Potential of the HyspIRI mission for monitoring the physiological condition of giant kelp forests

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Giant kelp is highly dynamic... and important

- Thallus lifespan: ~2.5 yr
- Frond lifespan: ~4 months
- Frond growth rate: 0.5 m d\(^{-1}\)
- Food and habitat for important species
- Canopy amenable to remote sensing
Landsat kelp canopy biomass timeseries

Cavanaugh et al. 2013

Cavanaugh et al. 2011

Cavanaugh et al. 2014

Bell et al. 2015
Physiologic state of marine flora is dynamic

- Aquatic photosynthetic organisms respond to changes in
  - Light
  - Nutrients
  - Temperature

- Quantify response by changes in the ratio of chlorophyll to carbon (Chl:C) (Geider 1987)

- Chl:C = physiological condition

(Behrenfeld et al. 2005)
Physiological state (Chl:C) dynamics are unknown for giant kelp

- Affect photosynthetic rates and net primary production
- Alter energy flows and change interaction strengths between kelp forest species
- Deterioration of fronds hinders ability to provide biogenic structure and withstand disturbance
- Likely to vary over time and space
Low light and high nutrients increase Chl $a$ in giant kelp

(Shivji 1985)
Giant kelp exists in a variable environment.

Surface NO$_3$ (1987 – 2011)

PAR (1987 – 2011)
Giant kelp blade color changes in time

Mohawk kelp forest blades
(Santa Barbara, CA)

March 2013

October 2014
HyspIRI Preparatory Airborne Campaign
Determining blade reflectance and Chl:C

- 3 Santa Barbara forests monthly (15 blades)
  - Arroyo Burro
  - Arroyo Quemado
  - Mohawk

- San Diego & Santa Cruz seasonally (15 blades)

- Reflectance, transmittance from 350 – 800nm

- Chl $a$, Chl $c$, fucoxanthin extracted and determined by spectroscopy (Seely et al. 1972)

- Pooled C/N analysis

- Timeseries continuing
Surface blade color has changed seasonally and interannually.
Pigments in the SB Channel resemble nutrient patterns more than insolation

\[ R^2 = 0.71 \]
\[ p < 0.001 \]

\[ R^2 = 0.67 \]
\[ p < 0.001 \]

Multiple linear regression against \( \text{NO}_3 \) and PAR

\[
\begin{array}{|c|c|c|}
\hline
 & \text{Chl} \ a & \text{Fuco} \\
\hline
\text{NO}_3 & 0.67 & 0.69 \\
\text{PAR} & -0.23 & -0.18 \\
\hline
\end{array}
\]

Coefficients estimated using ridge regressions

\( \text{NO}_3 \) estimated from SST (MODIS)
Pigments in Santa Cruz more closely resemble changes in insolation

\[ r^2 = 0.57 \quad p = 0.08 \]

\[ r^2 = 0.66 \quad p = 0.048 \]

Simple linear regression against PAR

NO\textsubscript{3} estimated from SST (MODIS)
Blade reflectance changes through time

% reflectance vs Wavelength (nm)

- Dec 2012
- Mar 2013
- Sep 2013
- Dec 2013

High Pigment
Low Pigment
Spectral slope from 658 – 667nm relates to Chl:C

Chl:C vs. δ(Log 1/R)

1:1 line

$\delta = 0.76$

$p < 0.001$
Santa Barbara box (4/11/2013)
Giant kelp canopy physiological condition varies over local scales
From Chl:C to NPP

\[ \text{NPP} = \mu \times \text{biomass} \]

\[ \mu = \mu_{\text{max}} \times \left[ \frac{\text{Chl:C}}{\text{Chl:C}_{\text{max}}} \right] \times g(\text{PAR}) \]

(Behrenfeld et al. 2005)

Landsat (Cavanaugh et al. 2011)

Giant kelp (this study)
Future directions

• Apply algorithm to all giant kelp canopy in HyspIRI Prep. Imagery

• NPP estimates of kelp canopy
  – Compare to diver estimated NPP from the SBC LTER
Acknowledgements

- Dan Reed
- Norm Nelson
- Clint Nelson
- Shannon Herrer
Thank You!

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Photo: Kenneth Kopp
HyspIRI will provide at least one seasonal cloud-free image in the vast majority of giant kelp’s range

<table>
<thead>
<tr>
<th></th>
<th>NW North America</th>
<th>SW North America</th>
<th>South America</th>
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<th>Tasmania</th>
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<td>Jan-Mar</td>
<td>1.0 (0.2)</td>
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<td>1.0 (0.6)</td>
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<td><strong>HyspIRI &amp; Landsat 8</strong></td>
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Variability in Chl a dominates the Chl:C ratio.
Equation

Chl:C = 0.0353^{-7.53x}