Leveraging Drone Imagery and Microclimate Models to Map Disease-Related Environmental Conditions in Coastal Shrublands

Jon Detka, PhD
CSU Monterey Bay

NSF GRFP
Natural Reserve System UNIVERSITY OF CALIFORNIA
CIDER UC Santa Cruz
Seed Funding Initiatives

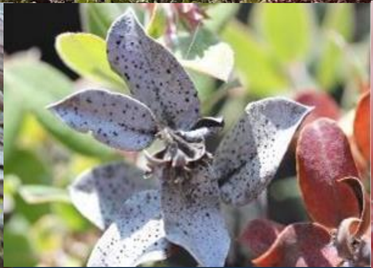
About Me

- CSU Monterey Bay B.S. Earth Systems, Science & Policy
- San Jose State M.S. Organismal Biology, Conservation & Ecology
- UC Santa Cruz Ph.D. Environmental Studies

- **CSU Monterey Bay**
    - STEM Lecturer, Staff Researcher
    - SI Science Coordinator
    - Adjunct Research Faculty

- **UC Santa Cruz**
    - Senior Drone Pilot
    - GIS Technician
    - Drone Instructor
- **Drone Camp** - Committee & Instructor

UCSC
Fort Ord
Natural Reserve



Neofusicoccum australe (Botryosphaeriaceae)

- Confirmed outbreaks in S. Cal. in cultivated and wildland landscapes
- Ubiquitous endophytic fungal pathogen
- Disease associated with prolonged leaf wetting and environmental stress.
- Causes blight and canker diseases in many woody plant species

Host Species

Wooly-Leaf Manzanita

Arctostaphylos tomentosa

Sandmat Manzanita

Arctostaphylos pumila

Is there a gradient of disease pressure with distance from the coast because of variation in leaf wetness duration?

Are the two manzanita species with differing coastal distributions affected differently by disease?

The Challenge

Working in often impenetrable shrubland:

1. Find the target plant species.
2. Measure disease severity in those plants.
3. Measure the gradient in leaf wetness.

Can we use drones and machine learning to provide useful and accurate data more easily or better than traditional approaches?

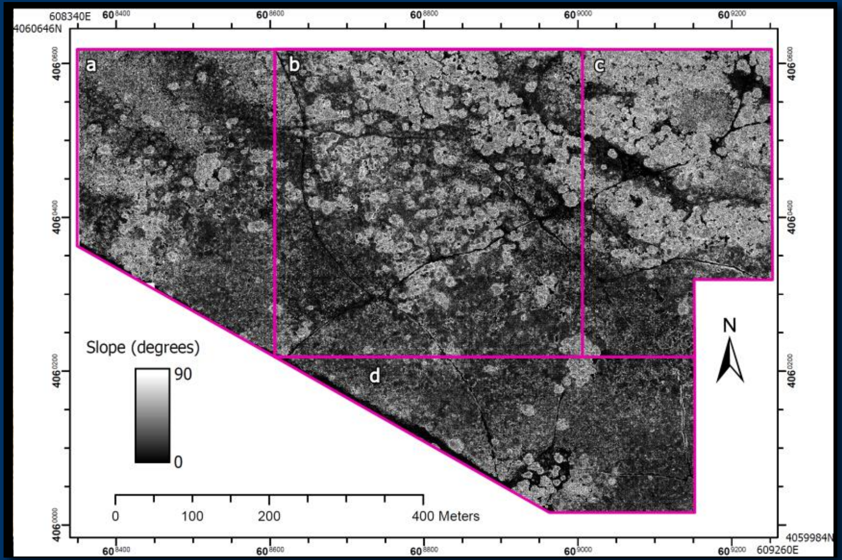
Why use drones to study plant health?

1. Increased canopy accessibility and reduced impact
2. Increased spatial extent at high resolution
3. Multispectral sensors
4. Topographic data
5. Cover Classification
6. Canopy Health Assessment

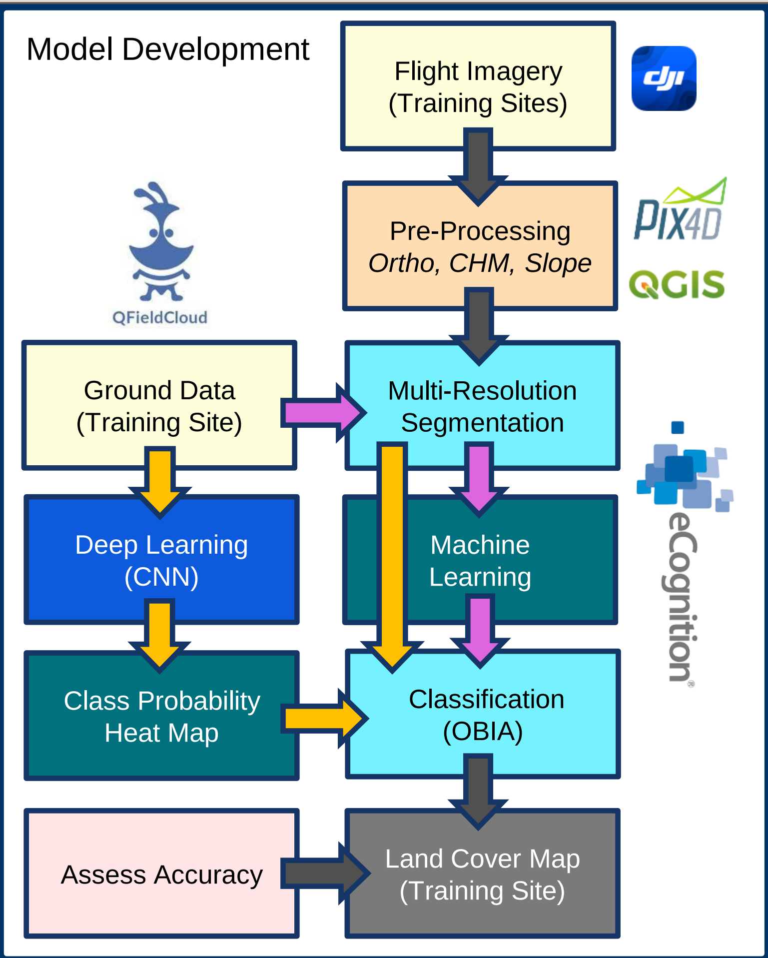
Drone Mapping

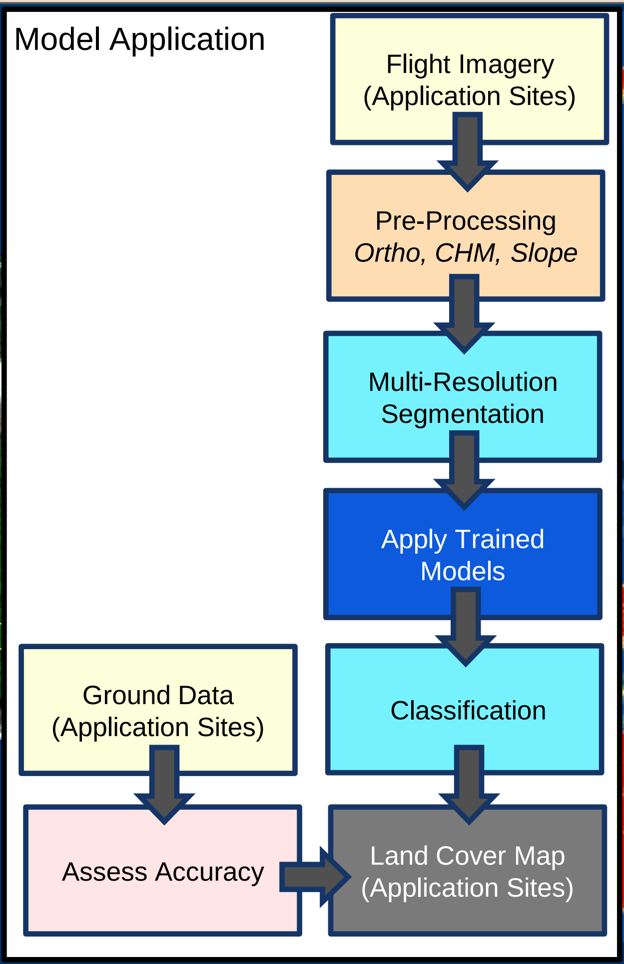
- 246-ha Fort Ord Natural Reserve
  - 40.7-ha study area
  - oak woodland, coastal sage scrub, maritime chaparral
- Flights: July 23-24, 2021
- Multispectral (2.5 cm/px)
- Topographic (5 cm/px)
- Canopy height
- Surface slopes

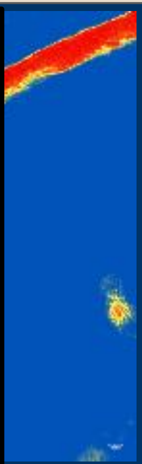
- Ground Survey Points
  - 11,622 total points
  - 10 shrub species
  - Bareground and deadwood
  - 6,973 in training site

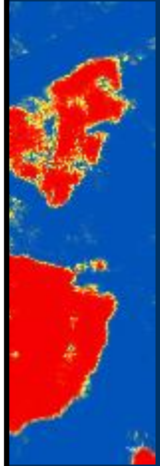


Imagery Classification Workflow

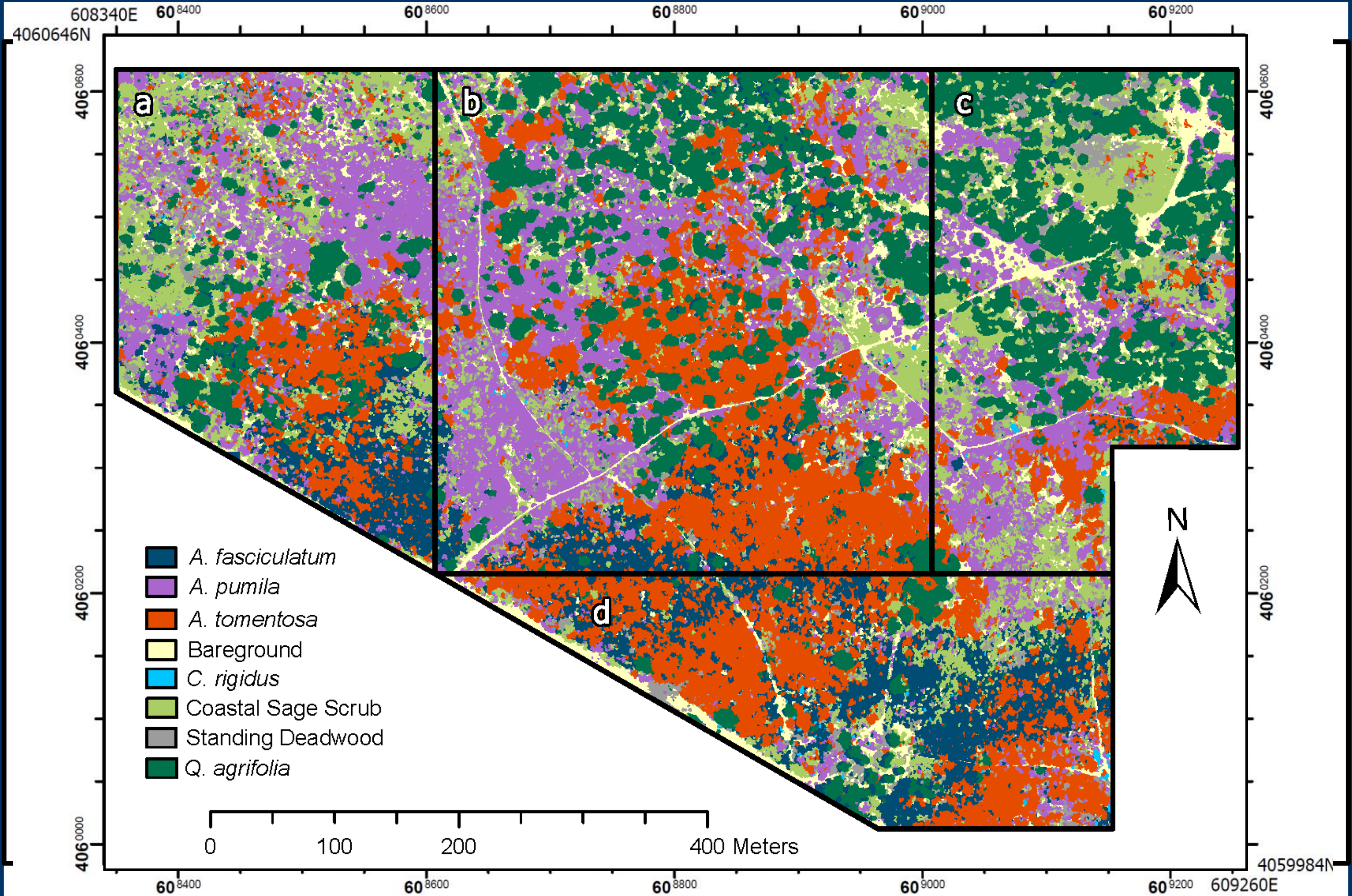








Cover Classification Results



Deep Learning Cover Classification Performance

	ADFA	ARPU	ARTO	CERI	SD	BG	CSS	QUAG
Precision	0.84	0.89	0.77	0.17	0.90	0.96	0.73	0.98
Recall	0.68	0.87	0.92	0.80	0.93	0.92	0.70	0.83
F1	0.72	0.88	0.83	0.28	0.91	0.94	0.71	0.89

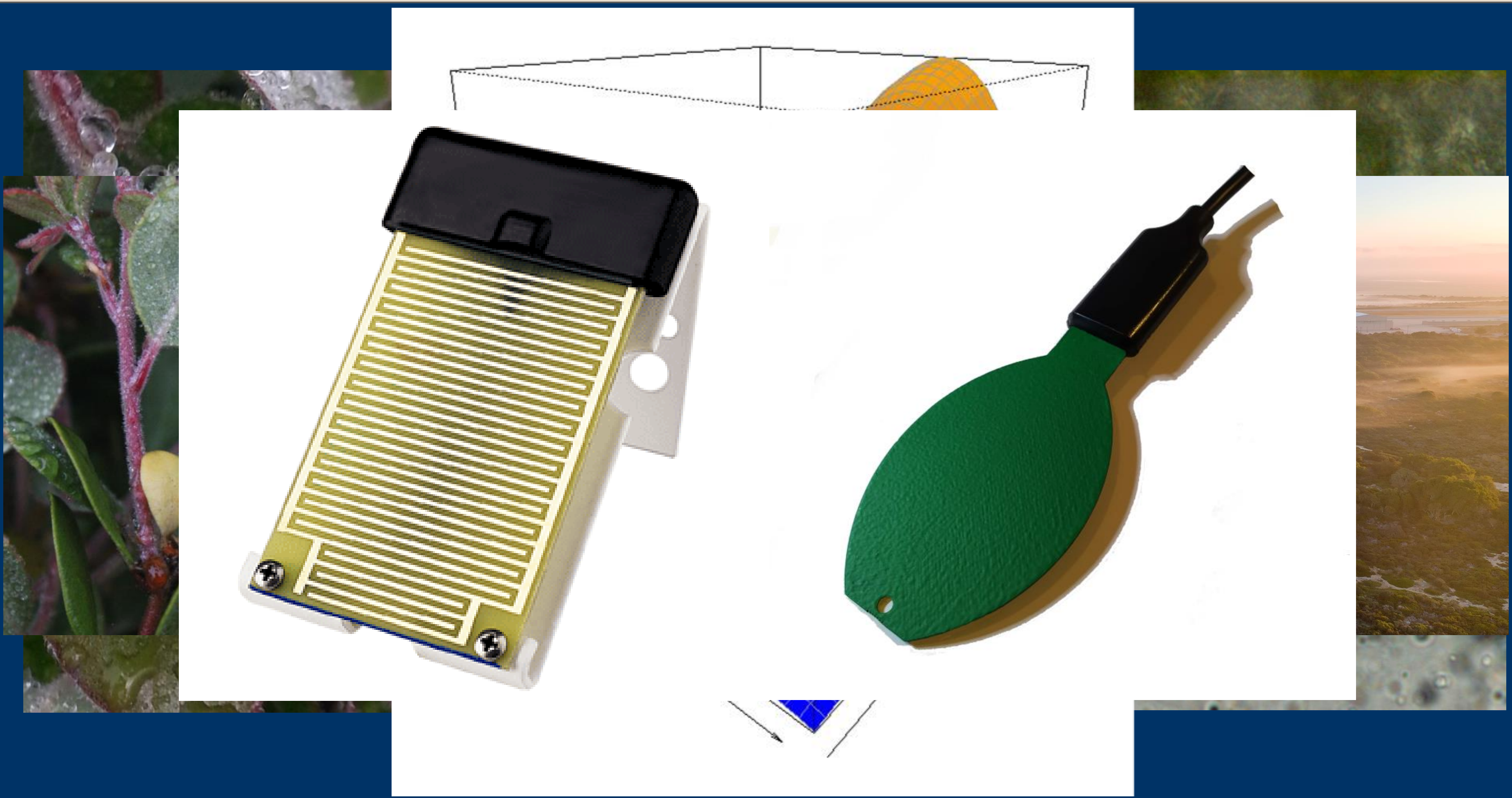
Overall Accuracy	**0.85**

Detka, J., Coyle, H., Gomez, M., & Gilbert, G. S. (2023)

Key Take-Aways

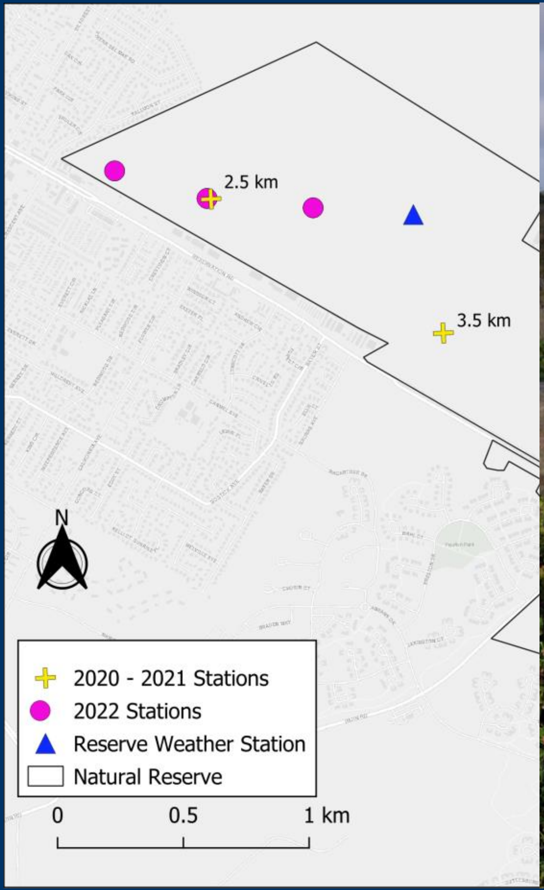
- Approach accurately identified tree and shrub species and vegetation gaps.
- Distinguishing between two manzanita shrub species
- Viable approach for accurate species identification and landscape mapping needs
- Some modeling uncertainty with:
  - Less common species (*C. rigidus*)
  - intermixed canopies (Coastal sage scrub)

Estimating Leaf Wetness Patterns



Methods – Meteorological Data Collection

- 2020-21 Water Year
  - 4 - Onset Hobo Dataloggers
    - RH, Air Temp, Leaf wetness
    - 10-min logging interval.
- Summer 2022
  - 7 – DIY Arduino Stations
    - RH, Air Temp
    - Solar-powered !!
- 2020-2022 UCNRS Met Station
  - RH, Air Temp
  - Solar Radiation
  - Windspeed



Leaf Wetness Modeling – Empirical Threshold Approaches

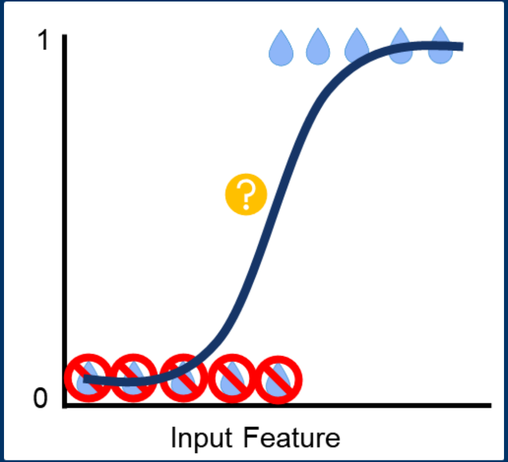
- *RH* > 87% (Wichink Kruit et al., 2004)
- *RH* > 90% (Gleason et al., 1994)
- *RH* > 92% (Gillespie et al., 2021)
- *Dewpoint depression ≤ 2°C

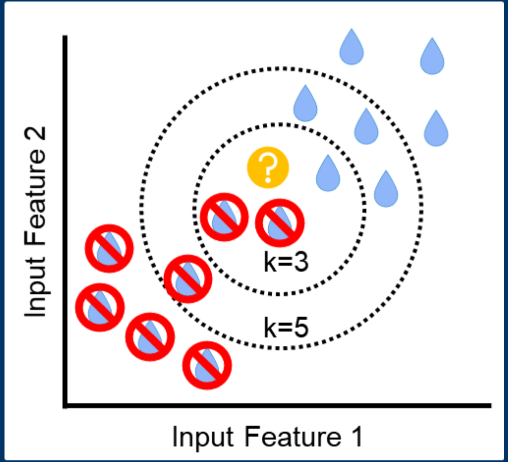
Dewpoint: *temperature at which the air can no longer hold all of its water vapor.*

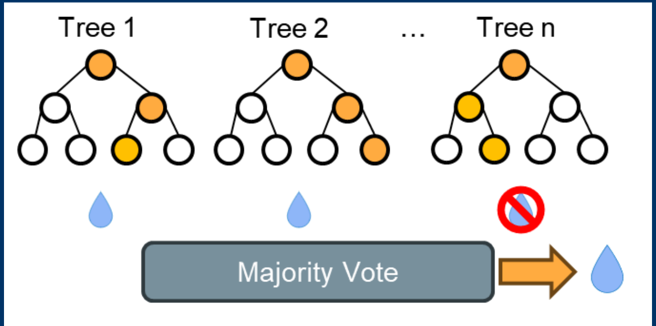
Dewpoint depression: difference between current air temperature and dewpoint temperature.

Statistical Models & Machine Learning Approaches

- Linear
  - Logistic Regression
  - Linear Discriminant Analysis
- Non-linear
  - Gaussian Naïve Bayes
  - Decision Trees
  - K-nearest Neighbor
- Machine Learning
  - Support Vector Machine
  - Random Forest
  - eXtreme Gradient Boosting
  - Multilevel Perceptron







Results – Empirical Model Performance

- DPD and *RH* > 90% model predictions performed best.

- *RH* > 87% model tended to overestimate ‘Wet’ events
- *RH* > 92% model most conservative model for ‘Wet’ classification predictions

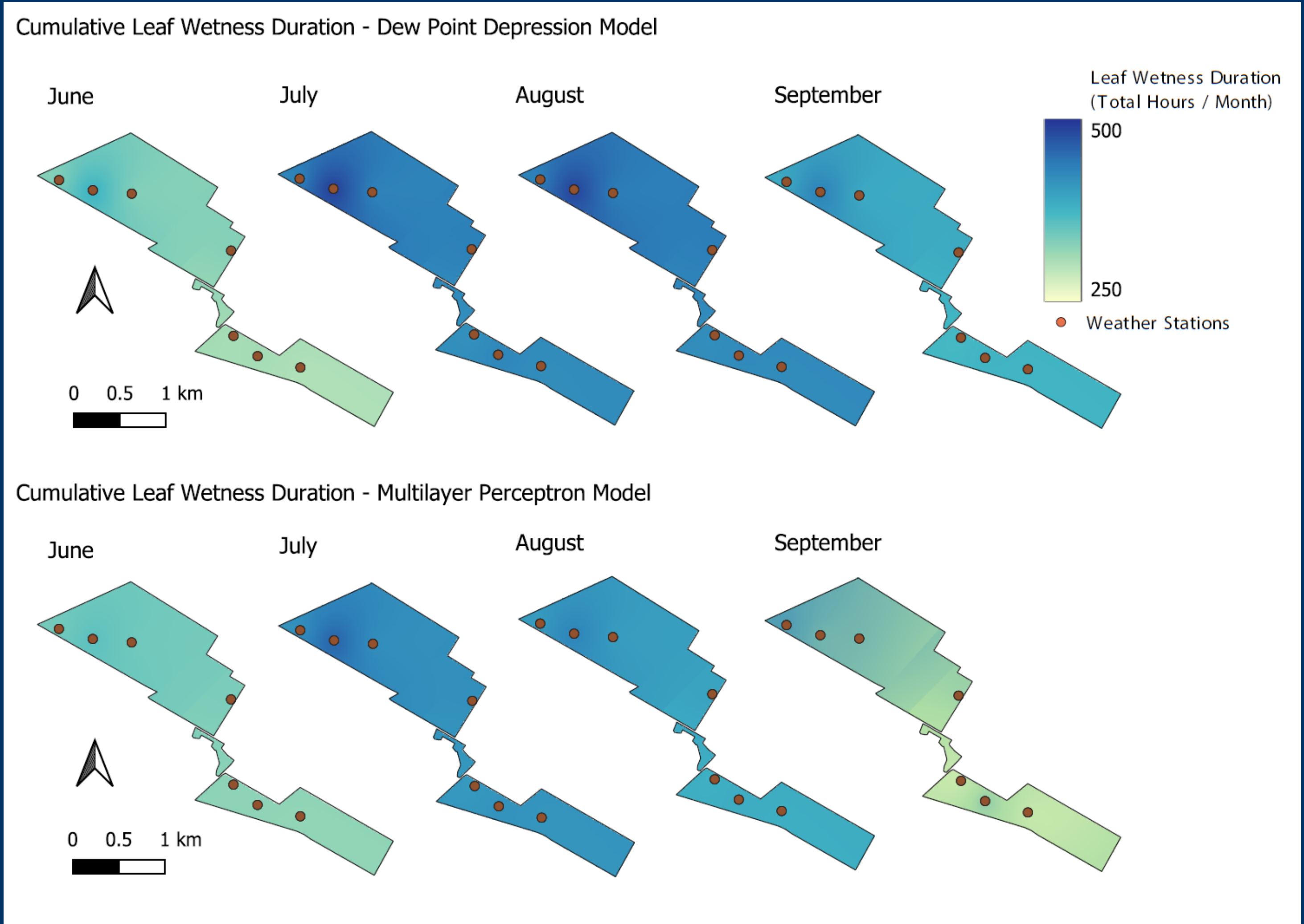
Models	Accuracy	Precision	Recall	F1
RH > 87	85.25 (84.95 - 85.55)	0.81 (0.003)	0.95 (0.002)	0.87 (0.002)
RH > 90	88.13 (87.91 - 88.35)	0.90 (0.003)	0.87 (0.002)	0.89 (0.002)
RH > 92	86.37 (86.05 - 86.69)	0.93 (0.004)	0.81 (0.005)	0.87 (0.003)
DPD	**88.50 (88.26 - 88.74)**	0.87 (0.003)	0.92 (0.003)	0.90 (0.002)

Statistical and Machine Learning Model Performance

- Highest performing models used only RH and DPD
- All performed similarly to winning empirical models

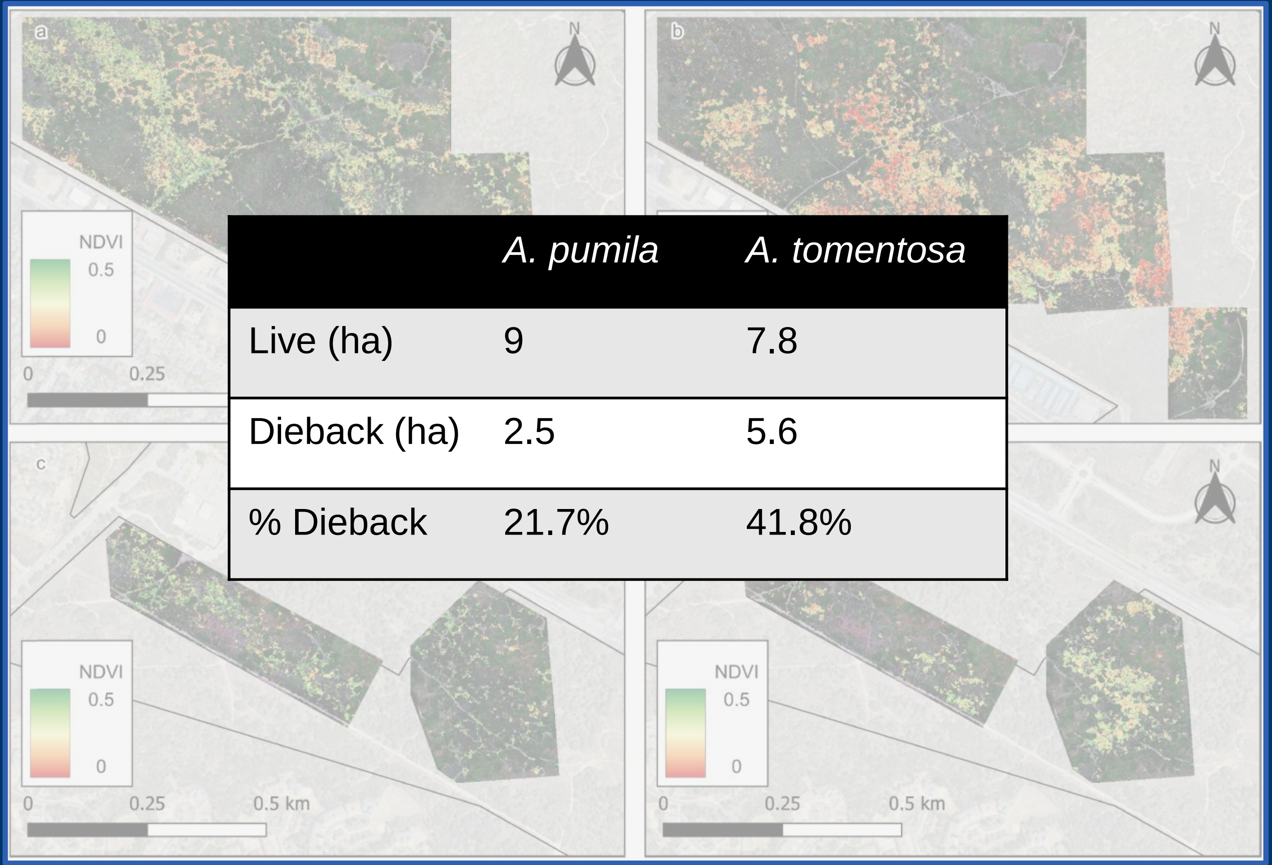
Models	Accuracy	Precision	Recall	F1
LDA	88.68 (88.43 - 88.93)	0.87 (0.005)	0.90 (0.005)	0.89 (0.002)
LR	88.64 (88.39 - 88.89)	0.86 (0.005)	0.92 (0.005)	0.89 (0.002)
GNB	88.61 (88.34 - 88.88)	0.87 (0.006)	0.90 (0.006)	0.88 (0.002)
CART	88.79 (88.52 - 89.06)	0.88 (0.007)	0.89 (0.007)	0.88 (0.002)
KNN	88.85 (88.50 - 89.20)	0.88 (0.004)	0.89 (0.007)	0.89 (0.003)
SVM	88.63 (88.38 - 88.88)	0.86 (0.005)	0.92 (0.005)	0.89 (0.002)
RF	88.24 (88.01 - 88.47)	0.87 (0.006)	0.89 (0.006)	0.88 (0.002)
XGB	88.29 (87.99 - 88.59)	0.87 (0.006)	0.89 (0.006)	0.88 (0.003)
MLP	88.65 (88.35 - 88.95)	0.87 (0.018)	0.90 (0.028)	0.88 (0.005)

MLP model was computationally FASTER!


Cumulative Leaf Wetness Duration - Dew Point Depression Model
June
July
August
September
Leaf Wetness Duration
(Total Hours / Month)
500
250
Weather Stations
0 0.5 1 km
Cumulative Leaf Wetness Duration - Multilayer Perceptron Model
June
July
August
September
0 0.5 1 km

Relating manzanita canopy health to leaf wetness duration

A. pumila *A. tomentosa*

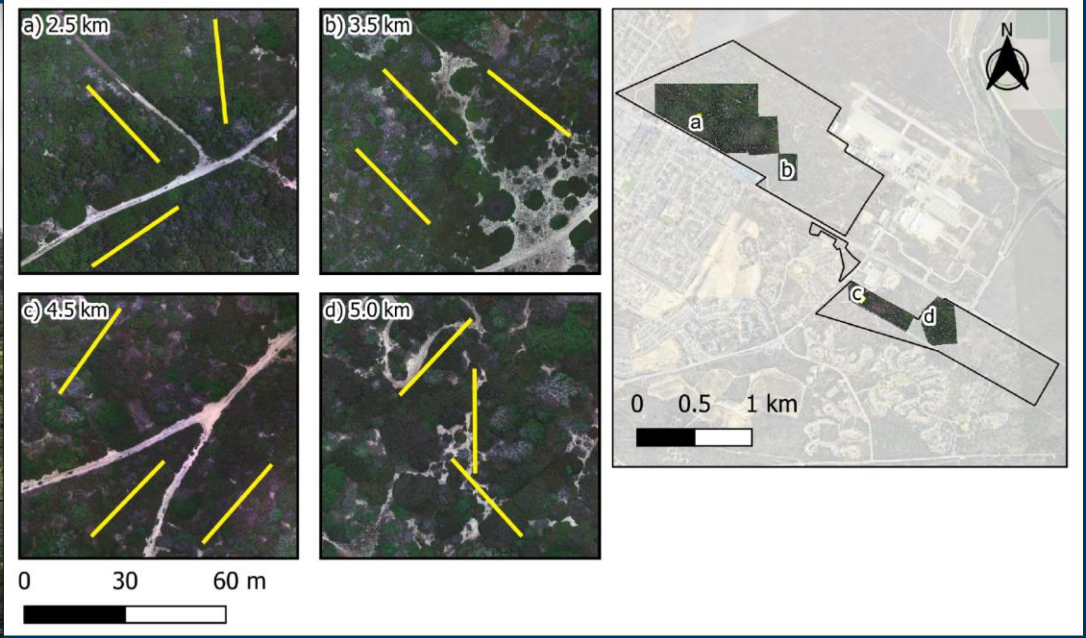


	A. pumila	*A. tomentosa*
Live (ha)	9	7.8
Dieback (ha)	2.5	5.6
% Dieback	21.7%	41.8%

$$NDVI = \frac{(NIR\ - R)}{(NIR + R)}$$

Ground surveys - manzanita canopy health

- 30-m line intercept transects
- Four coastal distances
- For each manzanita species : status, symptoms, dominant leaf color



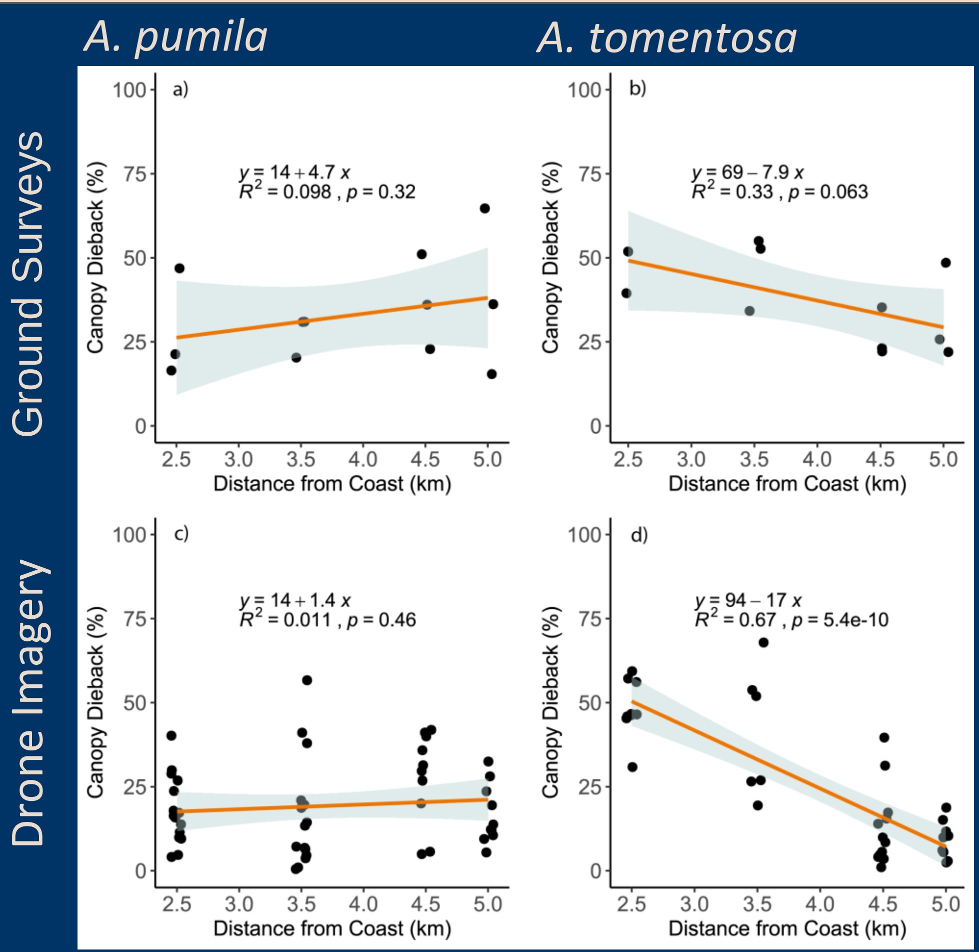
Results – Canopy dieback and coastal distance

- *A. pumila*

  No pattern in canopy dieback across coastal gradient

- *A. tomentosa*

  Decreasing % canopy dieback with increased distance from the coast

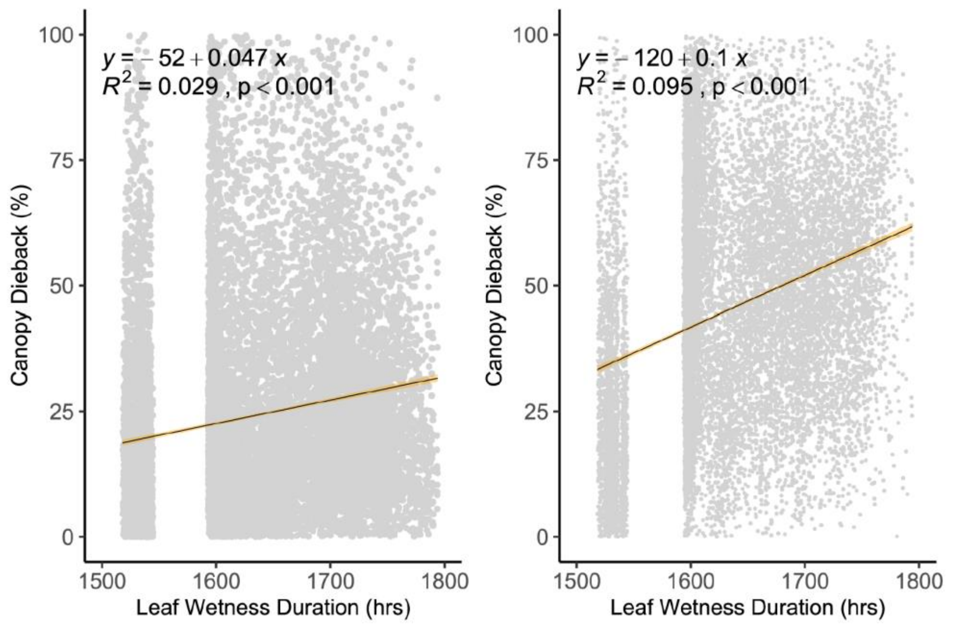


Detka, J., Jafari, M., Gomez, M., & Gilbert, G. S. – *In Review*
10.2139/ssrn.4977771

Results - Leaf wetness duration and manzanita canopy dieback

- Analysis of krigged DPD model vs. drone imagery canopy dieback
- Increasing leaf wetness duration, increased canopy dieback in *A. tomentosa*
- Weaker pattern for *A. pumila*

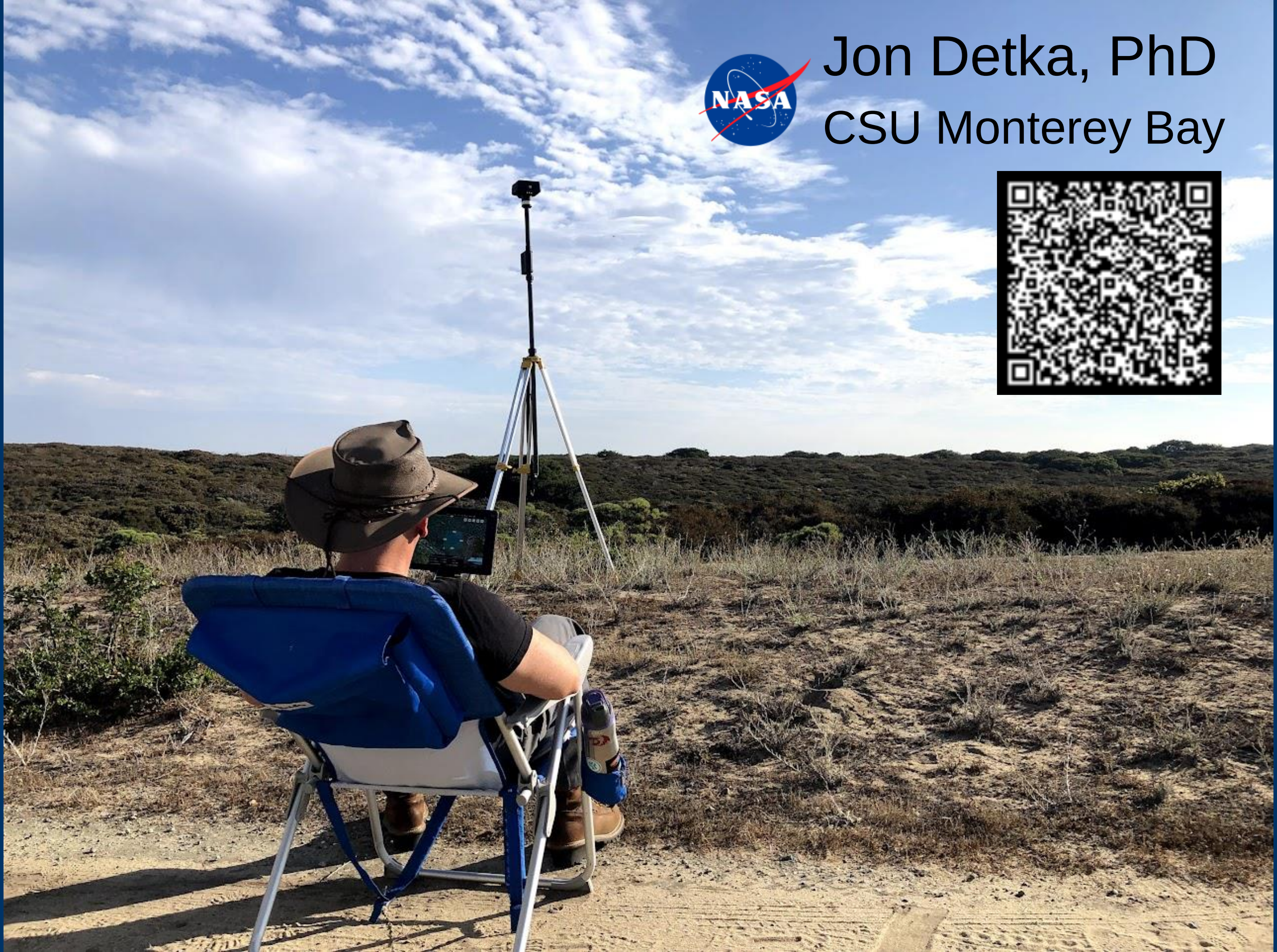
A. pumila *A. tomentosa*



Detka, J., Jafari, M., Gomez, M., & Gilbert, G. S. – *In Review*
10.2139/ssrn.4977771

Future Directions

1. Expand research to include diverse forest systems for pathogen impact studies.
2. Collaborate with forestry experts on drone-based pest detection and rapid response.
3. Enhance training for professionals in drone tech and geospatial analytics.


Jon Detka, PhD
CSU Monterey Bay

Acknowledgements

UCSC

- **My PhD committee!! Greg Gilbert, Laurel Fox, Brent Haddad**
- Gage Dayton & Joe Miller - UCSC Ft. Ord Reserve
- Sylvie Childress –Greenhouse Program
- Brett Hall – UCSC Arboretum & Botanical Garden
- Su-hua Wang – New Gen Learning Group
- Steve McGuire – Human Aware Robotic Exploration Lab
- Becca Fenwick & Michael Matkin – CIDER / CITRIS
- Mircea TeoDorescu, Mohammad Jafari, Marcella Gomez, Marco Rolandi
- Randall Morgan Insect Collection – Norris Center

- Andy Lyons & Sean Hogan – UCANR
- Pat Iampietro, Nelson Graff, Dan Fernandez, Swarup Wood – CSUMB
- Max Klepikov – Lepidopterist Society
- David Bettman & Chris Grinter – California Academy of Sciences
- Richard Lind – Naval Postgraduate School
- Don Miller – Chico State University

Undergraduate Researchers

UCSC: Hayley Coyle, Samuel Edwards-Marsh, Finn Amend, Kyle Jeffrey, Alyssa Kaatmann, Eilise McKenna, Fall 22 ENVS 163 class!

CSUMB - Erin Elm and Thomy Tran

Parker-Gilbert Lab

Ingrid Parker, Shannon Lynch, Asa Conover, Erica Mullins, Miranda Melen, Liz Rennie, Patrick Lee, Erin Aiello, Edith Lai, Nicky Lustenhouwer, Sara Grove, Zack Shearin, Juniper Harrower, Karen Tanner

NSF GRFP

Natural Reserve System
UNIVERSITY OF CALIFORNIA

CIDER
UC Santa Cruz

Seed Funding Initiatives

A. pumila and *N. australe* dieback

- *A. pumila* dieback extent may be underestimated.
  - Rapid dieback creates canopy holes
  - Difficult to determine dieback causes in standing deadwood.

A. tomentosa and *N. australe* dieback

- Endemic to foggy coastal hillsides
- Fuzzy leaves may explain disease
- Localized infection, persistent disease, but low plant morta