CRANES, PLANES, AND PLANKTONIC MEALS:
HABITAT CHARACTERIZATIONS IN GULF AND EAST COAST
NOAA NATIONAL ESTUARINE RESEARCH RESERVES

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http://www.learner.org/jnorth/tm/crane/indexCurrent.html
STUDENT RESEARCH MENTORING
A KEY COMPONENT OF THE EPP MISSION
NATURE IS OUR CLASSROOM
NERR PARTNERSHIPS AND LEVERAGING WITH STATE AGENCIES CRITICAL TO OUR SUCCESSES

NOAA - ECSC NERR PARTNERS
- ACE BASIN (SC)
- APALACHICOLA BAY (FL)
- DELAWARE BAY
- GRAND BAY (MS)
- MARYLAND-CHESAPEAKE
- MISSION-ARANSAS (TX)
- SAPELO ISLAND (GA)
WHAT DO CRANES, PLANES, AND PLANKTONIC MEALS HAVE IN COMMON?

I’LL TRY TO ADDRESS THEIR CONNECTIONS THROUGH A STORY ABOUT HABITAT
CLASSIFICATIONS USING REMOTE SENSING RESEARCH AT NOAA NERR SITES

The Outline for my Talk:

1. Framing the Problem
   Coastal Resource Inventories & Management, Research Objectives

2. Study Site Characteristics:
   Sapelo, Grand Bay, & Mission-Aransas NERRs

3. Methods:
   AISA Sensor, Field Surveys, Laboratory Analyses

4. Algorithm Development:
   Phytoplankton Chl \( a \), Wetland Plant Composition & Density

5. Case Studies of Phytoplankton, Marsh, and Mangrove Mapping
The Problem:

The wise management of NOAA’s Estuarine Research Reserves and other coastal sites requires accurate and timely information on the spatial extent, ecosystem health, and geospatial relationships of diverse habitats.

The Solution:

Tools to delineate habitats using high resolution imagery, masking techniques, and the unique spectral characteristics of micro and macro vegetation to map wetlands, water, mudflats, and other habitats.
NOAA-ECSC AISA Hyperspectral Flyovers

5. ACE Basin, SC: 2003
6. Chesapeake Bay, MD: 2005
7. Delaware Bay, DE: 2004
## Properties of National Estuarine Research Reserve Sites used in study

<table>
<thead>
<tr>
<th>NERR Site</th>
<th>Loc</th>
<th>Area (ha)</th>
<th>Temp (°C)</th>
<th>Prec(cm)</th>
<th>Tide</th>
<th>TIN (mg/L) *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mission-Aransas</td>
<td>TX</td>
<td>75,153</td>
<td>21.7 (0.5)</td>
<td>89</td>
<td>D 0.4</td>
<td>0.004 (0.001)</td>
</tr>
<tr>
<td>Grand Bay</td>
<td>MS</td>
<td>7,446</td>
<td>19.6 (0.5)</td>
<td>161</td>
<td>D 0.7</td>
<td>0.060 (0.007)</td>
</tr>
<tr>
<td>Apalachicola Bay</td>
<td>FL</td>
<td>99,863</td>
<td>20.1 (0.6)</td>
<td>144</td>
<td>S,D 0.3</td>
<td>0.760 (0.005)</td>
</tr>
<tr>
<td>Sapelo Island</td>
<td>GA</td>
<td>2,473</td>
<td>20.5 (0.7)</td>
<td>133</td>
<td>S 2.3</td>
<td>0.034 (0.004)</td>
</tr>
<tr>
<td>ACE Basin</td>
<td>SC</td>
<td>54,515</td>
<td>18.6 (0.5)</td>
<td>133</td>
<td>S 1.8</td>
<td>0.160 (0.004)</td>
</tr>
<tr>
<td>Maryland Chesapeake</td>
<td>MD</td>
<td>2,525</td>
<td>12.7 (0.4)</td>
<td>109</td>
<td>S 0.5</td>
<td>1.400 (0.015)</td>
</tr>
<tr>
<td>Delaware Bay</td>
<td>DE</td>
<td>1,995</td>
<td>13.3 (0.7)</td>
<td>113</td>
<td>S 1.7</td>
<td>0.780 (0.020)</td>
</tr>
</tbody>
</table>

- **Area (hectares)**
- **Temperature = annual average of monthly values (standard error)**
- **S = semidiurnal and D – diurnal**
- **Tide = average tidal amplitude**
- **TIN = total inorganic nitrogen, as sum of NH$_4$, NO$_2$, and NO$_3$ fractions [ reported as N; values are average (standard error) ]**

* Nutrient data: NOAA-NERR SWMP (System Wide Monitoring Program)

Normalized NDVI distributions
a) TEX, b) GB ’03, c) GB ’10, d) AP ’02, e) AP ’06, f) SAP, g) ACE, h) CB and i) DEL.
(Seminara & Schalles, In Prep)
CALMOT’s AISA-Eagle System Integrates Multiple Technologies
ENVI FLASH MODULE CORRECTION

Lower Patuxent River (July 10, 2005)

ENVI Z Profile (Ave 7 x 7 pixels)

Atmospherically Corrected Spectra

Uncorrected Spectra
From the Chesapeake Bay Joint Campaign – July, 2008

- AISA Eagle Imagery
- Optics: Refl, ABS, Scatter
- Pigments, TSM, Nutrients
- Hydrolight Modeling

CHESAPEAKE BAY SPECTRA - JULY, 2005

PERCENT REFLECTANCE

WAVELENGTH (nm)

Stations:
- Green Peak
- PHY
- CHL
- Red Peak

CHESAPEAKE BAY WATER QUALITY STATIONS

n = 46

Team:
Creighton, CCNY,
Morgan State, Florida A&M,
Kent State, NOAA-Beaufort
Comparison of different semi-empirical models with our 458 coastal and inland stations

<table>
<thead>
<tr>
<th>Model</th>
<th>Equation</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ocean Color (OC4)</td>
<td>Max($R_{443}, R_{490}, R_{510}$) / $R_{555}$</td>
<td>0.104</td>
</tr>
<tr>
<td>Depth of 675</td>
<td>($(AV_{650}+700)-675)$</td>
<td>0.300</td>
</tr>
<tr>
<td>Gilerson 3B MERIS</td>
<td>($(1/R_{665})-(1/R_{708})) \times R_{753}$</td>
<td>0.857</td>
</tr>
<tr>
<td>Schalles &amp; Hladik</td>
<td>($(AV_{650}+700)-675)/(AV_{440}+550)$</td>
<td>0.902</td>
</tr>
<tr>
<td>Gitelson 3 Band</td>
<td>($(1/R_{665})-(1/R_{710})) \times R_{740}$</td>
<td>0.924</td>
</tr>
<tr>
<td>Model</td>
<td>Author</td>
<td>$r^2$ (n=142)</td>
</tr>
<tr>
<td>-----------------------------------------------------</td>
<td>---------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>$[(R_{675}^{-1}) - (R_{695}^{-1})] \times R_{730}$</td>
<td>Gitelson et al. (2007)</td>
<td>0.947</td>
</tr>
<tr>
<td>$[(R_{665}^{-1}) - (R_{708}^{-1})] \times R_{753}$</td>
<td>Gilerson et al. (2010)</td>
<td>0.942</td>
</tr>
<tr>
<td>$[(\text{Ave } R_{650} + R_{700}) - R_{675}] / (\text{Ave } R_{440} + R_{550})$</td>
<td>Schalles &amp; Hladik (2004)</td>
<td>0.863</td>
</tr>
</tbody>
</table>

- 2002-2009
- Summer 2011

\[
\text{RMSE} = 12.2 \text{ ug/L}
\]

\[
\text{y} = 200.43x + 4.1
\]

\[
R^2 = 0.924
\]
FROM AISA PIXEL SPECTRA TO ALGORITHM PARAMETERIZATION FOR CHL a ESTIMATION:
1. EXAMPLES OF AISA SPECTRA
   (5 X 5 PIXEL AVERAGES)
2. COMPARISON OF AISA SPECTRA
   (63 BANDS, 5 X 5 PIXEL AVERAGE) VS. IN SITU OCEAN OPTICS SPECTRA
3. THREE-BAND INDEX VALUES FROM AISA 5 X 5 PIXEL AVERAGES VS. MEASURED CHL a AT STATIONS

**Graphs:**
1. AISA Eagle Spectra
2. DuBlin St 5
   Chl a = 12.4 µg/L
   DILEIN RIVER STATION 5
   JUNE 20, 2006; MID-MORNING
3. 3 Band Model (1/R675 - 1/R695) * R550

**Equations:**
\[ Y = 16.29 + 126.3 \times X \]
\[ R^2 = 0.593 \]
\[ Y = 11.10 \times 7.72^X \]
\[ R^2 = 0.621 \]

**Legend:**
- AISA SPECTRA
- OCEAN OPTICS SPECTRA

**Data:**
- N = 30
Processing AISA Imagery With ENVI Image Analysis Package

False Color Image Subset

Land Mask Applied

Chlorophyll Index (Grey Scale)

Chlorophyll Index (Density Slice)
Spartina plants
At Sapelo Island
April 20, 2001
Field Survey
- 24 Transects, 500 plots
- 1 m² quadrats
  plant species
  canopy height
- 0.25 m² clip plots
  plant species dry wt
  detritus dry wt
- soil cores
  % organic
  % moisture
- PVC reference poles
  sub-meter GPS
  reference photography
- Invertebrate survey
Sampling Approach:
- Minimum of 20 plots/species
- 24 transects across marsh elevation/soil salinity gradients
- Included salt pans, mud flats, and exposed die-back areas

Overview of results
- Five common plant species
- Biomass range 0 - 5000 g \cdot m^{-2}
- Ave. biomass \sim 1225 g \cdot m^{-2}
Vegetation Indices Examined in this study¹:

1. NDVI: \( \frac{R_{\text{NIR}} - R_{\text{red}}}{R_{\text{NIR}} + R_{\text{red}}} \)
2. Green VARI: \( \frac{R_{\text{green}} - R_{\text{red}}}{R_{\text{green}} + R_{\text{red}} - R_{\text{blue}}} \)
3. NIR / GRN: \( \frac{R_{\text{NIR}}}{R_{\text{green}} - 1} \)

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• NDVI most robust index, but saturates at higher biomass

• VARI Green Index relatively linear, but more scatter and poor fit with *Juncus* stands
Redfish Bay (TX) Transects & AISA Imagery

- 8 transects: 2 x 22 m
- 22 plots per transect
- 1 m² plots outlined with PVC frame
- Checkerboard pattern
- Nadir digital photography
- 6 measures of canopy height per plot
- Estimations of percent cover by plant species and other habitat conditions

Enlarged view of subscene, with plot locations matched to respective imagery pixels (pixel size is 1 meter)

Registration of sampling transect and AISA flight line subscene
Delineating Features in Wetland Hyperspectral Imagery

Salt Marsh Example (Duplin Watershed at Sapleo Island NERR)

Mask Water & Uplands

Supervised Classification
Grand Bay NERR
May, 2010

Baseline Map
(pre-oil exposure)
Salt Marsh Condition
NDVI Mosaic
Seminara & Schalles
SAPERO SOUND
BLACKBEARD ISLAND
SAPELO ISLAND
DOBOY SOUND
ATLANTIC OCEAN

SEMINARA (2010)

Data Source: Landsat 7
Projection: UTM, Zone 17 North
Datum: World Geodetic System, 1984

DUPLIN RIVER TIDAL WATERSHED
MARSH 1,003 ha / WATER 198 ha
Figure 12.
Spectral Library – Class AVES

Hladik, Alber, & Schalles (In Review)
DUPLIN RIVER WATERSHED

TOTAL MARSH WETLAND AREA
1003 HECTARES

MARSH PLANT BIOMASS (g dry wt / m²)
GRAND BAY NERR SALTMARSH COMPARISONS OF
A. TRUE COLOR IMAGE
(from 2011 WV2)
B. VEGETATION BIOMASS
(from 2010 AISA)
C. VEGETATION CLASSIFICATION
(from 2011 WV2)
MISSION-ARANSAS NERR

COASTAL BEND OF TEXAS NEAR CORPUS CHRISTI

AISA IMAGERY AND FIELD SURVEYS IN 2008

Data Source: Landsat 7
Projection: UTM, Zone 14 North
Datum: World Geodetic System, 1984

NERR Boundary
Flightline Boundary

SEMINARA (2010)
On the Texas coast, mangroves regularly expand from persistent populations into salt marshes during periods with warm winters, and occasionally contract in distribution during periods with severe freezes. Over the coming decades, mangrove distributions are expected to continue expanding due to rising global temperatures and milder winters. As a result, large areas of the Texas coast that historically have been dominated by salt marshes will become dominated by mangroves. Will this matter? We hypothesize that changes in coastal vegetation are likely to change the quality of coastal wetlands for supporting shrimp, fish and birds, and change the ability of coastal habitats to buffer wind and wave energy. We will test this hypothesis using a combination of field sampling and a manipulative experiment, working around and within the domain of the Mission-Aransas National Estuarine Research Reserve. Our work will provide information on which ecosystem services provided by coastal wetlands are most likely to be affected by the change from salt marsh to mangroves. This information will allow coastal industries such as fisheries and tourism to be adaptively managed in response to ongoing and future changes in the biological environment.

Hypothesized Impacts of Mangrove Invasion (Pennings et al):
* Alter food web structures and trophic support for shrimp, fish, and birds
* Change the ability of coastal wetlands to buffer wind and wave energy

In: Texas Bays and Estuaries Meeting, Port Aransas, TX (April, 2012)
Texas Mangrove Project
Mission-Aransas NERR

- Black Mangrove, *Avicennia germinans*, is invasive in the Texas Coastal Bend region
- Nearest native source: Brownsville, Texas
- Displacing salt marsh plants in Redfish Bay and vicinity
- Lack of freezes allows for taller, more dense growth (climate change signal?)
- Could threaten Whooping Crane marsh habitat ~ 20 miles north at Aransas NWR
Image Processing Steps for Estimating Canopy Height

1. True color
2. Water mask applied
3. Color density slice of canopy height
4. Gvari index applied
Redfish Bay Subscenes

- Gvari Index was the best predictor of canopy height ($R^2 = 0.583$)
- Median canopy height for all mangrove pixels was approximately 78.5 cm
- Mangroves were generally taller near larger channels and lagoons (older specimens and/or more favorable for growth?)
Mangroves covered 6.4 million m² (= 640 ha) in Redfish Bay
Close-up of Mustang Lake area of Aransas NWR:
These water bodies, surrounding by marsh, are vital feeding habitats for endangered Whooping Cranes
Blue Crabs are the most important food for Whooping Cranes during winter residence at Aransas NWR.

An adult crane can eat up to 80 crabs per day from ponds

Feeding is directly correlated with summer reproduction.

In extreme drought periods, these feeding ponds dry out or become hypersaline – greatly reducing invertebrate forage densities.

http://www.learner.org/jnorth/tm/crane/BlueCrabs.html
CROSS-SITE COMPARISONS
OF SALT MARSH COMMUNITY
STRUCTURE & PRODUCTION

SEMINARA & SCHALLES (IN PREP)
Summary and Conclusions:

• The NOAA Environmental Cooperative Science Center and the University of Nebraska CALMIT remote sensing group successfully collected hyperspectral AISA imagery for habitat classifications and ecological studies at seven NOAA NERR sites and nine campaigns.

• At least ten ECSC M.S. thesis and Ph.D. dissertations were completed or are in progress using our field survey and AISA imagery data. More than 100 students were trained in geospatial techniques and participated in our field survey remote sensing projects to date.

• The ECSC / NERR partnerships, along with leveraged funding and collaborations with many NOAA laboratories, universities, state and federal agencies, and conservation groups, are a major reason for our success.

• We succeeded in developing algorithm classifications for algal pigments in turbid, Case 2 coastal waters, species-level mapping of salt marsh plants, biomass and canopy height predictions for coastal wetlands, and (not reported here) new procedures for S.A.V. classifications and corrections for water column effects.

• We’ve produced useful habitat classification maps for NOAA NERR scientists and resource managers at our partner sites.

• Our next steps include seasonal assessments with World View2 imagery, change detection using archival legacy data, and HICO imagery assessments of coastal waters & wetlands.

http://www.washingtonpost.com/wp-dyn/content/gallery/2010/03/19/GA2010031901749.html