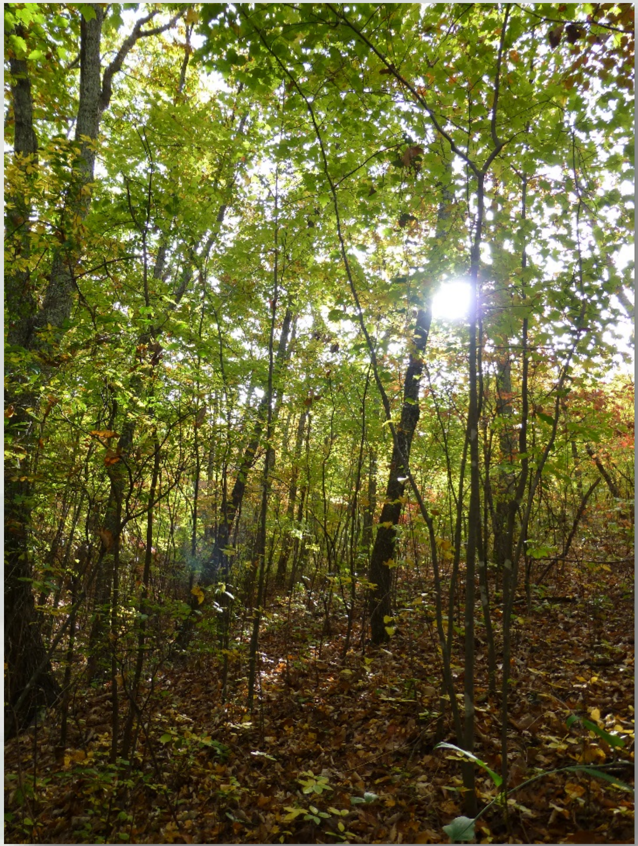
Monitoring Framework for Upland Hardwood and Grassland Restoration:

Integrating Innovative Spatial Technology



Heather Theel, Molly Reif,
US Army Engineer Research and Development Center (ERDC), Environmental Laboratory

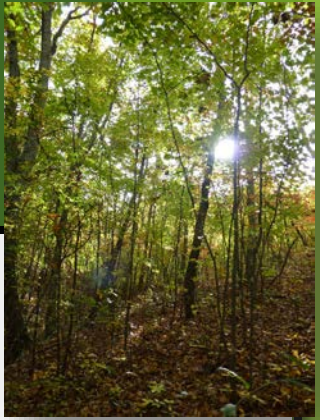
and

Robin Tillitt
(US Geological Survey, Columbia Environmental Research Center)

May 11, 2016
DOI National Restoration Workshop

GUHM Partners

(Grassland and Upland Hardwood Monitoring)



Project Partners:

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Overview

- Background
  - Universal Metrics vs. Goal Based Objectives
- Project Questions
- Approach
- Monitoring Framework for Upland Hardwoods and Grasslands
  - Traditional Field Surveys vs. Innovative Spatial Technology
- 2016/2017 Field Sampling Plan

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Restoration Science Support Need

- The need/importance of restoration monitoring is well documented (Hooper et al 2016)

Restoration Science Support Need

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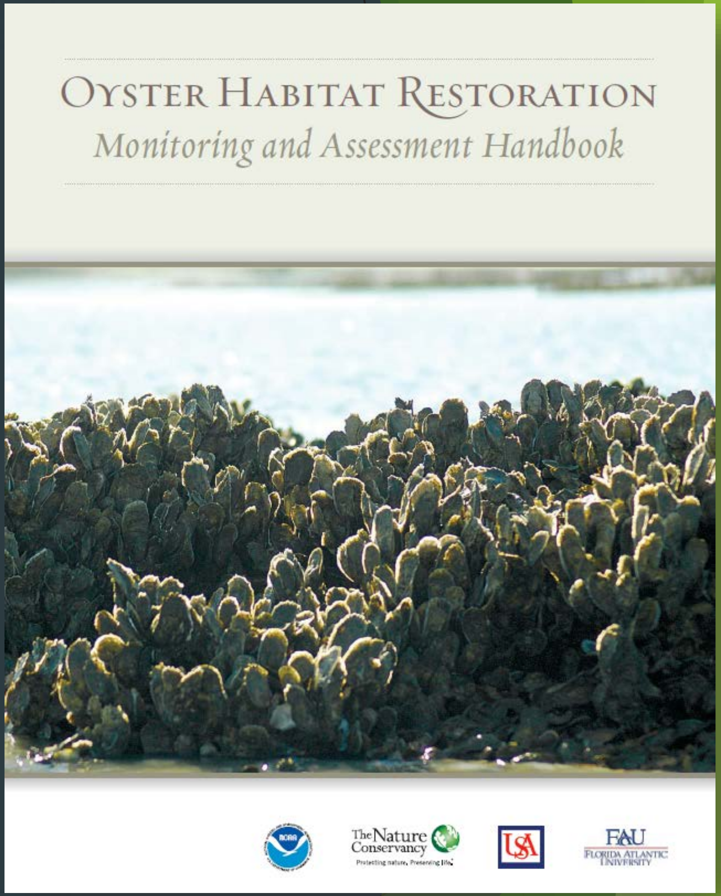
Restoration Science Support Need

- Restoration Science is trending towards the concept of Universal Metrics (Baggett et al 2014)
  - Lack of monitoring data
  - Unclear restoration goals/objectives
  - Therefore, unable to assess population changes



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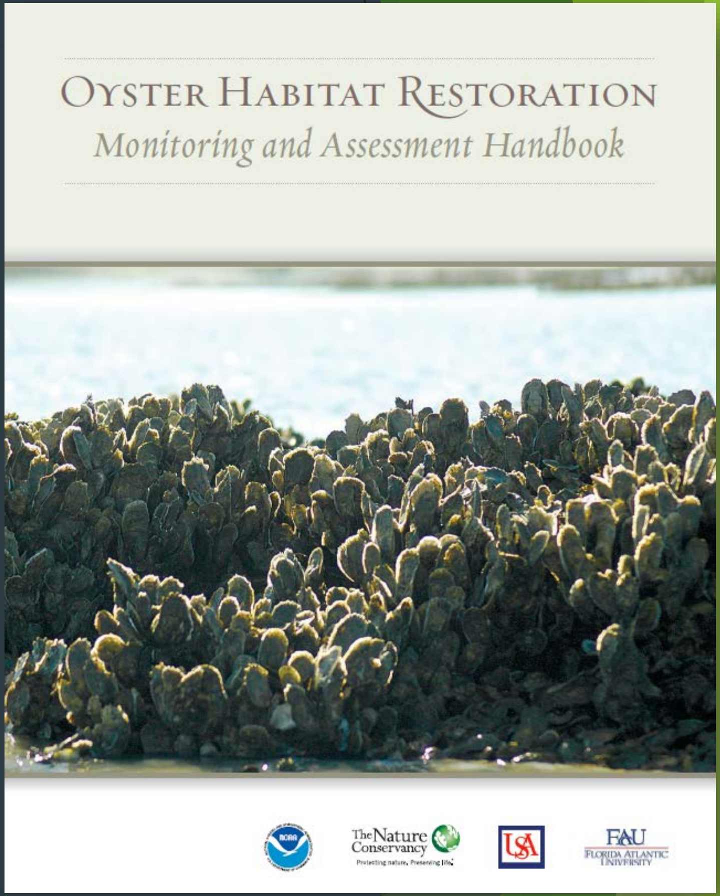

Lack of change detection = Unsuccessful Restoration

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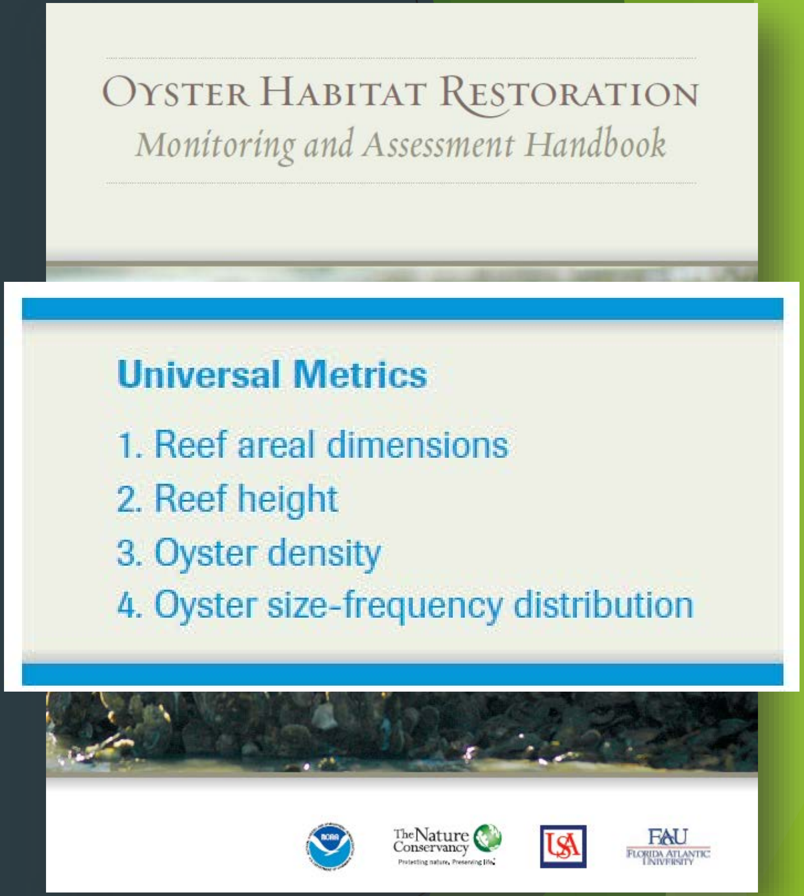
Utility of Universal Metrics

- Systematic Assessment of Basic Restoration Performance
- Consistent
- Comparable
- Simplified, Reduces burden

- May not adequately address goal-specific performance



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Definitions (Baggett et al 2014)

- **Universal metrics:** Metrics and variables that should be sampled for each habitat-specific restoration project

- **Goal-based Metrics:** Metrics that are specific to ecosystem service-based restoration goals and should be sampled for projects citing that particular restoration goal

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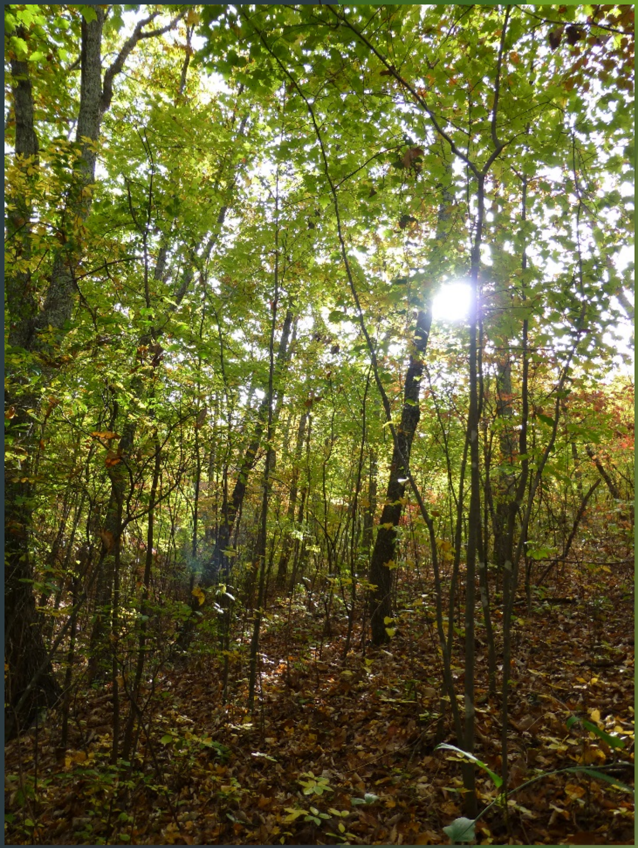
GUHM Project Questions

- What are common measures and/or metrics in the literature to monitor the basic performance of upland hardwoods and grassland restoration projects?
  - Traditional Field Based
  - Remote Sensing
- What are the advantages/disadvantages (precision, level-of-effort, etc.) between common monitoring metrics?



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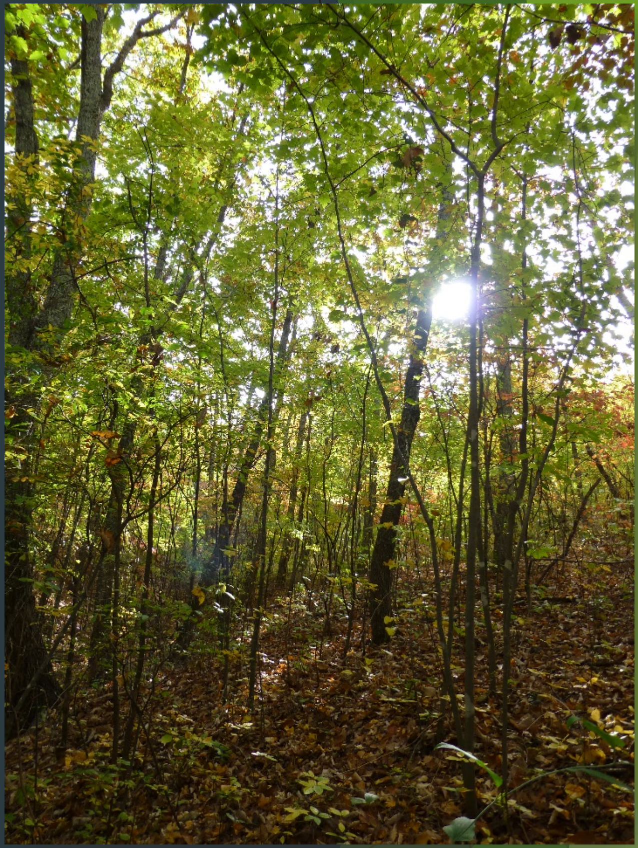
GUHM Project Approach

- Phase 1 (2015/2016):
  - Literature Review
    - Traditional Field Based
    - Remote Sensing

  ★ Reif, M., and H. Theel. *In Review.* Remote Sensing for Restoration Ecology: Application for Restoring Degraded, Damaged, Transformed, or Destroyed Ecosystems.

  - Draft Monitoring Frameworks for Upland Hardwood and Grassland Restoration Projects
  - Field Sampling Plan
- Phase 2 (2016/2017):



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Monitoring Framework

- Objective:
  - To develop habitat-specific restoration monitoring frameworks that provide universal metrics for evaluating restoration performance at varying levels of precision
- General Approach:
  - Compilation of Universal Monitoring Metrics
  - Tiered Precision (3 levels)
  - Traditional Field Based vs. Remote Sensing
  - Universal Environmental Metrics
  - Universal Human Use/Recreation Checklist

Upland Hardwood Draft Monitoring Framework

- Using the literature, the team is developing a tiered framework with the following kinds of information:

Upland Hardwood Site

Tier One (Universal Metrics for all Hardwood Restoration)							
Metric Type	Calculated Metrics 1-Structural Metrics 2-Compositional Metrics 3-Ecosystem Service Metrics	Field Collected Data	Methodology (plot size, distribution, and number of samples will be determined by consultation with statistician)	Level of Effort (estimates for field personnel hours and/or data processing hours)	Sampling Guidelines Post implementation Timeframe (Early, Mid, Late) Frequency (estimated time between sampling events for measurable change)	Precision (determined by confidence required/desired by practitioner and restoration objectives)	Product

- The tiers represent increasing levels of precision to meet the wide range of NRDAR needs. For example:
  - **Tier 1.** Structural and compositional metric for trees is % cover
  - **Tier 2.** # Trees/Hectare, Basal Area/Hectare (m^2/ha), and snag Density (# snags/ha)
  - **Tier 3**. Tier 2 plus survival

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Why Integrate Remote Sensing?

- Role of RS has increased with the advent of new sensors, improved technology, decreasing costs, and global increases in protected land area

- Increased need for rapid and remote ways to examine the effectiveness of restoration strategies

- Spatial measurements can be used to quantitatively assess restoration objectives in four main areas: 1) habitat extent and landscape structure, 2) habitat degradation, 3) biodiversity, and 4) threats/pressures

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Remote Sensing Examples

Medium Resolution Sensors
5-30 m

Applications

- Broad-scale land cover or habitat type/pattern
- General biodiversity or species richness
- Rapid change detection or loss/gain
- Seasonal/multi-year changes
- Overall forest extent clearance/regeneration
- Overall degradation or disturbance from fire grazing, drought, etc,
- Broad biophysical estimates from band ratios (NDVI, etc)
- Landscape metrics (landscape and class level), such as fragmentation

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Remote Sensing Examples

High Resolution Sensors (<5 meters)

Satellite, Airborne, UAS (multispectral and hyperspectral)

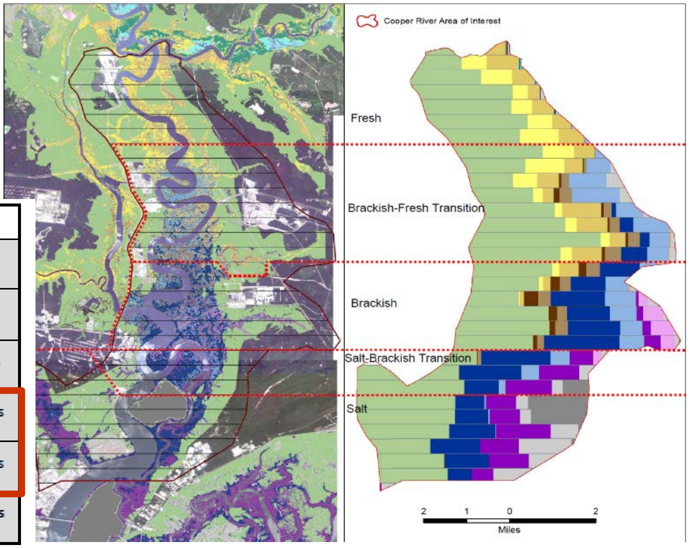
Applications

- Fine-scale land cover or habitat type/pattern
- Species mapping
- Composition/abundance, distribution
- Biodiversity/species richness
- Detailed degradation or disturbance (some invasive species, pest attacks, fire, grazing, etc)
- Individual feature delineation (e.g. tree crowns)
- More detailed biophysical estimates (NDVI, NPP, LAI, etc)
- Landscape metrics (landscape, class, and patch level)

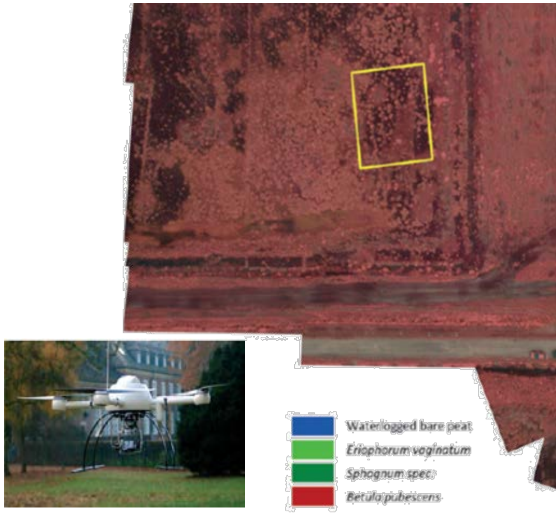
Detailed habitat abundance to assess potential project impacts for restoration planning

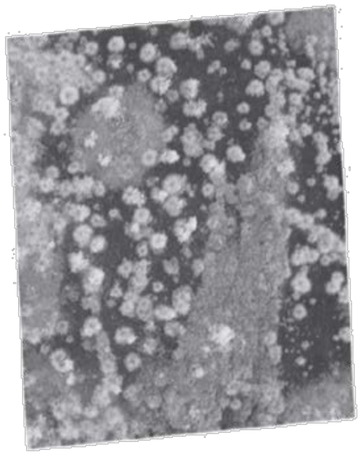
- High resolution satellite imagery provided through internal agency agreement

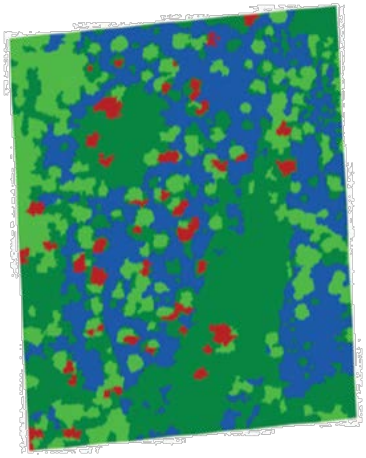
	Average Wetland Impacts (All Four Scenarios)	
Wetland Impacts	50/48	52/48
Ashley River forested wetlands	3.52 acres	4.36 acres
Ashley River marsh wetlands	10.86 acres	13.16 acres
Cooper River forested wetlands	89.65 acres	126.37 acres
Cooper River marsh wetlands	127.57 acres	179.83 acres
Total	231.60 acres	323.72 acres



Detailed species mapping in a restored blog complex







Knoth et al. (2013)

Remote Sensing Examples

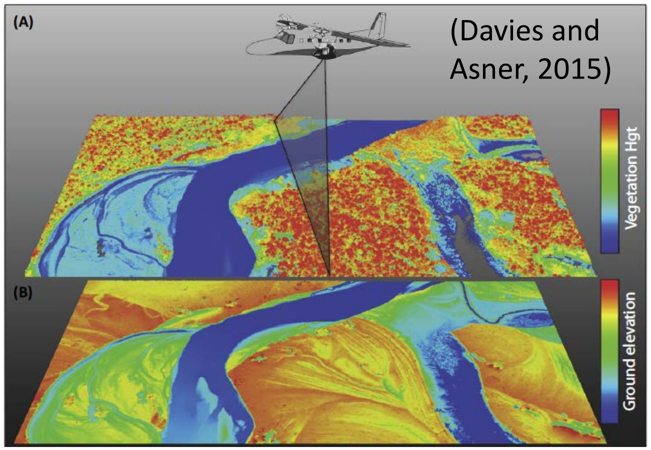
Active Sensors

Lidar and Radar

Applications

- Detailed vegetation structure, biomass, and height characteristics
- Combined with imagery for improved species identification
- Assist with biophysical estimates, detailed 3-D, height, LAI, biomass, age, succession, regeneration, and composition

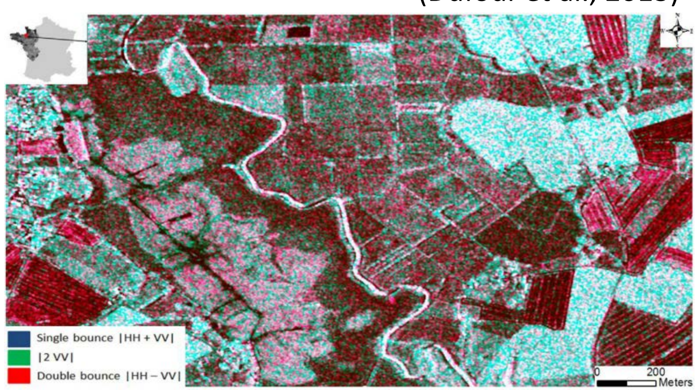
Lidar products: ground surface, canopy surface, and canopy height models, and intensity images



(Davies and Asner, 2015)

Radar backscattering and intensity to characterize riparian vegetation properties: size, orientation, and structure

(Dufour et al., 2013)



Structural Attributes related to Birds/Bats

Structural attribute	Response
Vegetation	
Canopy heterogeneity	22 (out of 44) species occupancy increased with increasing heterogeneity
	Two (out of 44) species occupancy decreased
	Species richness increased
	Bat activity and occurrence increased
Canopy vertical distribution	Two species (out of two) increased abundance and/or occupancy with increasing vertical distribution
	Species diversity increased
Canopy height	Chick mass increased in blue tits, decreased in great tits, was climate dependent for great tit chick mass (increased in warm springs, decreased in cold springs) with increasing height
	Native to exotic species ratio increased with increasing height
	Species richness (forest species richness increased, scrub species richness decreased)
	21 (out of 49) species abundance and/or occupancy increased with increasing height
	Nine (out of 49) species abundance decreased
	Species diversity increased
	Bat activity and occurrence increased
Canopy cover	Native to exotic species ratio increased with increasing cover
	Species diversity increased
	11 species (out of 23) increased abundance and/or occupancy with increased cover (horizontal extent and foliage density)
	Six species (out of 23) decreased abundance and/or occupancy with cover
Understory density	Species diversity increased with increasing density
	12 (out of 34) species increased abundance and/or occupancy with increasing understory density
	Seven (out of 34) species decreased abundance and/or occupancy with increasing understory density
	Foraging bat abundance decreased with increasing density
Horizontal structure	Two species (out of two) preferred intermediate or mixed levels of horizontal structure
	Species richness increased with increasing patch diversity
Contiguous forest	Native to exotic species ratio increased with larger forest patches
	One species (out of one) preferred larger forest patches
Topography	
Elevation	Species richness decreased with increasing elevation
Slope	Species richness decreased with increasing steepness

Remote Sensing for Restoration Ecology: Application for Restoring Degraded Ecosystems

(authors Reif and Theel, submitted to IEAM April 2016)

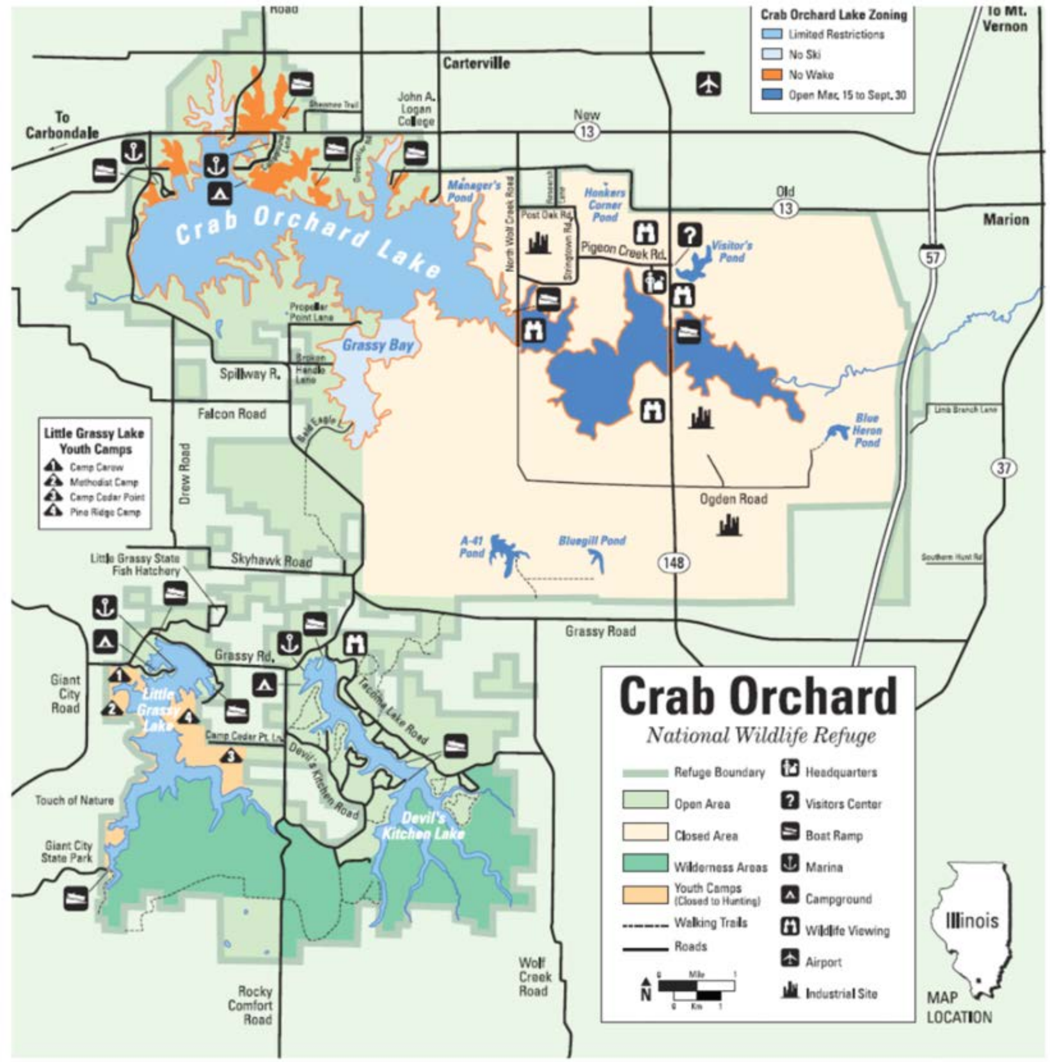
Platform	Sensor Type	Sensor	Spectral Bands (NM)	Spatial Resolution (M)	Swath Width	Revisit (Days)	Operator	Cost	Applications/Metric
Medium Resolution Spaceborne	Optical - Multispectral	Landsat-8	1-7, 9 (435-2294), Pan 8 (503-676), 10-11 (1060-1251)	15, 30, 100 (Pan, MS, TIR)	185 KM	16 days	USGS	Free	Broad-scale land cover or habitat type/pattern, general biodiversity/species richness, Rapid change detection or loss/gain, seasonal/multi-year changes, Overall forest extent/clearance/regeneration, Overall degradation or disturbance from fire, grazing, drought, etc, broad biophysical estimates (NDVI, NPP, LAI etc), landscape metrics (landscape and class level), such as fragmentation
Medium Resolution Spaceborne	Optical - Multispectral	Indian Remote Sensing-P5 (IRS-P6) also called Resourcesat-1 and 2	3 (520-860), 4 (520-1700), Pan (500-850)	5, 20, & 60 (Pan, MS)	70, 141 & 740 KM	5 days	Indian Space Research Organization	1700-4500 EUR/scene	
Medium Resolution Spaceborne	Optical - Multispectral	Systeme Pour l'Observation de la Terre (SPOT-7)	4 (455-890), Pan (450-745)	1.5-2.5, 6-10 (Pan, MS)	60 KM	1-5 days	Satish Dhawan Space Center	Some archives free; $32/KM	
Medium Resolution Spaceborne	Optical - Multispectral	Sentinel-2A	13 (400-2400)	10 (b2-4, 8a), 20 (b5-8b, 11, 12), 60 (b1, 9-	290 KM	10 days	ESA	availabe Oct 2015/Free	
Medium Resolution Spaceborne	Optical - Multispectral	RapidEye	5 (400-850)	6.5	77 KM	1 day	Blackbridge	0.95-1.05 EUR/KM	
Medium Resolution Spaceborne	Optical - Multispectral	TERRA ASTER	14 (520-2430)	15 (VNIR), 30 (SWIR), 90 (TIR)	60 KM	16 days	NASA RSE		
High Resolution Spaceborne	Optical - Multispectral	Worldview-3	8 MS (400-1040), 8 SWIR (1195-2365), Pan (450-800)	0.31, 1.24 (Pan, MS)	13.1 KM	1-4 days	DigitalGlobe	$18-40/KM	Fine-scale land cover, habitat type/pattern, some species mapping (homogenous areas), composition/abundance/distribution (homogenous areas), indicators of biodiversity/species richness (homogenous areas), detailed degradation or disturbance (some invasive species, pest attacks, fire, grazing, etc), individual feature delineation (e.g. tree crowns), more detailed biophysical estimates (NDVI, NPP, LAI, etc) such as with WV-2 and-3 (higher spectral resolution), and landscape metrics (landscape, class, and patch level)
High Resolution Spaceborne	Optical - Multispectral	Worldview-2	8 (400-1040), Pan (450-800)	0.31, 1.84 (Pan, MS)	16.4 KM	2-8 days	DigitalGlobe	$18-40/KM	
High Resolution Spaceborne	Optical - Multispectral	GeoEye-1	4 (450-920), Pan (450-900)	0.41, 1.64 (Pan, MS)	15.2 KM	2-11 days	DigitalGlobe	$14-28/KM	
High Resolution Spaceborne	Optical - Multispectral	OrbView-3	4 (450-900), Pan (450-900)	1, 4 (Pan, MS)	8 KM	2-11 days	DigitalGlobe		
High Resolution Spaceborne	Optical - Multispectral	IKONOS-2	4(450-860), Pan (450-900)	1, 4 (Pan, MS)	11.3 KM	2-11 days	DigitalGlobe	$10/KM	
High Resolution Spaceborne	Optical - Multispectral	Quickbird-2	4(450-900), Pan (450-900)	0.6, 2.4 (Pan, MS)	16.5 KM	2-12 days	DigitalGlobe	$14-28/KM	
High Resolution Airborne	Optical - Multispectral	Special Project Contract	3- or 4-bands	~0.5 or as specified	varies with altitude	Once	Vendor specific		
High Resolution Airborne	Optical - Multispectral	Programmatic (NAIP, NCMP)	Varies (3-and 4-bands)	Varies (~0.3 - 1)	varies with altitude	depends on program	Program specific	Free	
High Resolution Spaceborne	Optical - Hyperspectral	Hyperion	220 (400 - 2500)	30	7.5 KM	30 days	NASA		Detailed vegetation species discrimination (spectrally similar), detailed biophysical estimates and stress based on chemical composition, nutrient deficiency, etc, spectral heterogeneity related to species richness/diversity, detailed disturbance and degradation (invasive species, changes in foliage, biomass etc)
High Resolution Spaceborne	Optical - Hyperspectral	CHRIS	63 (400-1050)	36	13 KM	?	ESA		
High Resolution Airborne	Optical - Hyperspectral	CASI-1500	Programmable, up to 288 bands (380-1050)	Varies with altitude (~0.2-2)	varies with altitude	Once	ITRES		
High Resolution Airborne	Optical - Hyperspectral	HyMap	450-2480	3.5-10	varies with altitude	Once	HyVista		
High Resolution Spaceborne	Active - Radar	RADARSAT-2 (SAR)	C-band	3-100	varies (20 - 500 KM)	3 days	MDA (Kanada)		Detailed vegetation structure, biomass, and height characteristics, combined with imagery for improved species identification, assist with biophysical estimates, detailed 3-D, height, LAI, biomass, age, succession, and composition
High Resolution Spaceborne	Active - Radar	TerraSAR-X/TanDEM	X-band	1-16	varies (10 - 100 KM)	<3 days	EADS Astrium, DLR		
High Resolution Airborne	Active - Lidar	Vendor specific	1064 or 532 (terrestrial or bathymetric	spot spacing varies	varies with altitude	Once	Vendor specific		

2016/2017 Field Sampling Plan

- Objectives:
  - Evaluate the utility of the draft universal monitoring framework for grassland and upland hardwood restoration,
  - Identify low-cost remote sensing technologies to monitor grassland and upland hardwood restoration performance,
  - Compare traditional field-based surveys and remote sensing technology metrics for assessing performance of grassland and upland hardwood restoration,
  - Document costs (level-of-effort) associated with executing all tiers in the decision framework including field and data processing labor, travel, and any indirect costs, and
  - Develop universal field sampling data collection forms for restoration practitioners to ensure basic data are being collected.

Study Site

- Study Site:
  - Crab Orchard National Wildlife Refuge, IL
  - 43,890 ac
  - 4 primary purposes: Wildlife Conservation, Agriculture, Industry, and Recreation



https://www.fws.gov/uploadedFiles/general%20refuge%20map.pdf

Restoration Program

Natural Resource Damage Assessment and Restoration Program

CONWR Restoration Sites

	Forest	Grassland
Total # CONWR Sites	204	18
Restoration Implementation Completed	102	15
# Primary Restoration	17	4
# Compensatory Restoration	85	11
Mean Area (ac)	9.6	29.4
Min. Area (ac)	0.6	2.5
Max. Area (ac)	54.5	112.1
Standard Deviation (ac)	10.5	27.9

Sampling Design

- For each habitat type, 4 sites for each ‘treatment’:
  - Primary Restoration (NRDA contaminated sites)
  - Compensatory Restoration (ag prior land use)
  - Reference
- Use similar size sites (~ avg site size +/- 1 SD)
- At least 5 plots per site, additional RS Ground Truth info as necessary
- Implement and collect data from each tier (1-3) at each plot to characterize site

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Expected Products

- GUHM Field Data Report
- Final Monitoring Framework Report following field testing
- Level-of-Effort (costs) associated with each tier for field and RS
- Universal Field Sampling Data Collection Forms

Acknowledgements

DOI Office of Restoration and Damage Assessment (ORDA)

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GUHM Team

Not Pictured: K. Skrabis, M. Reif, N. Beane, M. Engelmann, D. Wood, J. Stanovick