Combating Aquatic Invasions: Operationalizing Remote Sensing and Modeling Tools to Improve Estuary Restoration and Water Management

Bailey D. Morrison, Erin L. Hestir – University of California Merced
Shruti Khanna – CA Department of Fish and Wildlife
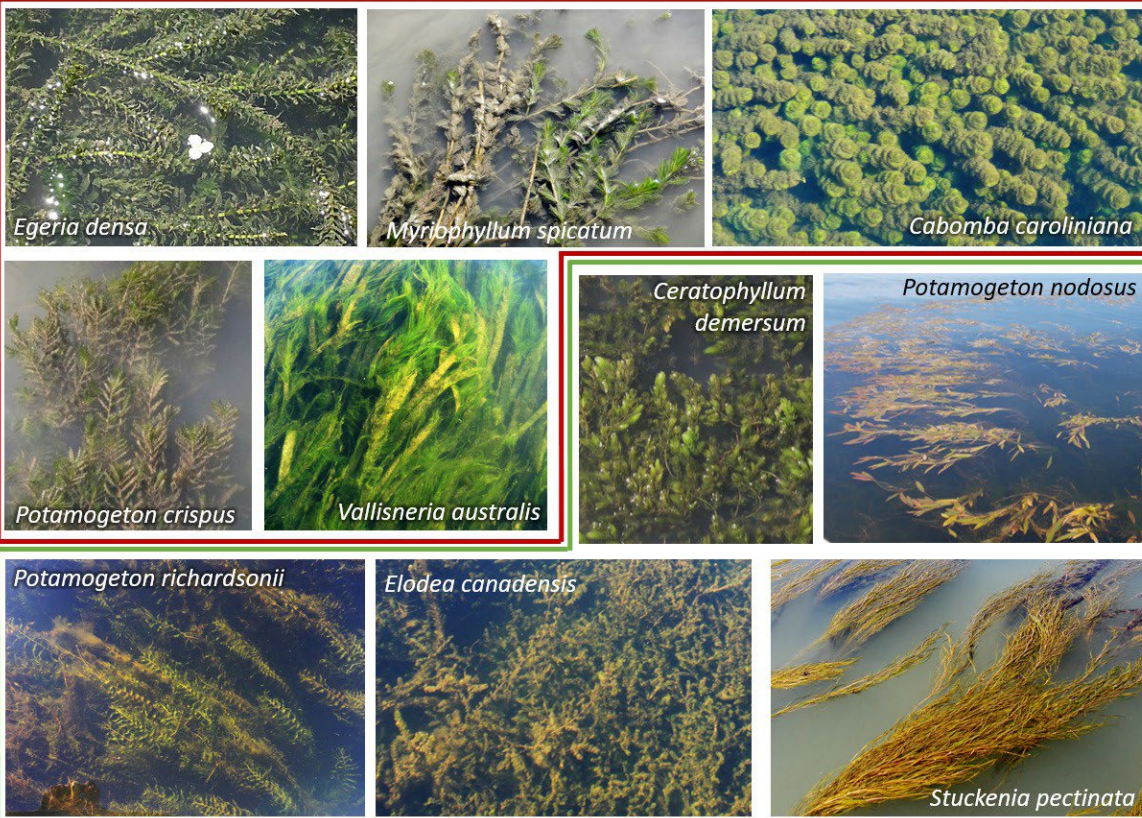29 October 2025 – State of the San Francisco Estuary Conference, Oakland CA

The Sacramento – San Joaquin Delta

- $5.3 billion economic output

- One of 25 global hotspots for biodiversity.

- One of the most invaded ecosystems in the world.

- Highly vulnerable to climate variability & change.

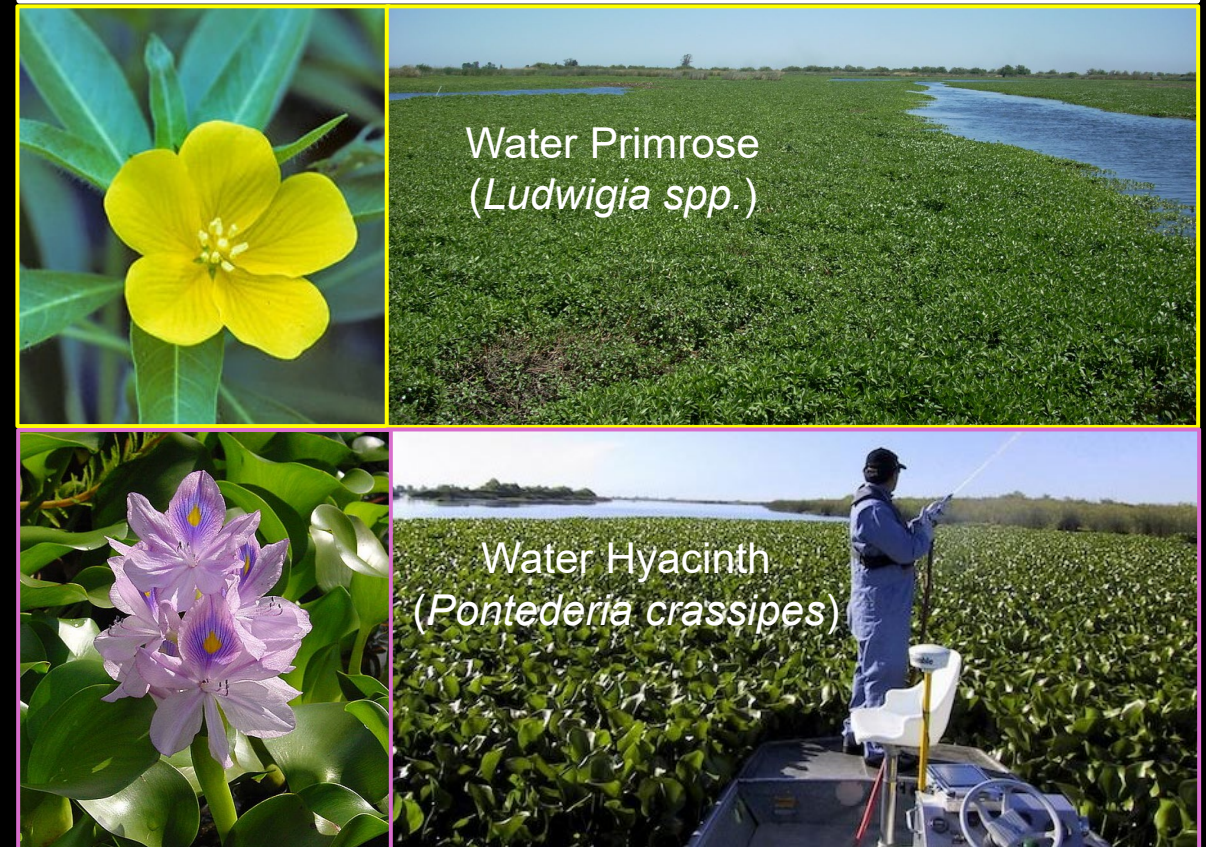- Biodiversity conservation and restoration are **required by law**.

Invasive aquatic vegetation (IAV) represent a major threat to global biodiversity

Submerged Aquatic Vegetation (SAV)

INVASIVE

Egeria densa

Myriophyllum spicatum

Cabomba caroliniana

Potamogeton crispus

Vallisneria australis

Ceratophyllum demersum

Potamogeton nodosus

Potamogeton richardsonii

Elodea canadensis

Stuckenia pectinata

NATIVE

Floating Aquatic Vegetation (FAV)

Water Primrose (*Ludwigia spp.*)

Water Hyacinth (*Pontederia crassipes*)

Invasive aquatic vegetation (IAV) represent a major threat to global biodiversity
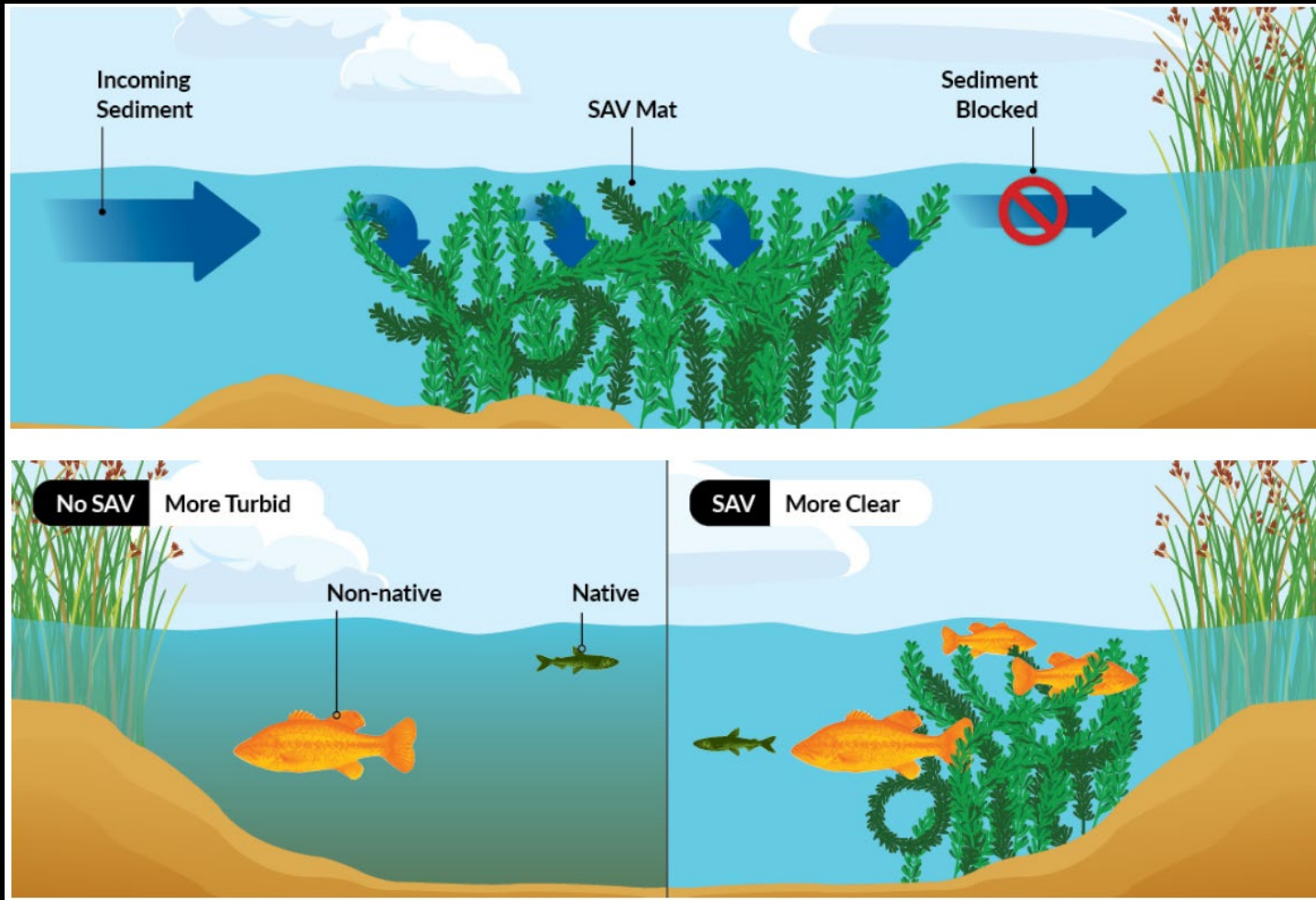
Ecological Impacts:
- Alter environmental conditions
- Reduce native biodiversity
- Replace key habitats
- Increase invader establishment

Human Impacts:
- Increase agricultural costs
- Increase flood risk
- Increase disease risk

IAV is also a major threat to Delta management

Water Quality:

- Impact sediment transport and turbidity
- Increase water temperatures
- Lower oxygen levels
- Contribute to harmful algal blooms

Management Challenges:

- Block irrigation systems, navigation channels, and other water infrastructure
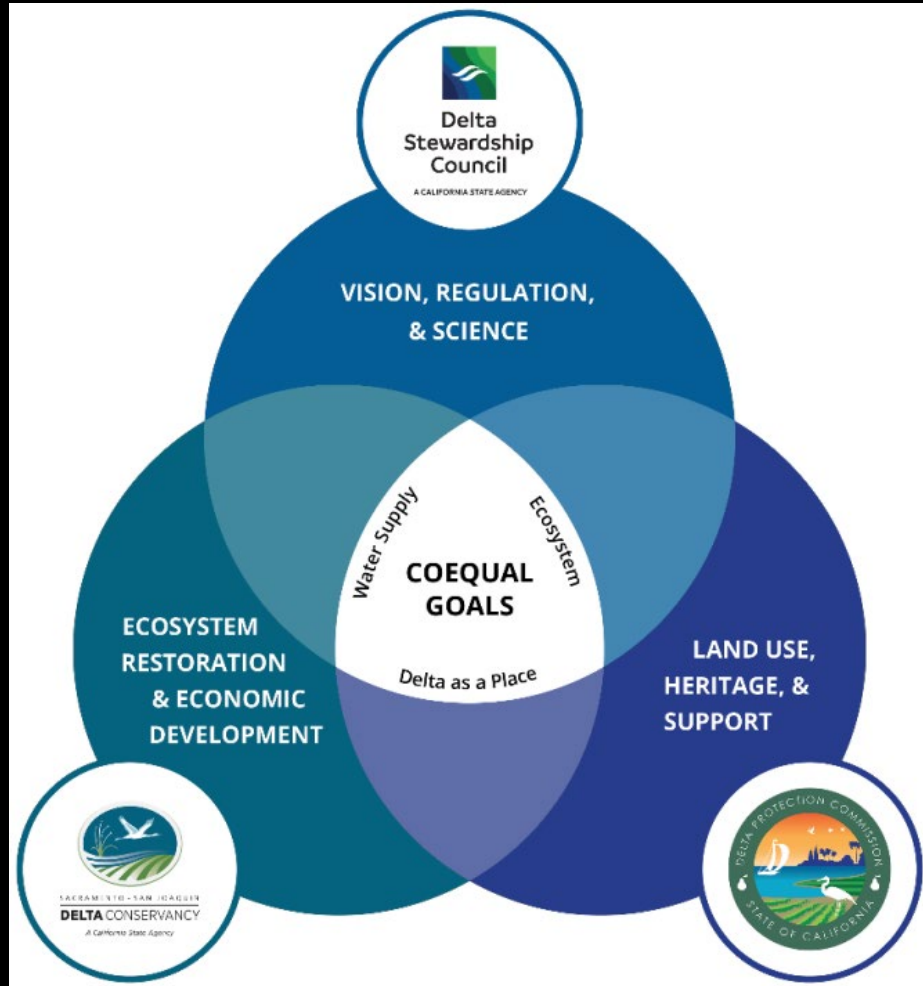- Impacts flow management actions

IAV is also a major threat to management

Restoration:

- CA has invested significant resources to conservation & restoration
- Impacts monitoring, success, and credits

IAV challenges coequal goals of the Delta

IAV has more than doubled over the past 15 years.

Consistent, Long-term IAV monitoring is a recognized major data gap

And yet....

Current decision-making frameworks do not currently consider management action impacts on IAV

Recognized Decision-Making Needs

State of the Bay-Delta Report:

1. Establish a consistent monitoring program for all IAV growth forms.

2. Develop modeling tools to enable prediction and preparation for a changing climate and IAV community

Conrad et al., 2023 – Chapter 5

Previous Mapping Efforts

Long Time-Series Airborne Imaging Spectroscopy (AIS)

- <u>Annual</u> vegetation classification maps have been produced since 2004.
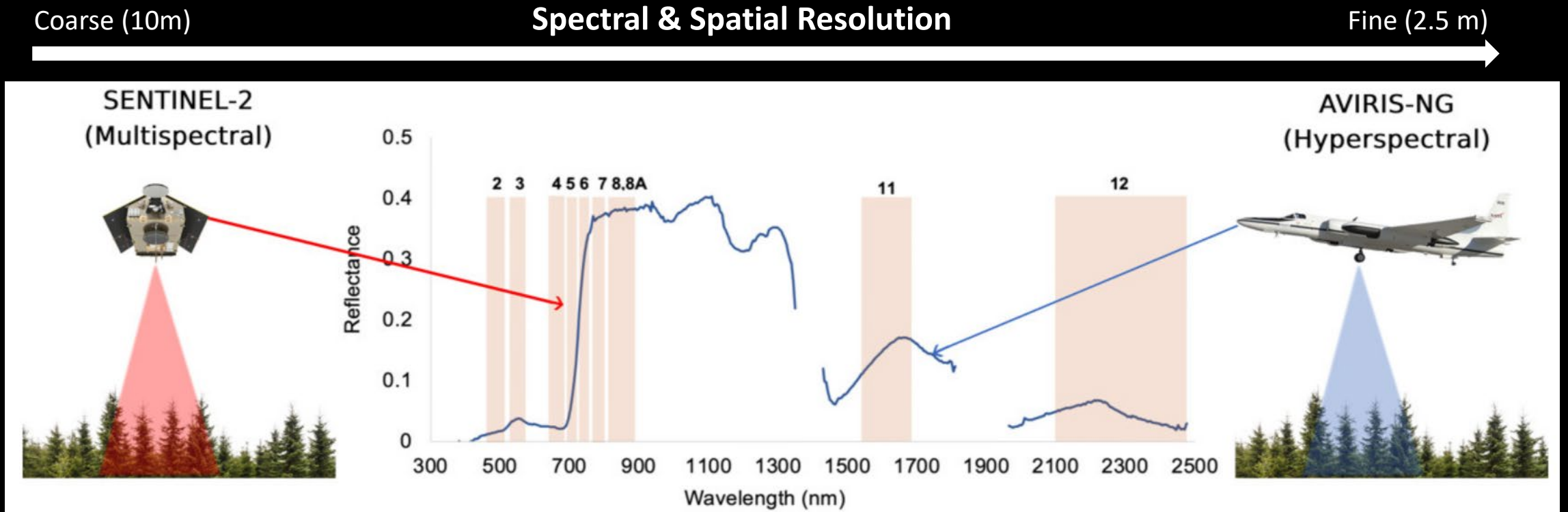

IAV Mapping with Satellite Remote Sensing

- Sentinel-2 Prototype model created in 2022.

- Potential Determined

** Not intended to replace AIS dataset, just fill data gap.
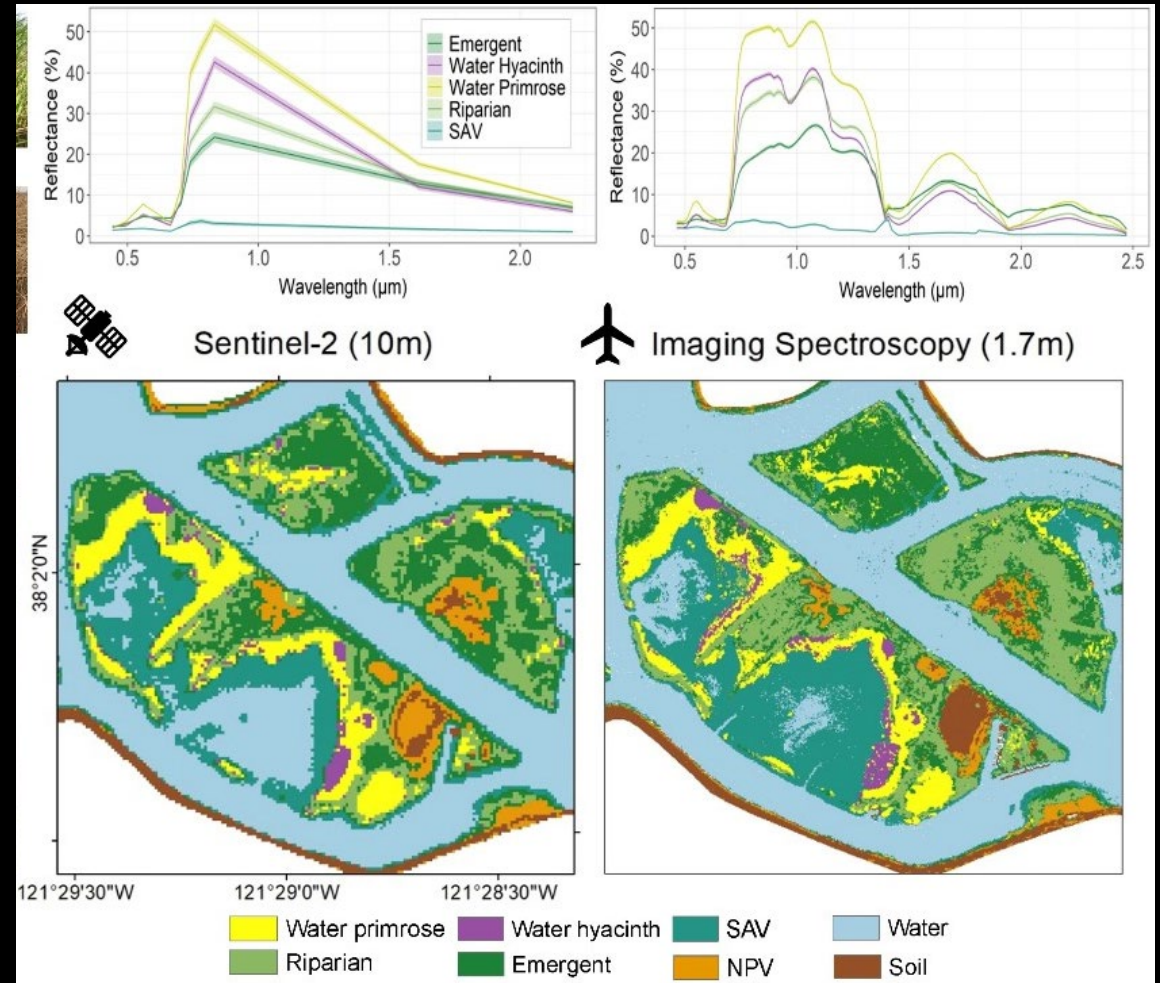
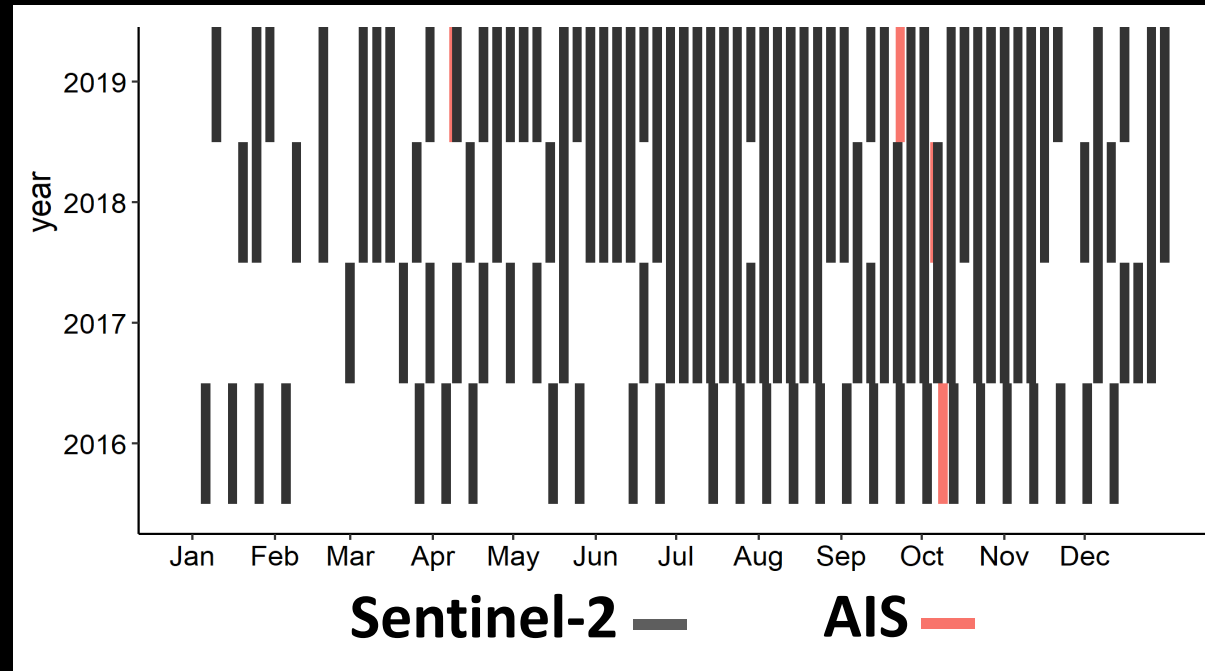# Why add satellite imagery?

Airborne Imaging Spectroscopy (AIS) Advantages:
Finer spatial & spectral resolution
Can control time of day and tidal stage aquisition

# Why transition to satellite imagery?

Sentinel-2 (S2) Satellite Advantages:
Finer temporal resolution (~5-10 day revisit)
Image Cost: Free

Earth Observations to Combat IAV

Project Goals

1. Operationalize the first sustainable mapping effort for vegetation in the Delta.

2. Advance modeling tools to assess IAV responses to past and future management actions.

3. Co-develop IAV mapping tool and integrate into the decision-making frameworks of stakeholders.
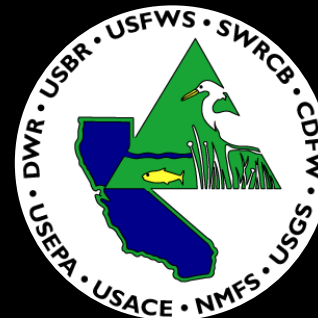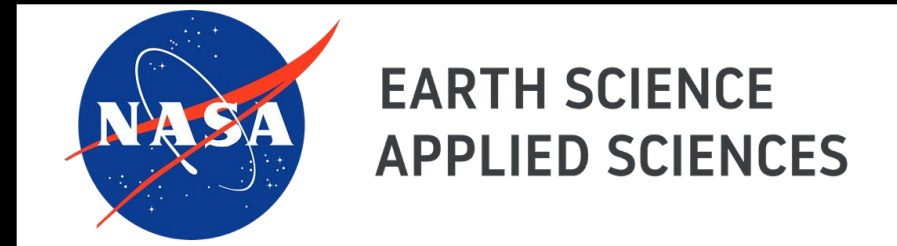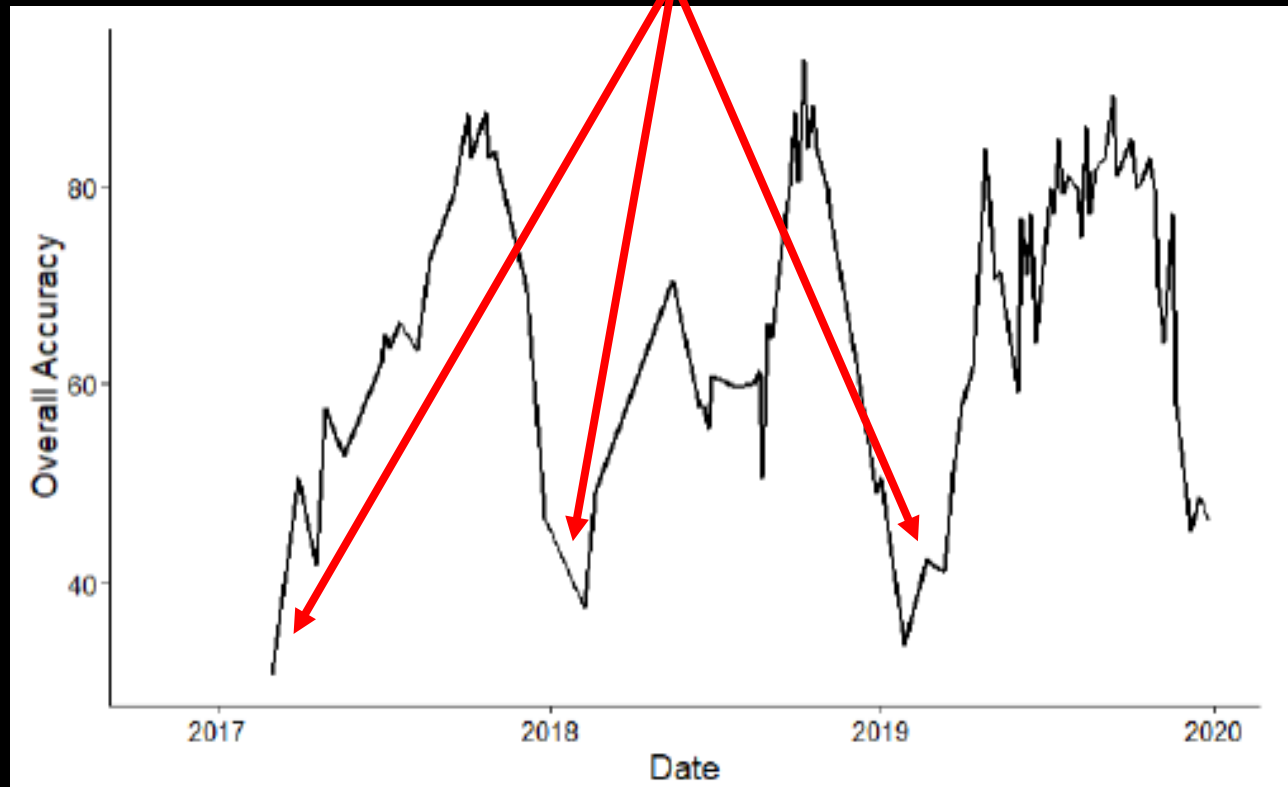
Goal 1: Operationalize S2 Class Mapper

Priority/Deliverable: Produce monthly S2 Class Maps

Needs to achieve goal:

- Improved classification performance

- Temporal transferability
  - Monthly class maps

- Full uncertainty assessment

Ustin et al. (2022); Ade et al. (2023)

Winter and Spring classifications perform worst

Overall accuracy for all S2 dates between 2017 and 2019.

Goal 2: SDMs to Assess IAV Responses to Management Actions

Species Distribution Model (SDM)

Predictor Variables	Why did we choose these predictors?
UnTrim 3D • Salinity • Turbidity • Speed Bathymetry • Depth	• Management decisions affect these variables • Need to understand their impact on IAV

Response Variable = AIS derived IAV class maps

San Francisco Chronicle

JUST IN   Air quality poor again Wednesday in S.F. Bay Area. Here's when it will improve 20m ago

Trending: S.F. Safeway to close | United flight diverted | Weather forecast | Poor air quality | Luigi Mangione's local ties | Willy Adames | H-1B visas

CLIMATE // CALIFORNIA DROUGHT

State plans $30 million wall to stop saltwater intrusion into delta — drought fallout

By Kurtis Alexander, Reporter
Updated May 19, 2021 8:22 p.m.

West False River salinity barrier

John Blanchard / The Chronicle
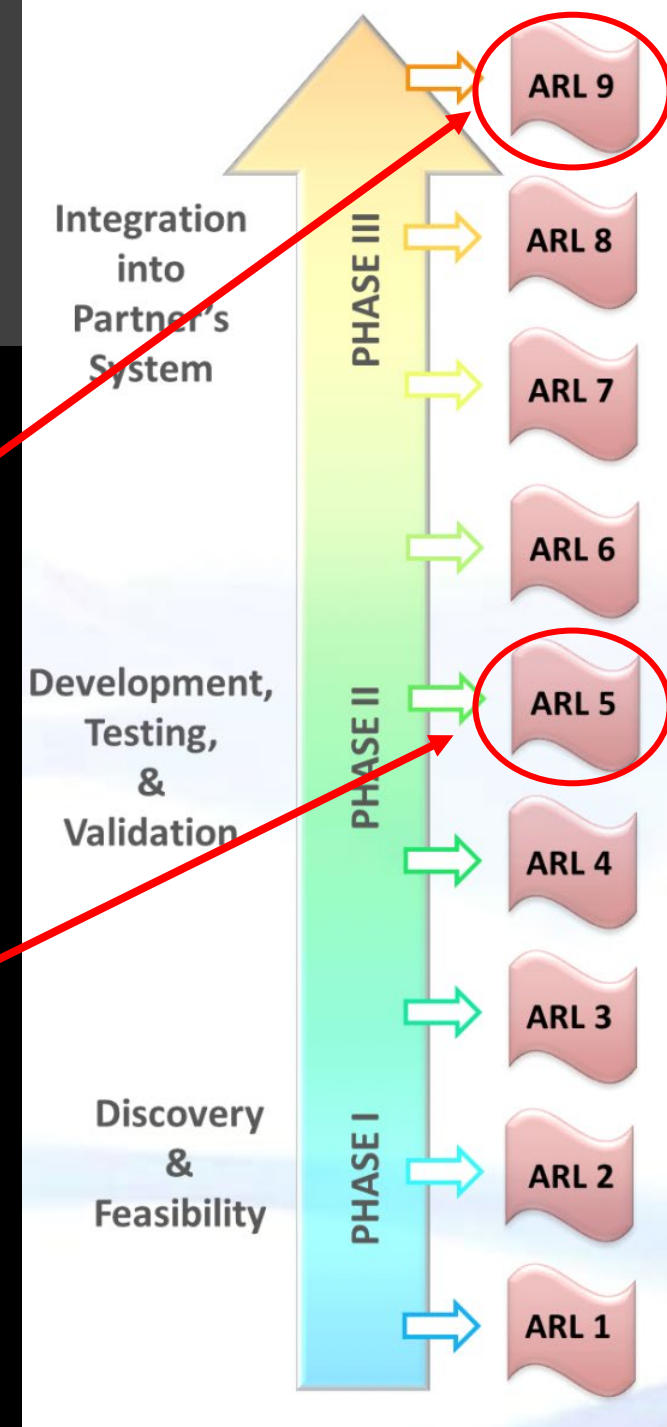
Goal 3: Co-Develop IAV Class Mapper

Approved, Operational Deployment & Use in Decision Making (Sustained Use).

- Demonstrate benefit to decision making activities

- Full integration into organizations operations

- Sustained use

- Ability to maintain after handover

Goal 1: Improved Classification Results

- Model accuracy improvements
  - All class accuracies improved from prototype
  - Nearing AIS confusion accuracies

- Improvements stem from...
  - Feature Reduction
  - Riparian/LiDAR mask
  - Photogrammetry class selection protocols developed.
  - Spring/Winter field observations

Overall Accuracy: 86.4% (91.6% AIS)
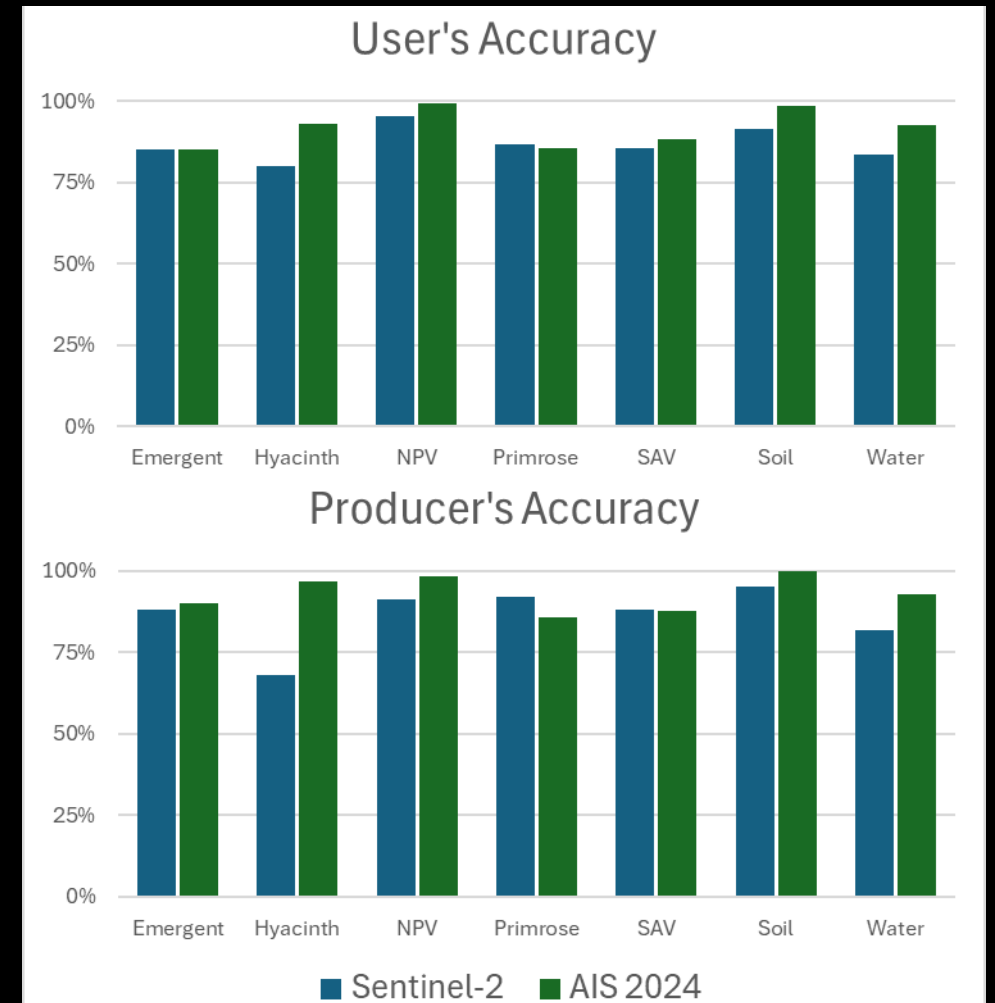
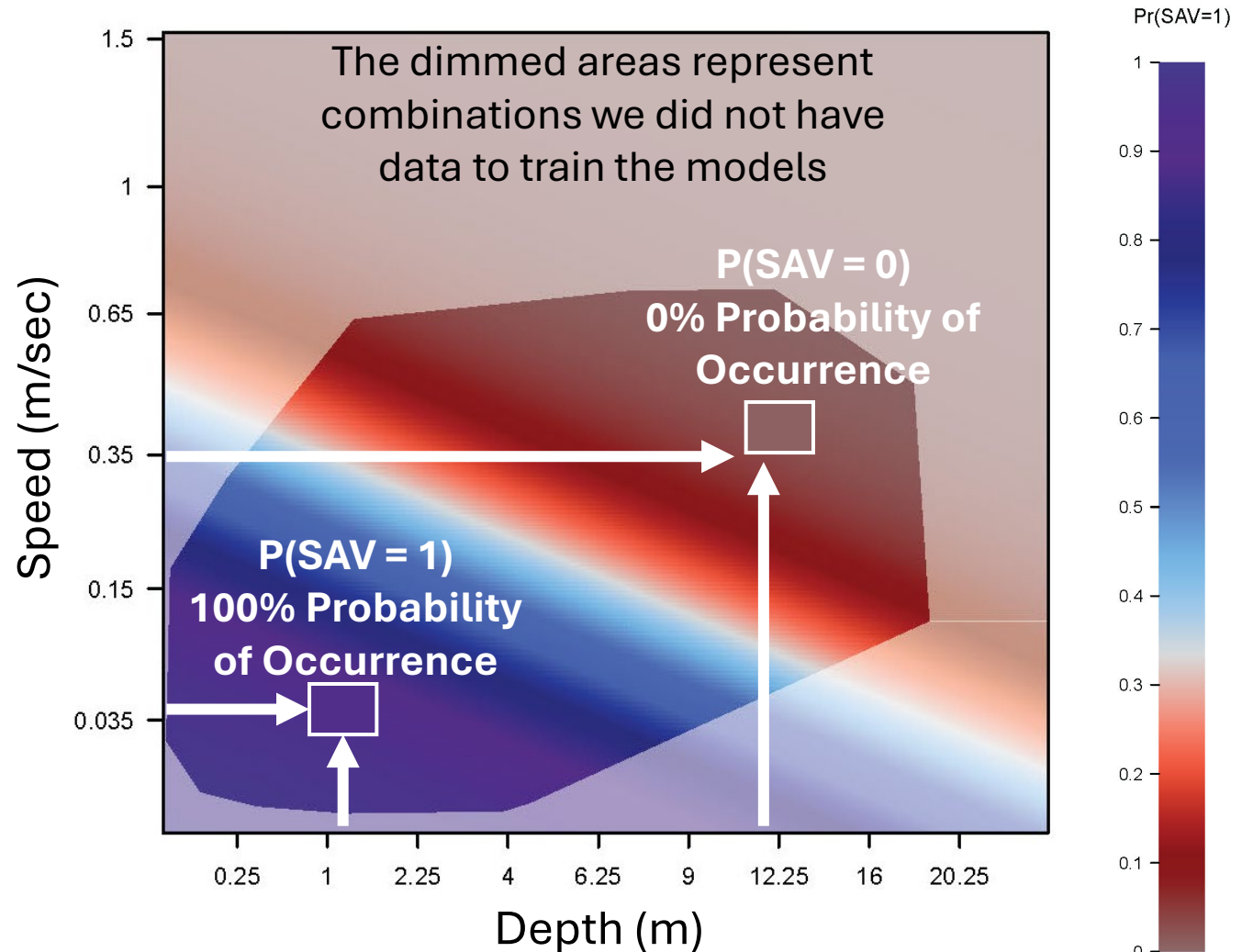# Goal 1: Improved Classification Results
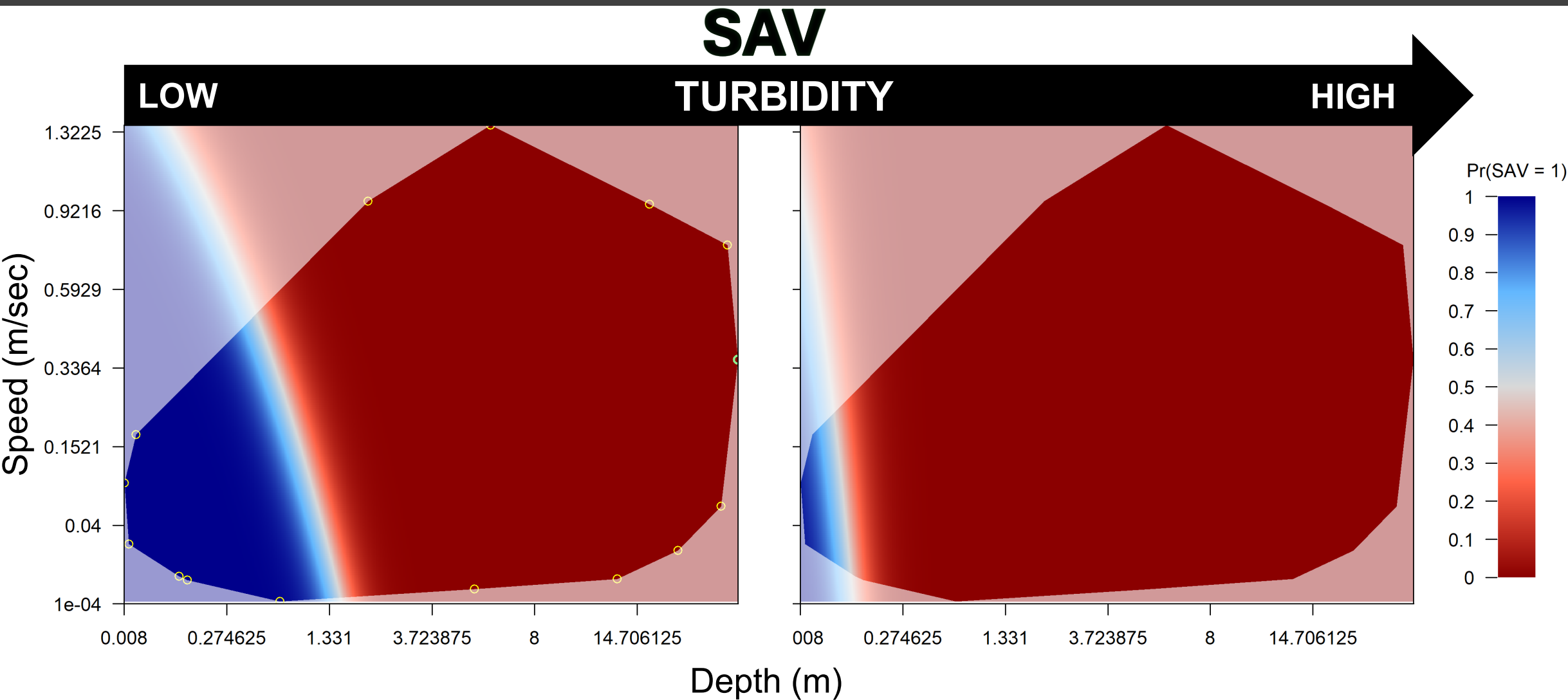
Functioning
Monthly
Model

More
accuracy
assessments
needed.
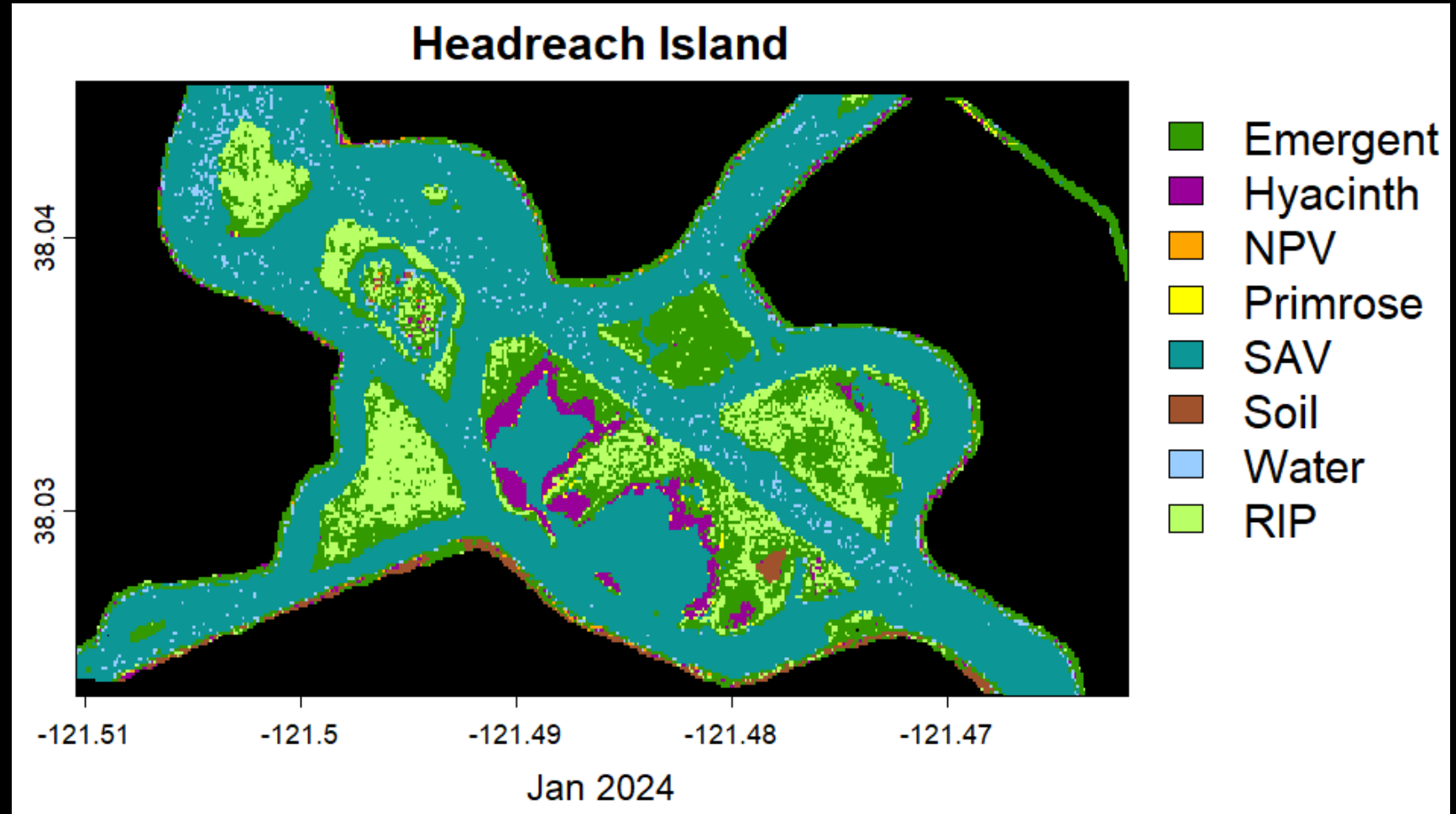
How to interpret heat maps

Simulate **probability of occurrence** for all possible **environmental combinations**

The dimmed areas represent combinations we did not have data to train the models

P(SAV = 0)
0% Probability of Occurrence

P(SAV = 1)
100% Probability of Occurrence

Speed (m/sec)

Depth (m)

Pr(SAV=1)

Goal 2: SDM Results

Goal 3: Mapper Tool Progress

- Working shiny app prototype (TinyShiny)
  - Basic plotting of Class
  - Interactive
  - Accessible to stakeholders/end users on github
  - Starting point for end user feedback

- Not necessarily final format of deliverable

PLEASE CONTACT US IF THESE MAP MAY BENEFIT YOUR DECISION MAKING!!!!!
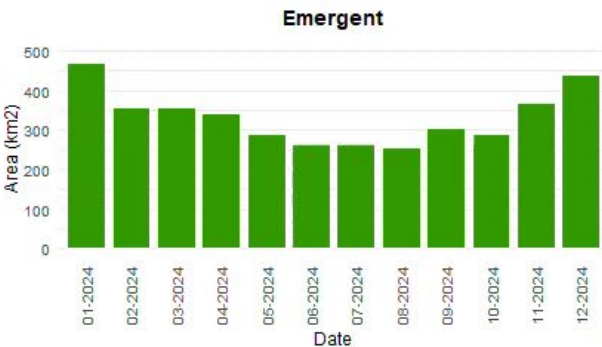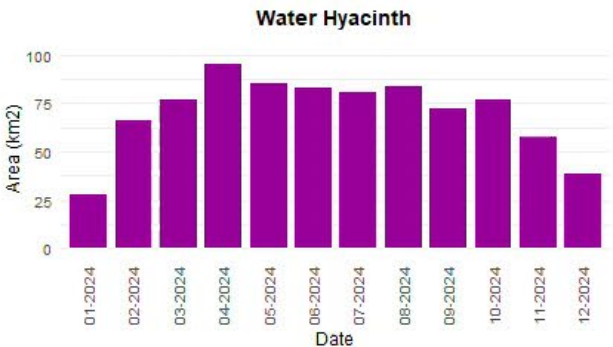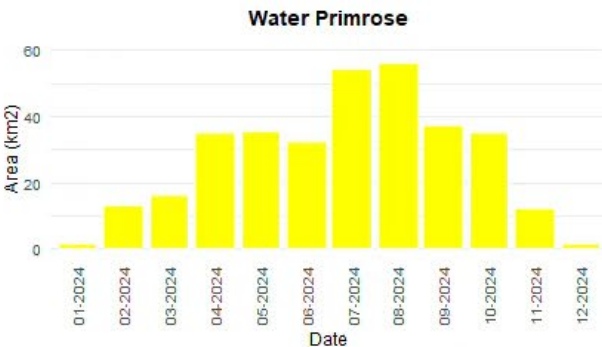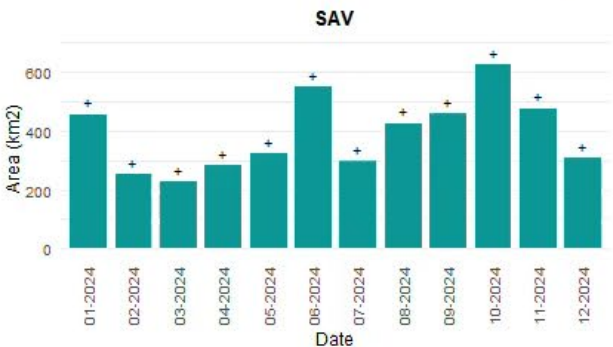
Goal 3: Mapper Tool Progress
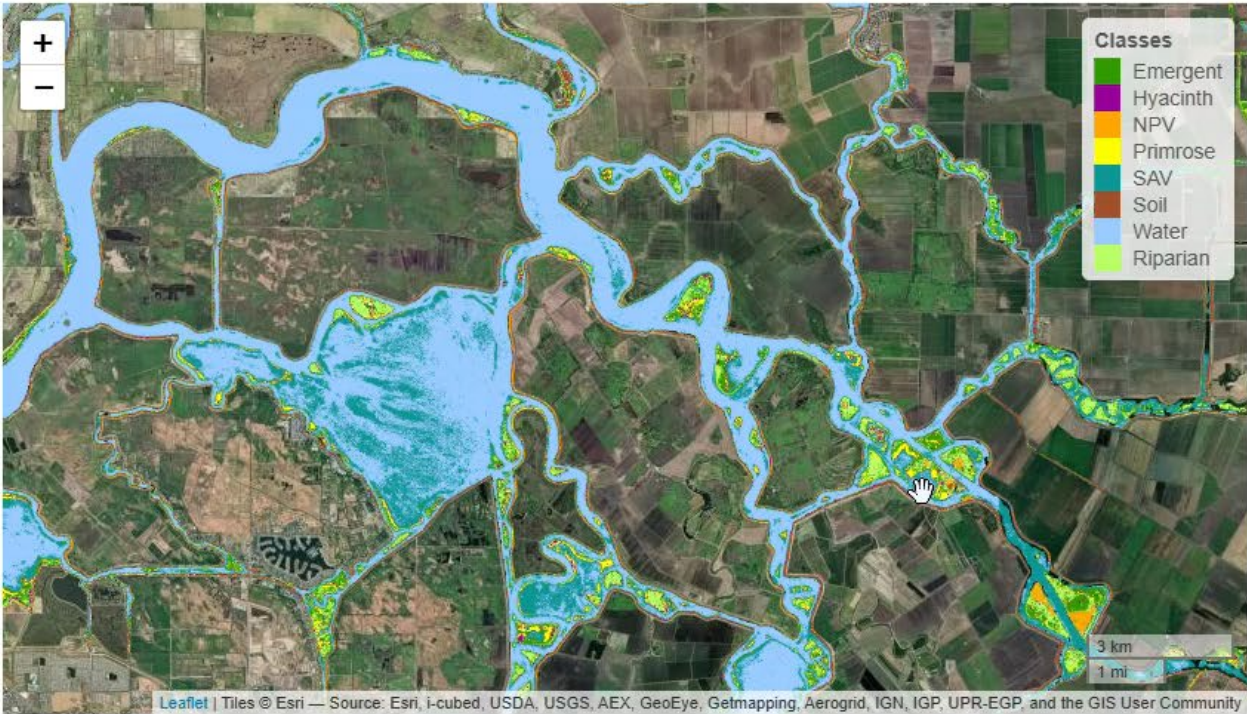
Summary Slide

- Goal 1: Operationalize S2 Class Mapper
  - Improved classification model(s)
  - Now generating monthly class maps

- Goal 2: SDMs to Assess IAV Responses to Management Actions
  - Working model
  - Developing scenarios for forecasting

- Goal 3: Co-Develop IAV Class Mapper/Tools
  - Prototype up and running
  - Co-development with End Users starting in Early 2026

Thank You
Questions?

Contact Info:
bmorrison3@ucmerced.edu