Dynamics of Giant Kelp Forests: The Engineer of California's Nearshore Ecosystems

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The "Kelp Remote Assessment Project"

Macrocystis pyrifera – Giant Kelp

- High economic & ecological importance

  "Ecosystem engineer" of the nearshore ecosystems

  Source of natural products

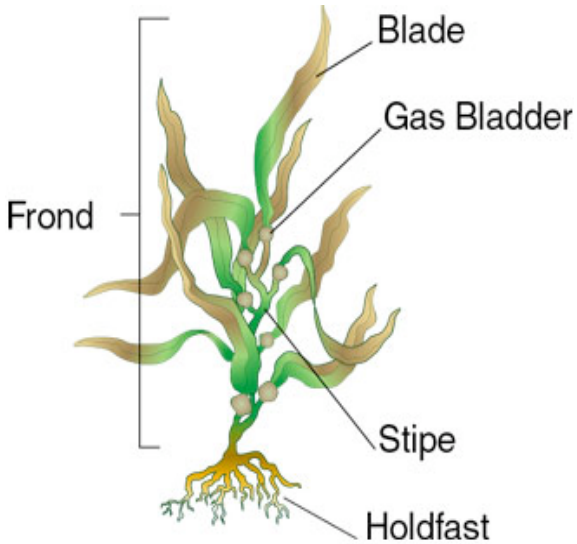
- Dominant canopy forming macroalga in So Cal

- Highly dynamic

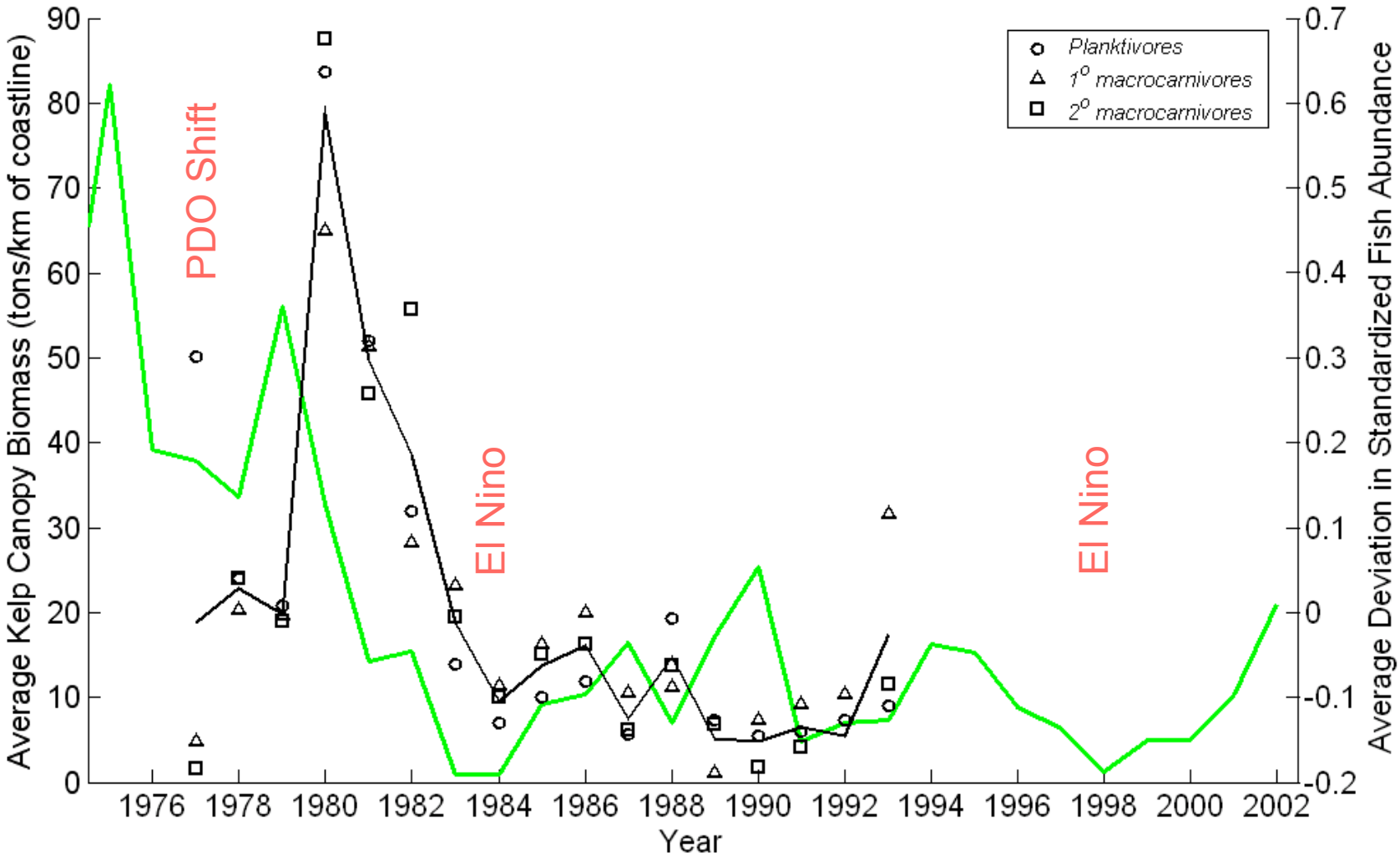
  Plant life spans ~ 2.5 years

  Frond life spans ~ 4 months

  Fronds growth can be 0.5 m/day



Macrocystis & Fish Stocks

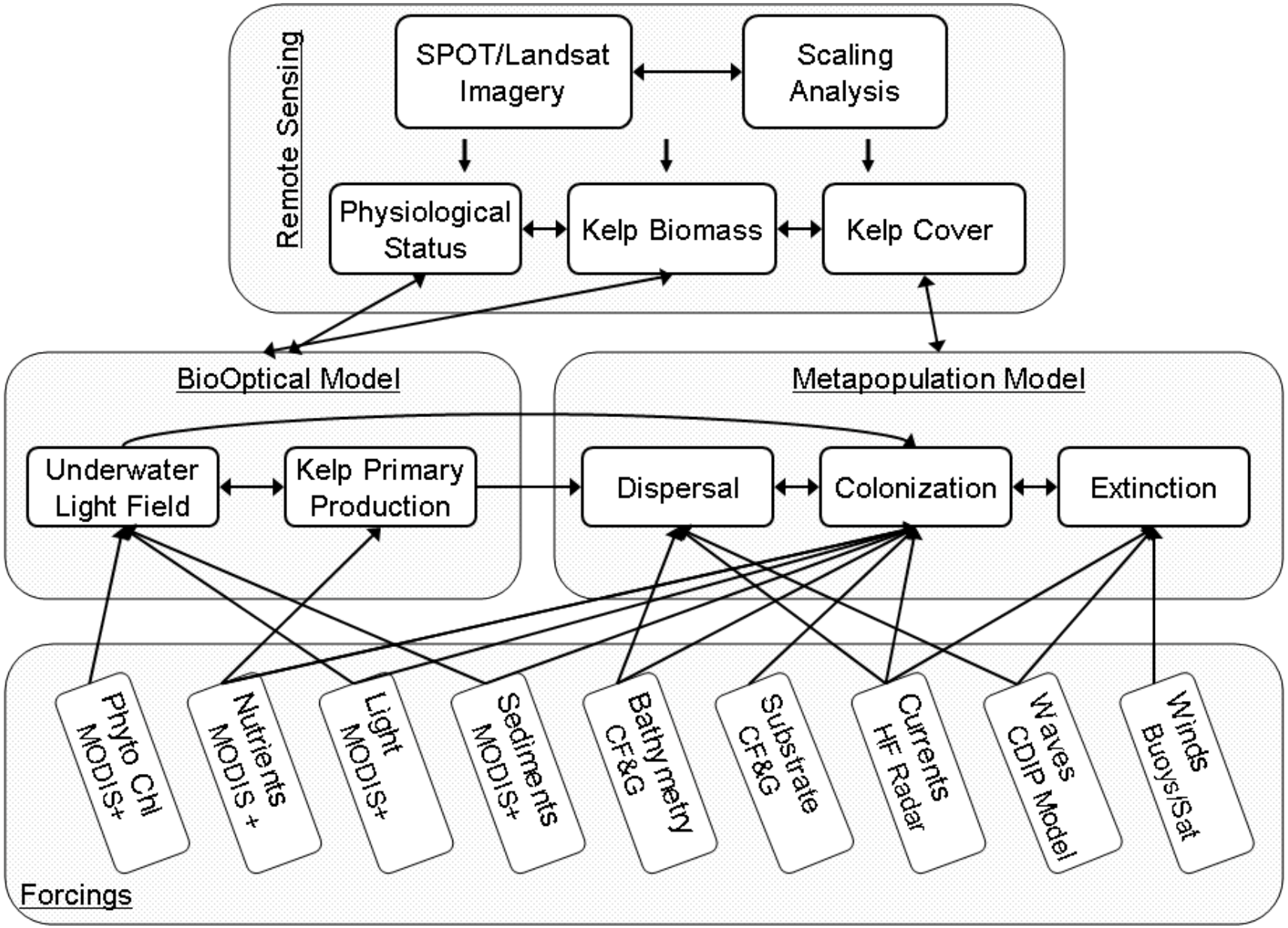


Kelp biomass data from Kelco visual estimates;
Fish observations from Brooks et al 2002

Reed et al. [2006]

Macrocystis Dynamics

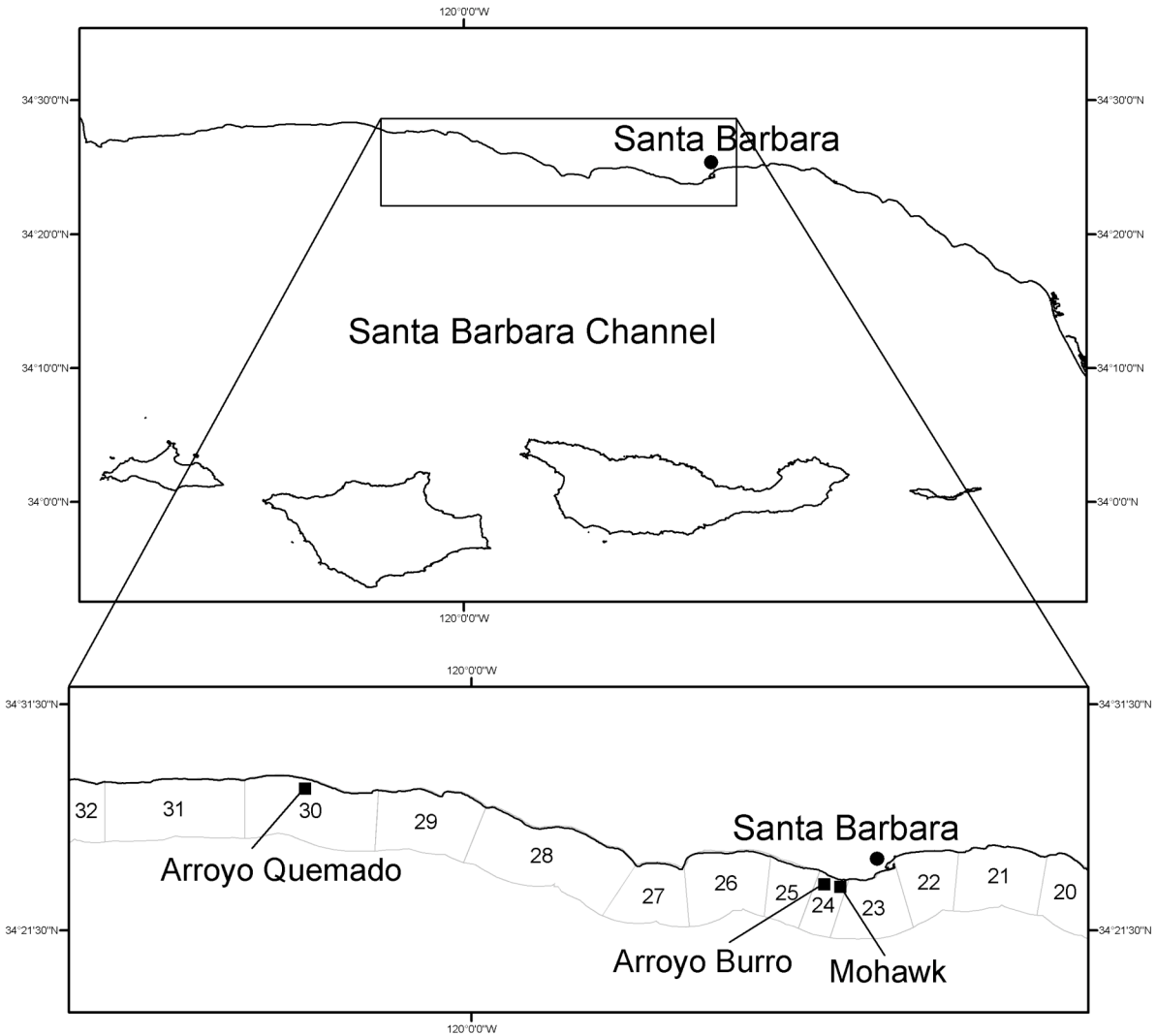
- Growth
  - Nutrients & seawater temperature
- Mortality / Disturbance
  - Wave action (esp. storms), senescence, predation, DOC release, etc.
- Colonization
  - Spore dispersal, benthic light levels, depth, substrate type, etc.


Remote Sensing
SPOT/Landsat Imagery
Scaling Analysis
Physiological Status
Kelp Biomass
Kelp Cover
BioOptical Model
Metapopulation Model
Underwater Light Field
Kelp Primary Production
Dispersal
Colonization
Extinction
Phyto Chl MODIS+
Nutrients MODIS +
Light MODIS+
Sediments MODIS+
Bathymetry CF&G
Substrate CF&G
Currents HF Radar
Waves CDIP Model
Winds Buoys/Sat
Forcings

Research Goals

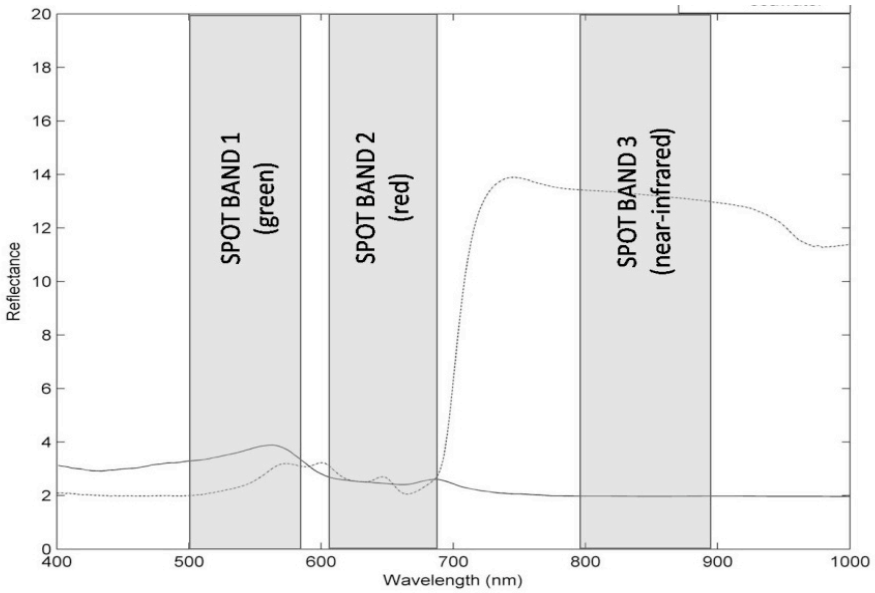
- Understand variability of giant kelp canopy cover & carbon biomass
  - High resolution satellite imagery (SPOT, Landsat, etc.) informed by SBC-LTER observations
- Develop models of kelp forest dynamics
  - Benthic light levels & colonization
  - Gross / net primary production
  - Patch dynamics models of canopy cover

Research Area



Remote Sensing of *Macrocystis* with Multispectral Imagery

- Surface canopy of giant kelp exhibits high near infrared (NIR) reflectance
- SPOT5 imagery well suited to differentiate kelp

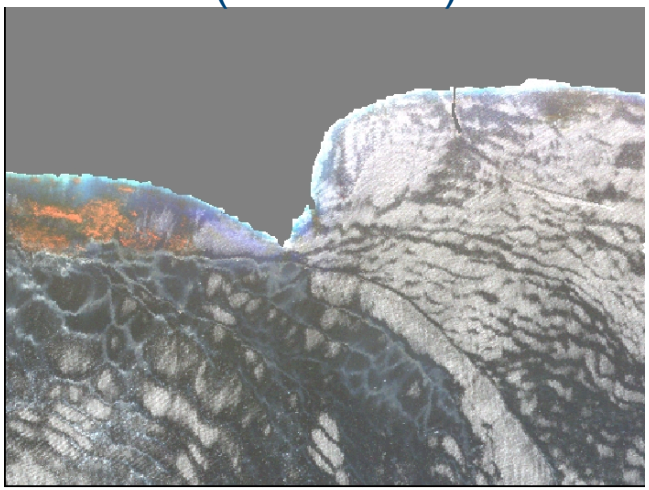


Canavaugh et al. [submitted]

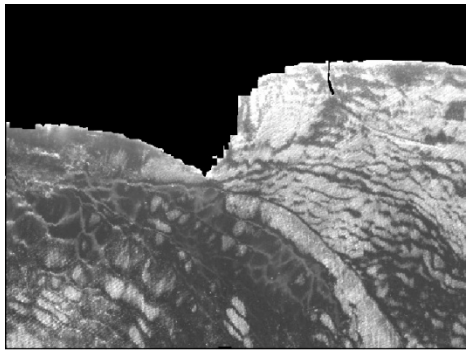
Methods: Canopy Cover

1. Perform dark pixel atmospheric correction
2. Principal components analysis to separate residual surface signal (PC1) from kelp (PC2)

False color SPOT image (8/15/2006)

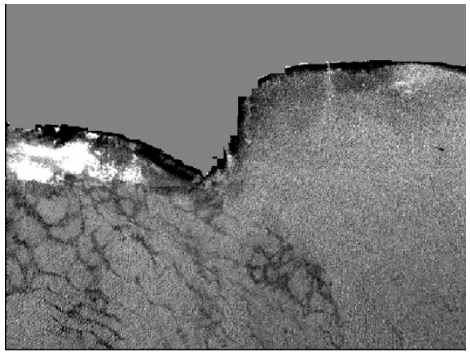


PC band 1



- Positive contribution from all 3 bands
- Glint, sediment loads, atmosphere variations, etc.

PC band 2



- High NIR, low green and red reflectance
- Kelp

Kelp Forest Biomass

- Useful for understanding & modeling ecosystem interactions
  - NPP, turnover, export, etc.

- Difficult to measure directly
  - Time and effort intensive
  - BUT SBC-LTER does monthly surveys…

SBC-LTER Diver Surveys

- Monthly measurements of kelp forest attributes at Arroyo Quemado, Arroyo Burro & Mohawk Area
- Assessment of areal kelp biomass, frond/blade density, net primary production, etc.
- Sampling for 160 m^2 transect
  - About 16 SPOT 5 pixels

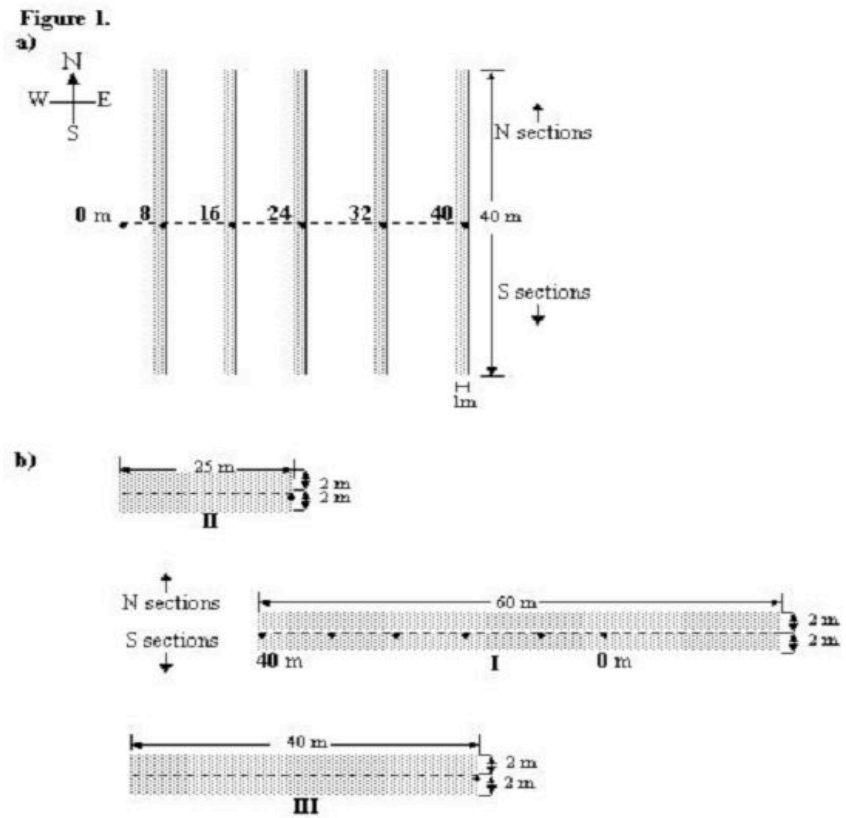


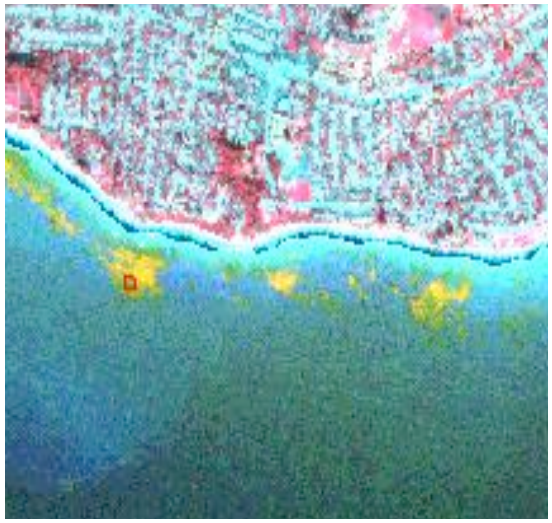
Figure 1. Transect layout and sampling areas of kelp NPP sites at (a) Arroyo Quemado, Mohawk and (b) Arroyo Burro. Bold numbers denote distances (meters) of permanent bolts along SBCLTER transect 1 at each site. Shaded areas are kelp NPP sampling areas.

Methods: Biomass

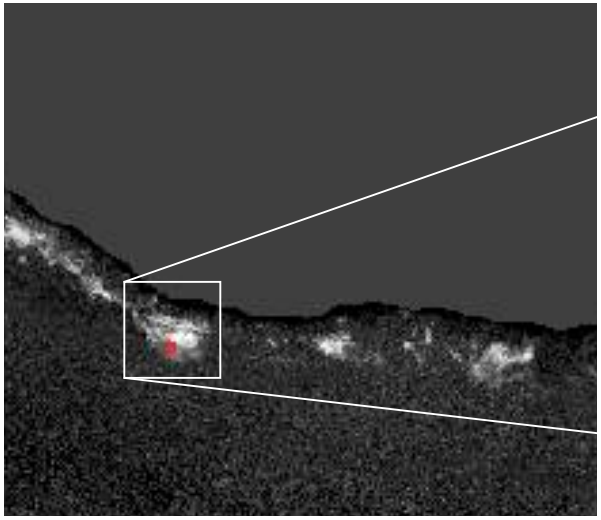
- Normalized Difference Vegetation Index (NDVI)

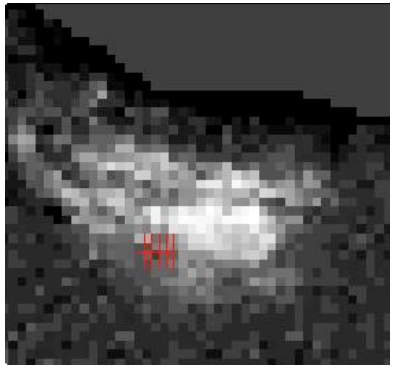
$$\frac{(NIR-RED)}{(NIR+RED)}$$

- Calculated for areas of kelp cover

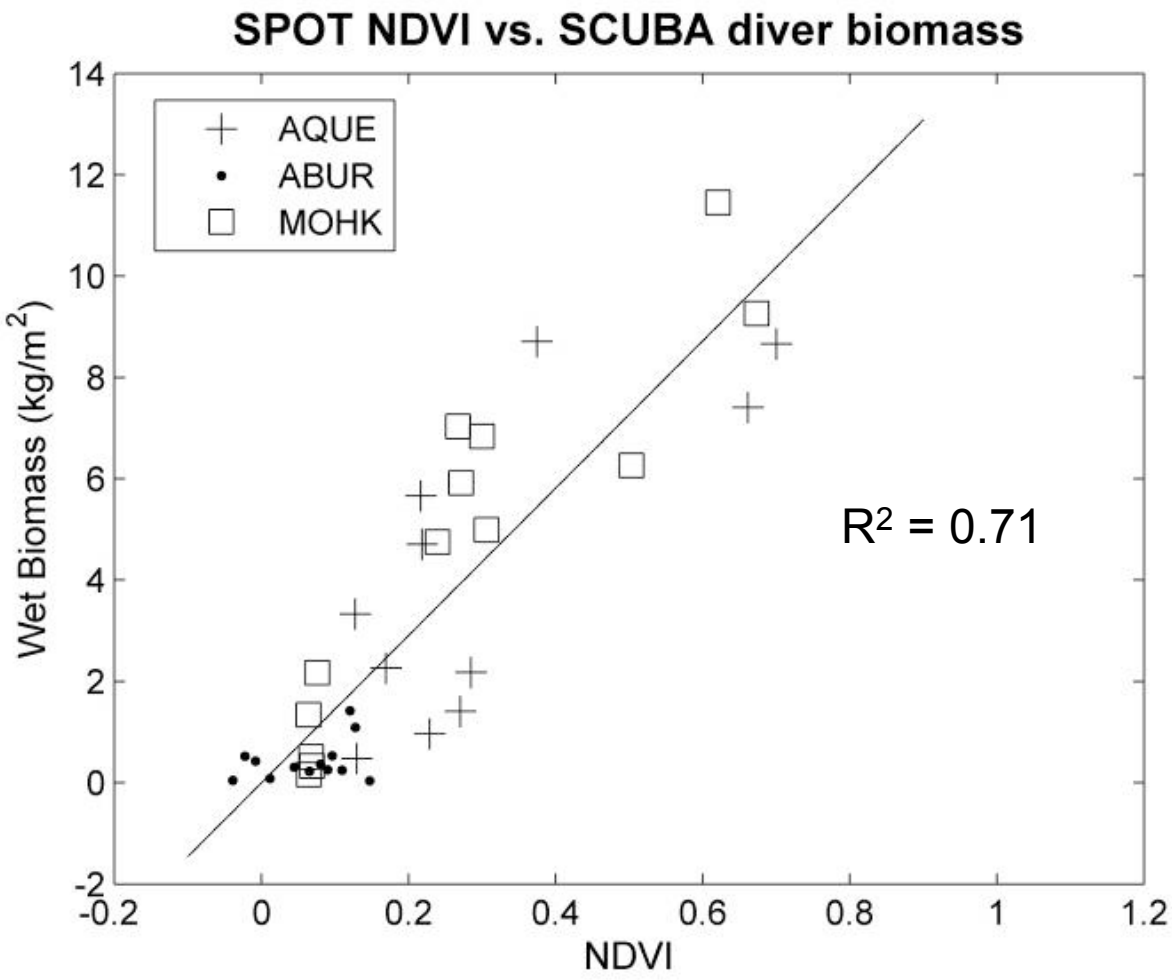


NDVI
Transform

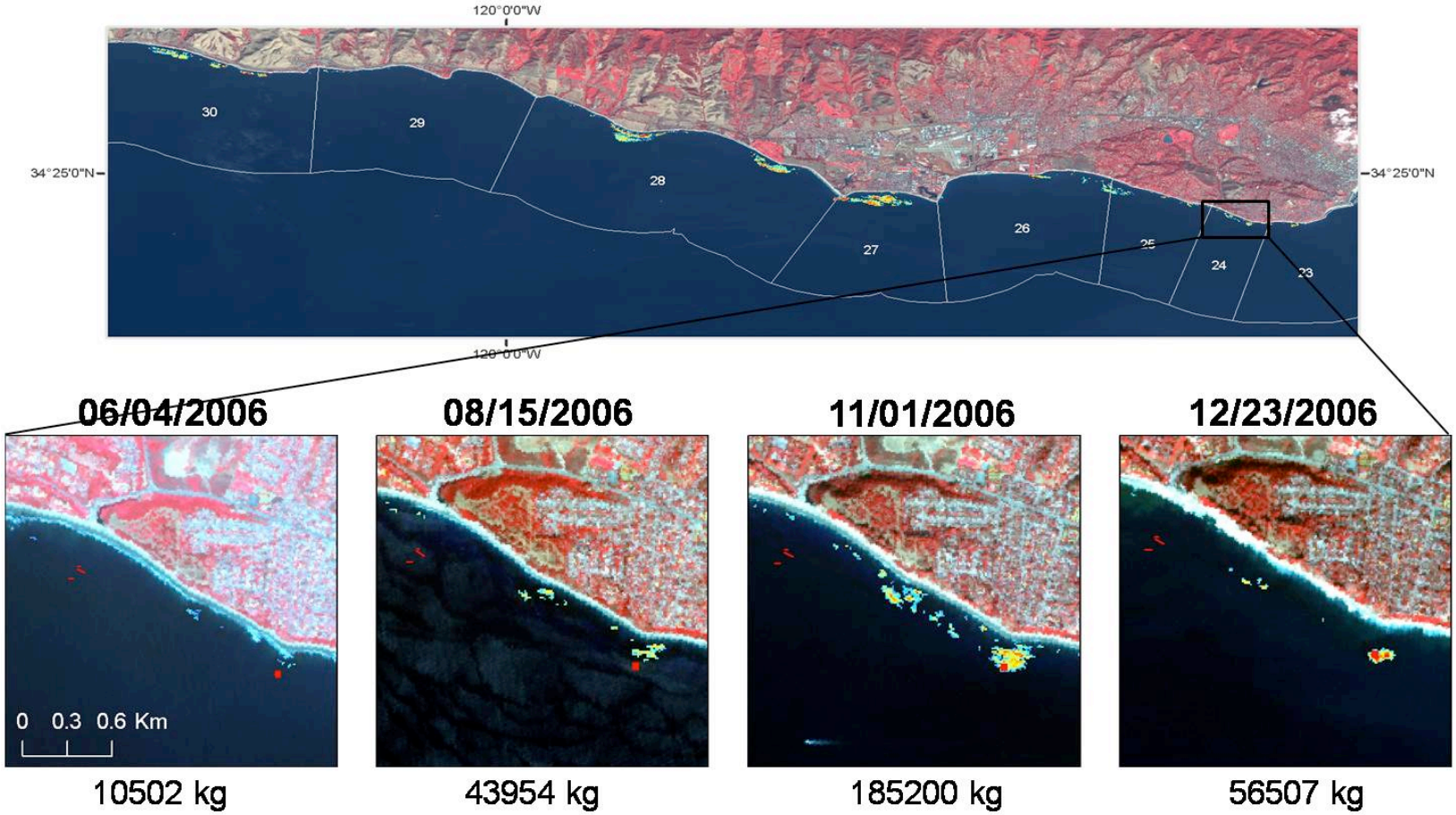




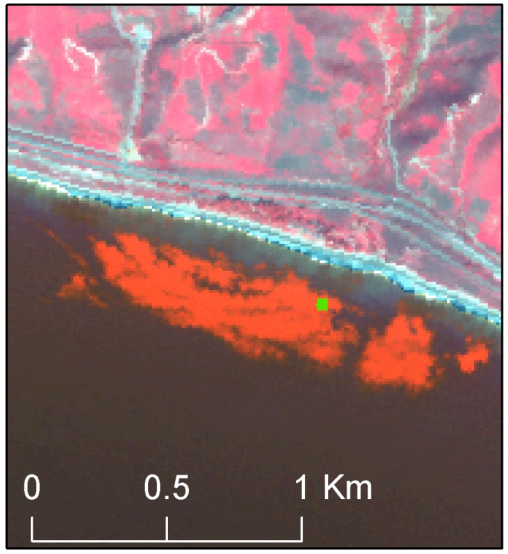
Biomass Calibration

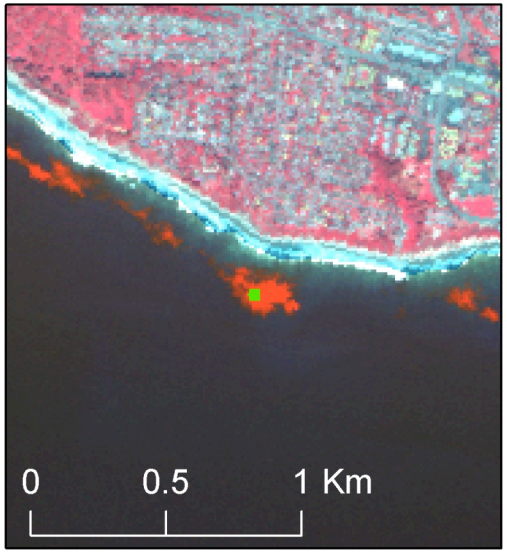


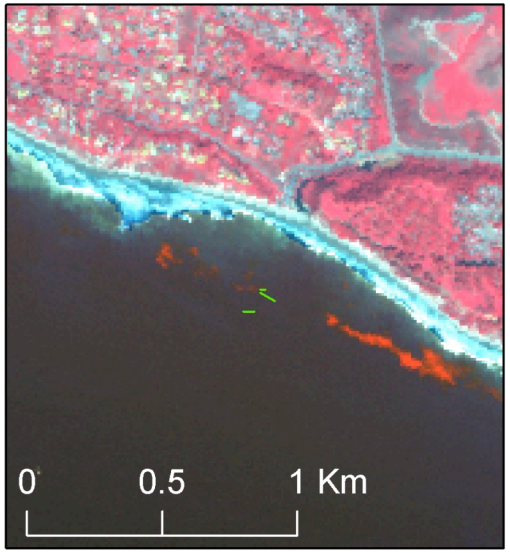
Seasonal Kelp Forest Changes

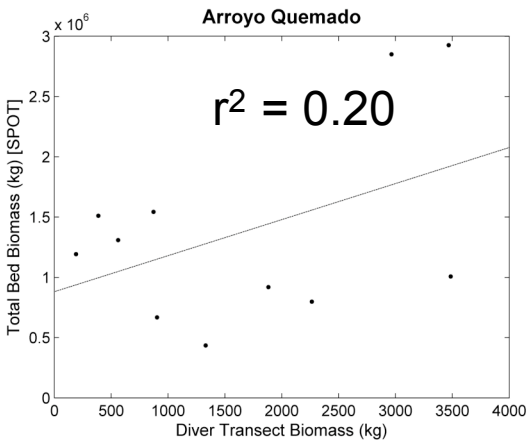


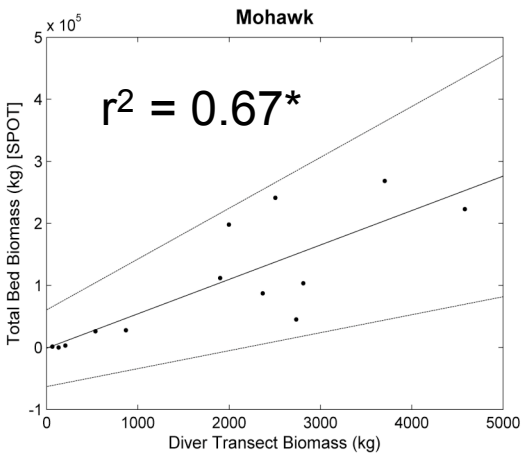
Biomass Determinations

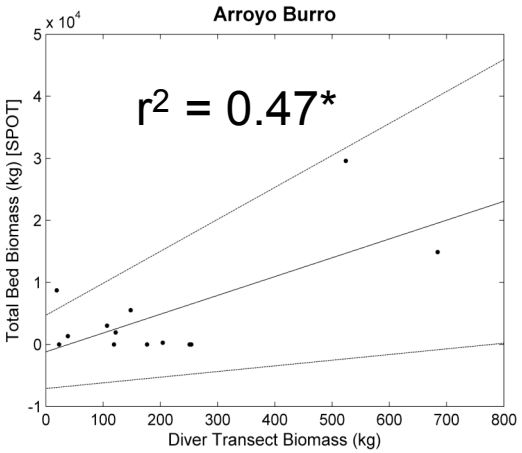






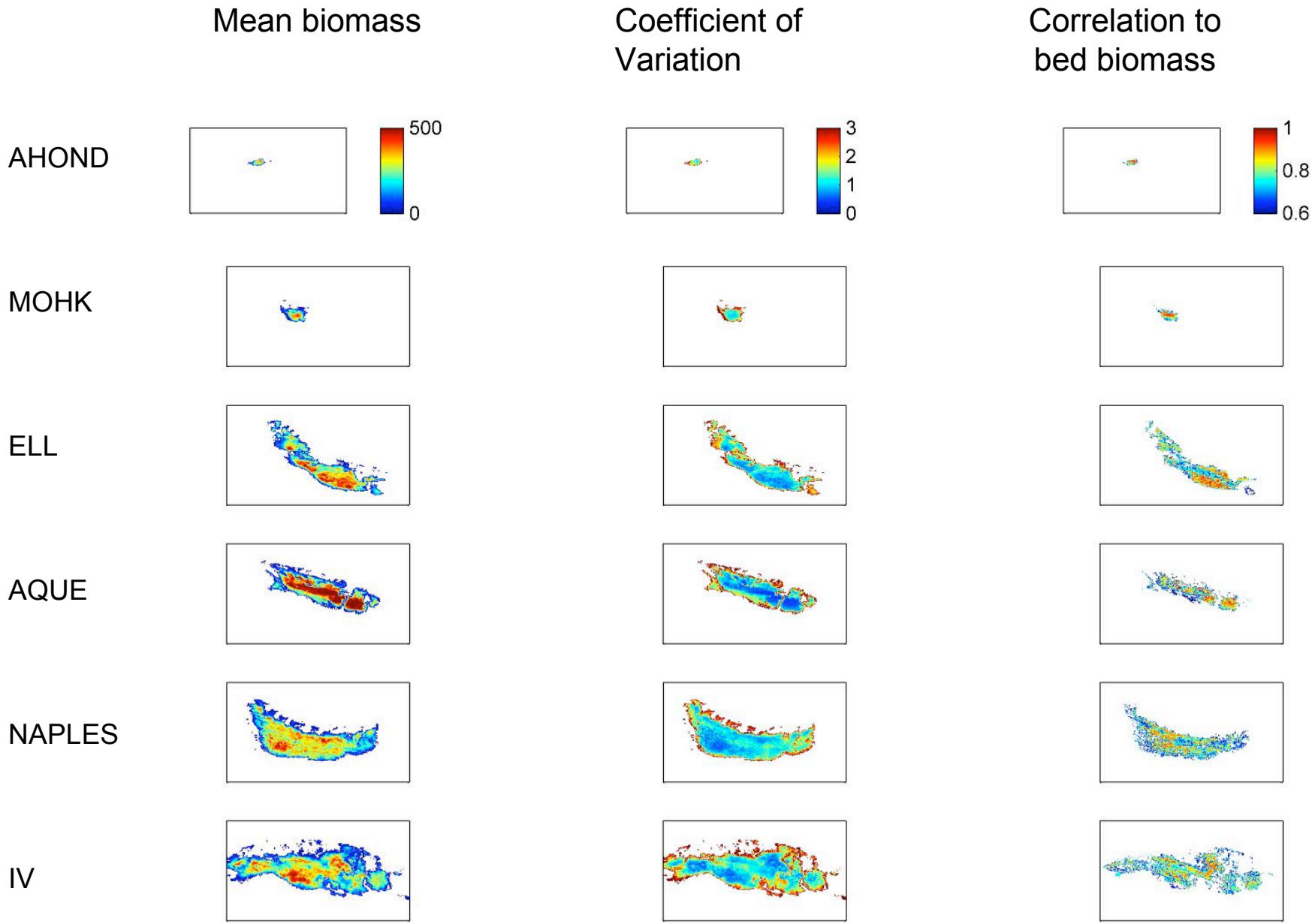




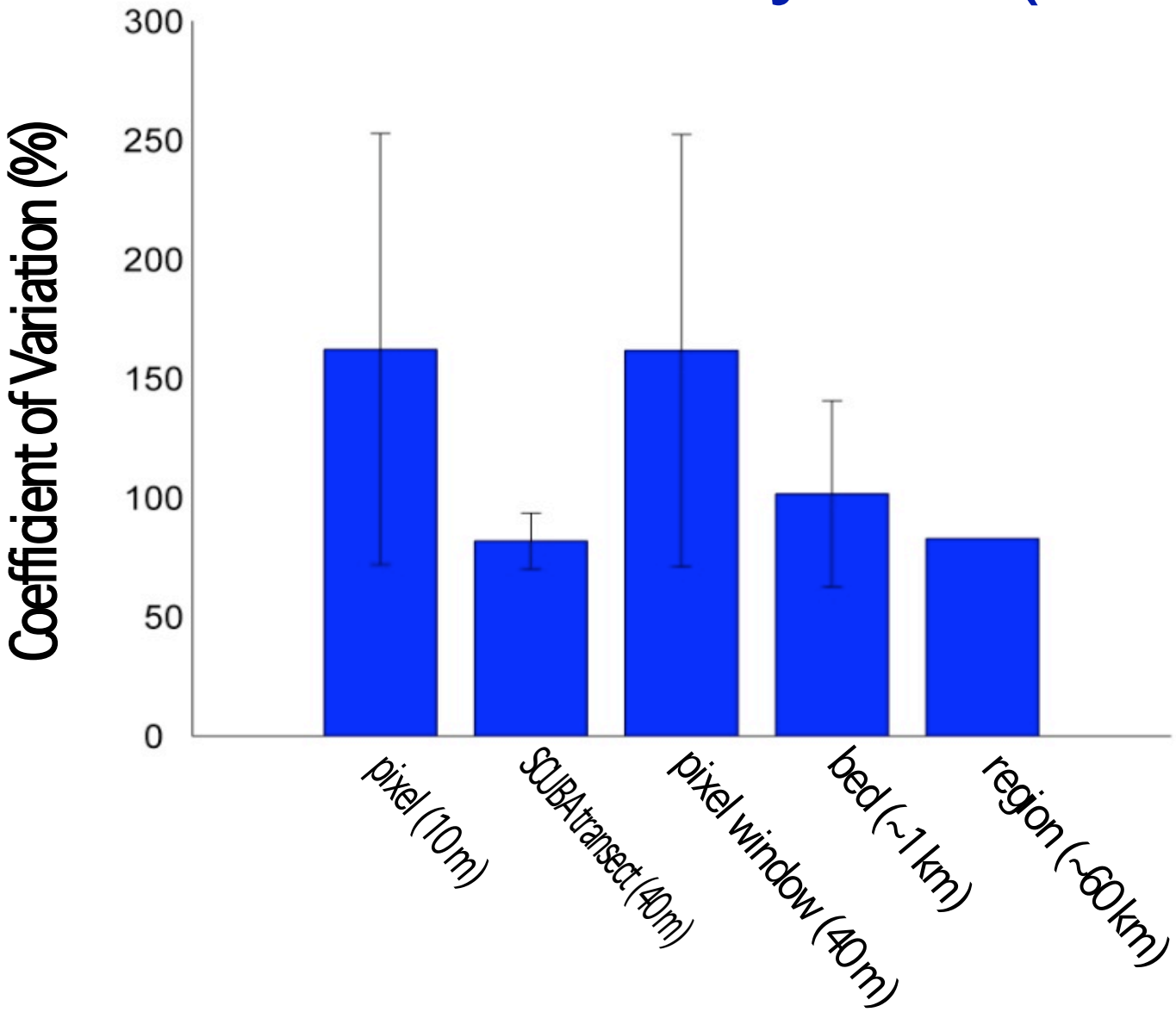


Matters where one samples to scale transect obs to bed scale

Intra-Bed Biomass Variability



Biomass Variability as f(Scale)



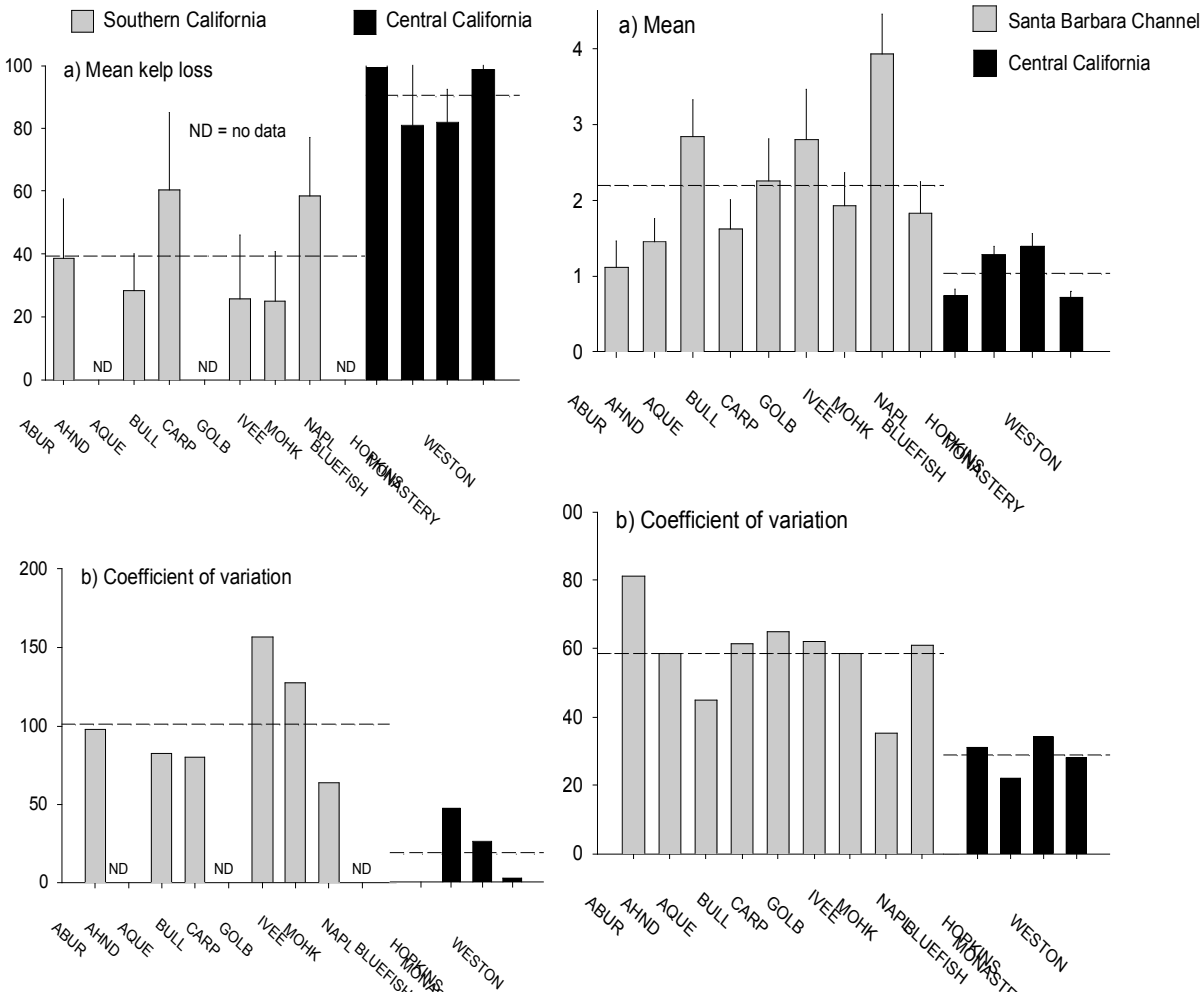
Remote Sensing Status

- Source of SPOT data has become “intermittent”
  - We have not sampled the disturbance regime (winter wave forcing) effectively
- We have turned to Landsat imagery
  - Imagery is now free
  - Spatial scale is 30 m vs. 10 m, BUT…
  - Landsat 5 & 7 imagery is regularly sampled and gives us a 25 year record to work with, BUT…
  - Harder to create a consistent atmospheric correction procedure (in progress)

Role of Wave Disturbance

Winter kelp loss

Annual NPP

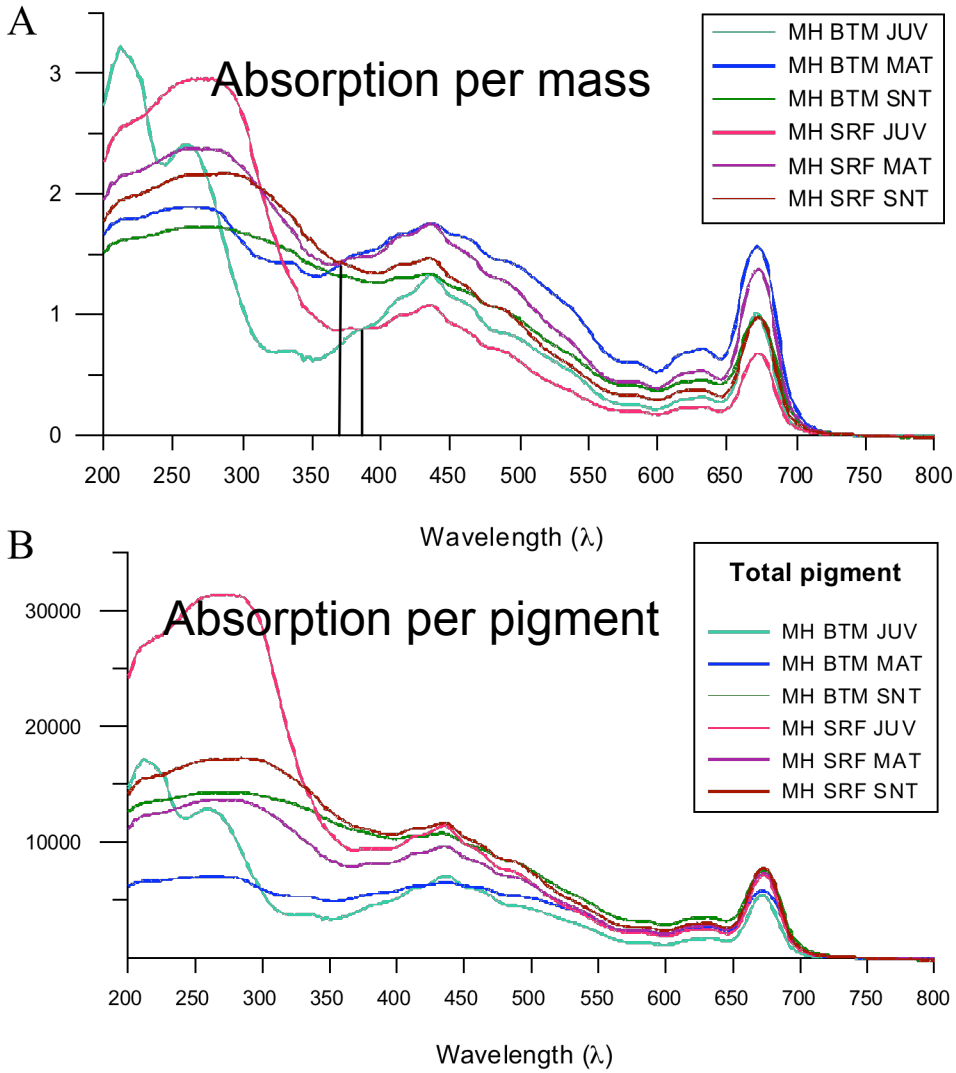


Reed et al. [submitted]
using Landsat imagery

- greater wave disturbance leads to lower mean annual NPP
- greater inter-annual variability in waves leads to greater inter-annual variability in NPP

Bio-Optical Assessments

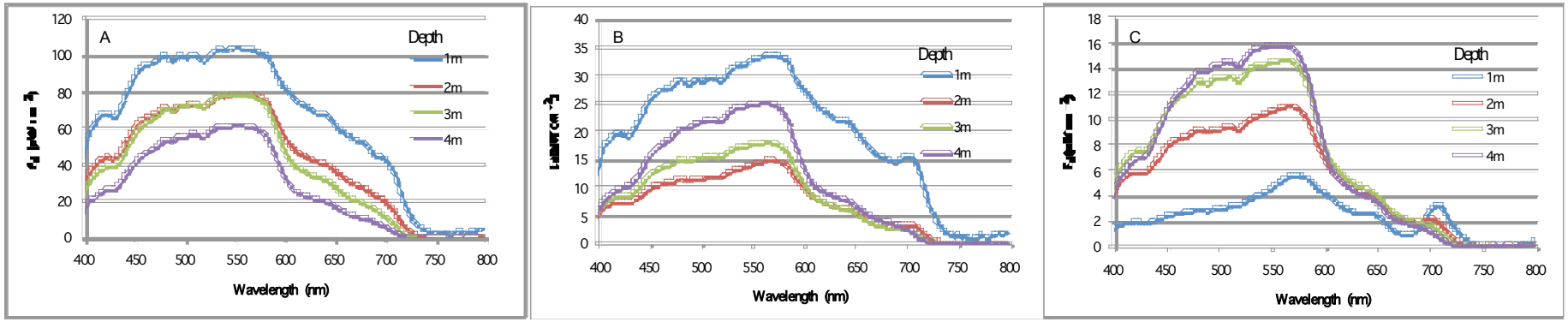
- Less absorption per mass for surface blades
- Juvenile blades have lower absorption per mass than mature one
- UV absorption features increase for shallow blades
- Optical cross sections greater for surface than deeper blades



Zimmerman & Hill [ODU]

Light in Kelp Forests

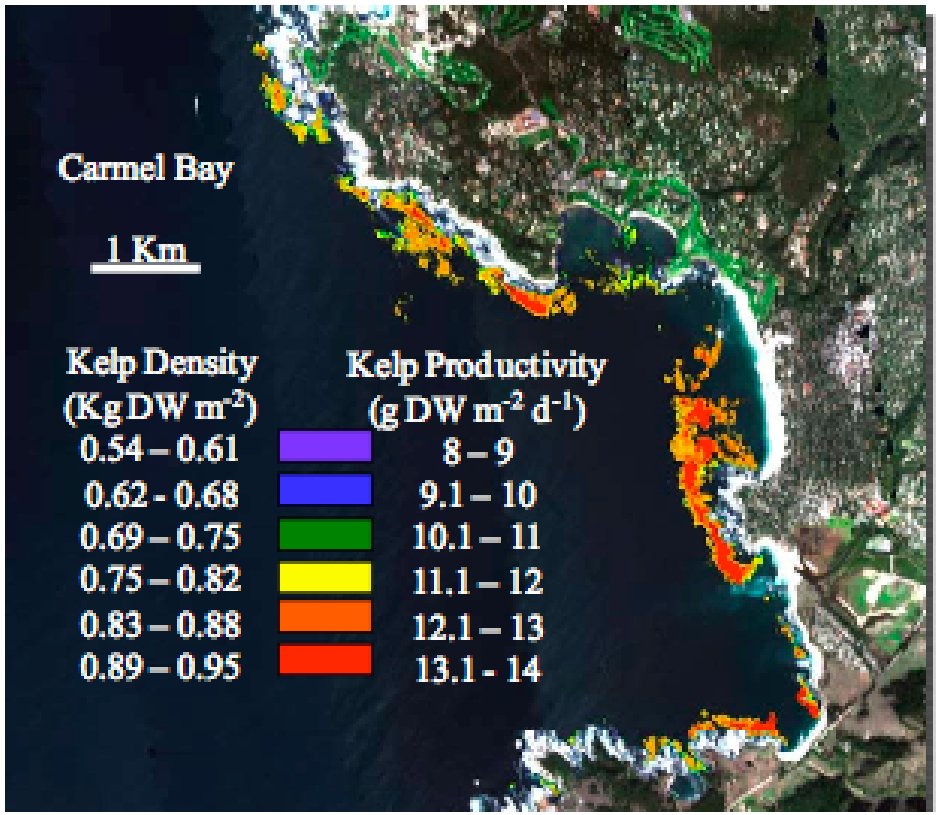
Edge of Canopy | Gap in Canopy | Under Canopy

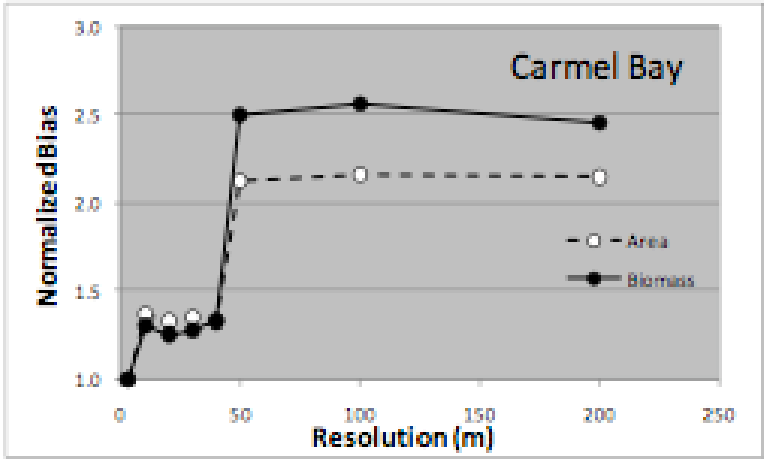


- Light quantity & quality are highly influence by canopy location
- Will be used in bio-optical modeling of kelp PP
- Field work underway to assess changes in seawater attenuation on/off shelf
- Applied to be a champion MERIS full resolution user…

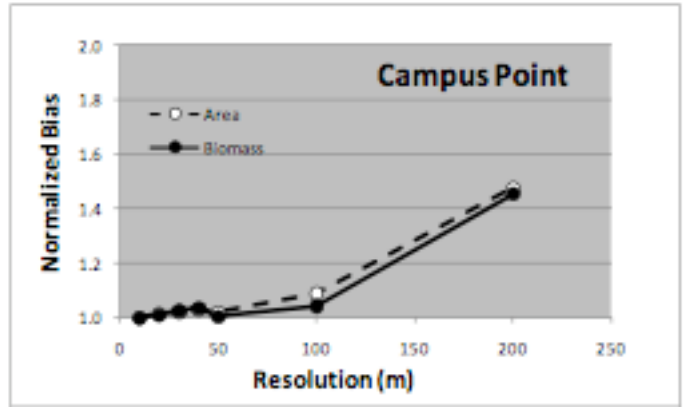
Resolution & Scaling

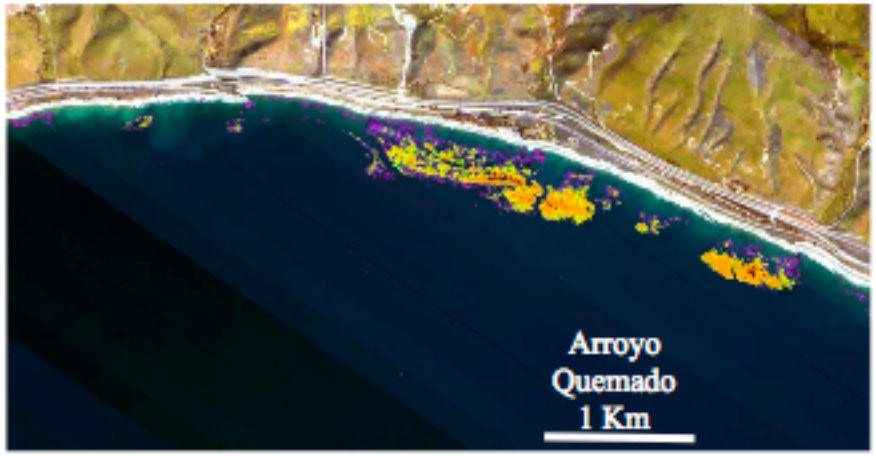
Airborne hyperspectral imagery….

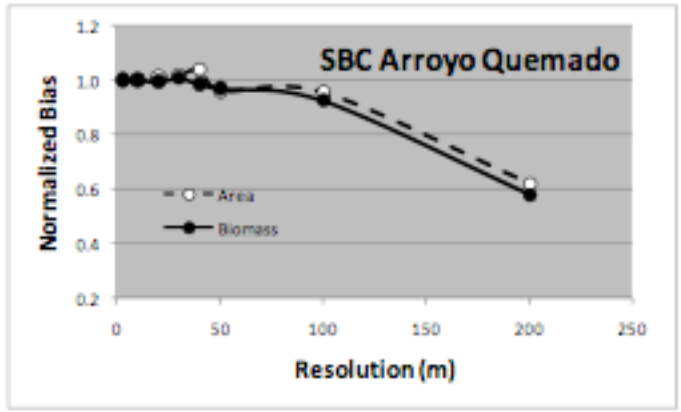




Resolution & Scaling







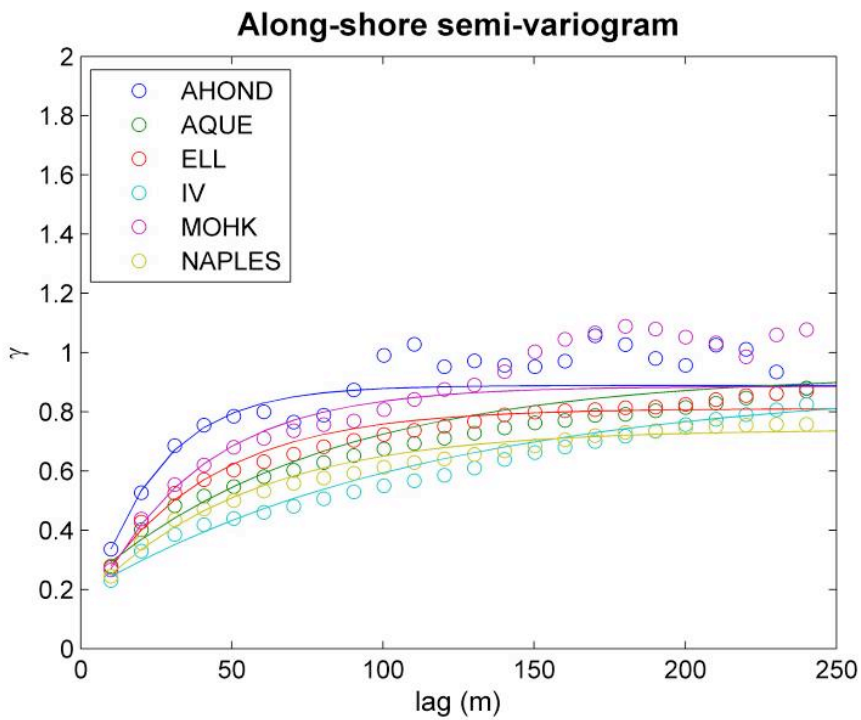
Resampling to lower resolution can create both positive & negative biases

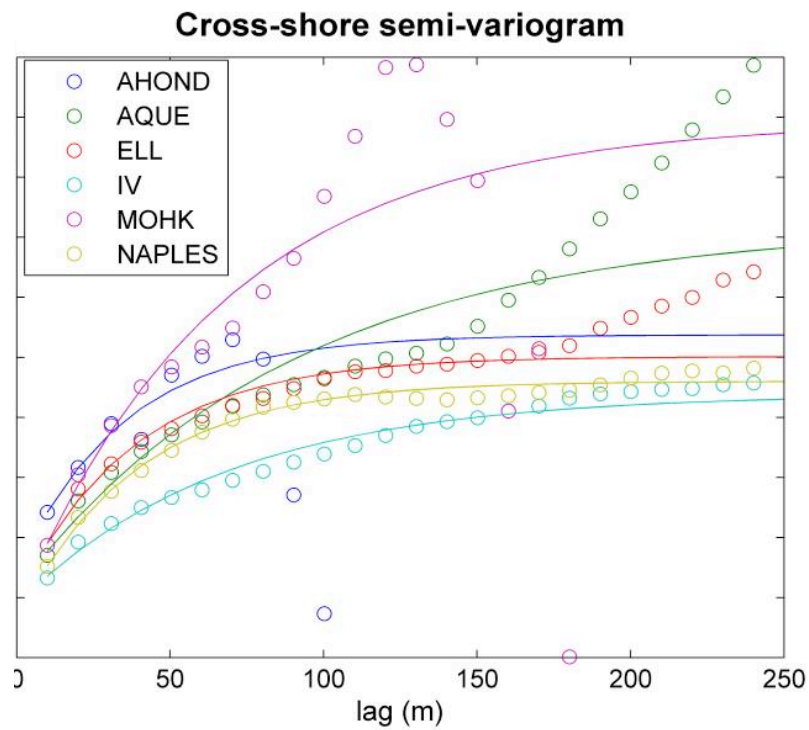
Next Steps

- Complete Landsat kelp quantification procedures
- Remote sensing of kelp forest variability
  - Characterize decadal scale changes using Landsat obs
  - Patch-level description of occupancy, etc.
  - Estimate regional scale kelp forest NPP
  - Evaluate disturbance factors (waves, etc.)
- Light propagation in & around kelp forests
  - Canopy light modeling & kelp blade photoacclimation
  - Assess on/offshore changes in seawater attenuation
- Compare models kelp of gross photosynthesis to NPP


Thank You!!

Semivariagram Analysis





Along-Shore

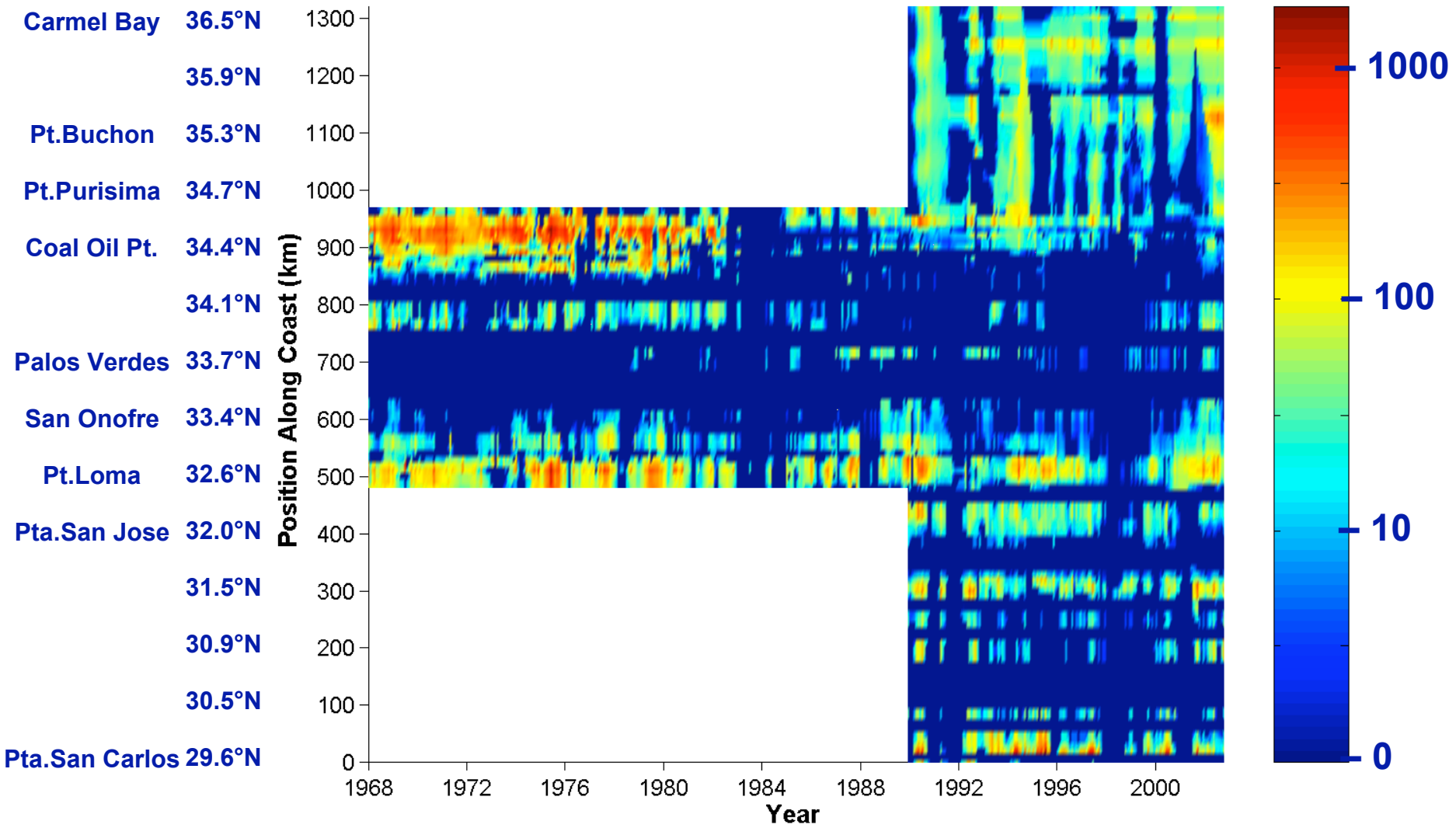
	nugget	sill	range (m)
AHOND	0.03	0.86	67.93
MOHK	0.07	0.82	107.72
ELL	0.13	0.69	116.70
AQUE	0.21	0.72	238.90
NAPLES	0.15	0.59	159.49
IV	0.19	0.71	350.17

Cross-shore

	nugget	sill	range (m)
AHOND	0.29	0.79	104.13
MOHK	0.16	1.63	201.86
ELL	0.19	0.81	113.94
AQUE	0.23	1.21	271.07
NAPLES	0.13	0.79	117.52
IV	0.18	0.70	204.37

ISP Alginates Visual Kelp Biomass

Kelp canopy biomass, 34-year monthly time series



Raw data provided by D. Glantz, ISP Alginates, Inc. & Santa Barbara Coastal LTER

Canopy Biomass (tons/km coast)