HYPERSPECTRAL BIOFILM CLASSIFICATION ANALYSIS TO DETERMINE CARRYING CAPACITY FOR MIGRATORY BIRDS IN THE SOUTH BAY SALT PONDS

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Applied Sciences Related to South San Francisco Bay Ecological Forecasting

• **Community Concerns**
  – Provide habitat for endangered animal and vegetation species
  – Increase Shorebird habitats for foraging and migration
  – Understand changes in vegetation colonization of marsh habitat during the restoration process.

• **Partners**

- US Geological Survey
- Coastal Conservancy
- San Francisco Estuary Institute
- US Fish and Wildlife Service
- California Department of Fish and Game
- San Francisco Bay Conservation and Development Commission
- US Geological Survey
- California Department of Fish and Game
- San Francisco Bay Conservation and Development Commission

• **Decision Making Process & Partner Needs**
  – Use NASA satellite data to map the spatial distribution and density of biofilm.
  – Need for improved understanding of biofilm’s role within the South San Francisco Bay’s wetland ecosystem.

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Project Objectives and Study Area

Objectives

- Use GER-1500 spectroradiometer to create Spectral Library of Biofilm
- Monitor the spatial distribution and density of biofilm throughout the South Bay
- Provide a taxonomic classification of the dominant biofilm species in the South San Francisco Bay Area
- Estimate the South Bay Salt Pond Restoration Area’s carrying capacity of shorebirds
Field and Laboratory Methodology

Species Classification

GER Measurements

Chlorophyll a Analysis
## Remote Sensing Methodology

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Purpose</th>
<th>Bands Used</th>
<th>Wavelengths (µm)</th>
<th>Resolution (m)</th>
<th>Dates used</th>
<th>Image Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landsat 5 TM</td>
<td>Detect Vegetation</td>
<td>3</td>
<td>0.45-0.69</td>
<td>30</td>
<td>8/18/94, 8/22/07, 8/27/09, 7/5/10</td>
<td>Glovis (USGS, 2010a)</td>
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<td>IKONOS</td>
<td>Detect Vegetation</td>
<td>1</td>
<td></td>
<td></td>
<td>2008, 2009</td>
<td>GeoEye</td>
</tr>
<tr>
<td>Hyperion on EO-1</td>
<td>Obtain spectral curve for biofilm</td>
<td>48</td>
<td>426.82-905.05</td>
<td>30</td>
<td>3/26/10, 7/7/10</td>
<td>Glovis (USGS, 2010a)</td>
</tr>
</tbody>
</table>

### Hyperion Classification procedure

Where:
- \( n \) = number of bands
- \( \alpha \) = angle formed between reference spectrum and image spectrum
- \( x \) = image spectrum
- \( y \) = reference or target spectrum

\[
\alpha = \cos^{-1} \left[ \frac{\sum_{i=1}^{n} x_i y_i}{\sqrt{\sum_{i=1}^{n} x_i^2} \sqrt{\sum_{i=1}^{n} y_i^2}} \right]
\]

**Spectral Angle Mapper Classification Algorithm**
Field and Laboratory Lab Results

Percent Distribution of Main Taxonomic Species

Chlorophyll $a$ and Observational Density

H = High Density Biofilm
M = Medium Density Biofilm
L = Low Density Biofilm
32 = Bayside
34 = Pondside
Remote Sensing Results

Hyperion Classification-Spectral Angle Mapper

Total Area of Biofilm

28,641,600 m²
Remote Sensing Results

Landsat NDVI

- Nine Landsat Images mapping the likelihood of biofilm presence
- June, 2006 through July, 2010
- ↑ Likelihood = ↑ Appearance

Likelihood of Biofilm Presence

High

Low

National Aeronautics and Space Administration
Carrying Capacity Results

Carrying Capacity = \(
\frac{A \times B \times D}{C}
\)

Where:
A = Area of Biofilm (m\(^2\))
B = Biofilm Biomass (g C/ m\(^2\))
D = Biofilm Energy Density (kJ/g)
C = Bird Consumption Rate of Biofilm (kJ/d bird)

Biofilm in the South Bay Salt Pond Restoration Area, alone, can feed
\(\approx 200,000 (\pm 25,000)\) shorebirds per day!
South San Francisco Bay Ecological Forecasting

Conclusions

• Biofilm has a distinguished spectral signature, which can be identified in satellite imagery.
• Biofilm appears to flourish in tidal, bay-side mudflats where vegetation is unable to grow, such as recently rehabilitated salt ponds.
• The dominant biofilm genus in the South San Francisco Bay Area is *Navicula*.
• Biofilm in the South Bay Salt Pond Restoration Area, alone, can feed ≈ 200,000 (± 25,000) shorebirds per day!
Transition to Partner

Partners:

- US Fish and Wildlife Service
- US Geological Survey
- California Department of Fish and Game
- San Francisco Estuary Institute
- San Francisco Bay Conservation and Development Commission

Benefits to Partner:

- Spectral library of various biofilm densities.
- Maps of biofilm density and spatial distribution.
- Estimated carrying capacity of South San Francisco Bay for shorebirds.
- Use remote sensing instead of field crew