Remote monitoring of giant kelp biomass and photosynthetic condition

An evaluation of the potential for the Hyperspectral Infrared Imager (HyspIRI) mission

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Photo: Stuart Halewood
Giant kelp is highly dynamic... and important

- Thallus lifespan: ~2.5 yr
- Frond lifespan: ~4 months
- Frond growth rate: 0.5 m d$^{-1}$
- Canopy amenable to remote sensing
- Food and habitat for important species
Landsat 5 kelp canopy biomass timeseries

Cavanaugh et al. 2013

Cavanaugh et al. 2011

Cavanaugh et al. 2013

Bell et al. *in prep*
Pigment dynamics are unknown

• 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
HyspIRI Preparatory Airborne Campaign

AVIRIS
Santa Barbara Box
4/11/2013
L2 Reflectance
Questions

• Will the 19-day revisit time of HyspIRI adequately capture giant kelp forest biomass and pigment state dynamics?

• Will the spectral resolution of HyspIRI allow for the assessment of pigment state of the giant kelp canopy?

• What new questions will HyspIRI allow researchers to answer concerning the ecological role of this globally distributed ecosystem engineer?
Landsat kelp biomass timeseries

- 1984 – 2011
- San Francisco to US/Mexico border
  - 8 scenes
    - 175 – 240 images each
- Wavelet analysis
Environmental conditions along the CA coastline are variable.

Sea Surface Temperature

Significant Wave Height
Kelp biomass patterns in CA a mix of seasonal and interannual fluctuations

Global Wavelet Spectrum

Kelp biomass Wavelet Power Spectrum

Period (years)


Time (year)

Power (kg^2)

0 1 2 x 10^16

kelp biomass (seasonal)

kelp biomass (0.5-1.5 yr Scale-average Time Series)

Time (year)

Avg variance (kg^2)

0 5 10 15

x 10^15
Central CA dominated by 1-year periodicity

Global Wavelet Spectrum

a) kelp biomass (seasonal)

b) kelp biomass Wavelet Power Spectrum

c) Global Wavelet Spectrum

0.5-1.5 yr Scale-average Time Series

Avg variance (kg^2)

Time (year)

Kelp biomass
Southern CA periodicity highly variable

Global Wavelet Spectrum

(a) kelp biomass (seasonal)

(b) kelp biomass Wavelet Power Spectrum
c) Global Wavelet Spectrum

Period (years)

Time (year)
There is spatial variability in the seasonal cycles of kelp biomass.
Will HyspIRI provide seasonal coverage of giant kelp globally?

Data kindly provided by Michael Mercury
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>
<th>Falkland Islands</th>
<th>South America</th>
<th>Tasmania</th>
<th>New Zealand</th>
<th>Sub-Antarctic Islands</th>
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<tbody>
<tr>
<td><strong>HyspIRI only</strong></td>
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<td>Jan-Mar</td>
<td>1.0 (0.2)</td>
<td>2.0 (0.5)</td>
<td>1.0 (0.6)</td>
<td>1.1 (0.2)</td>
<td>2.5 (0.8)</td>
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<td>Apr-Jun</td>
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<td>1.1 (0.4)</td>
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<td>Jul-Sep</td>
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<td>Oct-Dec</td>
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<td>0.9 (0.5)</td>
<td>1.1 (0.2)</td>
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<td><strong>HyspIRI &amp; Landsat 8</strong></td>
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<td>Jan-Mar</td>
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<td>4.4 (1.0)</td>
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Nutrient and light conditions vary seasonally at Mohawk reef.
Kelp pigments vary in space and time

- Chl $a$, Chl $c$, fucoxanthin
  - Apr & Dec 2013
  - Seely et al. 1972
- Reflectance and transmittance
  - Both at 1nm (350 – 800nm)
Pigments and reflectance change seasonally at Mohawk.
AVIRIS reflectance should be able to evaluate ChlA and fucoxanthin

- First derivative of pseudo absorbance $\delta(\log 1/R)$
- Leave-one-out cross validation

$R^2 = 0.71$

$R^2 = 0.18$

$R^2 = 0.61$
Mohawk reef canopy pigment varies in space

April 2013

Depth
- \( r = 0.36 \)
- \( p < 0.001 \)

Biomass
- \( r = -0.21 \)
- \( p < 0.001 \)
Future directions

• Examine kelp/frond age dynamics
  – Probability of frond mortality is dependent on frond age (Rodriguez et al. 2013)
  – Age can be linked to pigment concentrations

• Improve biomass estimates
  – Frond senescence drives biomass dynamics in some areas

• Test abundance/fitness peaks in range
  – Test biogeographic theories
  – ID environmental drivers of range limits
Take aways...

- HyspIRI should provide adequate temporal resolution to measure seasonal giant kelp dynamics – except sub-Antarctic islands

- The spectral resolution will be sufficient for estimating ChlA and fucoxanthin

- There are many interesting ecological questions that this new information can help answer
Acknowledgements

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Thank You!

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