella* and *Escherichia coli*, could provide far-reaching

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benefits for modern food-safety efforts. Other important preventable diseases common to Hawaii, such as *Leptospirosis*, Giardia, *Staphylococcus aureus* and methicillin-resistant *Staphylococcus*, could be included in K-12 public health education studies. Collectively, such efforts could be beneficial for public health outreach efforts in semi-tropical locations worldwide. Encouraging teachers and students to study disease-causing organisms could play a helpful role in disease prevention while augmenting the academic curriculum. There is national encouragement for this effort through the Center for Disease Control, Science Ambassador Fellowship Program, which supports the integration of epidemiology into the middle and high school grades as a means of bringing public health science into the classroom, and for the integration of STEAM subjects. Efforts such as this could have long lasting benefits for public health.

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Conflict of interest. There are no conflicts of interest.

Ethical standards. Not applicable.

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