HISC FY23 Final Report

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June 2023

Introduction

The ramie moth *Arcte coerula* (Lepidoptera: Noctuidae) is a large brown moth, with large, voracious feeding larval stages, that was first discovered in 2018 feeding on endemic Hawaiian māmaki *Pipturus albidus* (Urticaceae) on Maui in both wild and cultivated populations. As of November 2020, this new pest has spread to Hawaiʻi island. Native to Southeast Asia, this moth has the potential to inflict substantial damage through its leaf feeding on māmaki and other native nettles (Urticaceae). This will impact our native forests including endemic insects that depend on māmaki as a host plant, traditional lāʻau lapaʻau practices that rely on native medicinal plants like māmaki, and the state's emerging māmaki tea industry.

Project Objectives

1. Track the increasing geographic distribution of *A. coerula* in Hawaiʻi.
2. Understand the biology, host range, and impact of *A. coerula* on māmaki and other nettles found in Hawaiʻi.
3. Quantify impacts of parasitoids and predators present in Hawaiʻi on *A. coerula*.

Project Outcomes

OBJECTIVE 1 - DISTRIBUTION: During peak seasons, *A. coerula* was surveyed weekly on Hawaiʻi island to detect new populations and spread. As of May 2023, *Arcte coerula* has not been detected in any new regions of Hawaiʻi island or Maui. Surveys on Oʻahu have also not detected the presence of *A. coerula* on the island. All new reports in 2023 occurred in areas where *A. coerula* was already present, but from new proximal locations. Figure 1 shows the current distribution of *A. coerula.* Detections were based on monthly surveys and confirmed reports from residents through the Hawaiʻi Department of Agriculture 643pest hotline, Big Island Invasive Species Committee (BIISC), and māmaki growers. Previous field surveys on Maui and Hawaiʻi island have shown *A. coerula* to be multivoltine with populations peaking in the winter and spring, from January to May, and decreasing dramatically in the summer.

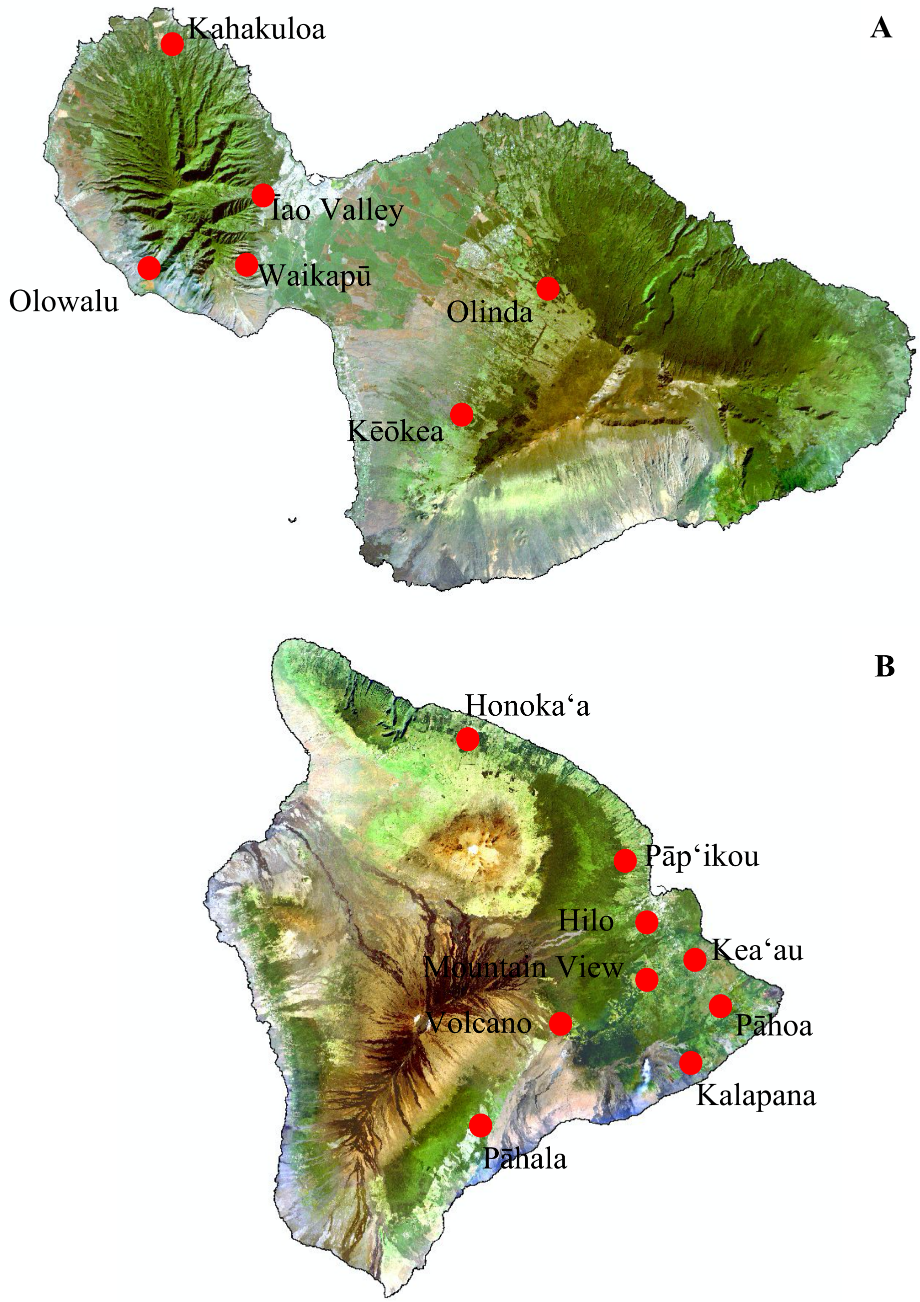

Figure 1: **A:** Known distribution of *A. coerula* on Maui **B:** Known distribution of *A. coerula* on Hawai‘i island. Distribution determined by field surveys and confirmed reports from the public.

Below is a list of all online resources available for the public to learn more about *A. coerula* and provides contact information if this pest is spotted. We have also partnered with organizations like BIISC to release social media posts on their platforms to increase public awareness of *A. coerula.*

- Hawai‘i Department of Agriculture New Pest Advisory (NPA)

- Big Island Invasive Species Committee (BIISC) ramie moth webpage
- Identifying Early Instar Caterpillars on Māmaki
- Au, MG, Wright, MG, 2022. Ramie moth, *Arcte coerula* (Lepidoptera: Noctuidae): A new invasive pest in Hawaiʻi on endemic plants. Proceedings of the Hawaiian Entomological Society (2022) 54:63–76
- CTAHR Cooperative Extension – New Pest of Māmaki

Continual communication with the public, especially with māmaki growers, will aid in the continued detection of the spread of *A. coerula.*

OBJECTIVE 2 – NO-CHOICE HOST TESTING: Preliminary trials were conducted to test the host range of *A. coerula.* Ten eggs were placed in a 9"x 6"x 2" container with a mesh lid and different leaves were fed to the larvae after emerging in a no-choice experiment. Six different Urticaceae species were tested including: trumpet tree (*Cecropia obtusifolia*), olonā (*Touchardia latifolia*), ʻakolea (*Boehmeria grandis*), ōpuhe (*Urera glabra* syn. *Touchardia sandwicensis*), *Pilea mollis*, *Phenax hirtus,* and māmaki (*Pipturus albidus*) as the control. In addition to the Urticaceae available for testing, gunpowder tree (*Trema orientalis*) and grape (*Vitis rotundifolia*) were added to this experiment because previous studies on *A. coerula* have shown feeding by the larvae on a *Vitis* sp. and *Trema tomentosa* (Robinson et al., 2010). Results showed that *A. coerula* completed development from eggs to adults on trumpet tree, ōpuhe, and māmaki. In all the other trials, the hatched caterpillars died before pupating. There was minor feeding on olonā, ʻakolea, and *Phenax hirtus* but no caterpillars developed past the 3rd instar. In the remaining trials there was no feeding on the leaves and the caterpillars died shortly after emerging from the eggs due to starvation.

OBJECTIVE 2 – CHOICE HOST TESTING: From the results of our no-choice host testing experiment, we conducted a choice experiment to determine host preference between māmaki and trumpet tree. Trumpet tree is an invasive species in Hawaii, and could provide a pathway for distribution of ramie moth. One leaf of each plant was cut to approximately the same size and placed in a 9"x 6"x 2" container with a mesh lid and ten unhatched *A. coerula* eggs. This was replicated five times. Every day new leaves were placed in the container, and the old leaves were measured for percentage consumed. At early instars, there was a preference for māmaki compared to the trumpet tree. However, by later instars, both plant species were equally consumed, often multiple leaves being eaten per day. The same experiment still needs to be conducted with ōpuhe as well as comparing it with trumpet tree. Because there was no significant preference for māmaki over trumpet tree and the rate of successful development on trumpet tree was comparable to māmaki at about 70%, trumpet tree can be a successful alternate host for *A. coerula* and field surveys should also be conducted to determine if *A. coerula* is present where trumpet tree has naturalized.

OBJECTIVE 3 - PARASITISM: Partial life table studies were constructed to determine and quantify mortality factors of *A. coerula.* Due to difficulties in developing captive colonies of *A. coerula,* sentinel eggs could not be obtained for this study. Instead, we placed eight māmaki plants in 5-gallon pots outside of the greenhouse at the CTAHR Waiākea Research Station and checked them weekly for eggs. Once eggs were detected, we returned five days later to assess mortality. For larval stages, field collected eggs were obtained from our surveys and reared in the greenhouse in 16" x 16" x 24" pop-up cages with 1-gallon māmaki plants. Once the larvae had reached the desired instar, they were placed outside on the same eight, 5-gallon māmaki plants and left exposed for five days. Life tables were modeled after similar studies done on *Udea stellata* by Kaufman & Wright (2009). Results from our partial life table study are shown in Table 1 below.

Larval Stage	**l_x**	**Mortality Factor**	**d_x**	**q_x**
Egg	166	Parasitized	108	0.65
		Disappeared	13	0.08
		Other	9	0.05
1st Instar	50	Parasitized	0	0.00
		Disappeared	41	0.82
		Other	0	0.00
2nd Instar	25	Parasitized	0	0.00
		Disappeared	22	0.88
		Other	1	0.04
3rd Instar	10	Parasitized	0	0.00
		Disappeared	4	0.40
		Other	0	0.00
5th Instar	8	Parasitized	0	0.00
		Disappeared	2	0.25
		Other	1	0.13

Table 1: Partial life table study for *A. coerula*: l_x Number that entered each stage, d_x number dying during each stage, q_x proportion dying at each stage (apparent mortality).

Egg parasitism comprised the majority (65%) of the apparent mortality for *A. coerula.* Egg mortality was high, reaching 78% with all factors included. There were two egg parasitoids that emerged from *A. coerula,* an Encyrtidae species (Figure 2a) and a *Trichogramma* species (Figure 2b). Further work is needed to identify the parasitoids to species using both morphological and molecular methods and determine the proportion of mortality each species inflicts. “Other” mortality is due to unknown causes of death. The presence of fungus was often associated with dead specimens. Due to the limitation in available eggs from the field, all larval stages could not be deployed for this year’s life table studies. Future work will continue with these partial life table studies to get a better understanding of the different mortality factors at each instar.

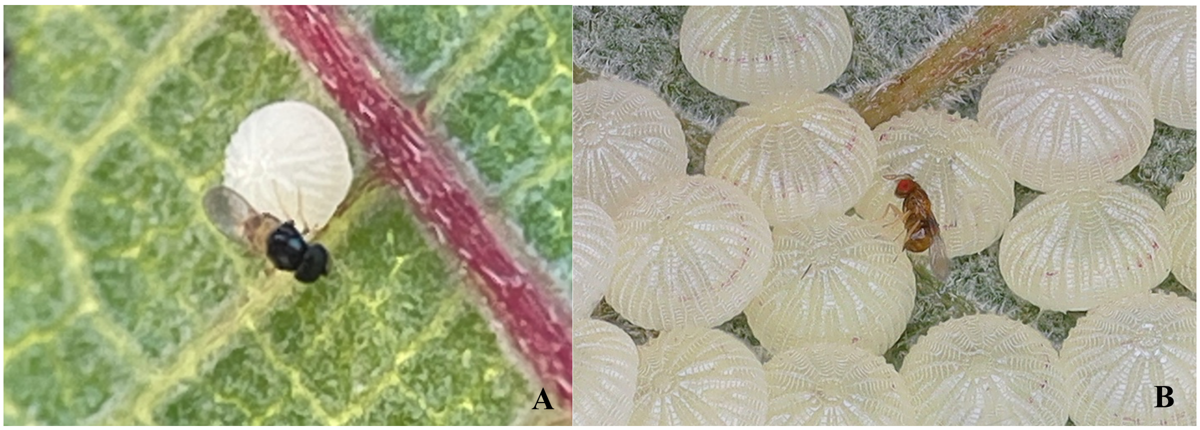

Figure 2: **A:** Encyrtidae species parasitizing the egg of *A. coerula*; **B:** *Trichogramma* sp. parasitizing the egg of *A. coerula*.

Surveys in 2023 continue to show an increase in egg parasitism (Figure 3), compared to previous years indicating that there may be a lag time in the parasitoids detecting and exploiting the recent invasion and impacts of resident natural enemies may continue to increase as *A. coerula* spreads.

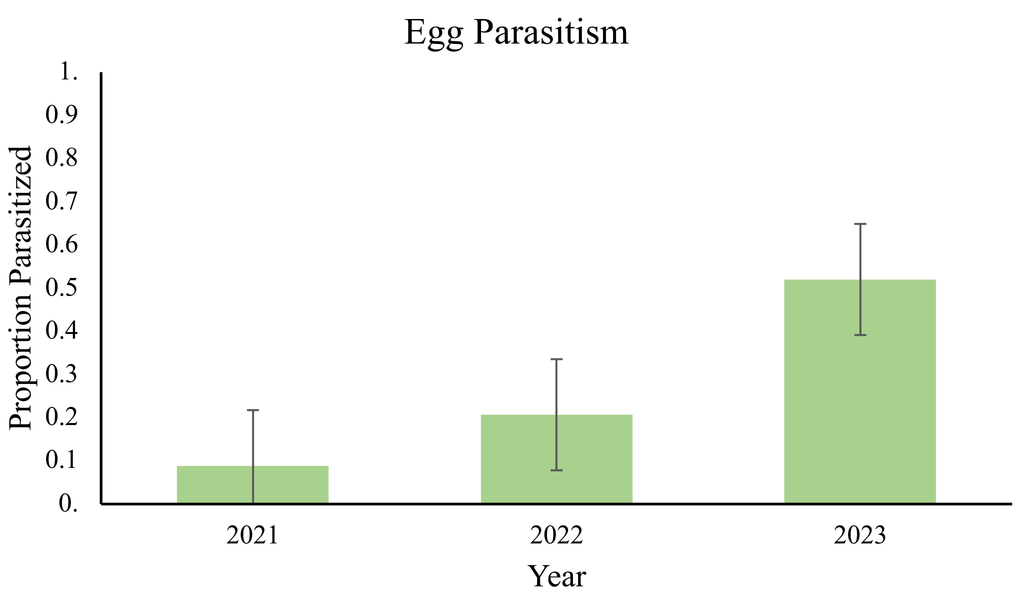

Figure 3: *Arcte coerula* egg parasitism from field surveys for 2021, 2022, and 2023.

Conclusions

The surveys to date have revealed new populations of *A. coerula* on Hawaiʻi island, with large numbers in some locations judging from egg and larval samples. *Arcte coerula* increase egg masses or deposit many eggs on a single plant, which can cause major defoliation and potential death of the plant if larvae are not removed or die early on. This is a cause for concern in cultivated and wild māmaki stands. The impacts on tea farmers and endemic insects dependent on māmaki are potentially substantial. However, egg parasitism is increasing with the spread of *A. coerula.* We have yet to determine if it is enough to provide adequate control in conjunction with other management strategies. We will continue to work on determining the extent of new infestations of *A. coerula*, damage to plants including other nettles in wild and cultivated areas, its impact on endemic insects also found on māmaki, the ability of resident natural enemies to exert population control, and the potential need for exploration for classical biological control agents.

Acknowledgements
We thank all the māmaki growers and conservation land managers that graciously allowed us to survey their properties. We thank all the faculty and staff at CTAHR Komohana Research & Extension Center and CTAHR Waiākea Research Station for allowing us to use their facility for our research. We thank the Department of Land and Natural Resources Division of Forestry and Wildlife (DLNR-DOFAW), Hawaiʻi Department of Agriculture (HDOA), and Big Island Invasive Species Committee (BIISC) for their assistance and reports of *A. coerula*.

Funding was provided by HISC and a USDA-NIFA grant to MGW.

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