Spectral characteristics & cyanobacteria abundance in the Indian River Lagoon

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Indian River Lagoon System (IRL)

Cyanobacteria

Microcystis aeruginosa, by Kristian Peters

Microcystis bloom St. Lucie Estuary, 2016

Hanisak & Davis, 2018

Phlips et al, 2020
Indian River Lagoon System (IRL)

Temperature (°C) —— Salinity (PSU)

wet season

dry season

Stations

South ———> North

Eu Gallie River

Atlantic Ocean

St. Lucie Inlet

Lake Okeechobee
Southern stations
Central stations
Northern stations
Algorithms tested for cyanobacteria detection in the IRLS

1. **Phycocyanin Index (PCI) - 620 nm**
   Baseline: 560, 665 nm Qi et al. 2014

2. **Cyanobacteria Index (CI) - 680 nm**
   Baseline: 665, 709 nm Wynne et al. 2008

3. **Maximum Peak Height (MPH2) - 709 nm**
   Baseline: 665, 885 nm Matthews et al. 2012
Algorithms tested for cyanobacteria detection in the IRL

Band Ratio (BR) Algorithm

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3. Maximum Peak Height (MPH2) - 709 nm  
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4. Band ratio (BR)  
   \[ \log_e(R_{\text{rs700}}/R_{\text{rs600}}) \] Mishra et al. 2009
Derivative equation for **spectral shape** algorithms

\[
SS(\lambda) = Rrs_\lambda - Rrs_{\lambda^-} - (Rrs_{\lambda^-} + Rrs_{\lambda^+}) \cdot (\lambda - \lambda^-) / (\lambda^+ + \lambda^-)
\]

central band, \( \lambda \)  
reference bands, \( \lambda^+, \lambda^- \)

Equation for **band ratio** algorithms

\[
BR = \text{LN} \left( \frac{Rrs_{700}}{Rrs_{600}} \right)
\]
model development

R² = 0.83

R² = 0.01

R² = 0.79

R² = 0.64

cyanobacteria abundance (cells/mL)
model development

- **a**
  - Cyanobacteria abundance (cells/mL) vs. MPH2 SS(709)
  - $R^2 = 0.83$

- **b**
  - Cyanobacteria abundance (cells/mL) vs. PCI SS(620)
  - $R^2 = 0.01$

- **c**
  - Cyanobacteria abundance (cells/mL) vs. CI -SS(680)
  - $R^2 = 0.79$

- **d**
  - Cyanobacteria abundance (cells/mL) vs. BR (700/600)
  - $R^2 = 0.64$
model predictions across IRL & Lake Okeechobee

![Graph showing model predictions across IRL & Lake Okeechobee](image)

<table>
<thead>
<tr>
<th>MODEL</th>
<th>n</th>
<th>$R^2$</th>
<th>p value</th>
<th>RMSE ($\log_{10}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPH2</td>
<td>11</td>
<td>0.89</td>
<td>&lt; 0.01</td>
<td>0.29</td>
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<tr>
<td>BR</td>
<td>23</td>
<td>0.41</td>
<td>&lt; 0.01</td>
<td>0.56</td>
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<tr>
<td>CI</td>
<td>23</td>
<td>0.06</td>
<td>0.28</td>
<td>0.71</td>
</tr>
</tbody>
</table>
Discussion

- 700 nm reflectance is a dominant optical feature in the IRL
Discussion

Integral-normalized Method by Craig et al., (2012)

un-normalized

Integral-normalized

mode 1, variance = 81.4%

mode 2, variance = 9.4%

mode 3, variance = 6.5%

mode 4, variance = 1.2%

mode 1, variance = 53.2%

mode 2, variance = 31.9%

mode 3, variance = 7.7%

mode 4, variance = 3.7%
Discussion

- 700 nm reflectance is a dominant optical feature in the IRL
- Ability to identify cyanobacteria not well developed
Discussion

- Larger dataset with Rrs spectra at 885nm is needed to test MPH2
Discussion

• Phycocyanin signature likely has high interference from Chl-a absorption and fluorescence
Laureano-Rosario et al., 2021

Southern stations
Central stations
Northern stations

Locations
SLE = St Lucie Estuary
SIRL = Southern IRL
CIRL = Central IRL
NIRL = Northern IRL
BRL = Banana River Lagoon
ML = Mosquito Lagoon

SLE SIRL CIRL NIRL BRL ML
south central north

Eukaryotes
- Alexandrium sp-
- Amphidinium belauense-
- Chaetoceros sp-
- Coccosidiscus sp-
- Didinium sp-
- Ebra tripartita-
- Eubodonia sp-
- Eucampia sp-
- Euglena sp-
- Pyrodinium sp-
- Arcobacter sp-
- Dolichospermum sp-
- Formosa sp-
- Haliscomenobacter sp-
- Luminiphilus sp-
- Methylonatronum sp-
- Planktothrix sp-
- Truepers sp-
- Ulvibacter sp-

Prokaryotes

wet season

Cyanobacteria (cells/mL) - Extracted Phaeophytin - Extracted Chl-a (mg/m³)

0 0.01 0.02
400 600 800
wavelength (nm)

0.0 5.E+06
0.1 3.E+06
0.2 2.E+06
0.3 1.E+06

0.4 0.0
0.5 0.008
0.6 0.006
0.7 0.004
0.8 0.002
0.9 0.000

400 500 600 700 800 900
wavelength (nm)
Summary

Mean Peak Height (for turbid waters)

• is viable in the IRL
• can be more robust with larger dataset
• requires wavebands in the far-red range of 885 nm
• model output likely influenced by other phytoplankton and not just cyanobacteria - likely beneficial in the IRL
Thanks

Alberto Tonizzo  •  Processing & providing field optical data
Malcolm McFarland  •  Providing other field & flow cytometry data
Twardowski lab at HBOI  •  Sampling & data collection