Enhancing classroom and undergraduate research opportunities with natural history collections

Wendy L. Clement
The College of New Jersey
clementw@tcnj.edu
@WLClement
• Public, residential, primarily undergraduate institution
• 6,800 undergraduates
• ~500 Biology Majors
• 30% self-described as members of groups traditionally underrepresented in STEM
Natural History Museums & Botanical Gardens
Biodiversity collections behind the scenes of Natural History Museums
The Team.

Dr. Katy Prudic
Dept. of Entomology
University of Arizona, Tucson

Dr. Jeff Oliver
Office of Digital Innovation & Stewardship
University of Arizona Libraries

TCNJ Plant-Insect Course (’14)
Creating an interdisciplinary experience.

- Develop an inquiry-based group project
- Provide an entry point for data science and big data
- Observation - Hypothesis - Analysis - Evaluation
- Increase awareness of local biodiversity and plant-insect interactions in temperate zones
- Draw students in as scientists
Objectives & Learning Goals

**Question:** How will climate change affect the distributions of butterflies and their larval hosts across a continent over time?

**Learning Goals**
1. **Describe** how biodiversity science data initiatives, such as ecoinformatics, can make use of citizen science and museum digitization efforts to ask and inform questions in ecology.
2. **Use** research computing tools (Citizen science crowd sourced data, R programming language, GitHub collaborative web platform, data visualization) to study a butterfly-host plant interaction
3. **Communicate** findings in the form of an oral presentation
4. **Synthesize** potential outcomes of the effects of climate change on plant-insect interactions
Project Introduction

1. Introduce biodiversity science and data science

2. Compare and contrast citizen science data and museum data
We are at a transition point in biodiversity research

- Research funding is decreasing
- Need for conservation research is increasing
- Wildlife enthusiasts:
  - 72 million US residents watch wildlife for fun
  - 10 million US residents watch butterflies a minimum of 85 hours a year each
  - ~$1,700,000,000 in butterfly volunteer hours a year

Biases in the data?
1. Introduce biodiversity science data science
2. Compare and contrast citizen science data and museum data
3. Introduce Species Distribution Modeling (SDM)
**Eurytides marcellus**

**Common name:** Zebra swallowtail

**Physical Appearance**
- long swallowtails
- 2.5-4 inches in wingspan
- Black stripes on white/pale green background on upper surface of wing

**Foraging Behavior**
- larvae feed on host plants
- adults forage on nectar plants on open fields and shrubby areas

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**Asimina triloba**

**Common name:** common pawpaw

**Range**
- commonly found in the eastern portion of the United States (Zhao et al. 1992)
- Only feeds on the *Asimina* family
Class 2

Learning Goal 2: Use research computing tools to study a butterfly-host plant interaction

Download Data from iNaturalist → Generate Occurrence Maps → Generate Species Distribution Model Maps

Download Data from iNaturalist
Working with iNaturalist
Git, R, & RStudio

- Students clone a Git repository
- Students run scripts in RStudio
- Tutorials walked students through modifying scripts, saving scripts, and running scripts
- Explanation of code available for instructors
Learning Goal: Use research computing tools to study a butterfly-host plant interaction
Hypothesis

Globally increasing temperatures will result in a larger overlap between the distributions of *Eurytides marcellus* and its host plant *Asimina triloba*, due to a greater migration of *E. marcellus* northward than that of *A. triloba* over the 53 year time period.
Class 3 - Forecast SDMs

Learning Goal 2: Use research computing tools to study a butterfly-host plant interaction

- Students modify and run scripts to generate predictive models of species distribution for the year 2070
- Use the GFDL-ESM2G model with a 4.5 increase in CO2
  - GFDL - Geophysical Fluid Dynamics Laboratory
  - ESM - Earth System Model which models a variety of atmospheric variables and cycles
Class 3

Learning Goal 2: Use research computing tools to study a butterfly-host plant interaction

Hypothesis → Forecast SDMs (2070) → Evaluate Hypothesis

46.77% overlap

36.55% overlap
Class 4

Learning Goals:
3. Communicate findings in the form of an oral presentation
4. Synthesize potential outcomes of the effects of climate change on plant-insect interactions

Investigating the Interaction Between *Papilio troilus* & *Lindera benzoin*

Nicole Gadda, Steve John, Daniela Nattes, and Kanza Tahir
Takeaways

• Introduction to R and big data

• Generate a hypothesis based on observations

• Evaluate the hypothesis based on their data analysis

• Communicate scientific results

• Examine effects of climate change in their lifetime
Applications to Independent Research

Using SDM to examine the role of species distribution and climate in assessing species boundaries in a species complex of honeysuckles.
Applications to Independent Research

Using SDM to examine impacts of climate changes on species distribution and phenology over the past 150 years in NJ Pine Barrens

Eupatorium resinosum
Eupatorium perfoliatum
We will impact plant-insect distributions and interactions using open-source tools.

Wendy L. Clement, Kathleen L. Prudic, Jeffrey C. Oliver

- Class slides
- Pre-class assignments
- Class plans (instructions)
- Five assignments with rubrics and answer keys
- Deep dive questions
- Butterfly-host plant suggestions with key natural history information
- Student instructions for downloading software & running SDMs in R
- R scripts, code explanations, trouble shooting information
Exploring how climate will impact plant-insect distributions and interactions using open data and informatics

By Wendy Clement¹, Kathleen Prudic², Jeffrey Oliver³

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• TCNJ School of Science
• Citizen science projects & Citizen scientists
Questions?
FLOWER POWER

STUDENTS FROM THE 1800s
PREERVED PLANTS FOR THEIR 21ST-CENTURY COUNTERPARTS

Not long ago, three students at TCNJ's first incarnation, the New Jersey State Normal School, collected about 450 plant specimens from the Trenton area. With care and precision, Sarah Kardie, Nelson Pepper, and Margaret Tidwell assembled them into herbarium books, bound in use to study biodiversity and ecology.

But at some point, the books fell off the radar until the STEM Building's construction in 2017 prompted a deep dive into storage in a hotbox lab.

"These books are a find," says biology professor Wendy Clement. "They are snapshots in time of the plant diversity in this region." In fact, one book traveled to the 1893 World's Fair in Chicago, included in exhibits, because the students' professor Austin Craig, vice president of the Normal School and member of the Class of 1852, was a well-known botanist.

Since the rediscovery, Clement's research students have compiled the plants' classification information, digitized the specimens, and registered TCNJ as an herbarium with the Index Herbariorum at the New York Botanical Garden.

The continuing importance of the books hit home for Matthew Petrucho '18, who wrote his senior honors thesis on herbarium collections. "Students can look at individual species," he says, "and study how plants are responding to changes in the environment over the course of 150 years."

- Hans Petrucho

Leptosiphon havardii
Common name: Sable Myrtle
BRIEF SUMMARY IN THE FIRST DECADE of New Jersey, the Chemical Plant of the Clayville and in the Roe Field Improvement.
Suidia varia
Common name: False Solomon's Seal
This plant was reclassified in the late 20th century as Melanocarpus racemosus.

Chrysopogon virginicus
Common name: Spring Beauty
Onitacaeae
Trumpt, Apr 21, 1994
Original label, 1904, Sarah Mundle