The problem

Timely, accurate detection of southern pine beetle (*Dendroctonus frontalis* Zimmerman; SPB) outbreaks is key to managing this tree-killing beetle (1,2). Early detection is key, and is effectively accomplished in the historical range using aerial flyovers. Observed differences in the attack phenology and the rate of visible symptom development in pitch pine on Long Island call into question the utility of this approach.

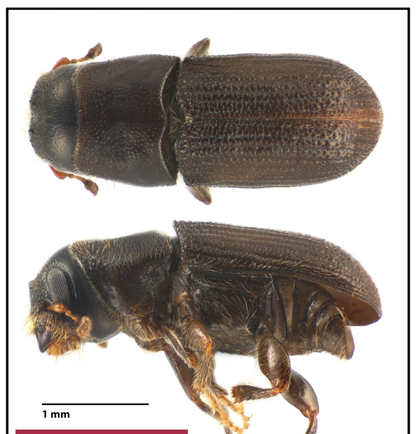
Our idea

Stressed trees are known to show spectral signatures that we can't see with just our eyes (3). **Can SPB attack be detected by multispectral cameras**, which capture infrared and near infrared light? These wavelengths of light are beyond the visible range, but have been used to identify tree stress in other situations (4,5).

We compare tree decline symptoms after SPB attack using ground-based surveys and unpiloted aerial vehicles (UAVs, or "drones").

DJI P4 Multispectral UAV

Spectral bands
Blue – 450 nm
Green – 560 nm
Red – 650 nm
Red edge – 730 nm
Near-infrared – 840 nm



1 mm

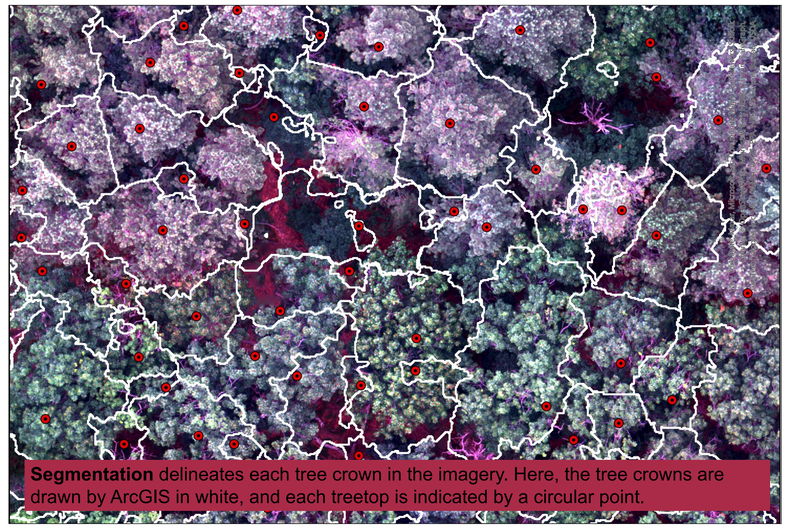
Southern pine beetle (SPB)
Marc DiGirolomo
US Forest Service

The foliage of SPB-attacked trees fades from green to red as the attack progresses. We test the correlation between needle color and SPB stage in over 300 attacked trees.

Methods

1. Located SPB-attacked pitch pine (*Pinus rigida* Mill.) on Long Island, New York (June 2022). We followed seven outbreaks throughout the season.
2. Recorded visible tree decline symptoms, including needle color, and SPB stage at breast height every two weeks.
3. Captured aerial multispectral imagery of each outbreak in July and September 2022 using a DJI P4 Multispectral UAV.
4. Image processing:
   - A. Segmentation:
     - i. Produce a 3D point cloud using Structure-from-Motion modeling in Agisoft Metashape software
     - ii. Run 8 tree detection algorithms: 6 in ArcGIS Pro (using a canopy height model) and 2 in R (using marker-controlled watershed segmentation)
     - iii. Validate the models using manually digitized (traced) tree crowns
   - B. Classification:
     - i. Extract spectral data from the best segmentation model using eCognition software
     - ii. Finalize decline class designations
     - iii. Run object-based classification in Python using Random Forest, Classification and Regression Trees, and Support Vector Machine algorithms
   - C. Calculation of image object features (10 geometric, 8 texture, 11 spectral) and 20 spectral indices in eCognition software

Currently: We are segmenting the imagery and evaluating which decline classes to use for classification. We have identified 20 spectral indices to calculate.



Segmentation delineates each tree crown in the imagery. Here, the tree crowns are drawn by ArcGIS in white, and each treetop is indicated by a circular point.

We ground-truthed SPB attack intensity and beetle life stage to be correlated with tree crown condition as recorded from the ground and from above.

Revisiting aerial and ground-based detection protocols for the management of southern pine beetle in its expanding northern range:

Can drones detect early attack of SPB in New York pitch pines?

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See our webpage for references and more information!

bit.ly/spb_uav

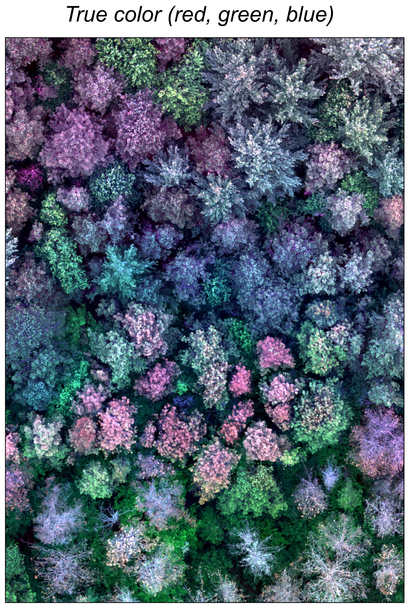
Preliminary Results – Ground

Visual assessments of needle color from the ground suggest that by the time needles turn red, the next generation of SPB have already emerged from the tree. Of 1000 foliage observations, we recorded only 6 trees with yellow needles. Most SPB-attacked pitch pine foliage transitioned directly from green to red. This stands in sharp contrast with tree decline behavior in the southern range, where yellow/orange needles indicate both active SPB trees and the direction of spot growth. We also observed a wide variation of pitch tubes and are working on quantifying characteristics.

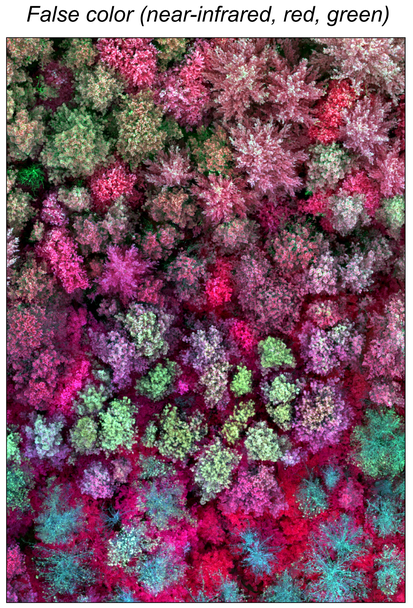
The variety of pitch tubes surprised us. Fresh pitch tubes ranged from dark and crumbly to light and gooey.

Preliminary Results – Aerial Imagery

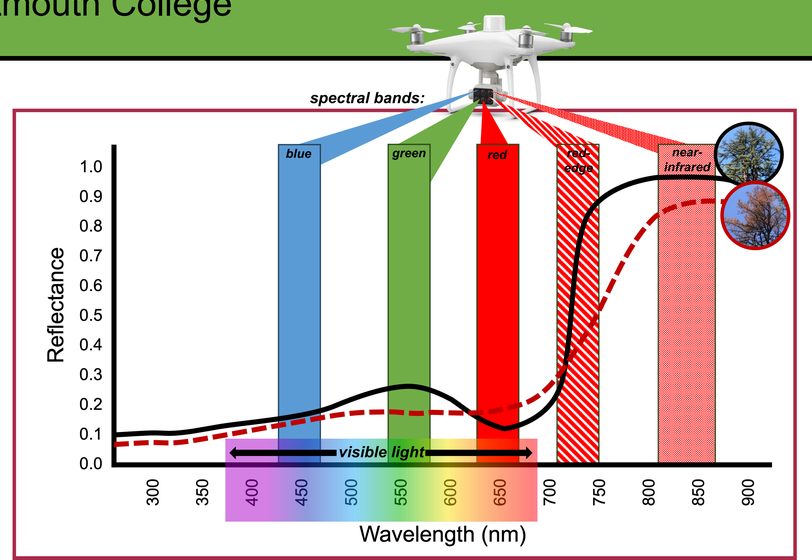
True color (red, green, blue)



False color (near-infrared, red, green)



Orthomosaics, created by stitching together thousands of drone photos, provide detailed representations of the canopy. Comparing true and false color orthomosaics suggests that near-infrared reflectance correlates with tree stress. In false color, tree decline is shown in green. Through segmentation, we will calculate each tree crown's average reflectance for each of our 5 spectral bands. We will calculate spectral indices for each tree crown, with the goal of differentiating between healthy & unhealthy trees.



We expect healthy & SPB-attacked trees will show different spectral signatures. The example reflectance curves of healthy and visibly declining foliage above depict how the greatest differences occur beyond the visible light spectrum. Green (early) attack may result in intermediate reflectance, between these two curves.

Take-home points

- **We present the first analysis of UAV-collected multispectral imagery in the SPB system**.
- We are currently running segmentation algorithms.
- **Needle color may not be a good indicator of SPB brood stage.**
  - This contradicts previous literature, which suggests management decisions based on needle color (1,6,7). We found that the foliage of SPB-attacked pitch pine trees rarely ever turned yellow. By the time needles changed color from green to red, the next generation of SPB already emerged.

Poster Template by Susanna L. Harris