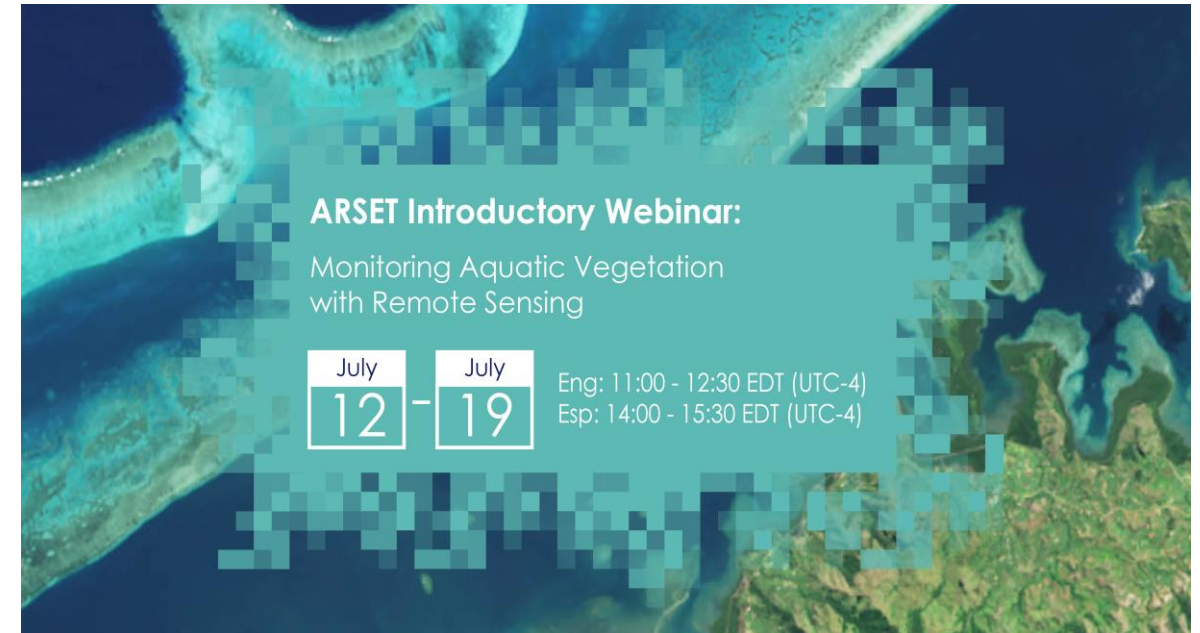# Monitoring Aquatic Vegetation with Remote Sensing

Juan L. Torres-Pérez, Amber McCullum

July 14, 2022

Course Structure and Materials

- Three, 1.5-hour sessions on July 12, 14 and 19
- The same content will be presented at two different times each day:
  - Session A: 11:00-12:30 EDT (UTC-4) (English)
  - Session B: 14:00-15:30 EDT (UTC-4) (Spanish)
  - **Please only sign up for and attend one session per day.**
- Webinar recordings, PowerPoint presentations, and the homework assignment can be found after each session at:
  - https://appliedsciences.nasa.gov/join-mission/training/english/arset-monitoring-aquatic-vegetation-remote-sensing
- Q&A following each lecture and/or by email at:
    - juan.l.torresperez@nasa.gov or
    - amberjean.mccullum@nasa.gov

ARSET Introductory Webinar:

Monitoring Aquatic Vegetation with Remote Sensing

July 12 – July 19

Eng: 11:00 - 12:30 EDT (UTC-4)
Esp: 14:00 - 15:30 EDT (UTC-4)

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Answers must be submitted via Google Forms
  - **HW Deadline: Tuesday August 2nd**

- **Certificate of Completion:**
  - Attend both live webinars
  - Complete the homework assignment by the deadline (access from ARSET website)
  - You will receive certificates approximately two months after the completion of the course from: marines.martins@ssaihq.com

Prerequisites

- Prerequisites:
  - Please complete [Sessions 1 & 2A of Fundamentals of Remote Sensing](#) or have equivalent experience.
- Course Materials:
  - https://appliedsciences.nasa.gov/join-mission/training/english/arset-monitoring-aquatic-vegetation-remote-sensing

Learning Objectives

By the end of this session, you will become familiarized with:

- The ecology and importance of the kelp forest
- Historical and recent remote sensing and in-situ techniques used to study kelp forests
- Floating Forests: A citizen science tool for mapping the extent of kelp forests in the west coast of the United States
- Kelp Watch: A tool that uses Landsat data to visualize kelp coverage in western US

Kelp stand. Credit: www.pixabay.com

A Short Summary of Kelp Biology and Ecology

Structure of an Individual Kelp

- Typical Structures Include
- Holdfast
- Tallus (Body)
- Blades
- Pneumatocysts
- Stipes

Terminal blade
Canopy
Stipe
Blade
Float
Sporophyll
Holdfast
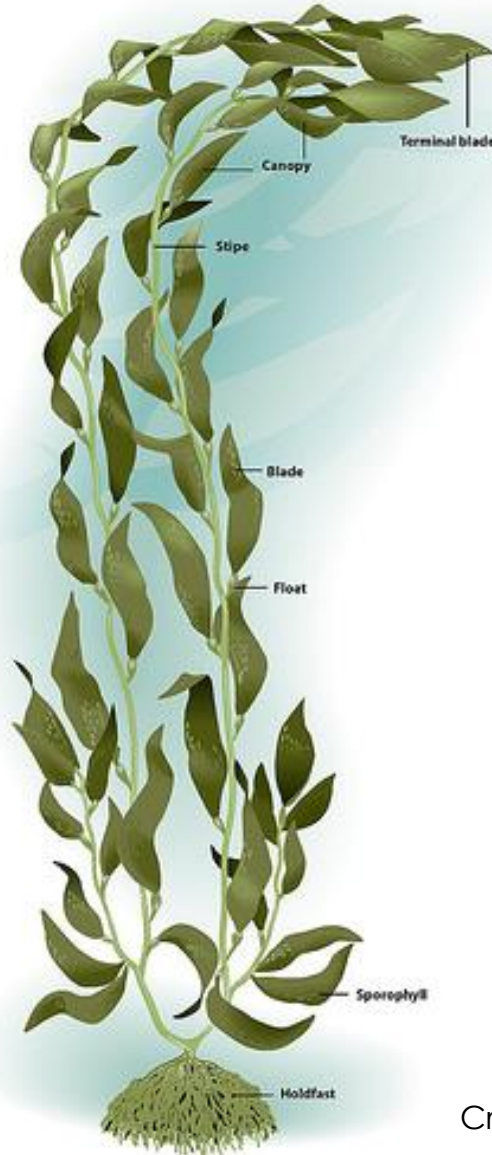
Credit: Kyle Cavanaugh (UCLA)

Kelp Forests

- Under ideal conditions, individuals can grow up to 18 inches per day.

- Many species have pneumatocysts (gas-filled bladders) that aid in their buoyancy.

- They harbor a diversity of other organisms.

- Many mammals and birds use the kelp forest for protection and finding food.

- They are recognized as one of the most productive and dynamic ecosystems on the planet.
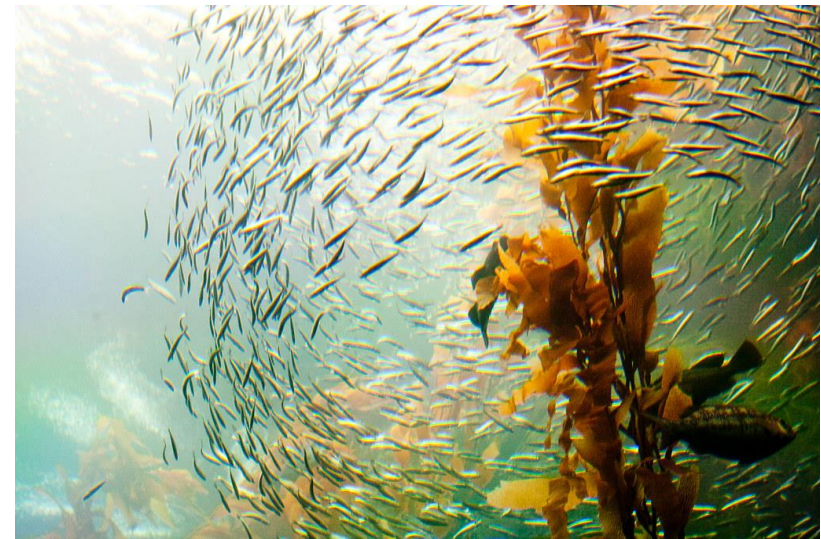
Credit: www.flickr.com

Kelp Distribution

- Estimated 2 million km^2

- About 36% of the World's coastlines

- The largest marine biome in the World

- Dominates temperate and cold waters

- *Macrocystis* is the most dominant genus.
  - One of the biggest SAVs with some individuals measuring > 30m in height
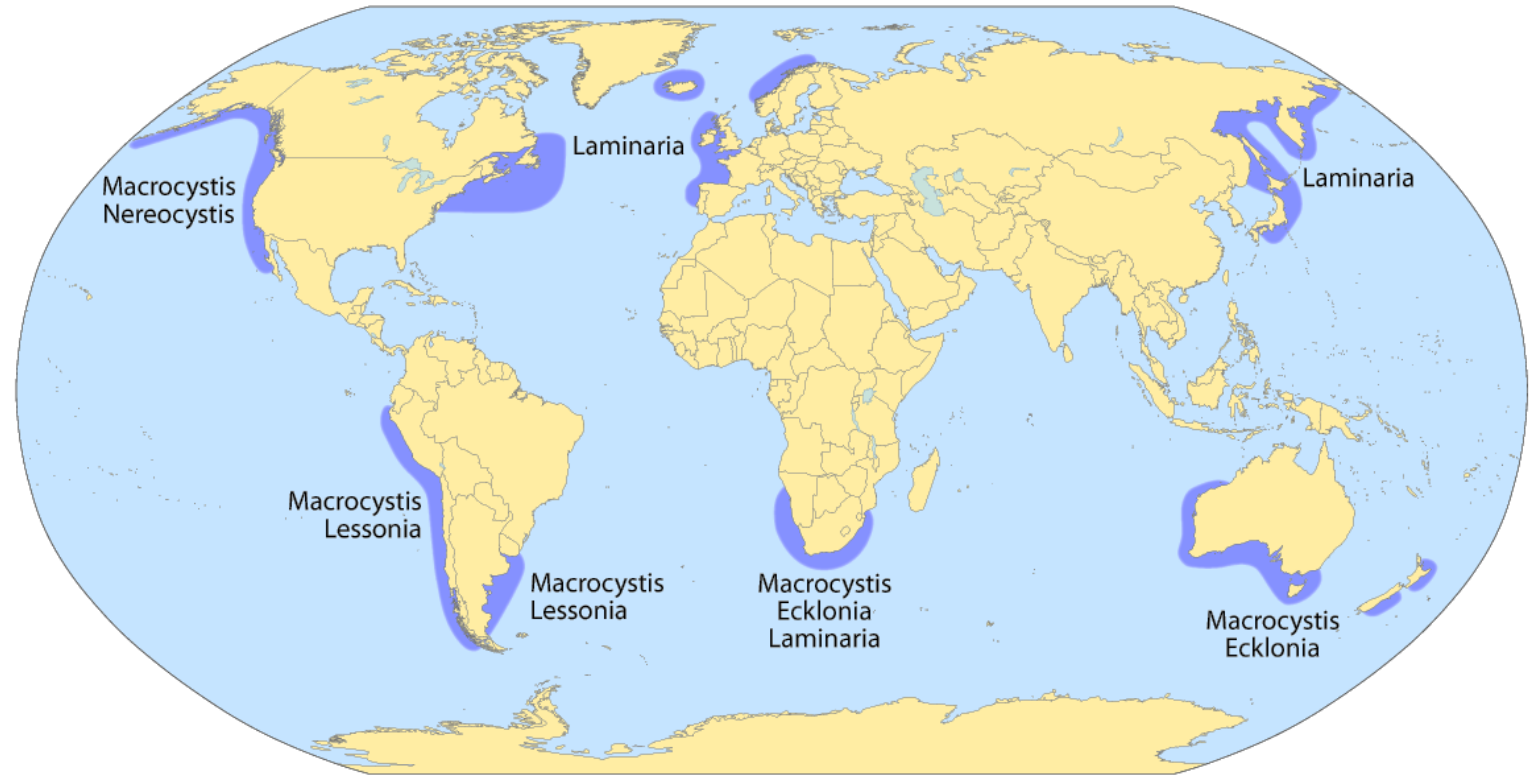
Credit: www.commons.Wikimedia.org

Factors Affecting Kelp Distribution

- Sea Surface Temperature (SST)

- SST increases at fine spatial scales (a few km) can cause extensive kelp loss (Starko et al 2022).

- Other factors include:
  - Wave height
  - Distance from the coast
  - Human-related impacts (e.g., eutrophication, mechanical damage)
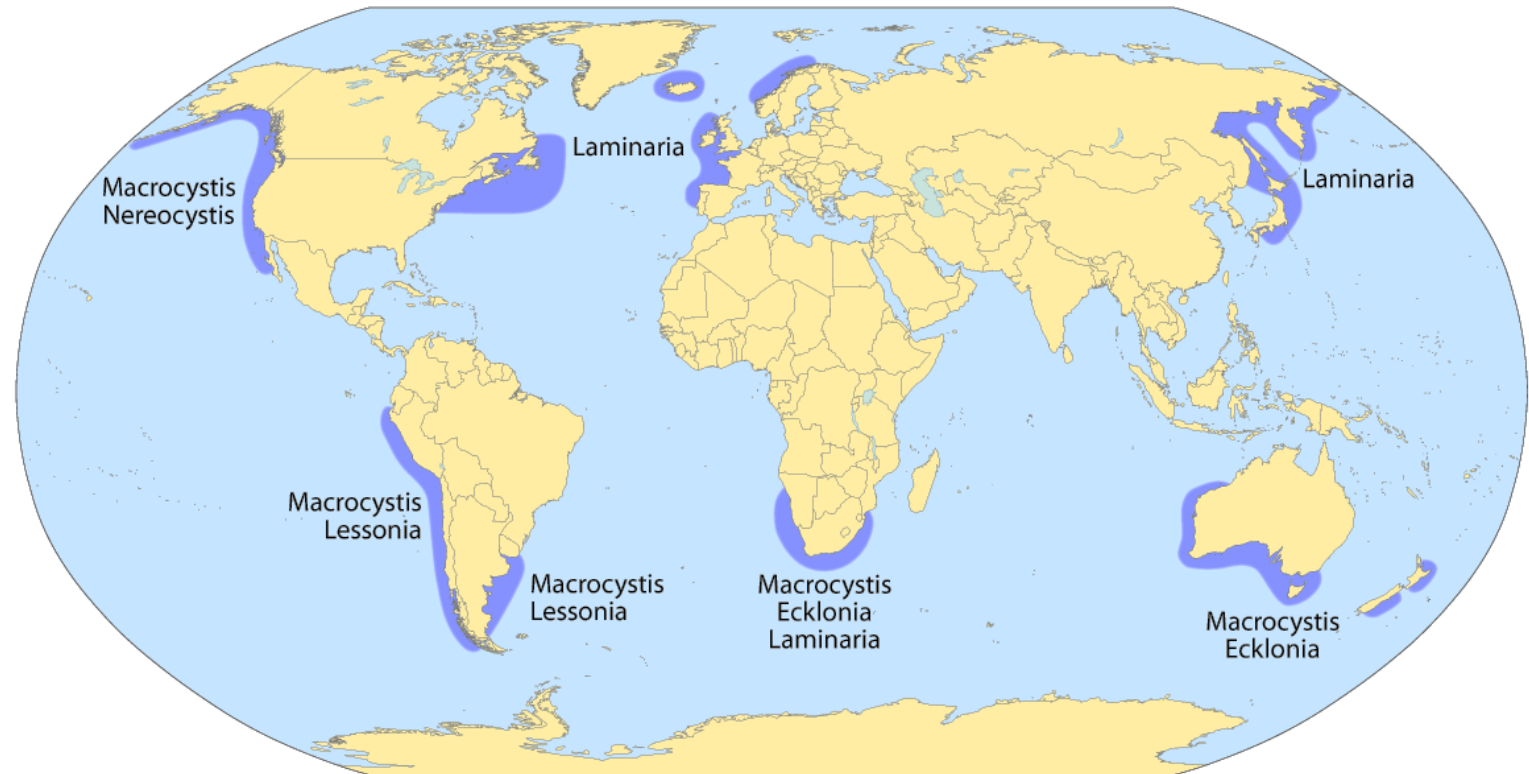
Credit: www.commons.Wikimedia.org

Kelp Ecology

- Kelp forests harbor a large diversity including invertebrates, fish, birds, and marine mammals.

- Many mammals and birds use the kelp forest for protection and finding food.

Credit: www.commons.Wikimedia.org

Credit: Juan L. Torres-Pérez
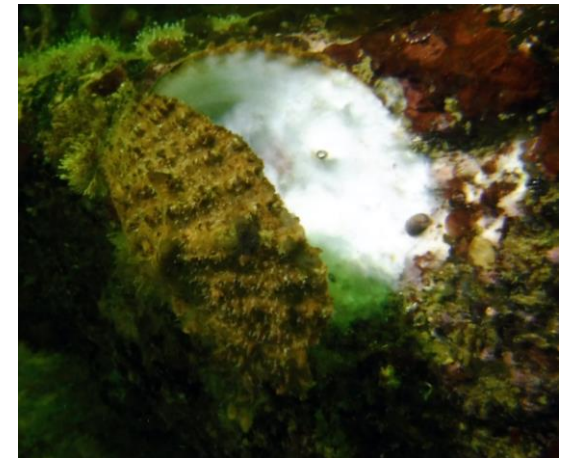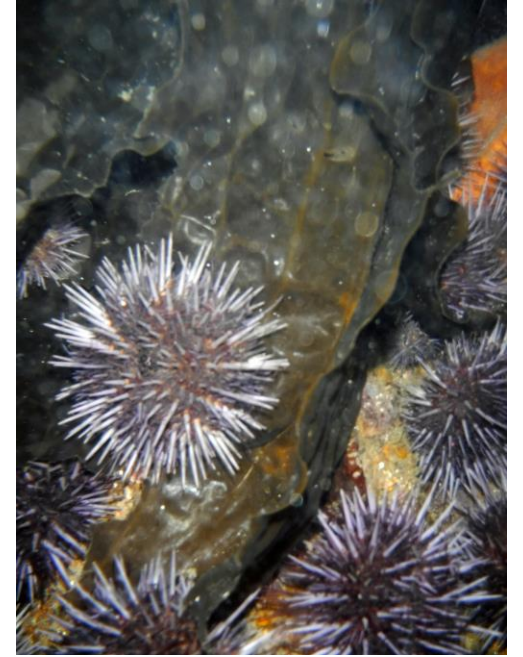
Spectral Discrimination of Kelp

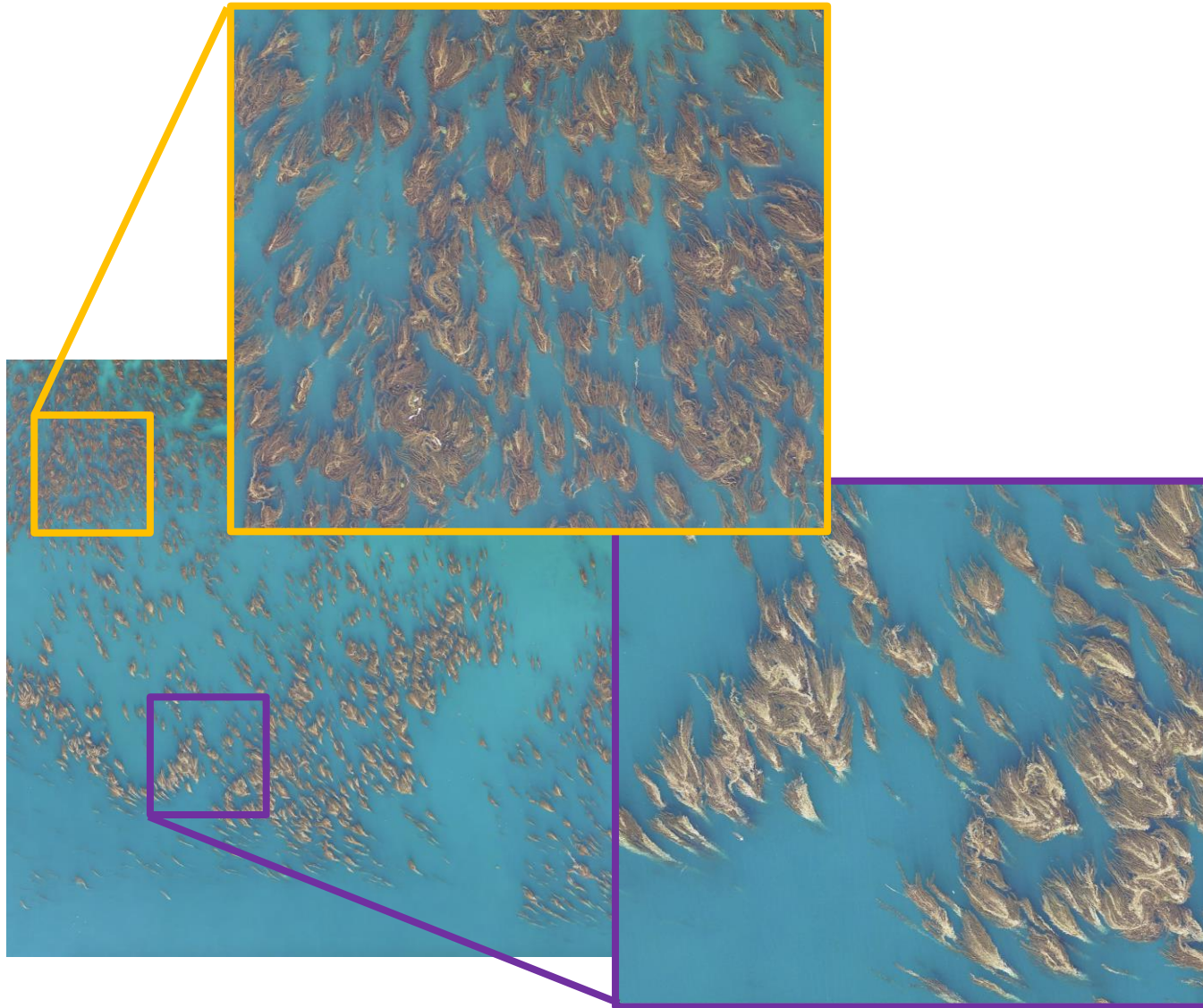# Reflectance of giant kelp canopy is affected by changes in photosynthetic pigments related to growth and age.
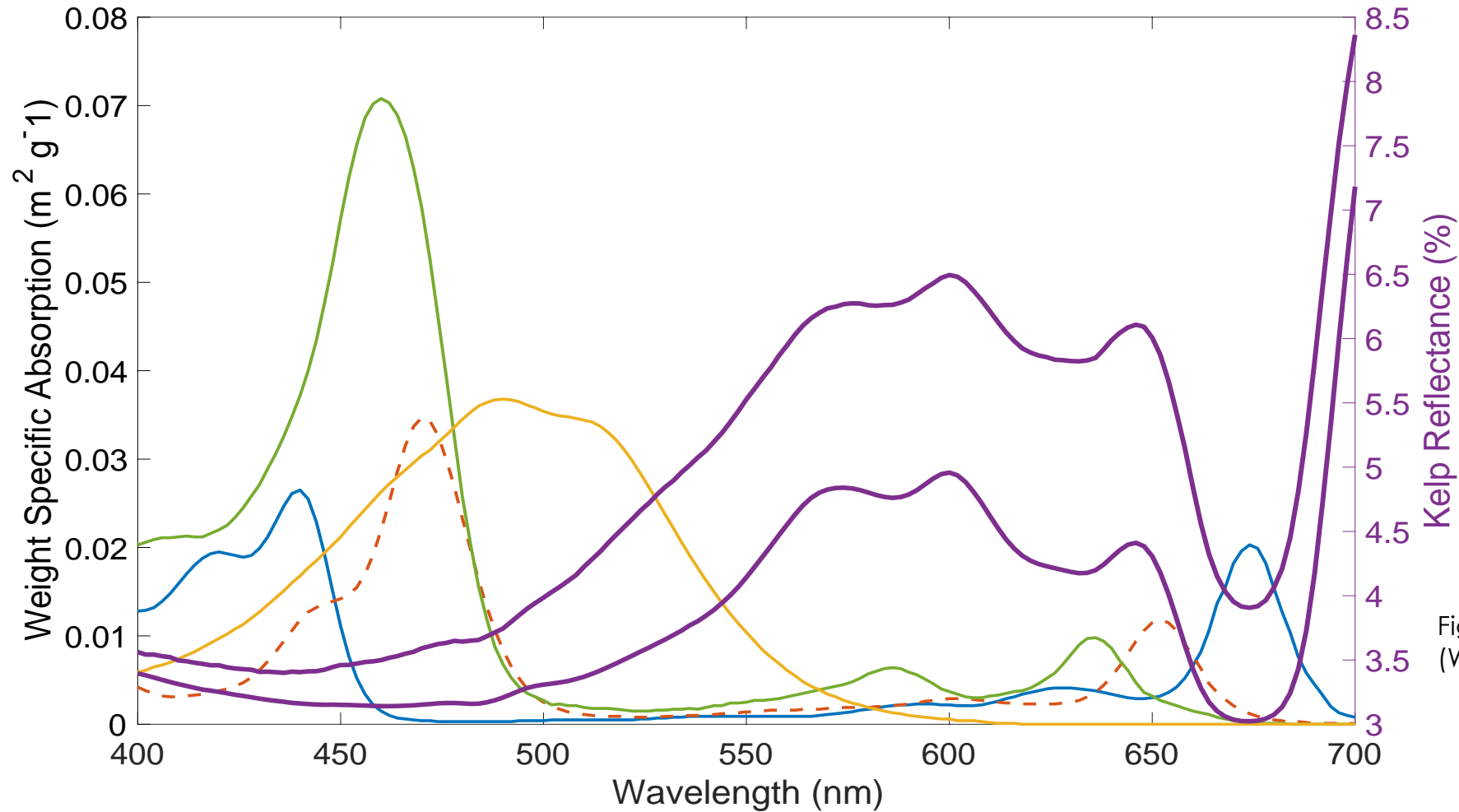
Figure Credit: Tom Bell (WHOI)

Landsat 8 OLI Visible Bands

Canopy senescence varies at local scales.


Mature

Senescent

Credit: Tom Bell (WHOI)

Field sampling shows a predictable reduction in physiological condition with age.
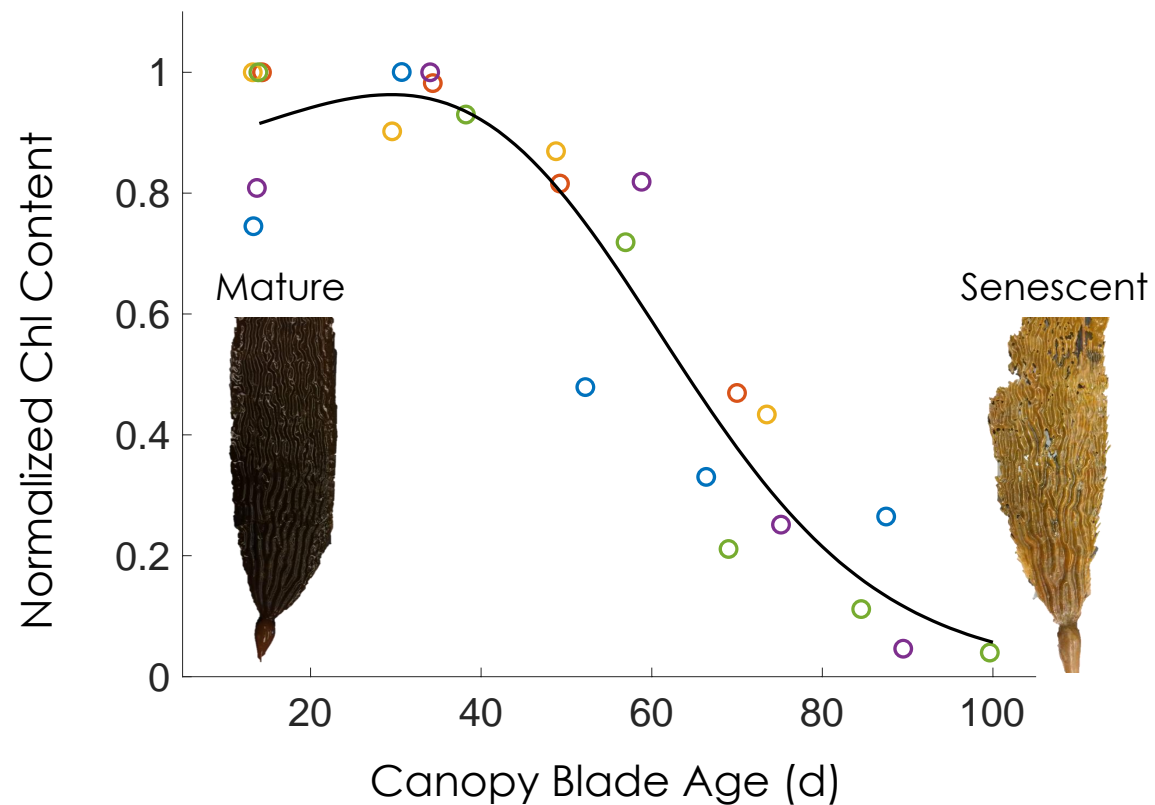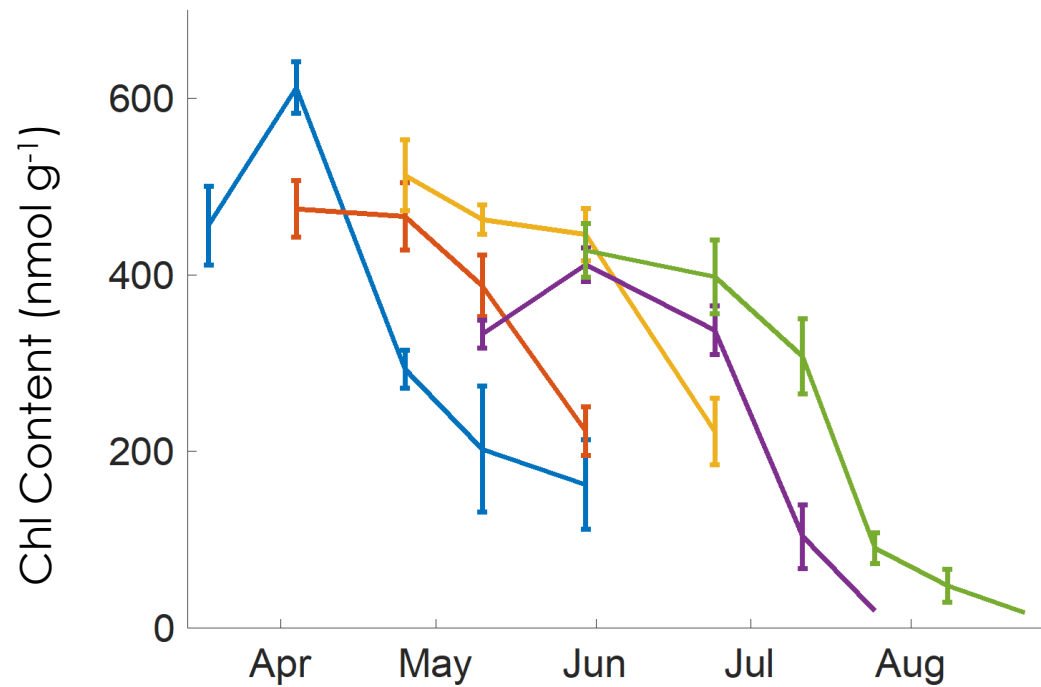
Discrimination of Kelp at Water Surface

- Dense kelp at the water surface reflects strongly in the NIR.

- Sparse and submerged kelp signals reflect the high influence of the water absorption of NIR, even in the first centimeters of the water column.

- Signals are also influenced by the presence of phytoplankton, suspended sediments, and Colored Dissolved Organic Matter (CDOM).
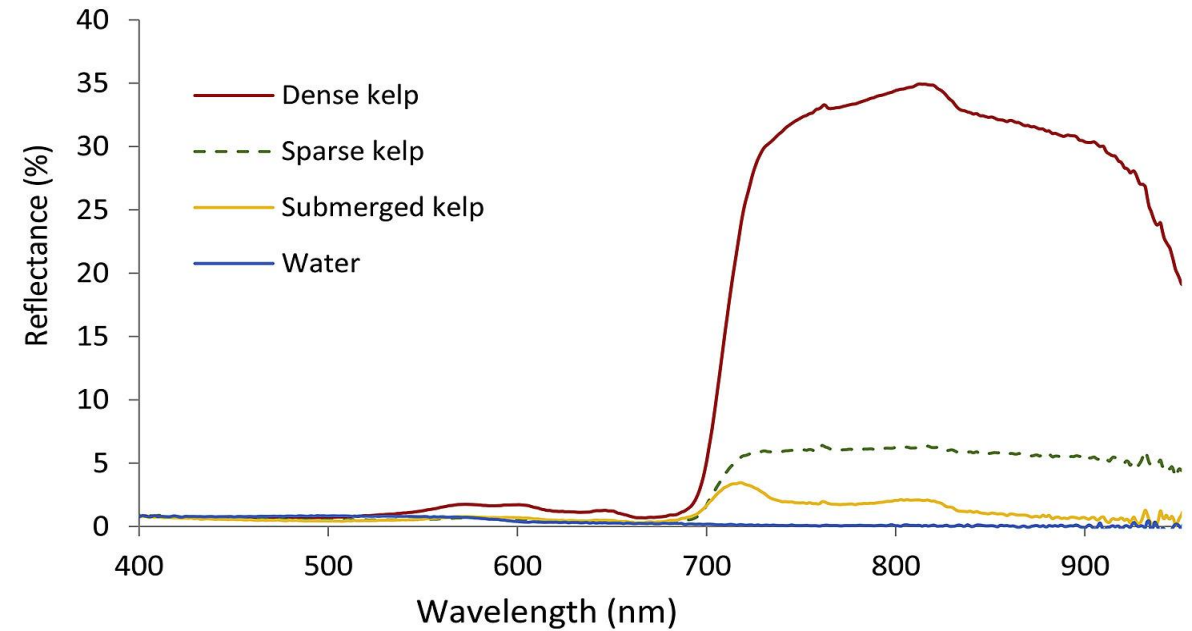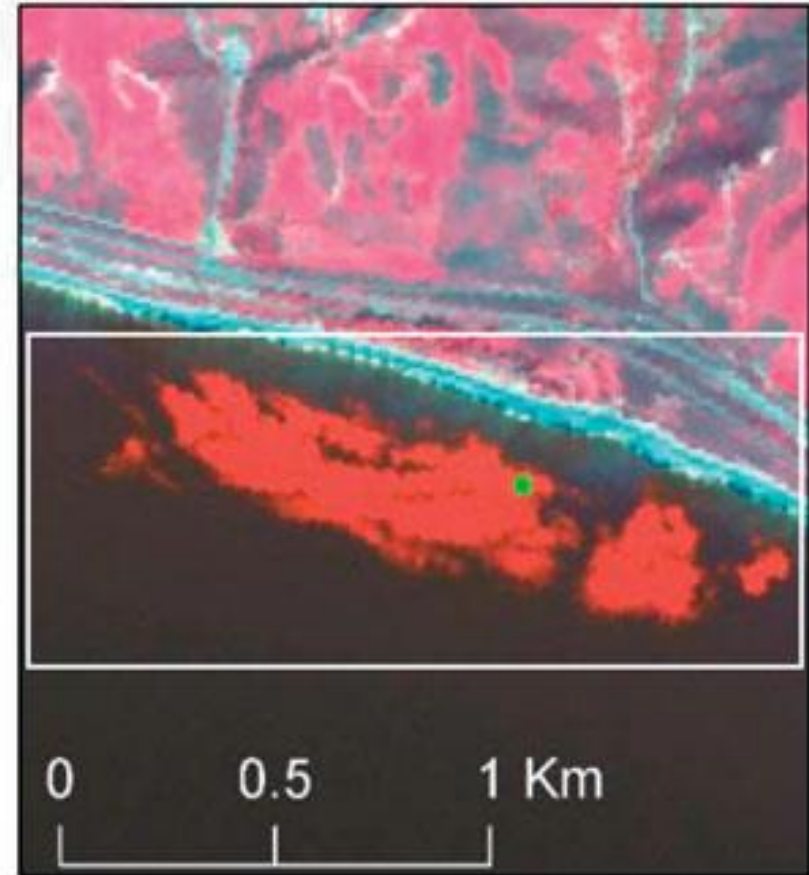

Schroeder et al (2019) Global Ecol. Cons.

Discrimination of Kelp Canopy Cover with Multispectral Imagery

Canopy Cover Delineation with SPOT Imagery
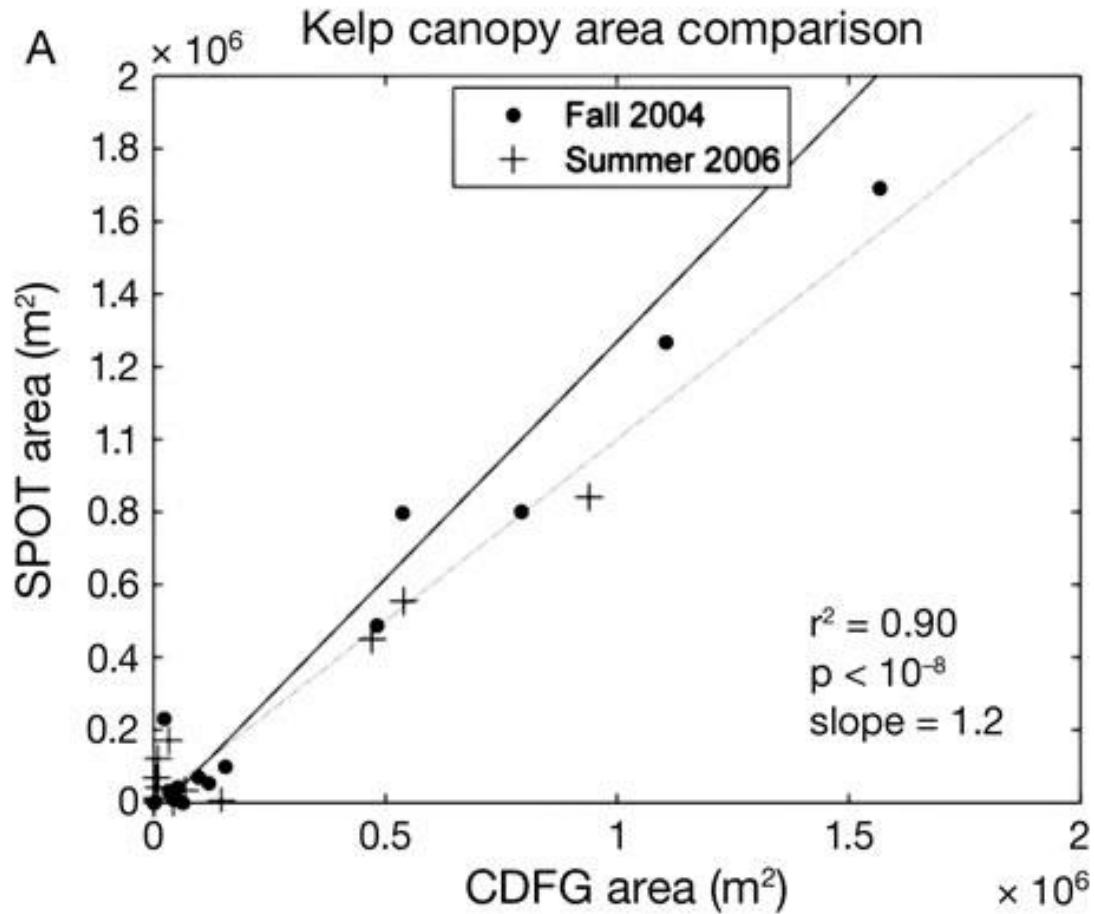
From: Cavanaugh et al (2010) Mar. Ecol. Prog. Ser.
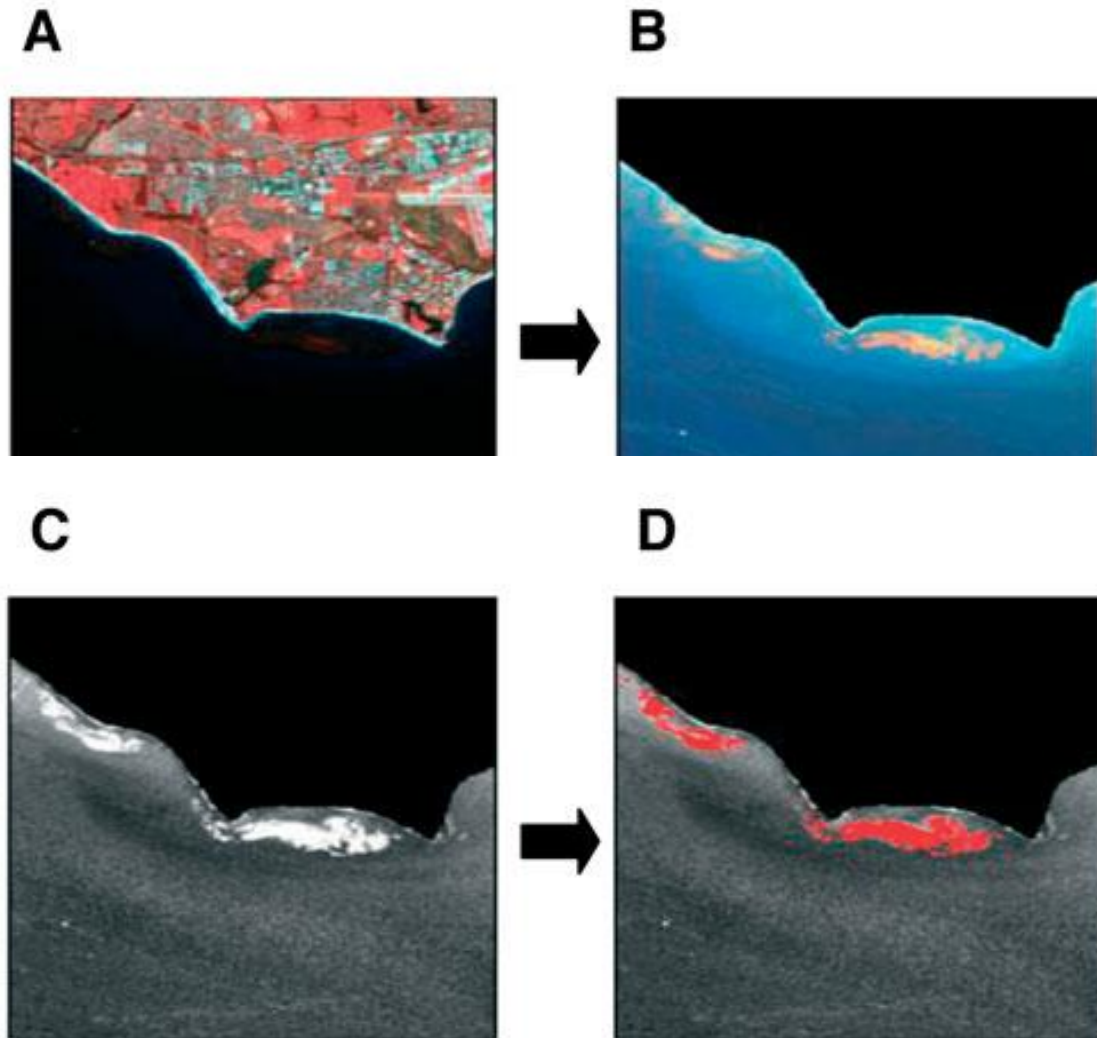
Validation of Canopy and Biomass Estimates from SPOT Imagery
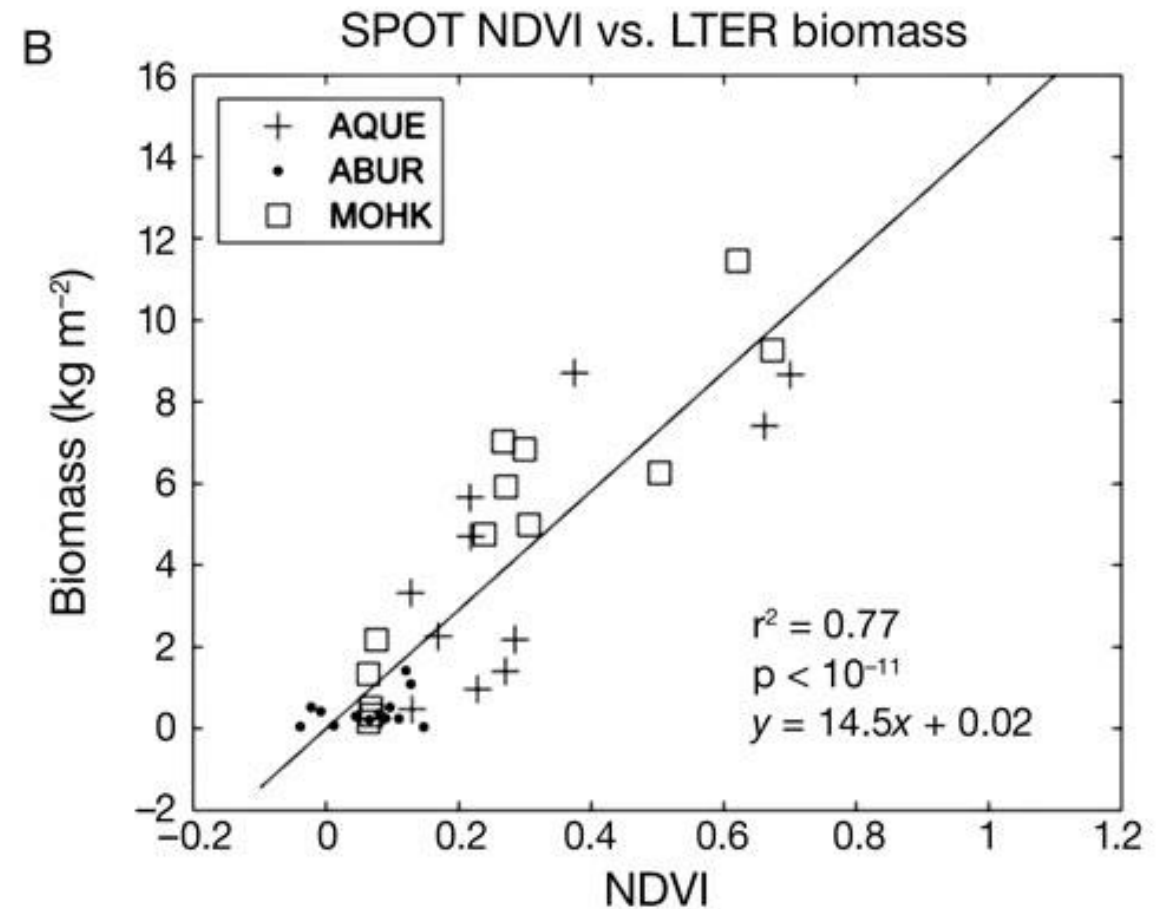
Kelp Monitoring with Landsat Data

- The Landsat series provides an unprecedented record of multispectral imagery ideal for monitoring SAV at diverse temporal scales.

- 30m spatial resolution

- 16-day revisit cycle

- At least one cloud-free image every 1-2 months if atmospheric conditions allow it

- Kelp Watch – A new, online tool for kelp monitoring using Landsat (Kelpwatch.org)
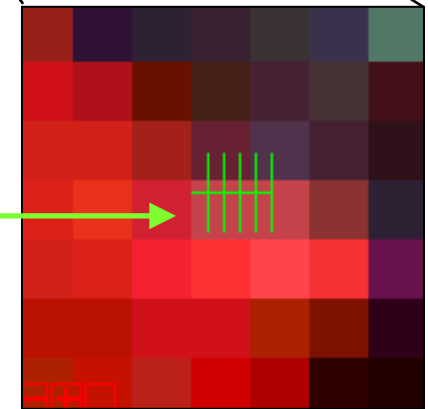

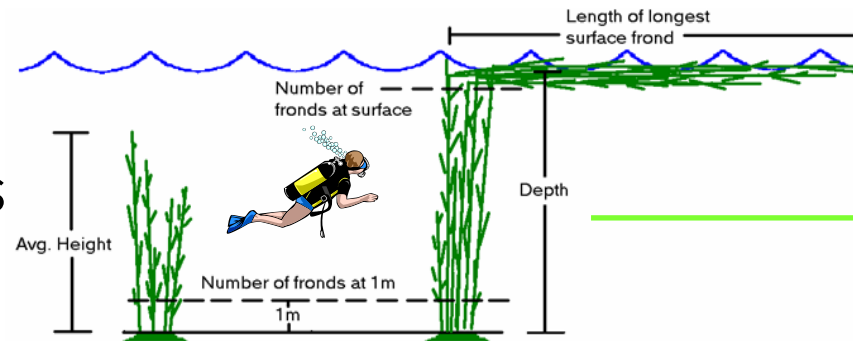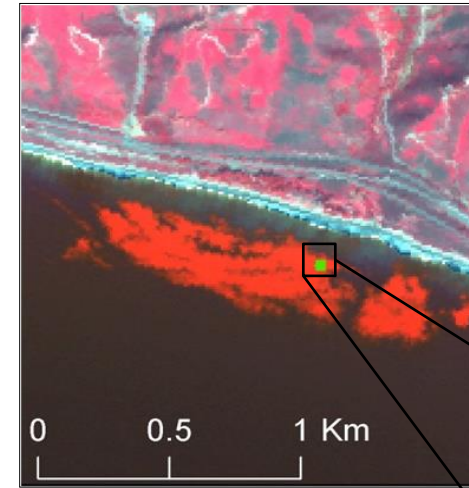AQUE

MOHK

LTER Field Sites
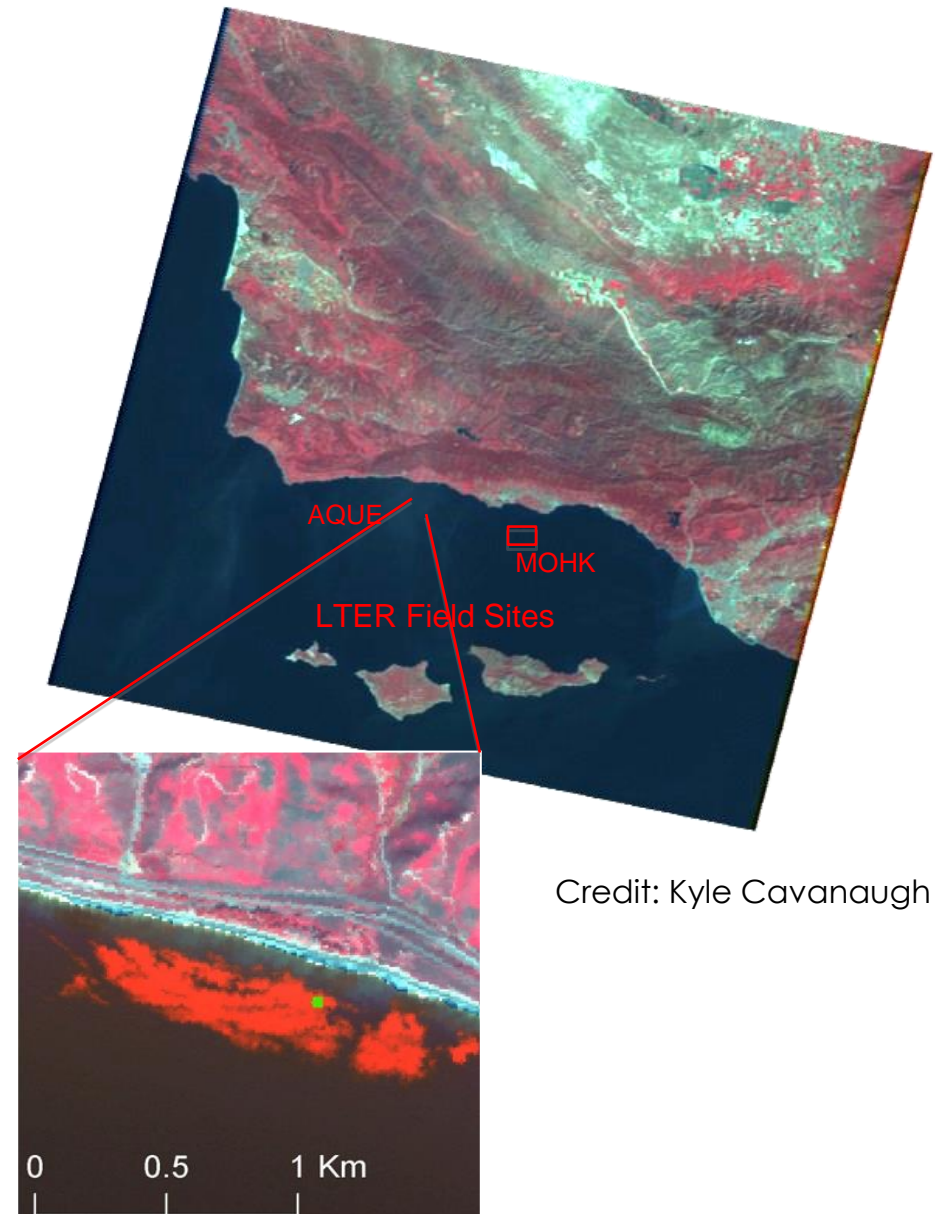
Credit: Kyle Cavanaugh (UCLA)

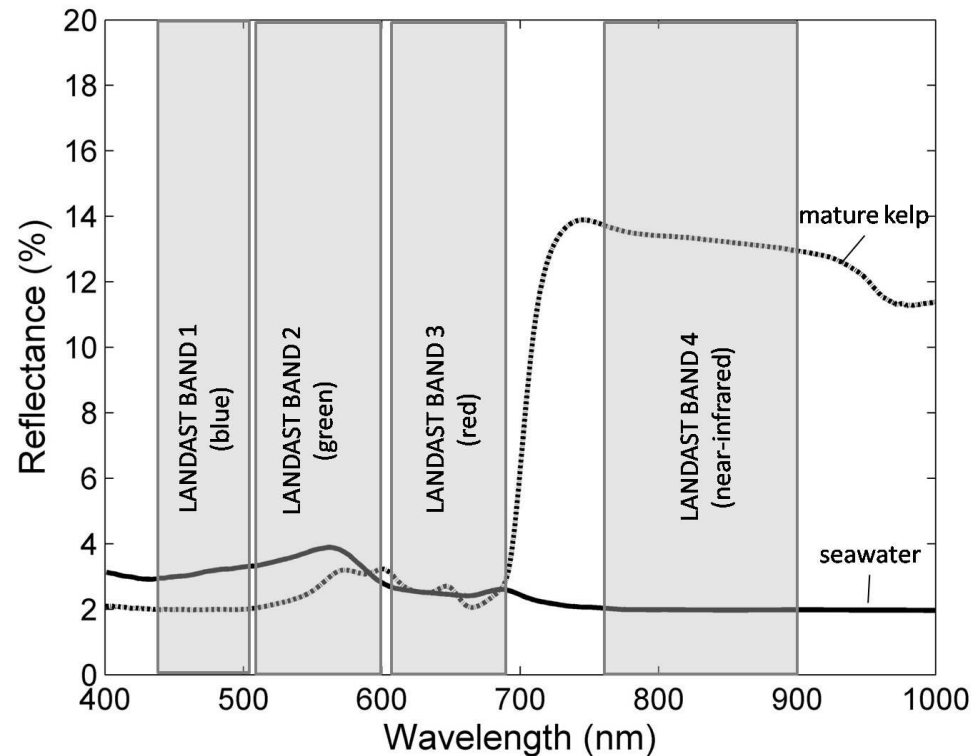# The SBC-LTER In-Situ Kelp Data to Validate Satellite Imagery

- The Santa Barbara Coastal Long-Term Ecological Research (SBC-LTER) was established in 2000.
  - Interdisciplinary program
  - Goal: Understand the ecology of the kelp forest ecosystem
- Focuses on Southern California, particularly the Southern California Bight
- https://sbclter.msi.ucsb.edu/
- Monthly non-destructive diver surveys since 2002 to monitor kelp canopy biomass
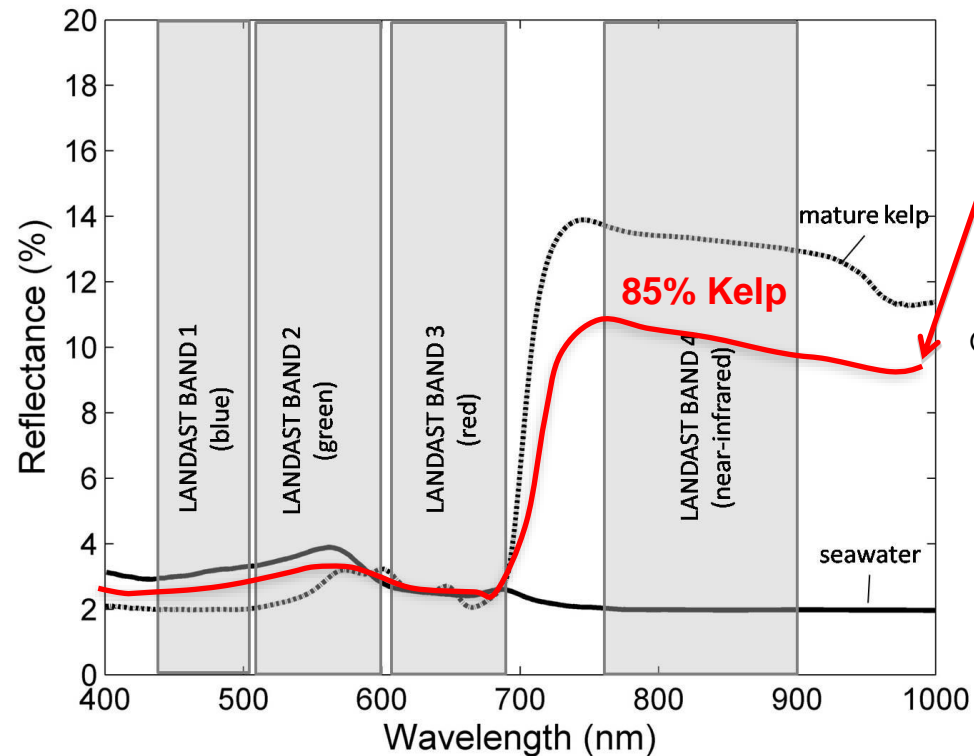
Credit: Kyle Cavanaugh (UCLA)

Spectral Unmixing of Landsat Data

- Every pixel needs to be modeled as a combination of water and kelp endmembers.

- Due to Landsat pixel size (30m) and heterogeneous canopy cover at water surface
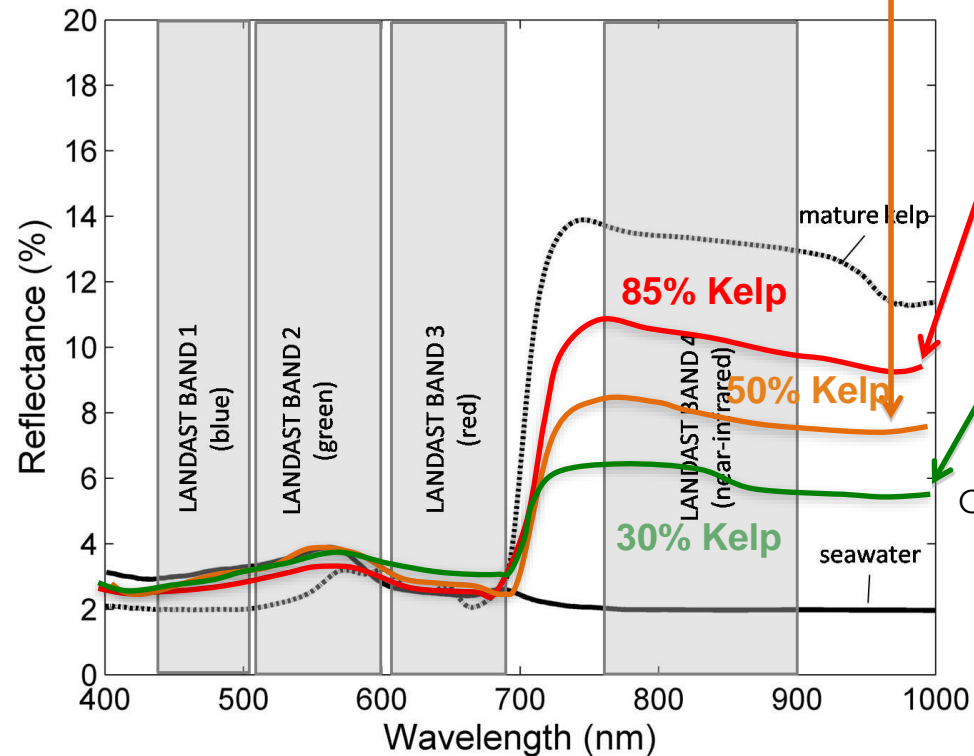
Credit: Kyle Cavanaugh (UCLA)

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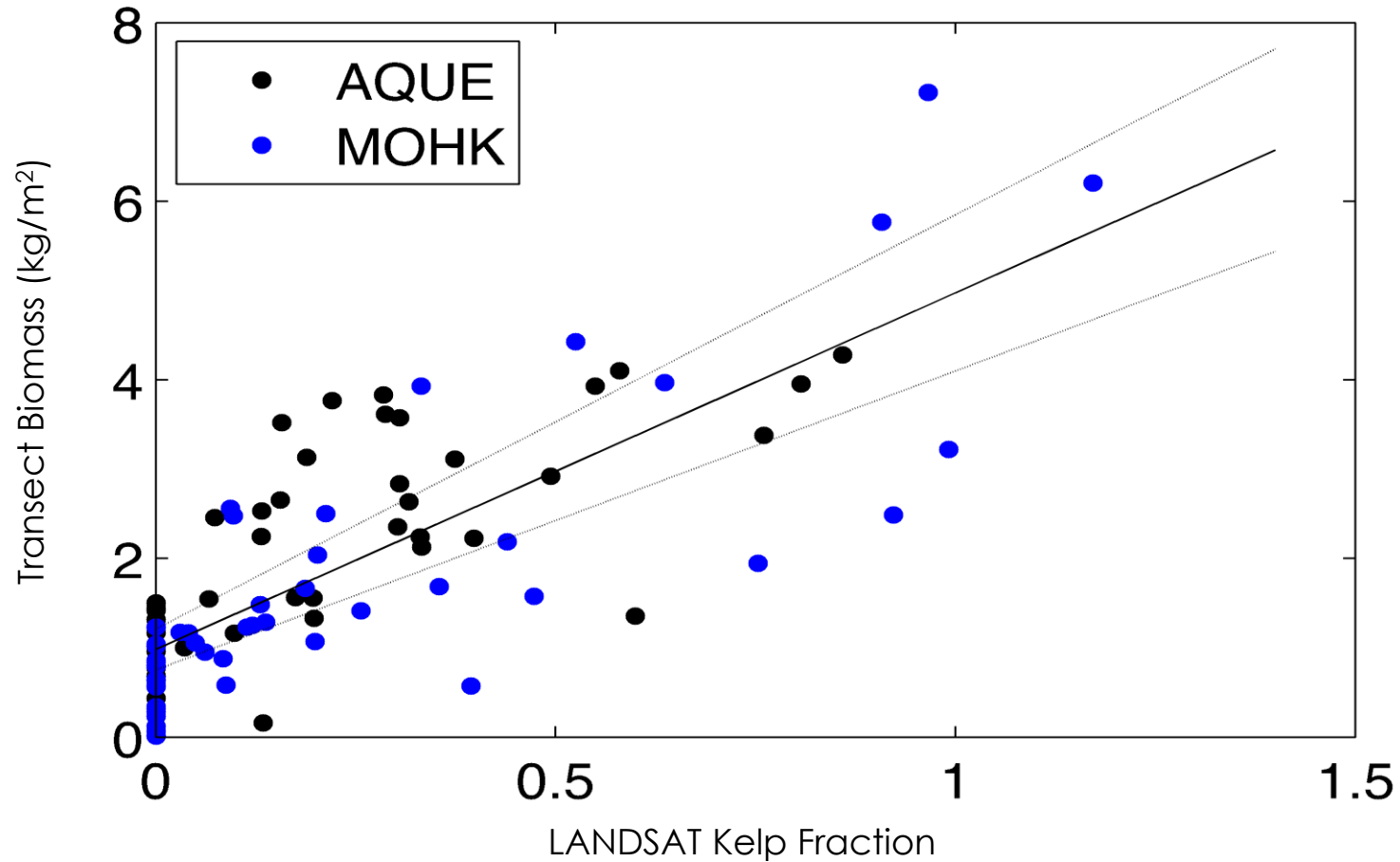

Credit: Kyle Cavanaugh (UCLA)

Biomass Estimation with Landsat Data

- Kelp fraction estimated with Landsat data correlates very well with diver-based measured canopy biomass.


Credit: Kyle Cavanaugh (UCLA)

Temporal Dynamics of Kelp and ENSO

- Dynamics of kelp biomass in the Santa Barbara Channel are strongly correlated with El Niño Southern Oscillation (ENSO) events.

- Warm ENSO phases bring nutrient-depleted waters to coastal zones, negatively affecting kelp biomass.

Credit: Kyle Cavanaugh (UCLA)
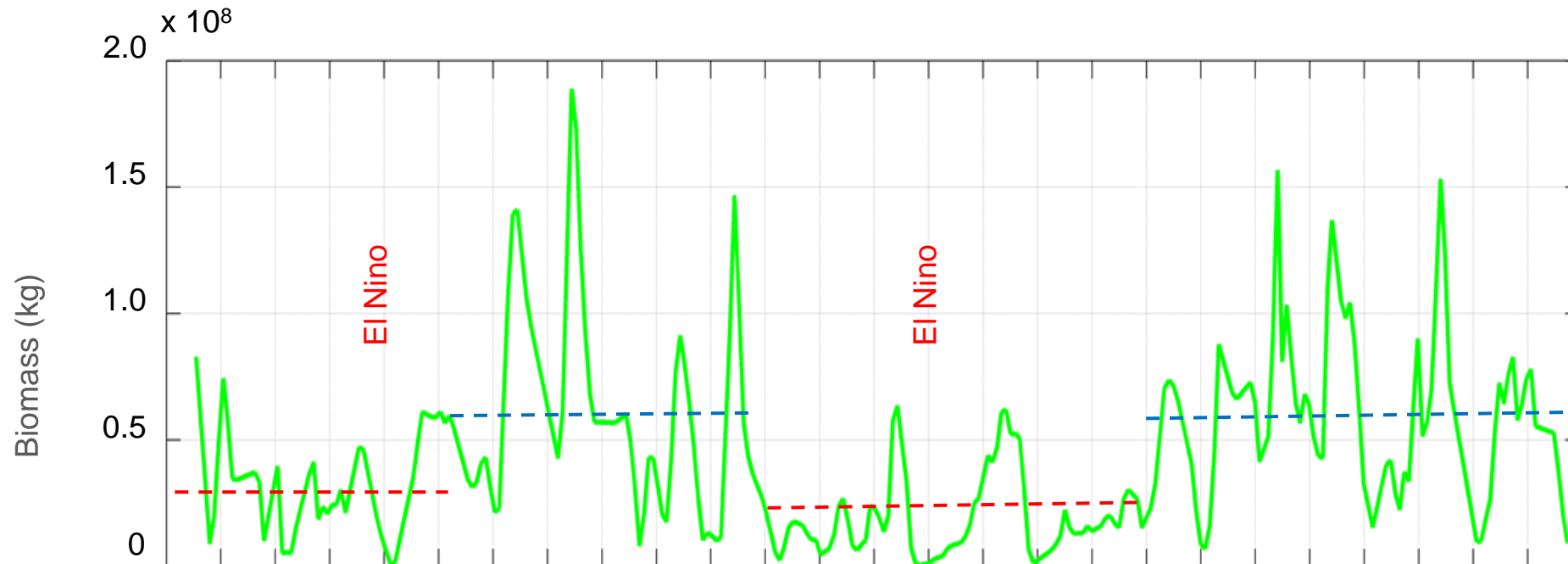
Landsat vs. Aerial Photographic Surveys

- Hamilton et al (2020) identified kelp canopy using NDVI and binned pixels in the aerial photos to match the Landsat 30x30m pixel size.

- Used a Multiple Endmember Spectral Mixing Analysis (MESMA) to estimate kelp and water fractional cover within pixels

- Found a strong correlation ($r^2 = 0.779$) between Landsat-based kelp canopy estimates and verified kelp cover documented by high-resolution aerial photography

Credit: Hamilton et al (2020)
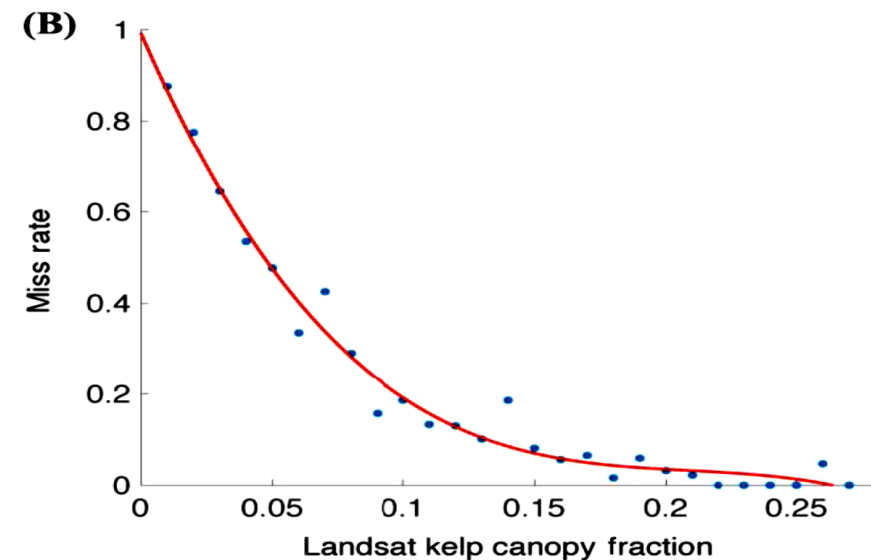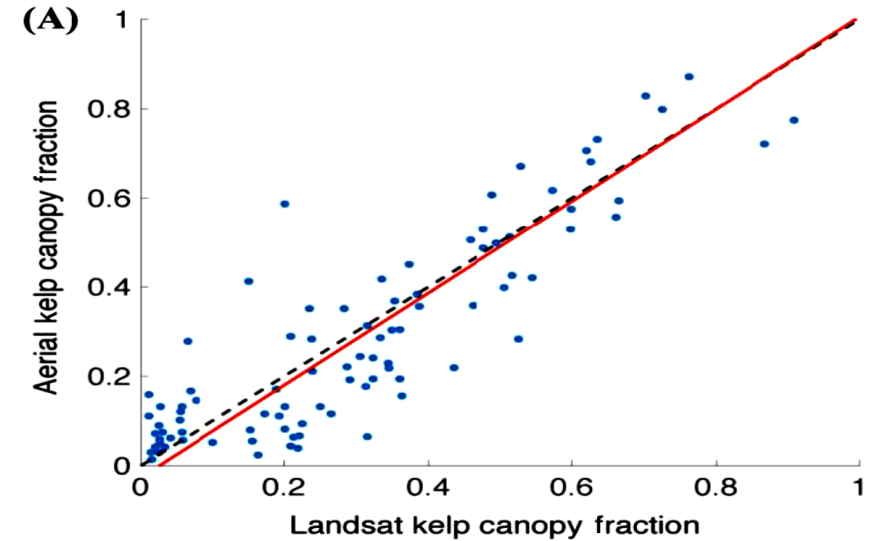
Comparing Kelp Canopy Products from Different Sensors
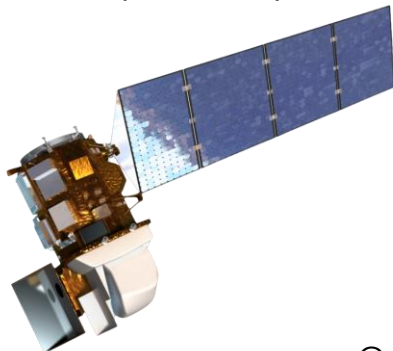
Color Camera
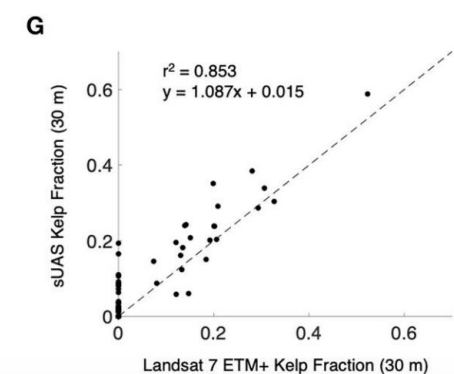(DJI Phantom 4 Pro)

Multispectral
(Micasense Altum)

Hyperspectral
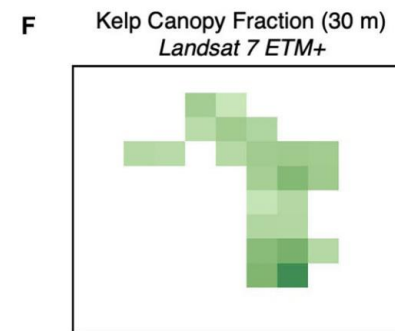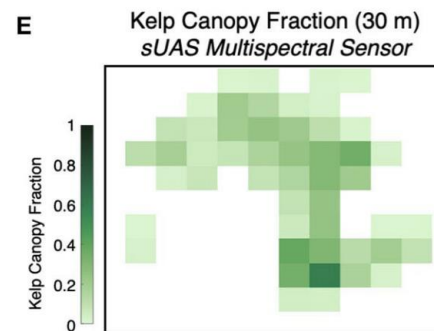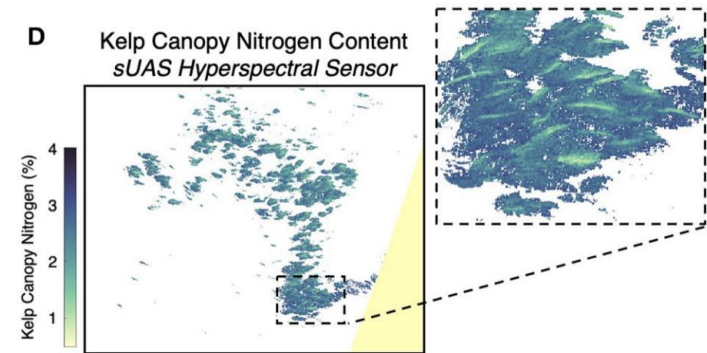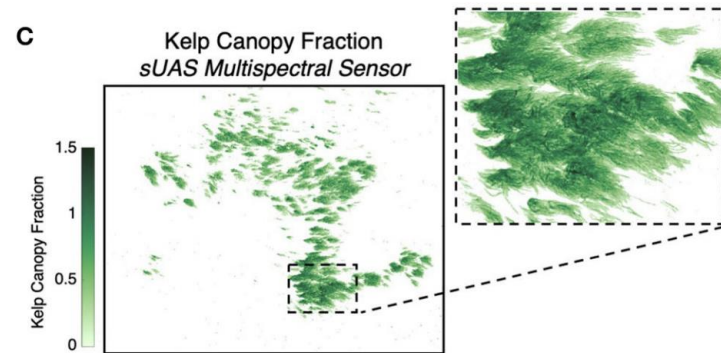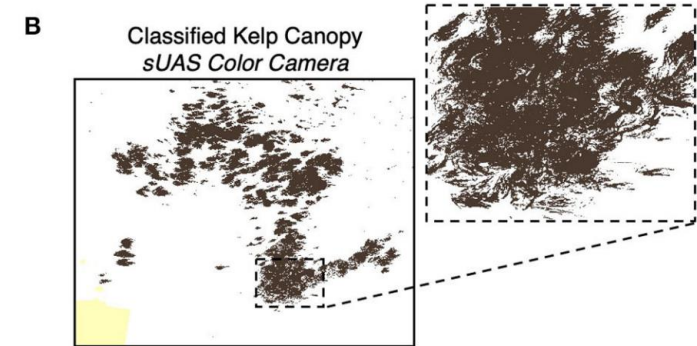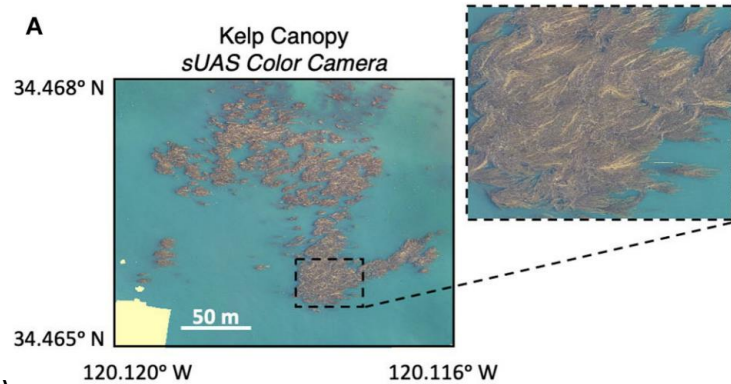(Headwall Nano-spec)

Multispectral
(Landsat)

Credit: Bell et al. (2020)

Floating Forests: A Citizen Science Tool for Monitoring Kelp Extension

Kelp Watch: Monitoring Kelp Coverage with >30 Years of Landsat Data

Concluding Remarks

- Undoubtedly, kelp forests are one of the most important coastal ecosystems on the planet, providing habitat for thousands of species and food services for millions of humans around the World.

- The capacity of kelp to produce floating canopies provides a great advantage for remote sensing researchers, as these are easier to monitor with satellite or airborne imagery.

- The unique Landsat series dataset is ideal for monitoring trends of kelp biomass and coverage over diverse time scales.

- Online tools like Floating Forests and Kelp Watch provide opportunities for citizen scientists and managers to collaborate and retrieve datasets collected with remotely-sensed imagery.

Contacts

- ARSET Contacts
  - Amber McCullum: AmberJean.Mccullum@nasa.gov
  - Juan Torres-Pérez: juan.l.torresperez@nasa.gov

- ARSET Website:
  - https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset

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Thank You!