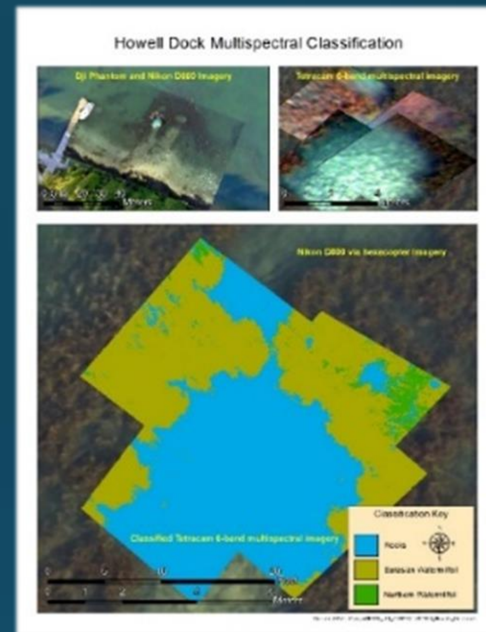
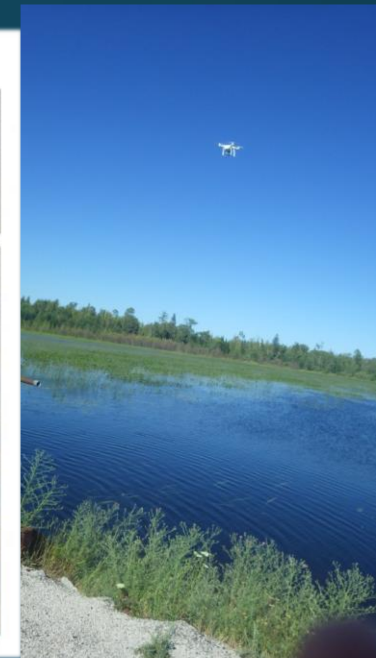
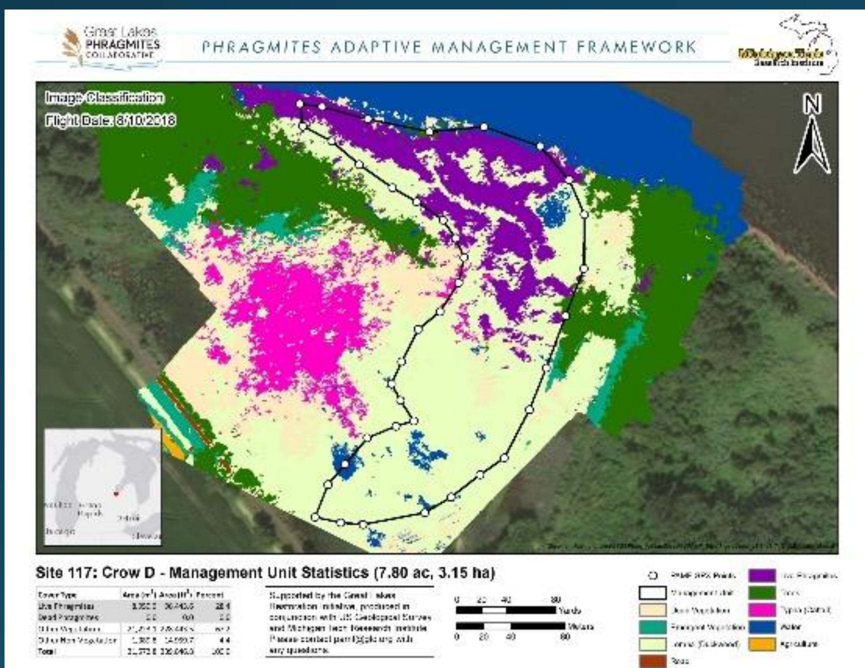
Remote sensing surveillance of invasive aquatic plants







Great Lakes PHRAGMITES COLLABORATIVE

Great Lakes Research Center
Michigan Technological University

DEPARTMENT OF NATURAL RESOURCES DNR MICHIGAN

Great Lakes RESTORATION

USGS
science for a changing world

Great Lakes Commission des Grands Lacs

Michigan Tech Research Institute

Regional Invasive Aquatic Plant Surveillance Best Practices Workshop, February 2023

Remote sensing options for monitoring

- Invasive species can be monitored via multispectral remote sensing at a few different general scales:
  - Moderate-resolution satellite (e.g., Landsat)
  - High-resolution satellite (commercial satellites like WorldView)
  - UAV-borne sensors
- Each have different tradeoffs depending on the characteristics of your target species and your monitoring area
- Early detection of small IAP patches requires the higher spatial res of commercial satellites or UAV

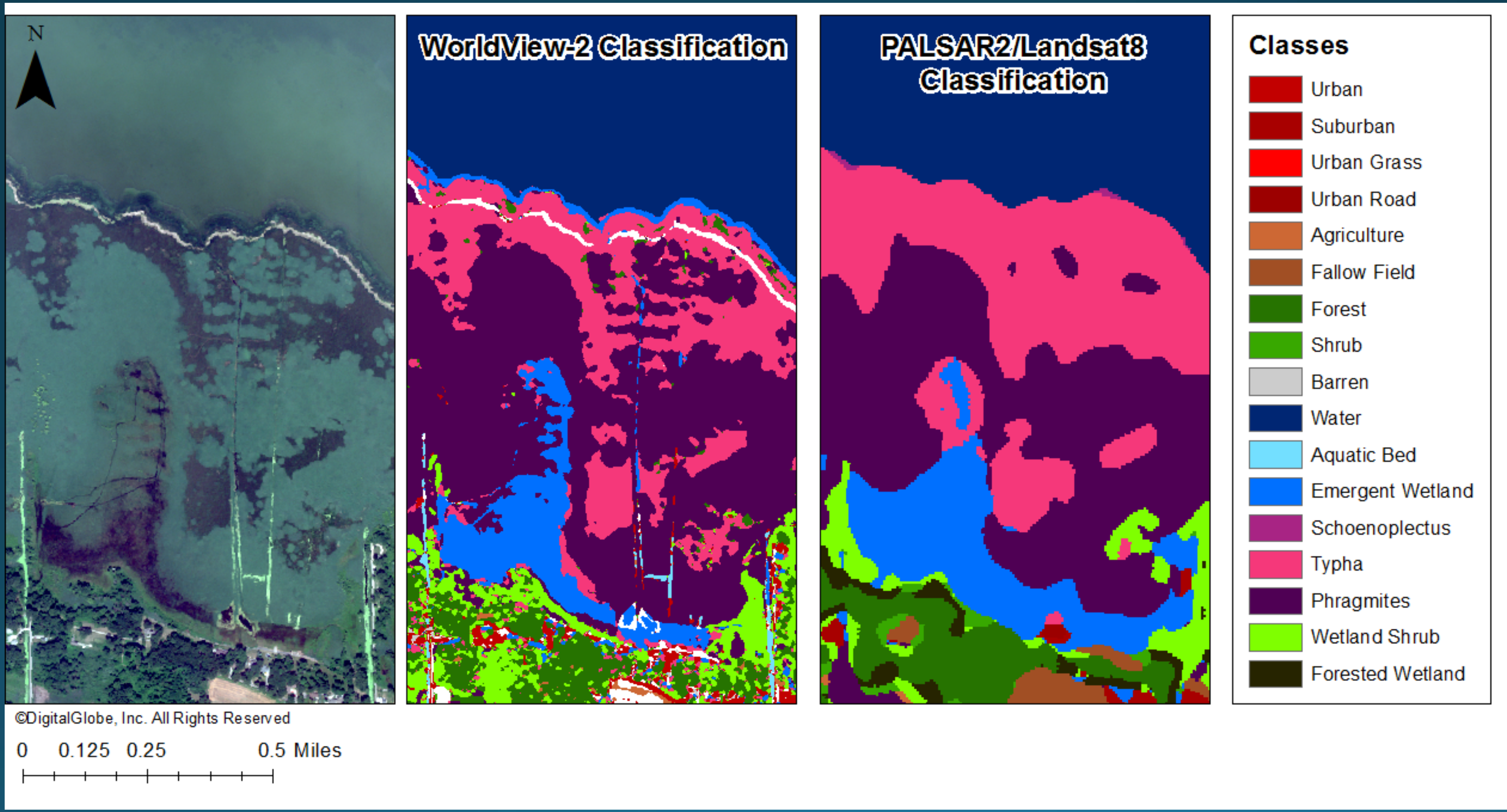
Case 1: *Phragmites*

- Examples from project "*Mapping and Monitoring of Invasive Phragmites in the Coastal Great Lakes Using Remote Sensing Data from Multiple Platforms*" funded by USGS Great Lakes Science Center
- PI: Laura Bourgeau-Chavez, Ph.D.

USGS science for a changing world

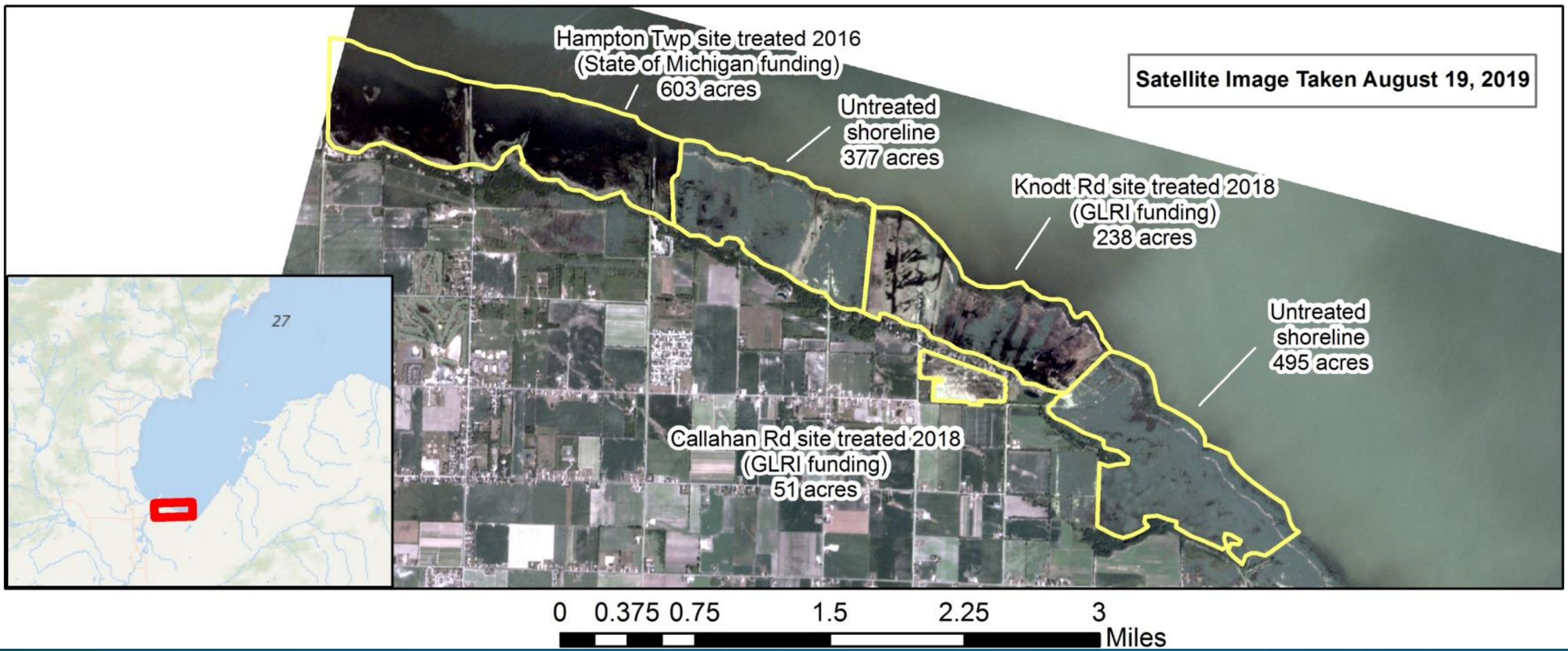
Satellite mapping

Commercial satellites can provide finer spatial resolution but have a significantly higher cost (although work that involves/is funded by federal agencies can access commercial imagery through the Civil Applications Committee)



Classified images of the same area along Saginaw Bay based on imagery of different resolutions

Example WorldView commercial satellite image of *Phragmites* treatment area



- ~1 meter pixels, 13 km swath
- Daily revisits

UAV (drone) imagery mapping

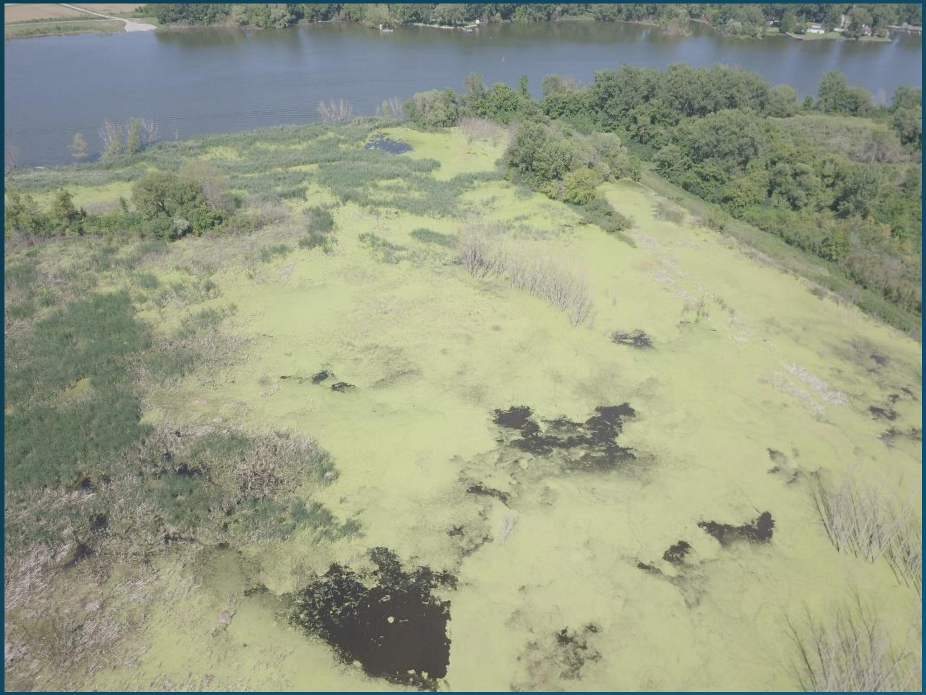
- UAVs: DJI Mavic Pro and Phantom 3 Advanced
- Flight altitude: 100 m
- Auto flight used to ensure adequate image overlap
- Camera: built-in 12-megapixel RGB

Nadir image (looking directly down) of Site 124

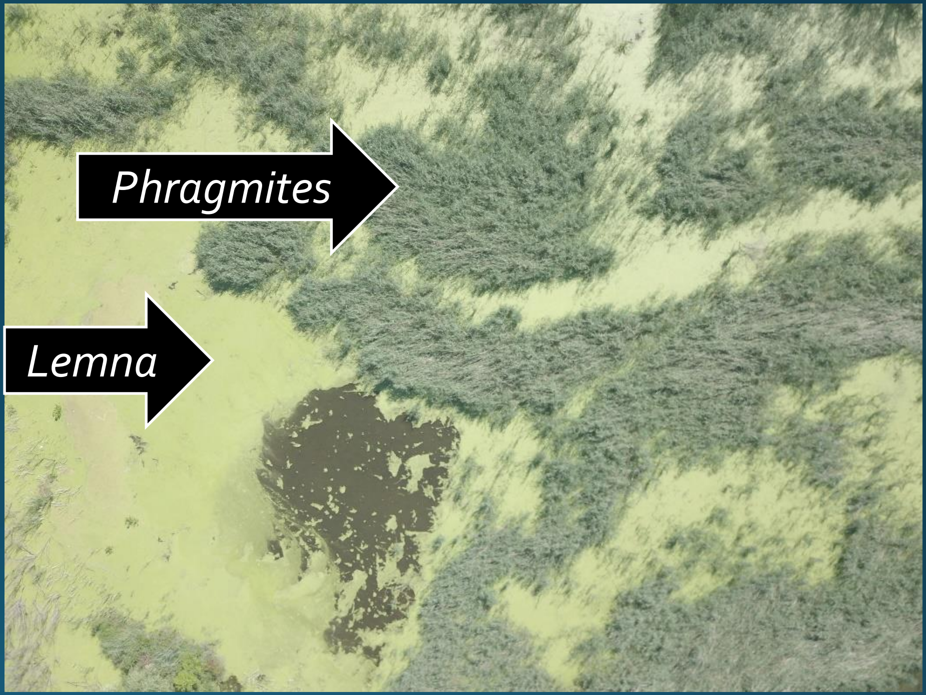
DJI Mavic Pro at Site 70

MTRI staff flying the Phantom 3

Example UAV images of PAMF site



Site 117 Oblique



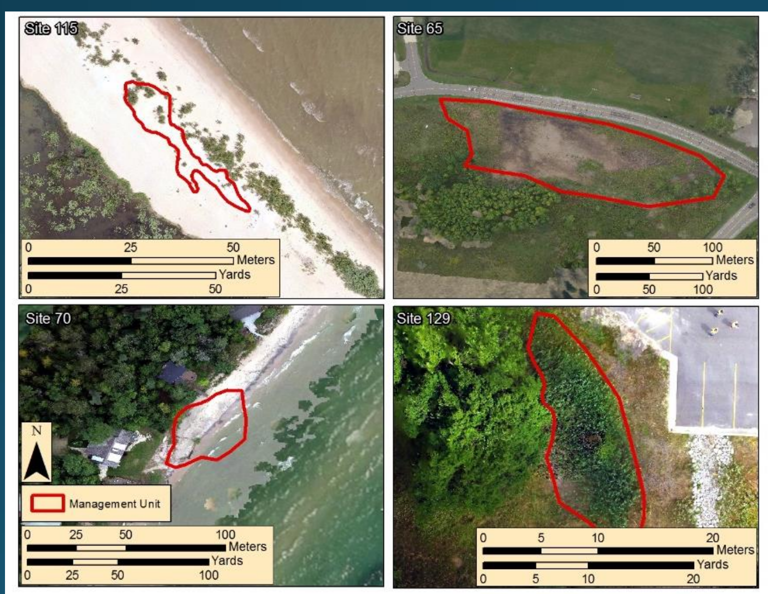
Site 117 Nadir

Methodology Overview

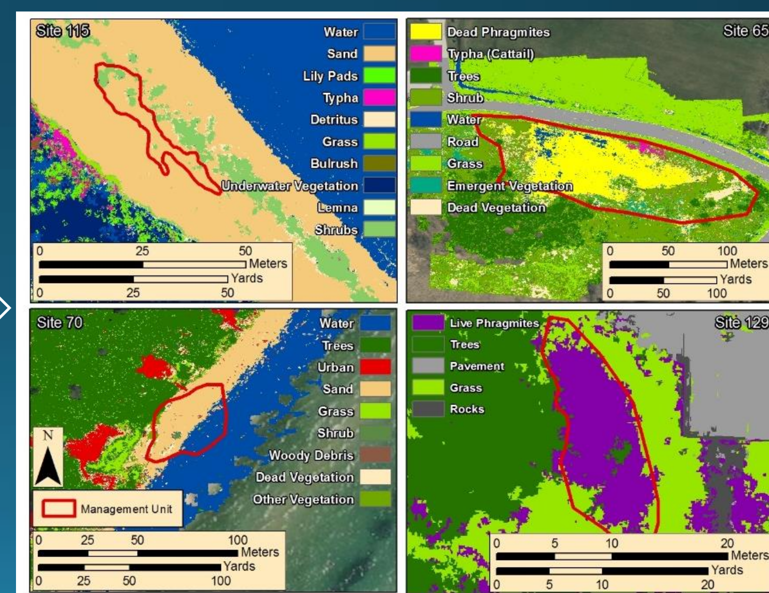
Data Collection
- UAV or satellite imagery
- Coincident vegetation characteristics

Data Processing
- UAV: Orthophotos, digital surface model
- Satellite: mosaicking, georeferencing, radiometric correction, normalization

OBIA Classification
- Image segmentation
- Select training samples
- Define statistics
- Classify & assess accuracy



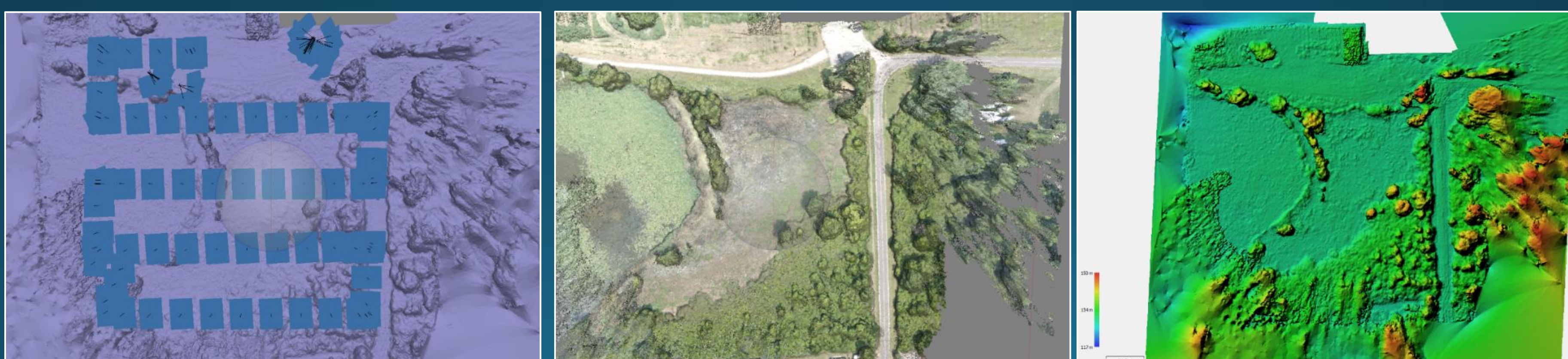
Overview images at four sites



Overview classifications at four sites

UAV Data Processing

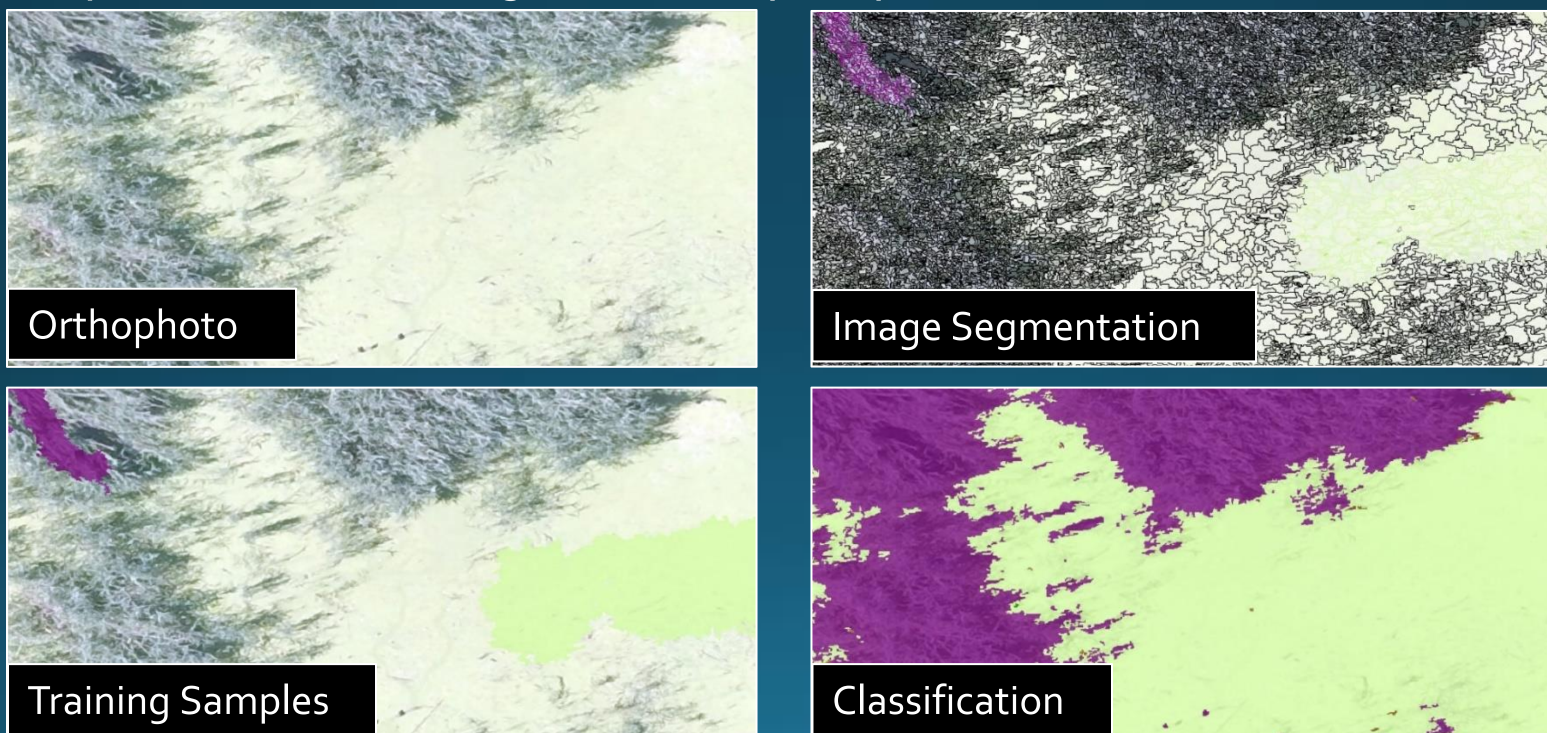
- UAV image processing done using Agisoft
- Images aligned to create overview orthophoto mosaics
  - Merged composite image georeferenced to the site's location
  - Image resolution: 3 cm
- Generated digital surface models (DSM) of elevation
  - Image resolution: 13 cm



Screenshots of imagery processing steps in Agisoft

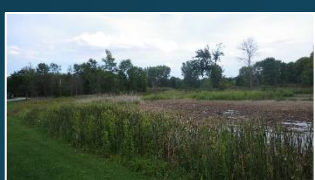
Classification

- Object-based classification performed using eCognition
  - Nearest neighbor algorithm
  - Metrics (classification criteria) used: mean pixel value for each band, VARI (visible atmospherically resistant index), mean and standard deviation of elevation from surface model, segment size/shape/texture, etc.
  - **Output: Measurement of *Phragmites* cover to quantify treatment effectiveness**



Phragmites
Lemna (Duckweed)

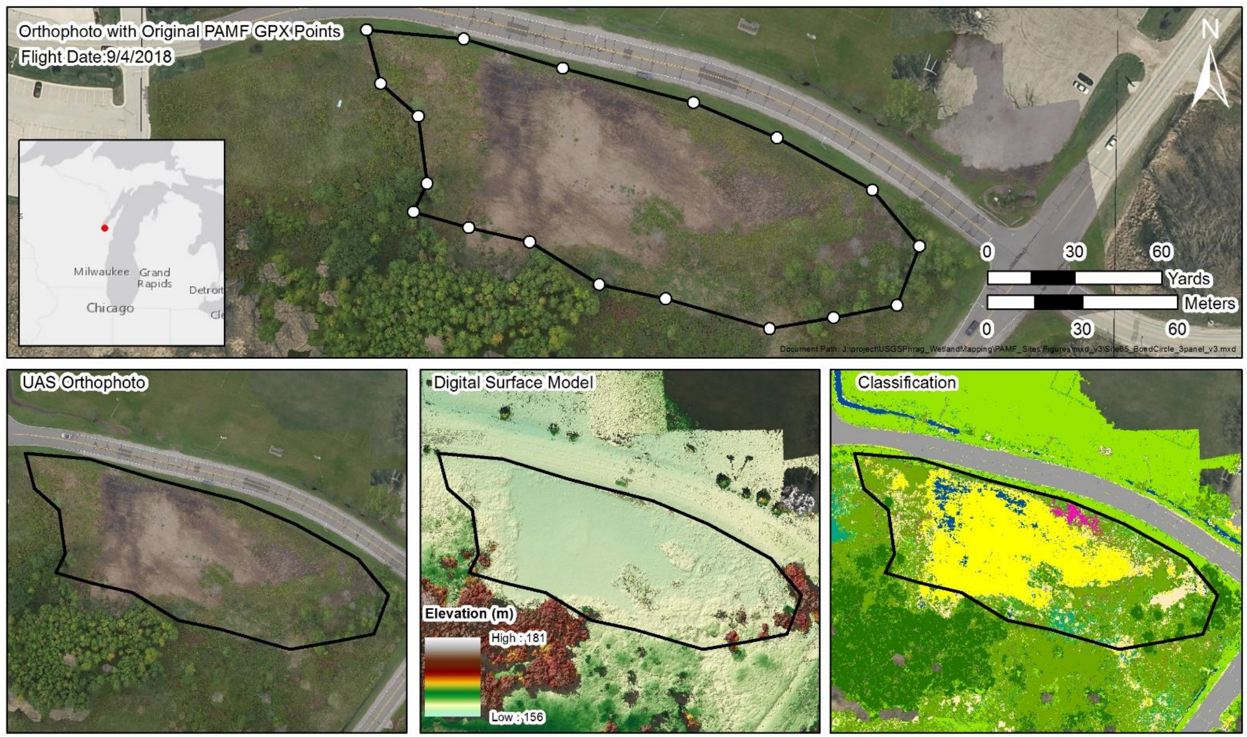
Example results: UAV monitoring of a PAMF site



Great Lakes PHRAGMITES COLLABORATIVE

PHRAGMITES ADAPTIVE MANAGEMENT FRAMEWORK

Michigan Tech Research Institute



Site 65: - Management Unit Statistics (2.22 ac, 0.89 ha)

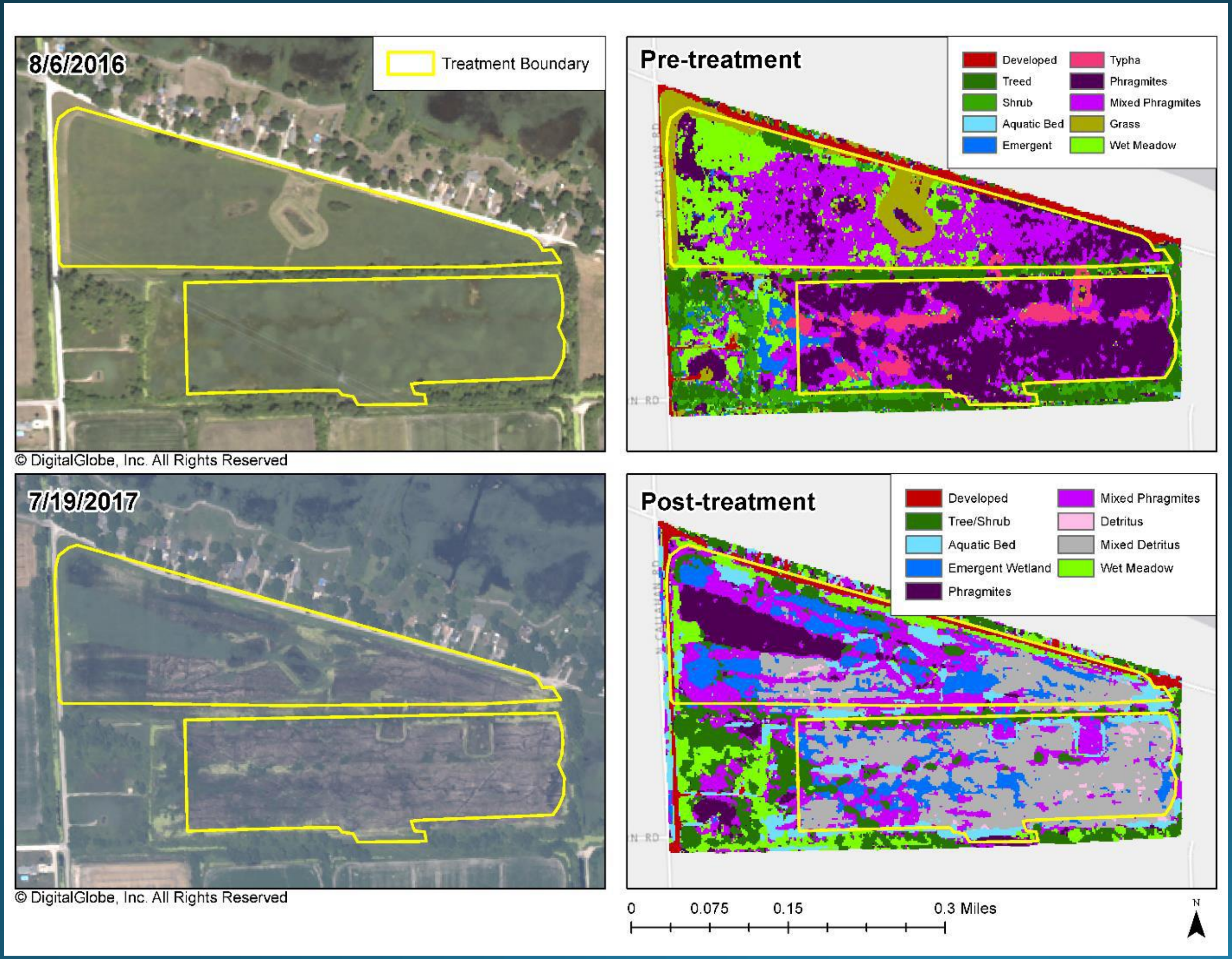
Cover Type	Area (m^2)	Area (ft^2)	Percent
Live Phragmites	0.0	0.0	0.0
Dead Phragmites	3,438.8	37,014.9	38.2
Other Vegetation	5,237.7	56,378.1	58.2
Other Non-vegetation	318.2	3,425.1	3.5
Total	8,994.7	96,818.1	100.0

Supported by the Great Lakes Restoration Initiative, produced in conjunction with US Geological Survey and Michigan Tech Research Institute. Please contact pamf@glc.org with any questions.

0 50 Yards
Meters 0 50

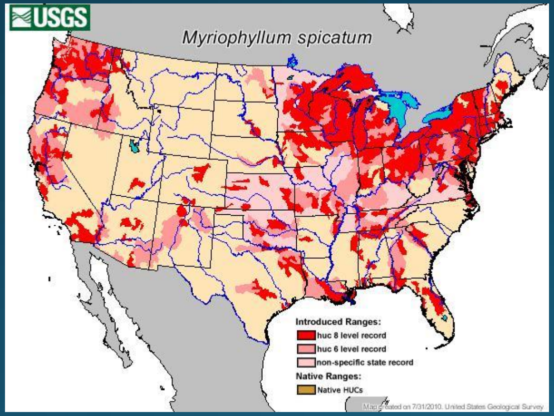
Management Unit
Dead Phragmites
Typha (Cattail)
Trees
Shrub
Water
Road
Grass
Emergent Vegetation
Dead Vegetation

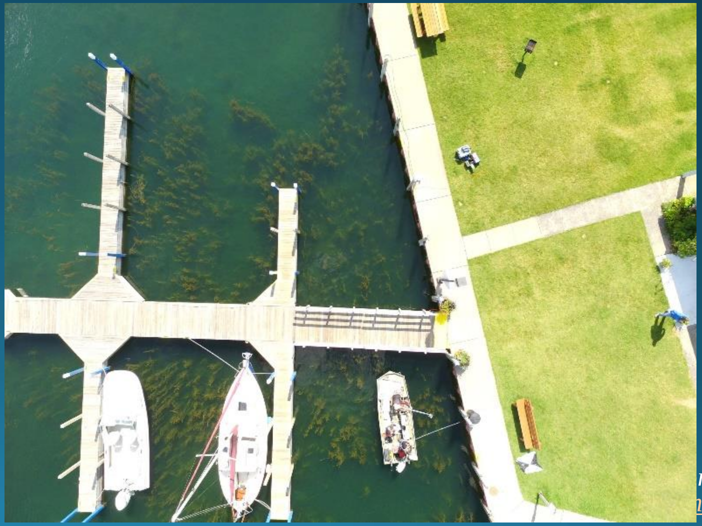
Example results: Commercial satellite monitoring before/after *Phragmites* treatment



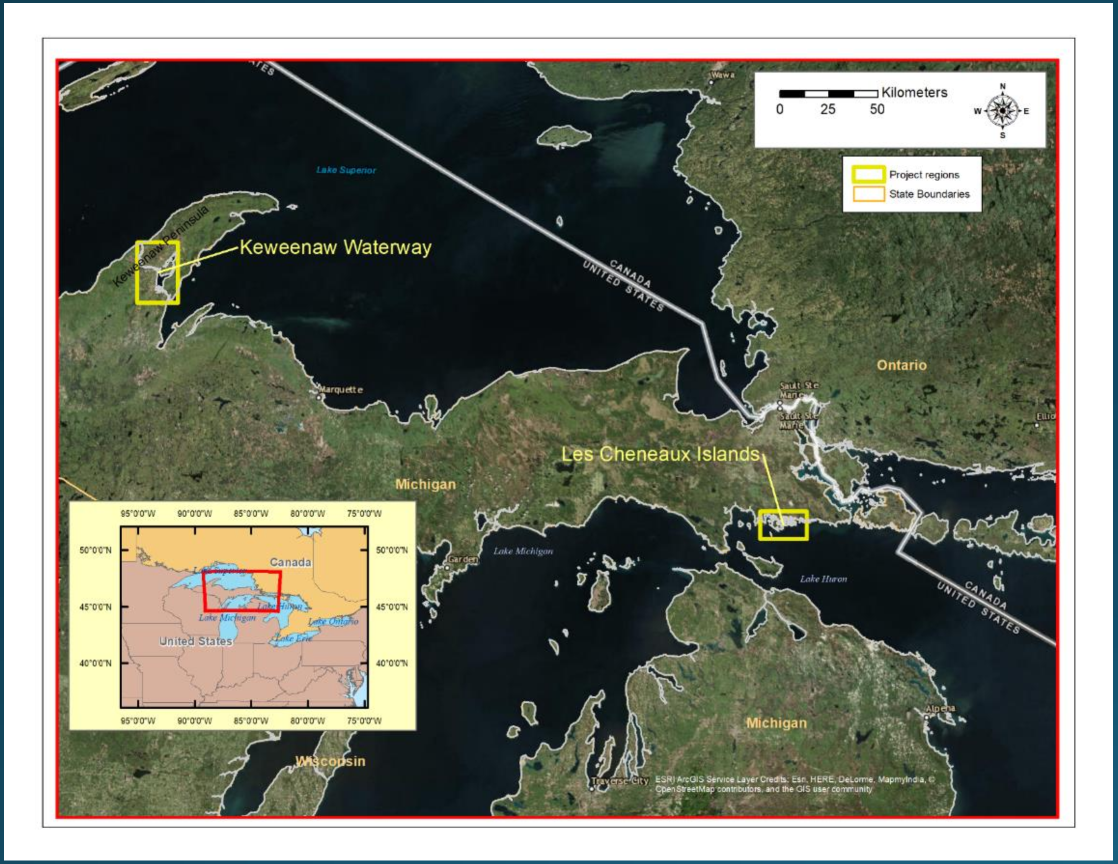
Case 2: Eurasian watermilfoil

- Eurasian watermilfoil (**EWM**) *Myriophyllum spicatum* and its hybrids, or collectively invasive watermilfoil (**IWM**)
- PI: Colin Brooks, Ph.D.





Data Collection Areas for IWM projects



– Keweenaw Waterway (Pike Bay)

– Les Cheneaux Islands (NW Lake Huron), 2015, 2016, 2017, 2018

Methods: UAS (drones)


- Michigan-manufactured Bergen hexacopter with 30 minute flight time, 5 kg payload
- DJI Phantom very useful for collecting basemap of site

Boat-deployable platforms: the ~1 m diameter Bergen Hexacopter (left) and 350 mm DJI Phantom
15-20 minutes flight time, ~300m to 1 km radius, 15-30 ha

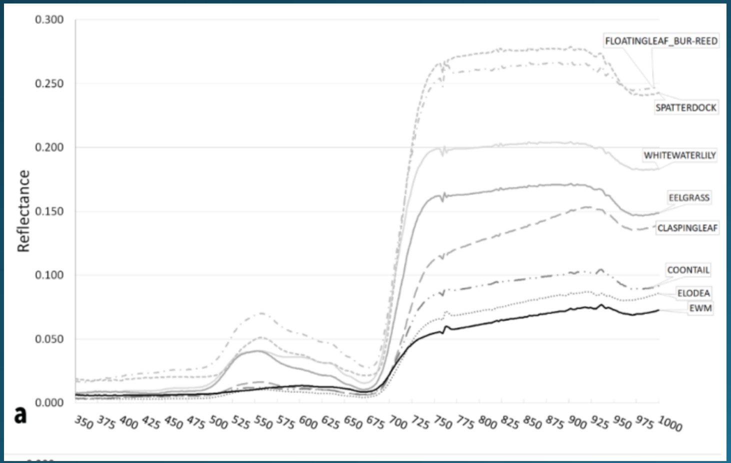
DJI Phantom has an integrated RGB camera

Methods: Spectral profiles

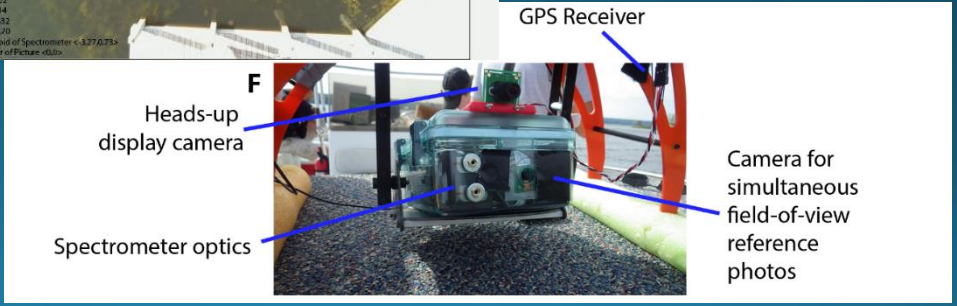
- Initial question: is IWM spectrally distinguishable from other submerged plant species?
- Collected out-of-water, boatside, and UAV-based spectra to compare the spectral signatures of IWM and other species at different scales
- Used both a traditional ASD backpack Fieldspec3 spectrometer and portable OceanOptics STS *lightweight portable radiometer* (LPR) developed by MTRI
- Visible + NIR range

Collecting boatside spectra

Reference photo overlaid with the footprint of the spectrometer at the water's surface

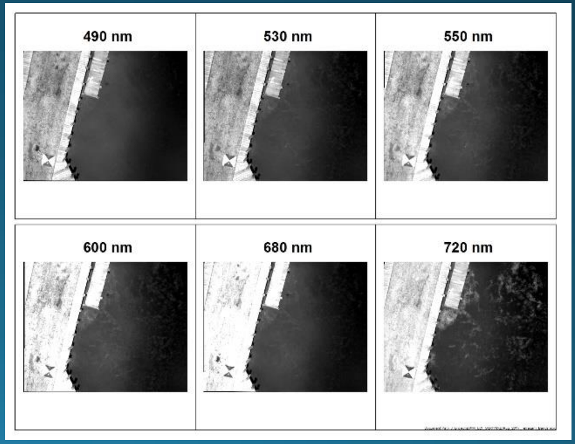


LPR system

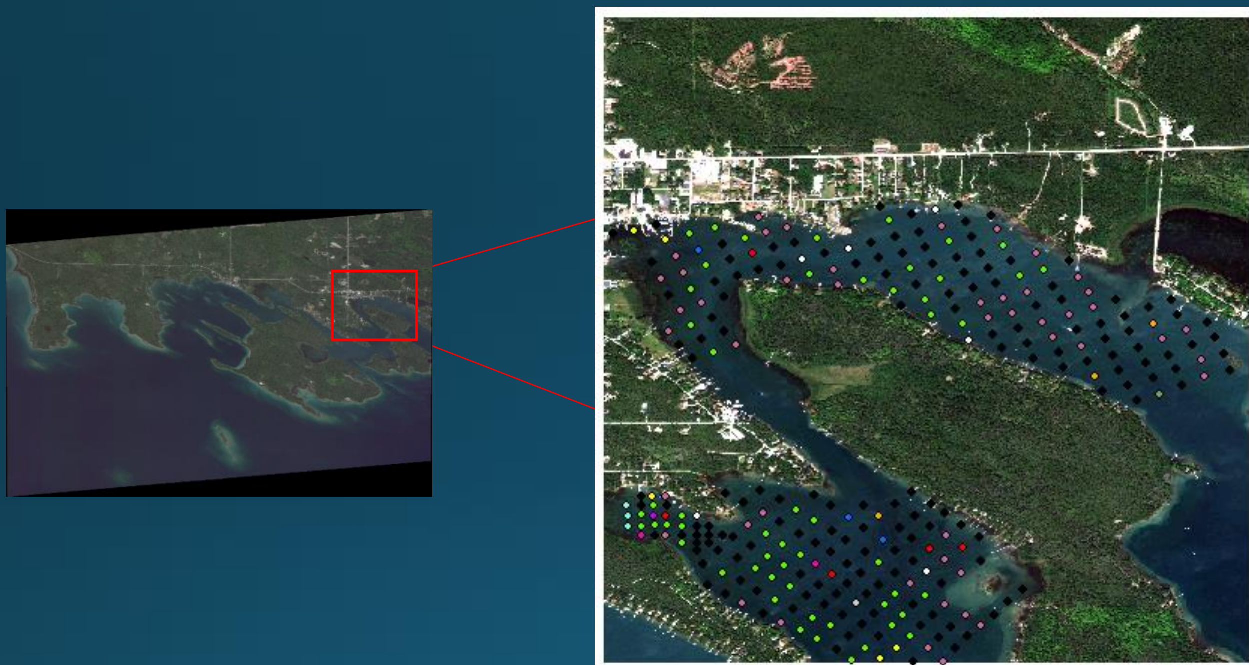


Methods: two multispectral cameras

- Tetracam Micro-MCA, 6 imaging sensors, 1.3mp CMOS
- Default bands, but can request custom filters
  - Standard are 490, 550, 680, 720, 800, 900 nm
  - Operated in Les Cheneaux Islands using 490 (blue), 530 (green 1), 550 (green 2), 600 (yellow/orange), 680 (red) and 720 (red edge) nm filters more suited to aquatic mapping
- GPS input capability & incident light sensor for radiance calibration
- Also tested MTRI-built 4-band (RGB + near infrared) “VISNIR” two-camera system



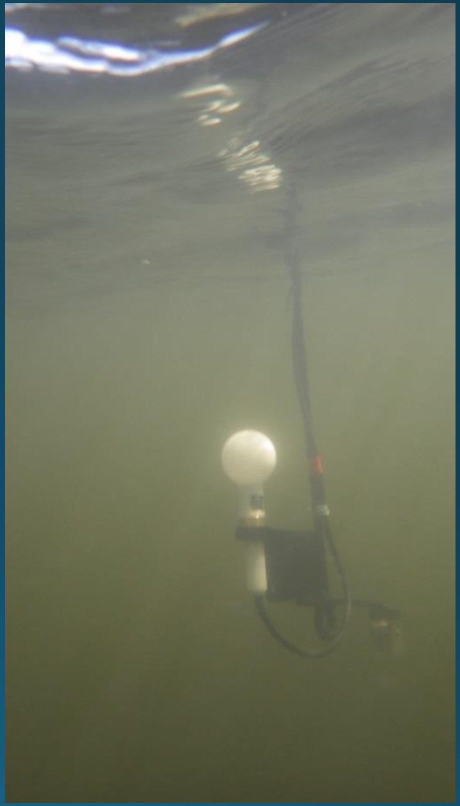
Point intercept field data



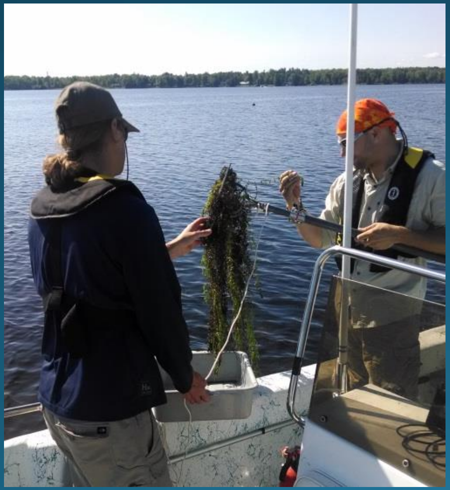
- Field observations (rake toss) collected by trained surveyors
- ‘Field truth’ for training classification

Field vegetation/water data collection

Rake toss sampling



Twist rake sampling



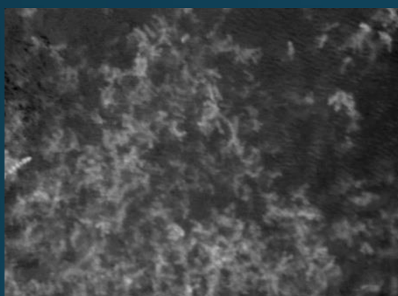
Sonde

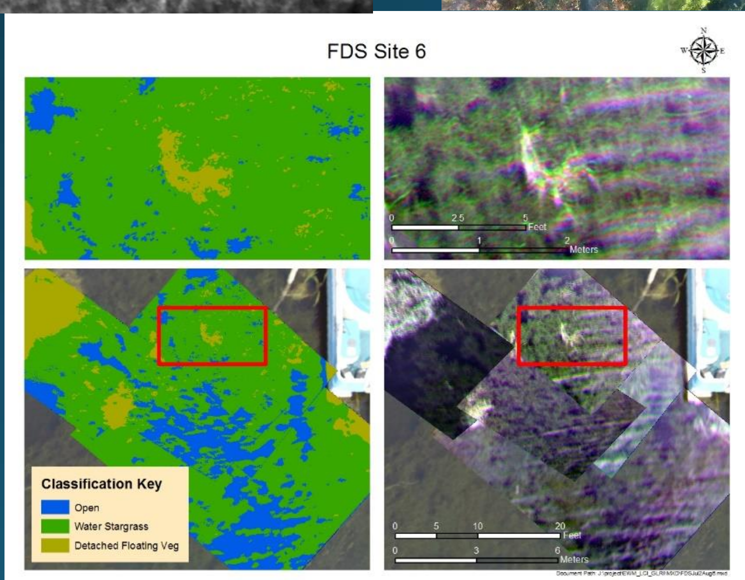
LI-COR light meter

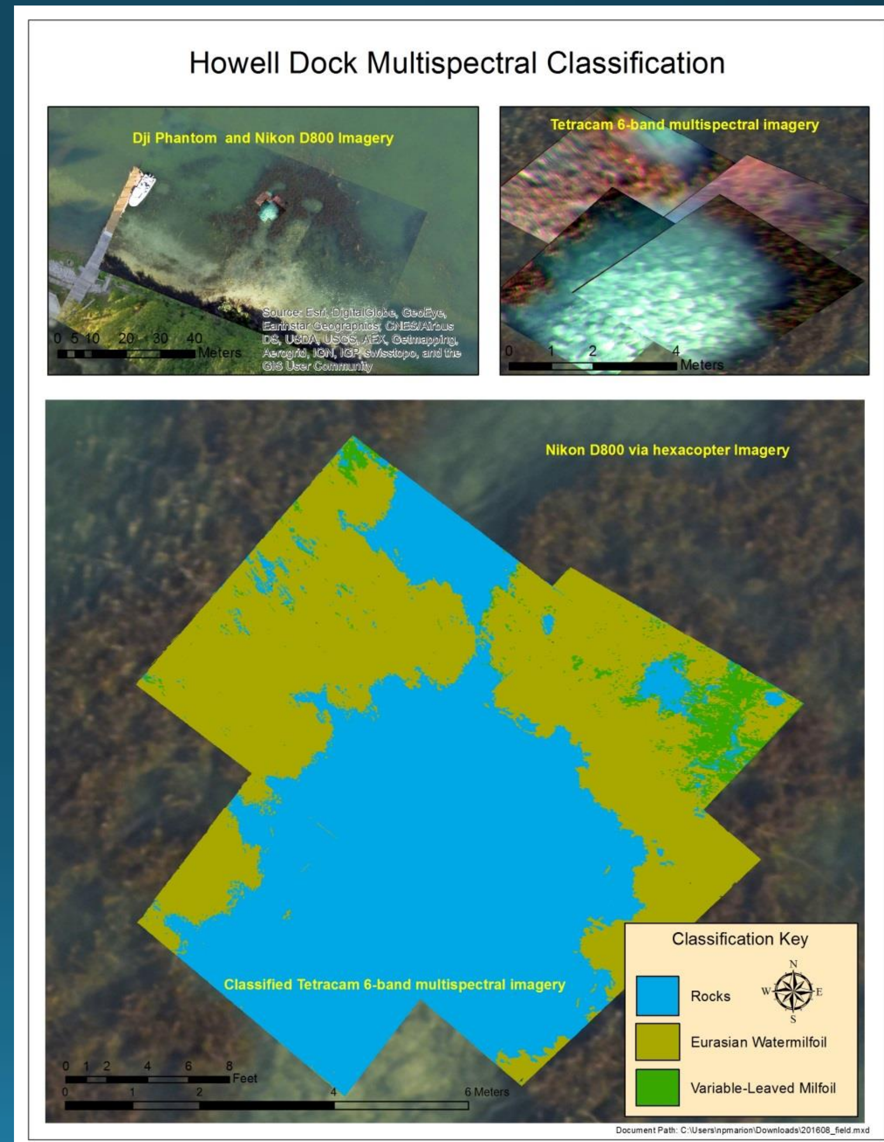
Characterize the water (chl, sm, doc), vegetation (species/frequency/biomass) & light levels (a/b, SDT)

Tetracam 6-band multispectral camera results

Given favorable conditions, the 6 narrow Tetracam spectral bands can enable differentiation between EWM and the desirable native milfoil present at Les Cheneaux

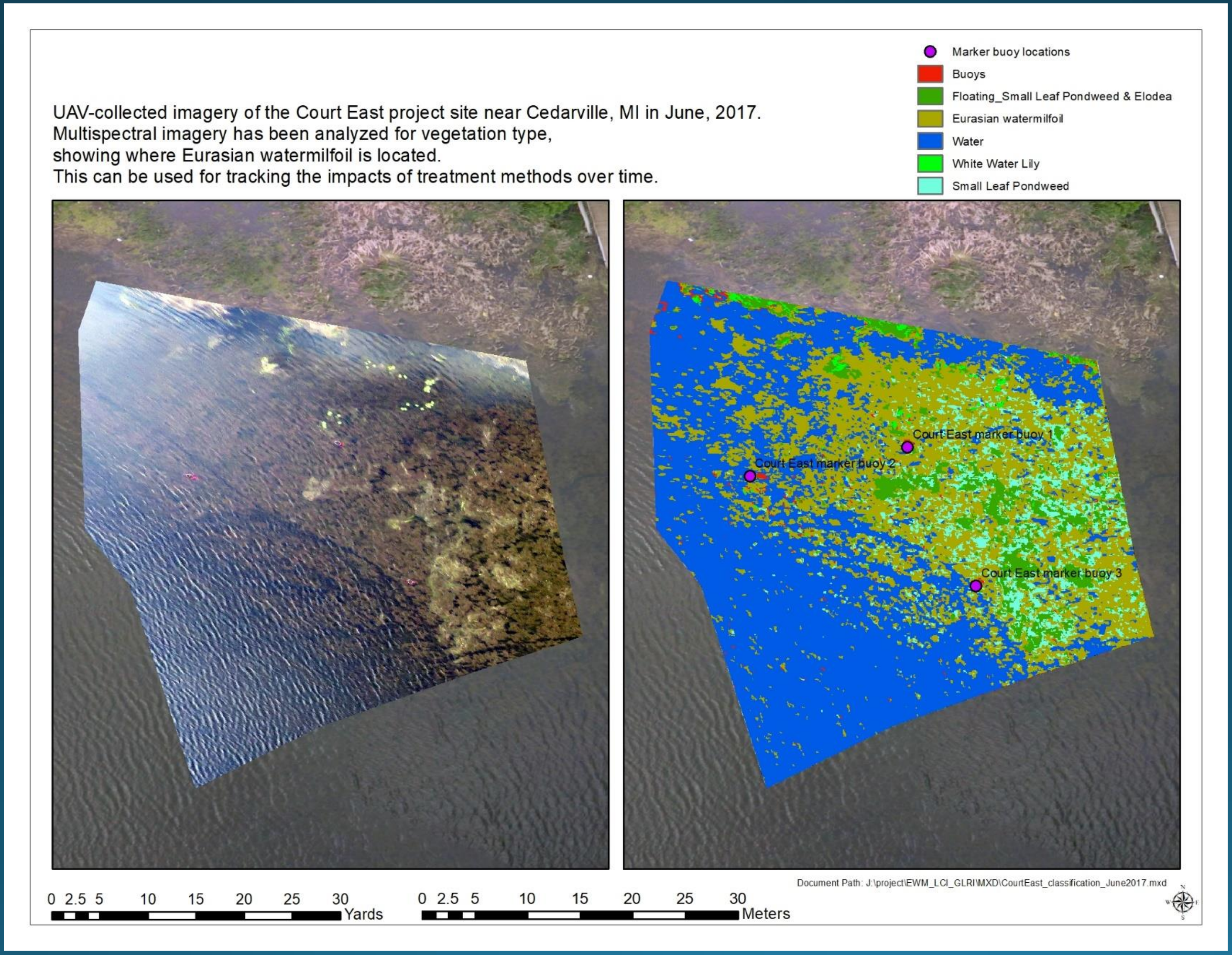






VISNIR two-camera low-cost system example results

Multispectral imagery mapping results – EWM is distinguishable



Comparison of Benefits of Remote Sensing/Mapping with commercial satellite vs. UAV imagery

Source	Resolution	Cost of Imagery	Areal extent	Processing time	Flexibility	Other limitations
Commercial satellite multispectral imagery	~1 m	High, Low to zero for Federal Agencies/partners	Daily regional coverage priced per sq. km.	Low	Collection limited by cloud cover and satellite orbits	Resolution may not be high enough to distinguish spectrally similar species, especially underwater
UAV-based imagery	~3cm	High initial hardware/training cost, then mostly labor	A single flight can cover ~15-30 ha	Medium	High but cloud cover still reduces image quality, esp. for submerged targets	Higher SNR than satellite; UAV must stay in pilot's line of sight; excluded from no-fly areas

Contact

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(Phragmites/wetland mapping, radar)
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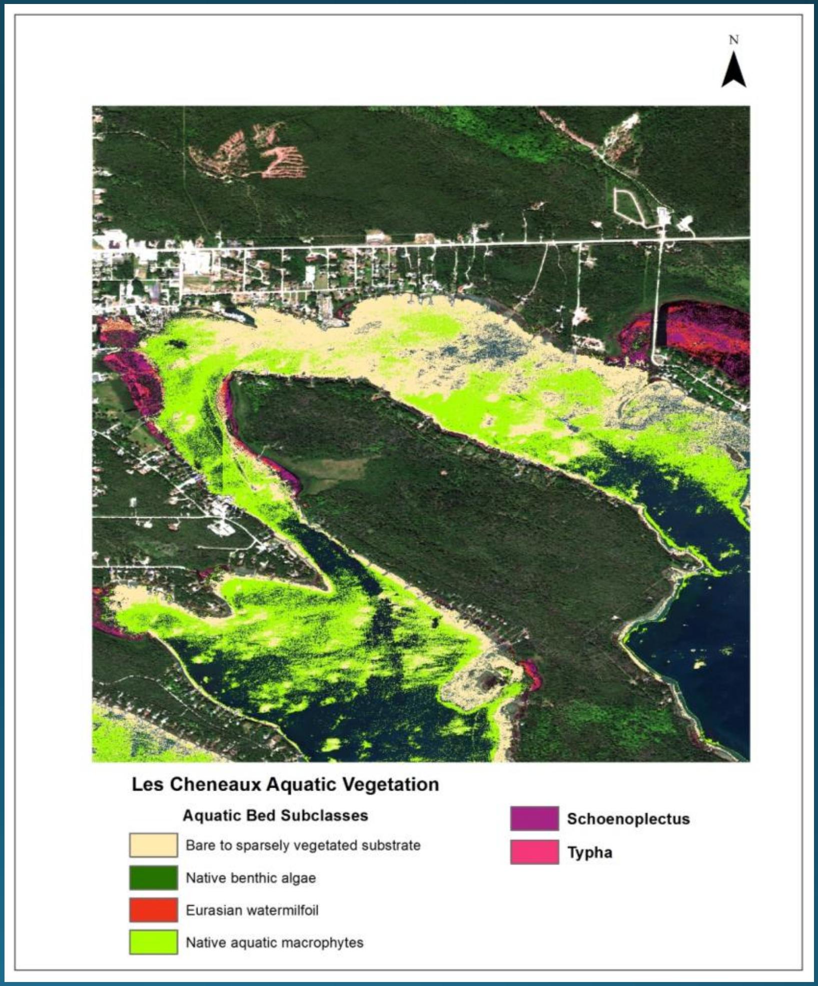
Other considerations for using remote sensing for IAP detection/monitoring

- Site characteristics
  - Especially useful for sites difficult to access on foot/via boat
  - Sensing of submerged vegetation limited by water clarity
- Target characteristics
  - Many species are more easily detected during specific seasonal windows
  - Submerged vegetation species are spectrally very similar; the very high spatial resolution available from drone data can help, but more than RGB imagery is usually needed
  - Emergent and floating plants (Phragmites, Typha, European frogbit, loosestrife) and to a lesser extent species such as IWM or *Hydrilla* that form near-surface canopies are better candidates for UAV monitoring, especially for inland water bodies with lower water clarity

Mapping results

- A lot of field data needed to produce satellite-based EWM extent map with acceptable classification accuracy

	Bare	Schoenoplectus	Algae	EWM	SAV (non-EWM)	Typha	ACTUAL	PRODUCER'S ACCURACY
Bare	5	0	0	0	0	0	5	100.0%
Schoenoplectus	2	1	0	1	0	0	4	25.0%
Algae	8	0	25	0	0	0	33	75.8%
EWM	0	0	0	3	0	0	3	100.0%
SAV (non-EWM)	0	0	0	0	38	0	38	100.0%
Typha	0	0	0	0	0	4	4	100.0%
PREDICTED	15	1	25	4	38	4		
USER'S ACCURACY	33.3%	100.0%	100.0%	75.0%	100.0%	100.0%		
TOTAL ACCURACY		87.4%						

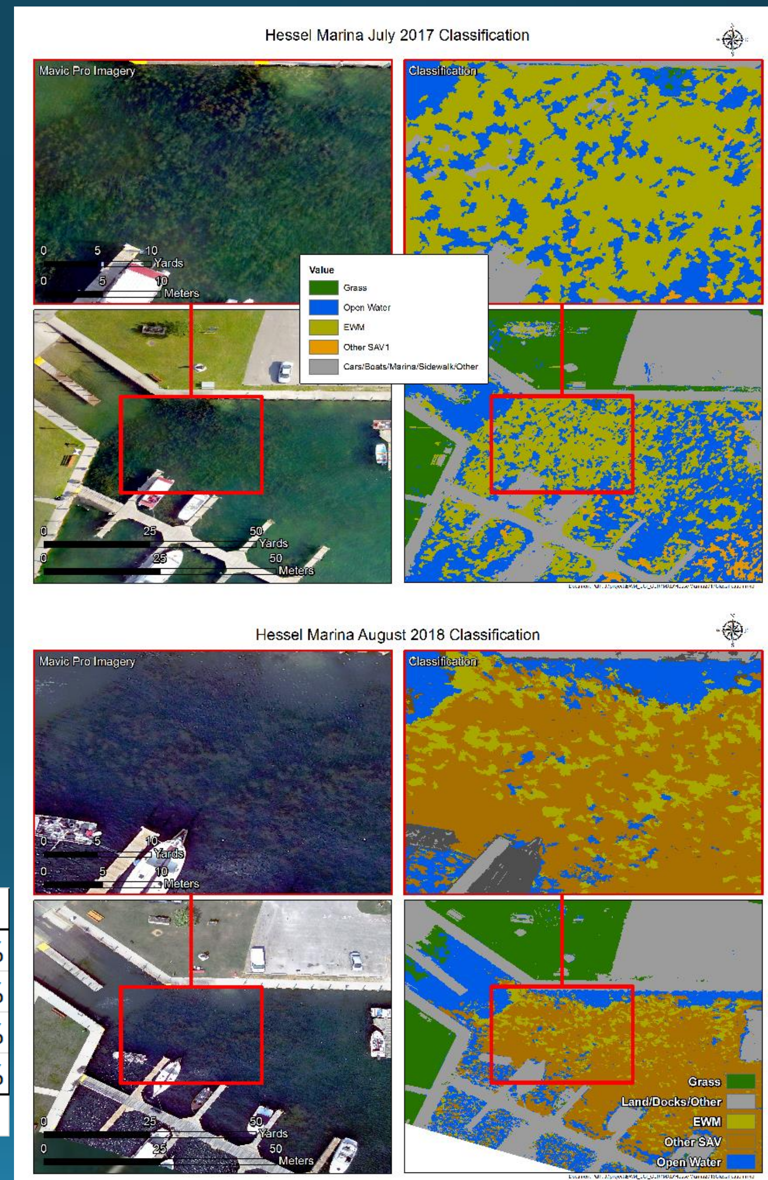


Evaluating Mt fungus treatment sites

- Mt fungus applied late July, 2017 (7/28/17)
- Visited application areas in early season, midseason, and almost 4 weeks (26 days) after application
- Partners at Les Cheneaux Watershed Council visited up to 70 days later
    - Up to 70% biomass decline 70 days later; not seen at untreated site
- Revisited in Aug. 2018 – what do these sites look like 1 year later? Long-term effect?

Cover type	July, 2017	% of area	Aug., 2018	% of area
Open Water	1918.39	30.3%	566.96	9.0%
EWM	3769.85	59.6%	1041.906	16.6%
Other SAV	109.10	1.7%	4175.084	66.4%
Cars/Boats/Other	529.24	8.4%	501.89	8.0%
	6326.59		6285.84	

Area units are in ft²



Classification Schematic