Mystery in the marsh

Something is killing off the precious plant life that holds Louisiana’s wetlands together and the consequences could be devastating, both for the environment and the economy. Page 18
Remote Sensing Methods for Mapping the Onset and Progression of Dieback in *Spartina Alterniflora* in Coastal Louisiana

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Leaf Optical Properties

Date of Site 1: 09/20/00
Date of Site 2: 09/28/00
Date of Site 3-5: 10/05/00

Canopy Hyperspectral Reflectance

16-20 m ground area (pixel)
Date: 10/12/00

Satellite Broadband Reflectance

Landsat 7 ETM+
30 m ground area (pixel)
Dates: 08/14/99; 11/18/99; 01/05/00; 04/26/00; 09/18/00; 12/22/00
Study Unknowns

- **Impact onset**
  - Without a history of each impact site, there was no clear way to discern when the impact onset occurred at any one site

- **Natural variability in the marsh**
  - The non impact spatial and temporal spectral variability of the marsh must be known or minimized with respect to spectral variability due to marsh dieback onset and progression
Proposed Solutions

- A quantifiable method for measuring changes due to marsh dieback onset and progression
  - Proposed a conceptual model of impact that accounted for both the dieback onset and progression
- Initiated measurements at the plant leaf level
  - If changes are not detectable at the plant leaf level, the onset and initial progression of dieback cannot be detected and monitored
- Apply leaf results to canopy reflectance spectra
  - Quantify impact at the marsh canopy reflectance level
Zonation implies variation in plant stress

Note: Healthy and dead plant distribution relative to sites.
Site 1, 3, 4 and 5 impacted transect sites.
Site 2 healthy reference site.
Sites 6 to 13 additional sites only occupied by helicopter.
Leaf absorption is the leaf optical property most directly linked to the pigment concentrations.
Site 4 Transect

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Healthy

Dead

N

USGS
Increasing time since dieback onset

<table>
<thead>
<tr>
<th>Plant height</th>
<th>Healthy</th>
<th>25m</th>
<th>20m</th>
<th>10m</th>
<th>5m</th>
<th>Center impact</th>
</tr>
</thead>
</table>

Images showing different stages of plant growth and dieback progression.
The Spectron Engineering Field Spectroradiometer
We measured Reflectance and Transmittance

Plant Sample    Leaf Samples

Only green leaves sampled
2 to 4 leaves per leaf sample
3 to 4 samples per plant

USGS
Leaf Reflectance

• Reflectance variability in the visible wavelengths is dominated by variability in leaf pigment concentrations. Specific to chlorophyll influences,
  – Reflectance increases are normally associated with a decrease in chlorophyll
  – Reflectance decreases are normally associated with an increase in chlorophyll

• Green and red edge reflectances are more sensitive while blue and red reflectances are less sensitive to changes in chlorophyll concentration.
  – This relationship was used throughout the study
Reflectance + Transmittance + Absorption = 1

Leaf Reflectance

Leaf Transmittance

Visible
Near Infrared
Leaf Pigment
Leaf Structure
Red band leaf reflectance

SITE 3

SITE 4
Red edge leaf reflectance

SITE 3

SITE 4
Leaf Reflectance

• Green and red edge reflectances are more sensitive while blue and red reflectances are less sensitive to changes in chlorophyll concentration.

• Trends suggest that
  sites 1 and 3 are at an earlier stage of impact while sites 4 and 5 are at a later stage of impact
Reflectance changes in the green and red edge are more sensitive to changes in the chlorophyll absorption

References
Gitelson et al., 2002. Assessing Carotenoid content in the plant leaves with reflectance spectroscopy. Photochemistry and Photobiology 75:272-281 and

Leaf pigment concentrations

For SITE 3:
- Carotene Concentration (nmol/cm²) ranges from 1.4 to 2.8.
- Chlorophyll Concentration (nmol/cm²) ranges from 1.4 to 2.8.

For SITE 4:
- Carotene Concentration (nmol/cm²) ranges from 1.4 to 2.4.
- Chlorophyll Concentration (nmol/cm²) ranges from 1.4 to 2.4.
Leaf Pigments

- Carotene
  Sites 1 and 3 - initial decrease then overall increase
  Sites 4 and 5 - increase throughout

- Chlorophyll
  Sites 1 and 3 - decrease throughout
  Sites 4 and 5 - increase throughout

Sites 1 and 3. Carotene increases or remaining nearly constant while chlorophyll decreases suggest an earlier stage of impact

Sites 4 and 5. Carotene and chlorophyll corresponding trends suggest a later stage of impact
Remote Sensing Leaf Reflectance Ratios

To provide an operational satellite remote sensing solution that could detect both the initial onset and monitor impact progression.
Remote Sensing Leaf Reflectance Ratio-NIR/GREEN

SITE 3

NIR/GREEN vs Transect Distance (m)

SITE 4

NIR/GREEN vs Transect Distance (m)
Summary Leaf Analyses

• The conceptual model
  – optical property changes were related to distances along transects and to impact progression

• Leaf reflectance spectra
  – Blue and Red leaf reflectances identified later stages of impact progression
  – Green and Red edge leaf reflectances identified impact onset and earlier as well as later stages of impact progression
Leaf Summary continued

• Pigments
  – Carotene and chlorophyll trends did support reflectance indicators of dieback progression and indicated differences of dieback onset between sites

• Reflectance ratios
  – The NIR/Green reflectance best portrayed the dieback progression from onset through later stages of progression
  – The NIR/Green ratio also indicated the time since dieback onset at each site.
Site 6 Brown Green
Site 7 Green Brown
Site 1, 3, 4 and 5 impacted transect sites.
Site 2 healthy reference site.
Sites 6 to 13 additional sites only occupied by helicopter.
Site 4 Transect
Canopy Reflectance

- Local Healthy marsh
- Impacted marsh 1
- Impacted marsh 2
- Dead marsh

Wavelength (nm)

Site 4 Transect

USGS
Healthy
Impacted
Dead

Shadows Shade Veg Less green Healthy Dead Mud Dead grass

SLIDE CLASSIFICATION

USGS

Shadows Shade Veg Less green Healthy Dead Mud Dead grass
Whole spectral analysis

- Extract characteristic spectra
  - Dead
  - Healthy
- Apply the characteristic spectra to all sites
  - Determine dead and healthy indicators
- Combine indicators into a dieback onset and progression classification
PVA spectra loadings characterized as dead

Eight dead canopy spectra

<table>
<thead>
<tr>
<th>Site names and descriptions</th>
<th>Dead Characteristic Spectra-1</th>
<th>Dead Characteristic Spectra-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site GB1 (□) Ground-based mud flat with dead marsh vegetation</td>
<td>0.00</td>
<td>1.00</td>
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<tr>
<td>Site GB2 (■) Ground-based moist mud background</td>
<td>0.74</td>
<td>0.26</td>
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<tr>
<td>Site 1i (•)</td>
<td>1.00</td>
<td>0.00</td>
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<tr>
<td>Site 1d (○)</td>
<td>0.38</td>
<td>0.62</td>
</tr>
<tr>
<td>Site 3d (△)</td>
<td>0.36</td>
<td>0.64</td>
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<tr>
<td>Site 4d (▲)</td>
<td>0.43</td>
<td>0.57</td>
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<tr>
<td>Site 5d (◊)</td>
<td>0.58</td>
<td>0.42</td>
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<tr>
<td>Site 5i (♦)</td>
<td>0.19</td>
<td>0.81</td>
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Site 1i and Site GB1 Represent the two Dead Characteristic Spectra
PVA spectra loadings characterized as healthy

<table>
<thead>
<tr>
<th>Site names</th>
<th>Healthy Characteristic Spectra-1</th>
<th>Healthy Characteristic Spectra-2</th>
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<tbody>
<tr>
<td>Site 1h1 (•)</td>
<td>0.07</td>
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<td>Site 1h2 (○)</td>
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<tr>
<td>Reference</td>
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<td>Site 3h (□)</td>
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<td>Site 5h (◊)</td>
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Site 5h and the Reference Site represent the two healthy Characteristic Spectra
<table>
<thead>
<tr>
<th>Site name</th>
<th>Dead Characteristic Spectra</th>
<th>Healthy Characteristic Spectra</th>
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<tbody>
<tr>
<td>Site 13h</td>
<td>-0.30</td>
<td>1.30</td>
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<tr>
<td>Site 12h</td>
<td>-0.21</td>
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<td>Reference</td>
<td>-0.01</td>
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<tr>
<td>Site 10h</td>
<td>0.03</td>
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<tr>
<td>Site 1h1</td>
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<tr>
<td>Site 7i</td>
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<tr>
<td>Site 6i</td>
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<td>0.89</td>
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PVA similarity between healthy and dead characteristic spectra with canopy spectra from each transect location and marsh site

Numeric Entries Correspond to Composition Weights Associated with the Dead and Healthy Characteristic Spectra
Broad band spectral analysis

• Generated nir/green and nir/red ratios from site-specific canopy spectra
  – Simulate ETM and EO1 ALI resource satellite sensors

• Assessed the validity of canopy nir/green and nir/red indicies by regression comparison to slide classification indicators
Regression results of nir/green and nir/red with transformed slide classification indicators

<table>
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<tr>
<th>Site</th>
<th>Ratio</th>
<th>Site</th>
<th>Ratio</th>
<th>Site</th>
<th>Ratio</th>
<th>Healthy Characteristic Spectra</th>
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<td>2.9</td>
<td>Site 4h</td>
<td>0.62</td>
<td></td>
</tr>
</tbody>
</table>

Nir/green was more closely aligned with the leaf analysis results.
Summary Canopy Analyses

- Both broad band—simulating ETM and ALI resource sensors and whole spectral—simulating Hyperion hyperspectral sensors generally defined broad divisions of healthy, impacted, and severely impacted marsh.
- Both broad band and whole spectral analyses discriminated dieback onset and early stages of dieback progression.
- Whole spectral analysis provided better definition of dieback progression in impacted marshes than broad band analysis.
Leaf spectral properties


Canopy reflectance


Satellite mapping

Ramsey, E, III, and A. Rangoonwala, in progress. Mapping the occurrence and progression of coastal marsh dieback with a temporal suite of satellite images; progressing from the leaf to the canopy.
Satellite mapping

- Generate atmospherically corrected reflectance images from Landsat ETM images
- Transform image spectral data into nir/green broad band indicators
- Assess validity of satellite nir/green index mapping
Landsat 7 ETM+
Uncorrected

Corrected

Blue, Green, Red Band Composite
Healthy Site

NIR Reflectance

NIR Brightness Values

08/14/99  11/18/99  01/05/00  04/26/00  09/18/00

00.00  0.05  0.10  0.15  0.20  0.25

08/14/99  11/18/99  01/05/00  04/26/00  09/18/00

00.00  20.00  40.00  60.00  80.00
Impacted Site

Red Reflectance

Red Brightness Values

08/14/99 11/18/99 01/05/00 04/26/00 09/18/00

0.00 0.01 0.02 0.03 0.04 0.05

0.00 10.00 20.00 30.00 40.00 50.00 60.00 70.00 80.00
Impacted Site Vegetation Index

Based on Reflectance

Based on Brightness Values

08/14/99 11/18/99 01/05/00 04/26/00 09/18/00

08/14/99 11/18/99 01/05/00 04/26/00 09/18/00
Near Infrared Reflectance

Healthy

Impacted

USGS
Thank you

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