Monitoring the Phenology of *Chromolaena odorata* to Inform Management of an Incipient and Highly Invasive Species in Hawai‘i

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Chromolaena odorata (Devil's Weed)

- Herbaceous to woody perennial plant
- Aggressive colonizer
- Native to South and Central America

- Distinctive 3-vein "pitchfork" pattern
- Asexual seed formation (w/o male fertilization)
- 800,000 seeds per individual per year

- HWRA Score = 28
- Extremely high potential to increase outside of its current habitat, making **early control critical for Hawaiʻi**

C. odorata in Kahuku Training Area (KTA)

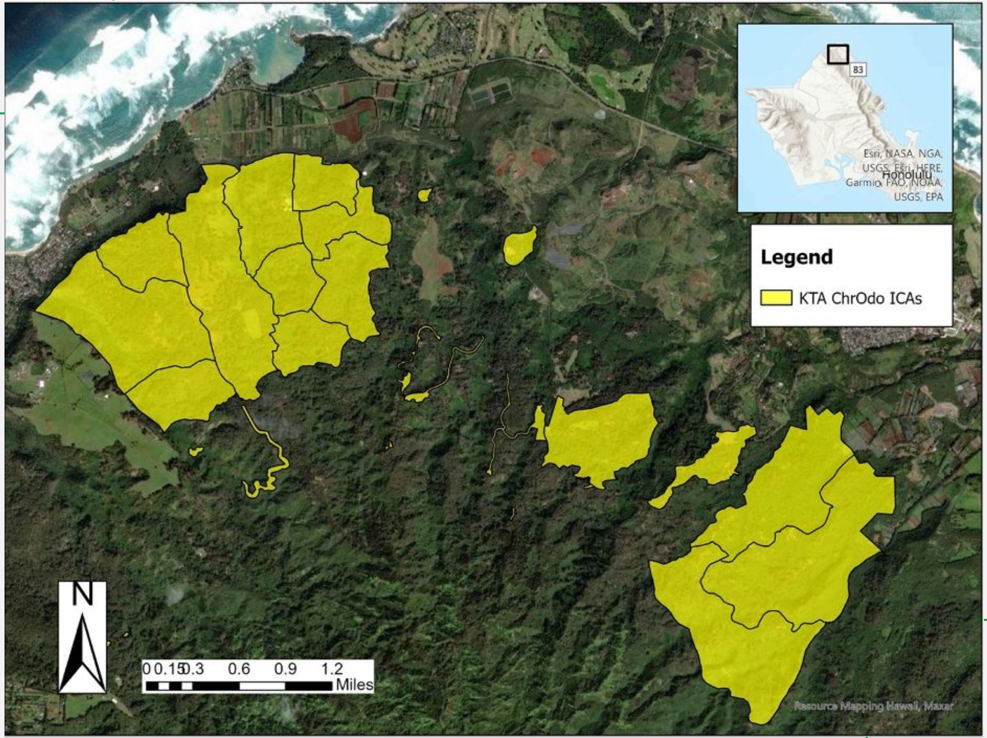


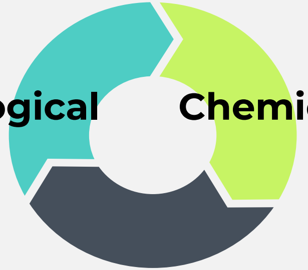
Figure 1. *C. odorata* incipient control areas in KTA

- 2011, detected in Kahuku Training Area (KTA) during scheduled road survey
- **54** *C. odorata* incipient control areas (ICAs)
- **ICA**: weed control target areas with the goal of eradication of specific species

- **26** of the 54 *C. odorata* ICAs are located in KTA
- **1042 hectares (~2573 football fields)**
- **54%** of time spent on incipient control efforts

Integrated Weed Management (IWM)

- ***Cecidochares connexa***, gall fly host specific to *C. odorata*
  - Induces galls into the stems, reducing the plant's ability to grow and reproduce



- **Integrated Weed Management (IWM)**
  - Requires sufficient knowledge of the ecology and phenology of the species
- Flowering known to occur in the dry season
- In Hawai'i, flowering observed from January to March

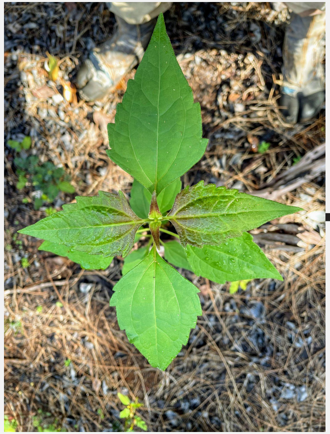
Figure 2. (A) Adult of *C. connexa* (photo from C. Wilson, Australia); (B) swelling of the stem of *Chromolaena odorata* due to the presence of *Cecidochares connexa*; (C) exposed larva of *C. connexa*.

Van Wilgen, Brian W et al. "A Preliminary Assessment of the Extent and Potential Impacts of Alien Plant Invasions in the Serengeti-Mara Ecosystem, East Africa." *Koedoe* 59.1 (2017): 1–16. Web.

Phenology of *C. odorata*

- **Phenology**: Study of the onsets and durations of growth and reproductive cycles (i.e., flowering and seed dispersal)
    - Plant responses to climate variables, such as temperature and precipitation
- **Phenophase**: *an observable stage or phase in the annual life cycle of a plant that can be defined by a start and an end point*

Understanding the relationship between phenophases of *C. odorata* and climate variables to better predict the phenology of the species based on readily available climate data



Vegetative

Flowers/Buds

Fruits/Seed Drop

Objectives

1. What is the relationship between phenophases of *C. odorata* and climate variables (e.g., current precipitation and temperature)?
2. What is the relationship between reproductive phenophase output of *C. odorata* and its seed germination?
3. What is the relationship between reproductive phenophase output and plant condition?

1. USA-NPN Standardized Phenology Monitoring

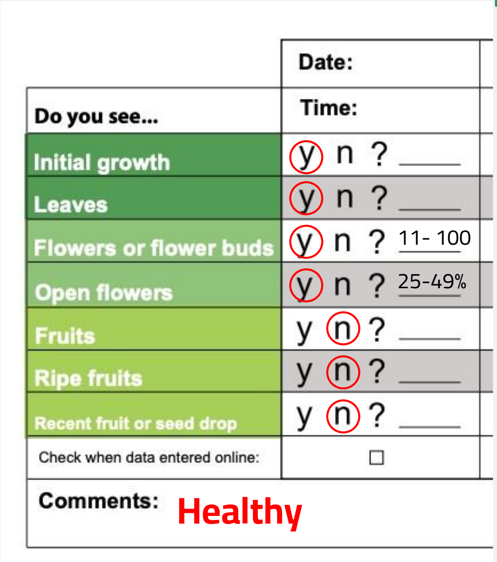
Study Site

Kahuku Training Area (KTA)

Monitoring the phenology of *C. odorata* for one year from February 2021 to January 2022

Study Plots

- Five 10x10 m plots
- 15 tagged individual plants
- Monitored every 2 weeks
- Documented the onset, duration, and intensity of observed phenophases of *C. odorata*



	Date:
Do you see...	Time:
Initial growth	(y) n ? ____
Leaves	(y) n ? ____
Flowers or flower buds	(y) n ? 11- 100
Open flowers	(y) n ? 25-49%
Fruits	y (n) ? ____
Ripe fruits	y (n) ? ____
Recent fruit or seed drop	y (n) ? ____
Check when data entered online:	☐
Comments: Healthy	

2. Composite soil samples for germination trials

- 3 soil samples from each plot, 1x month
- Emerging seedlings were identified, documented, and immediately removed

03. Relationship between phenophases and climate variables

- Recorded monthly:
  - Average temperature
  - High temperature
  - Low temperature
  - Total precipitation
- Sunset Beach Earth Station
  - Weatherunderground.com

04. Data Analysis

- Generalized Linear Model (GLM)
- Linear Regression

- RStudio
  - $\alpha = 0.05$

Results - Phenological activity of *C. odorata* in KTA

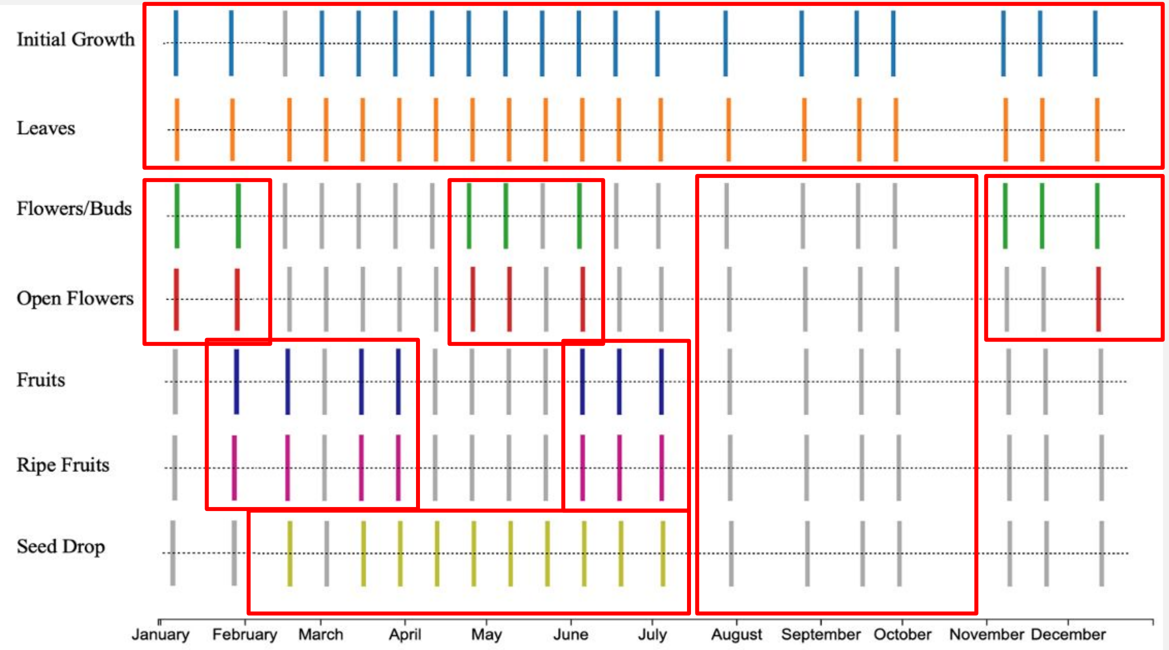


Figure 2. Phenological activity (presence/absence) for *C. odorata* in Kahuku Training Area, observed from February 2021 to January 2022.

- Leaves and Initial Growth
  - Year round
- Flowering
  - Bimodal distribution
  - November - February
  - May - June
- Fruiting
  - Bimodal distribution
  - February - April
  - June - July
- Seed Drop
  - February - July
- No reproductive activity between August - October

Results - Relationship between phenophases of *C. odorata* and precipitation

- Significant positive relationship between precipitation and:
  - Flowers/Buds ($p < 0.001$)
  - Open Flowers ($p < 0.001$)
  - Fruits ($p < 0.05$)
  - Ripe Fruits ($p < 0.05$)

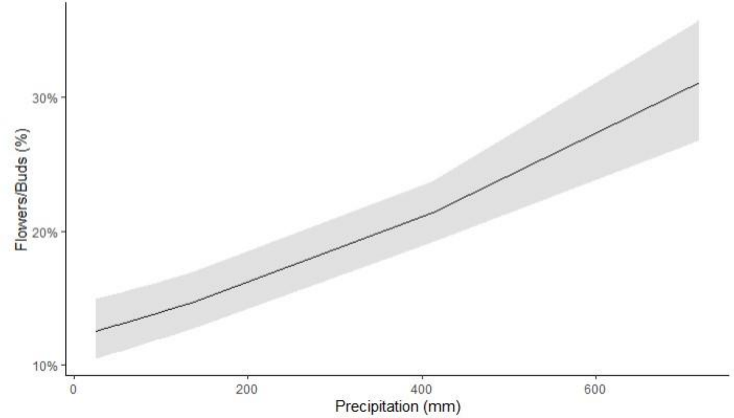


Figure 3. Predicted values (marginal effects) from GLM depicting relationship between Flowers/Buds and precipitation.

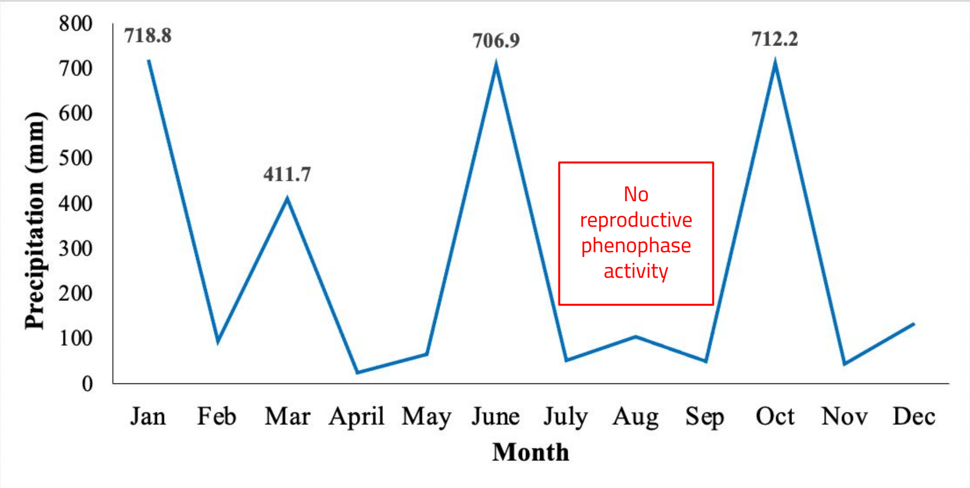


Figure 4. Total monthly precipitation (mm) recorded from the Sunset Beach Earth Station from February 2021 to January 2022.

- Flowering and Fruiting
  - Occurred between November - July
- No reproductive activity
  - August - October
- **Increase in precipitation triggered the onset and duration of flowering and fruiting of *C. odorata***

Results - Relationship between phenophases of *C. odorata* and temperature

- Significant negative relationship between temperature and:
  - Flowers/Buds ($p < 0.001$)
  - Open Flowers ($p < 0.001$)
  - Fruits ($p < 0.001$)
  - Ripe Fruits ($p < 0.001$)

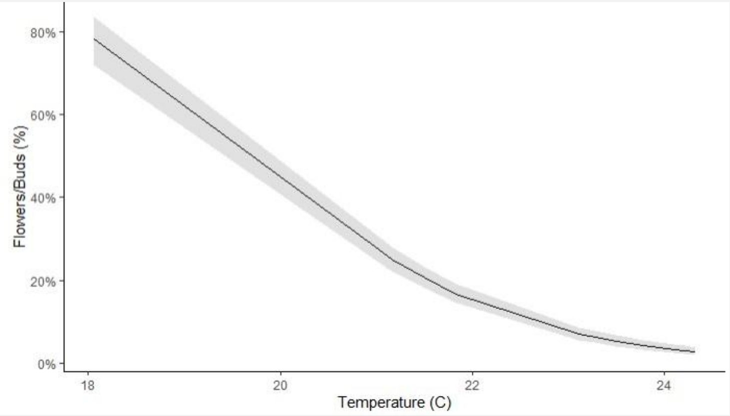


Figure 5. Predicted values (marginal effects) from GLM depicting relationship between Flowers/Buds and average temperature.

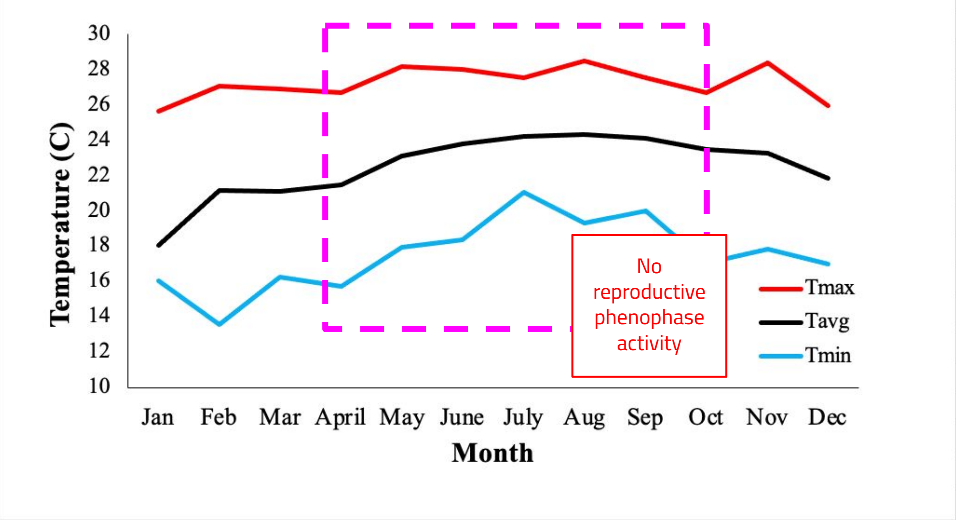


Figure 6. Monthly average, low, and high temperatures (C) recorded from the Sunset Beach Earth Station from February 2021 to January 2022.

- Dry season / Summer
  - Temperature ↑
  - Precipitation ↓
- No reproductive activity
  - August - October

Results - Relationship between reproductive phenophase output (%) and average plant condition/seedling germination

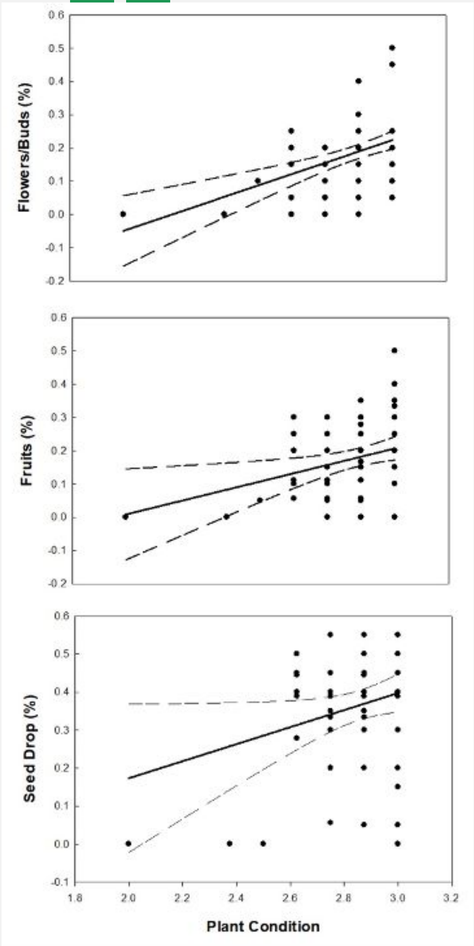


Figure 7. Relationship between reproductive phenophase output (%) and average plant condition

- Significant positive relationship between reproductive phenophase output (%) and average plant condition

$$\text{Reproductive phenophase output (\%)} = \frac{\text{Reproductive phenophase occurrence}}{\text{Total site visits}}$$

- **↑ Average Plant Condition ~ ↑ Reproductive phenophase output (%)**

- Significant positive relationship between reproductive phenophase output (%) and seedling germination
  - Flowers/Buds ($p < 0.05$)
  - Open Flowers ($p < 0.001$)

- **↑ Flowering (%) ~ ↑ rate of seedling germination**
- **Low seedling germination → results remain inconclusive**

Discussion - *C. odorata* phenology

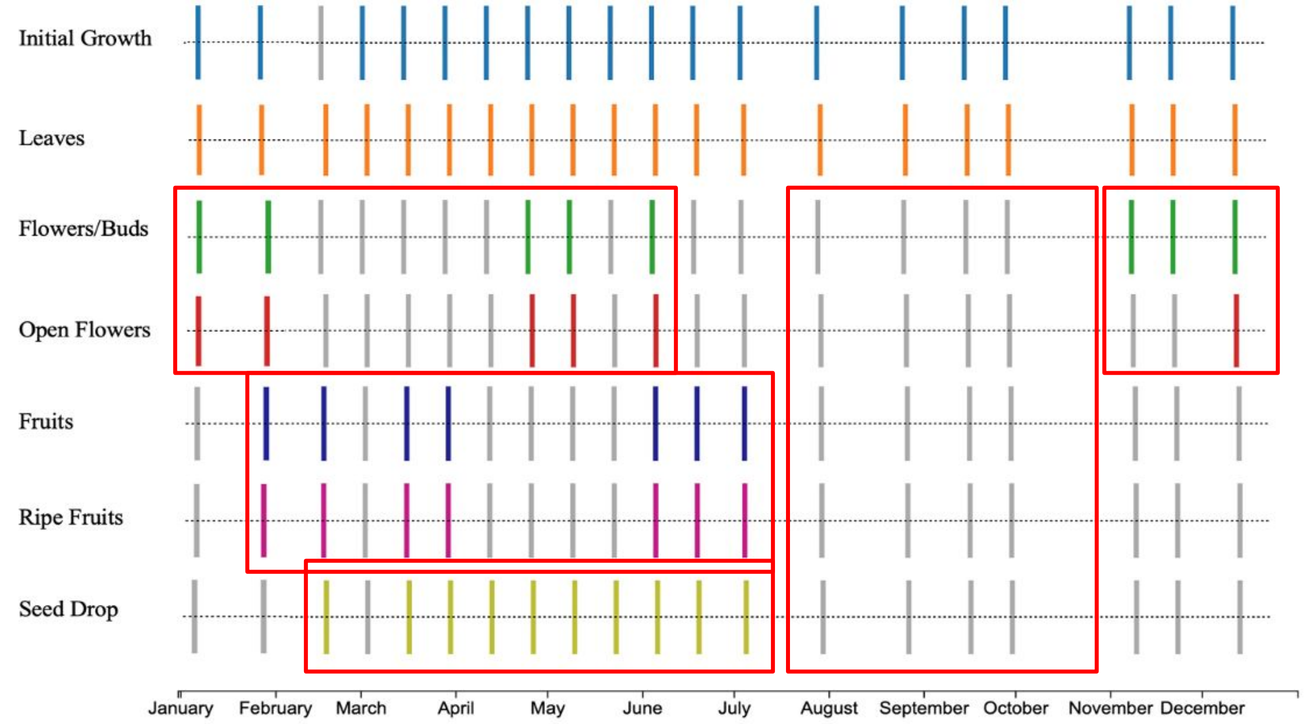


Figure 2. Phenological activity (presence/absence) for *C. odorata* in Kahuku Training Area, observed from February 2021 to January 2022.

- ↑ precipitation → onset and duration of flowering and fruiting
- ↑ temperature, ↓ occurrence of reproductive phenophases

- *C. odorata* is known to flowering in the dry season, triggered by decreased rainfall and day length (Gautier, 1993)
- Continued long-term monitoring to analyze relationship

Discussion - Adjustment of treatment schedules

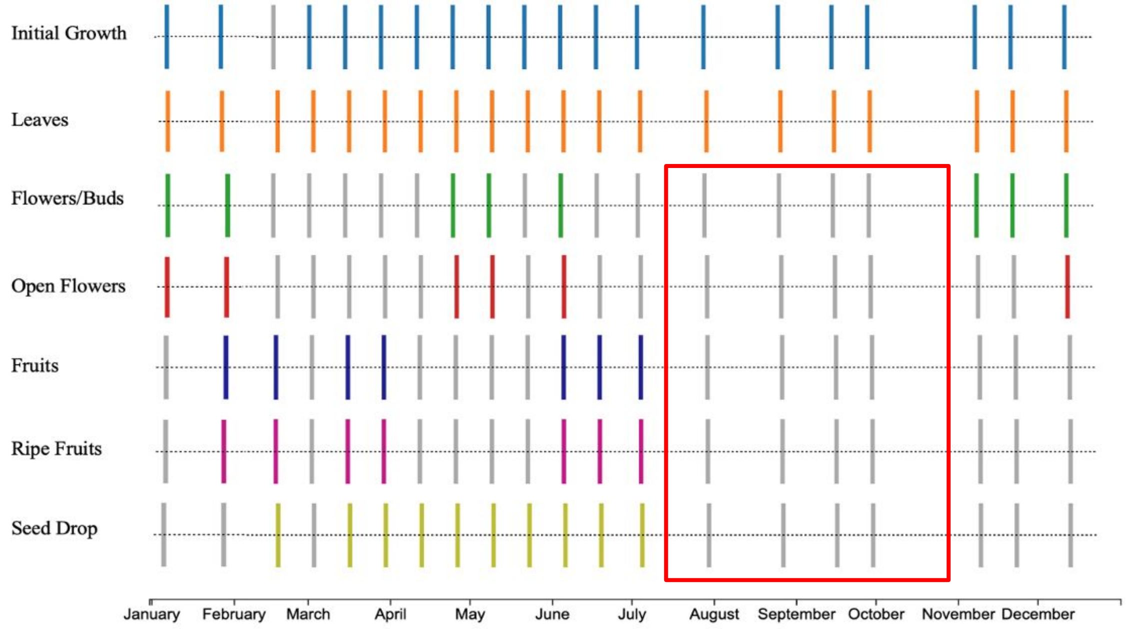


Figure 2. Phenological activity (presence/absence) for *C. odorata* in Kahuku Training Area, observed from February 2021 to January 2022.

- Understanding how climate variables interact with phenology, able to better predict plant behavior, adjust treatment schedules, and optimize control efforts

- **Adjust treatment schedule**
  - **August - October**
- Prevent spread of seeds
- Reduce overall density by removing plants before they flower

Discussion - Biocontrol

- Aigbedion-Atalor et al. (2018) → studied the success of *C. connexa* in Ghana
  - Low density of *C. connexa* in the dry season

- **Future integrated weed management strategies should take into account both the phenology of *C. odorata* and observed behavior of biocontrol**
- Herbicide/Mechanical control during the summer when *C. connexa* is low in density

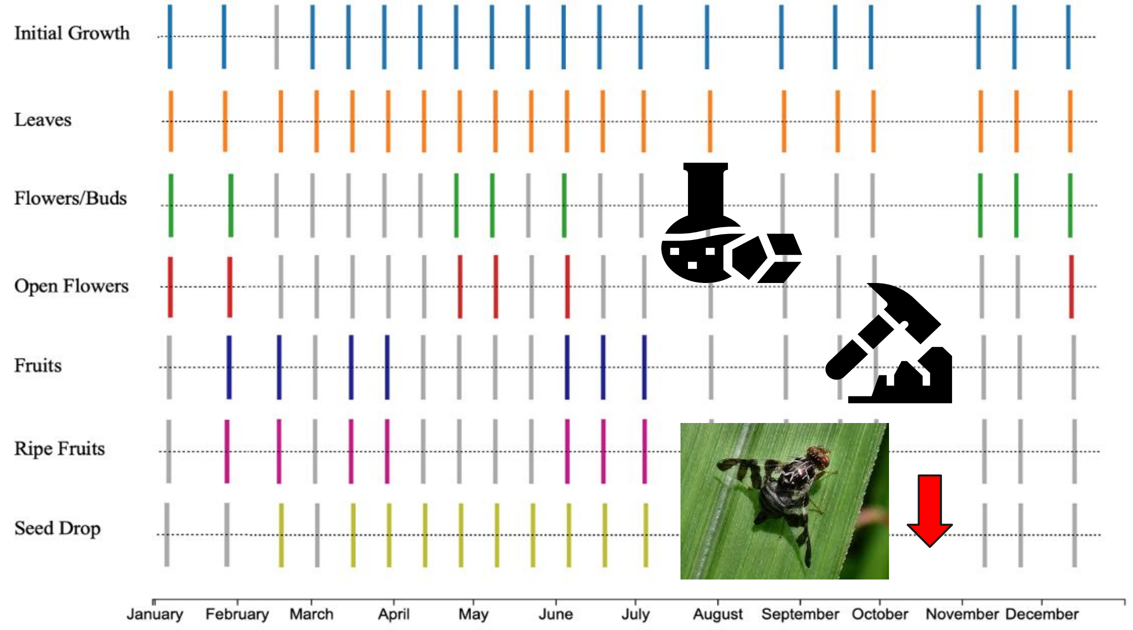


Figure 2. Phenological activity (presence/absence) for *C. odorata* in Kahuku Training Area, observed from February 2021 to January 2022.

Conclusions

Improve the use and integration of phenology into invasive species management in Hawaiʻi

- Successfully add *C. odorata* onto the USA-NPN Nature's Notebook species list
  - Provide valuable long-term data

(Chromolaena odorata)

nature's notebook

Phenophase Definitions

Directions:
As you report on phenophase status (Y, N or ?) on the datasheets, refer to the definitions on this sheet to find out what you should look for, for each phenophase in each species. To report the intensity of the phenophase, choose the best answer to the question below the phenophase, if one is included. Feel free not to report on phenophases or intensity questions that seem too difficult or time-consuming.

Leaves

Initial growth
New growth of the plant is visible after a period of no growth (winter or drought), either from above-ground buds with green tips, or new green or white shoots breaking through the soil surface. Growth is considered "initial" on each bud or shoot until the first leaf has fully unfolded. For seedlings, "initial" growth includes the presence of the one or two small, round or elongated leaves (cotyledons) before the first true leaf has unfolded.

Young leaves
One or more young leaves are visible on the plant. A leaf is considered "young" before it has reached full size or turned the darker green color or tougher texture of mature leaves on the plant. Do not include fully dried or dead leaves.

Leaves
One or more live, fully unfolded leaves are visible on the plant. For seedlings, consider only true leaves and do not count the one or two small, round or elongated leaves (cotyledons) that are found on the stem almost immediately after the seedling germinates. Do not include fully dried or dead leaves.

Flowers

Flowers or flower buds
One or more fresh open or unopened flowers or flower buds are visible on the plant. Include flower buds or inflorescences that are swelling or expanding, but do not include those that are tightly closed and not actively growing (dormant). Also do not include wilted or dried flowers.

How many flowers and flower buds are present? For species in which individual flowers are clustered in flower heads, spikes or catkins (inflorescences), simply estimate the number of flower heads, spikes or catkins and not the number of individual flowers.
Less than 3; 3 to 10; 11 to 100; 101 to 1,000; More than 1,000;

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Mahalo!

Mahalo nui to my capstone committee:

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