National Aeronautics and Space Administration

Puget Sound
Water Resources

Using Earth Observations to Map Bull Kelp in the Puget Sound, Washington, to Support Conservation and Restoration

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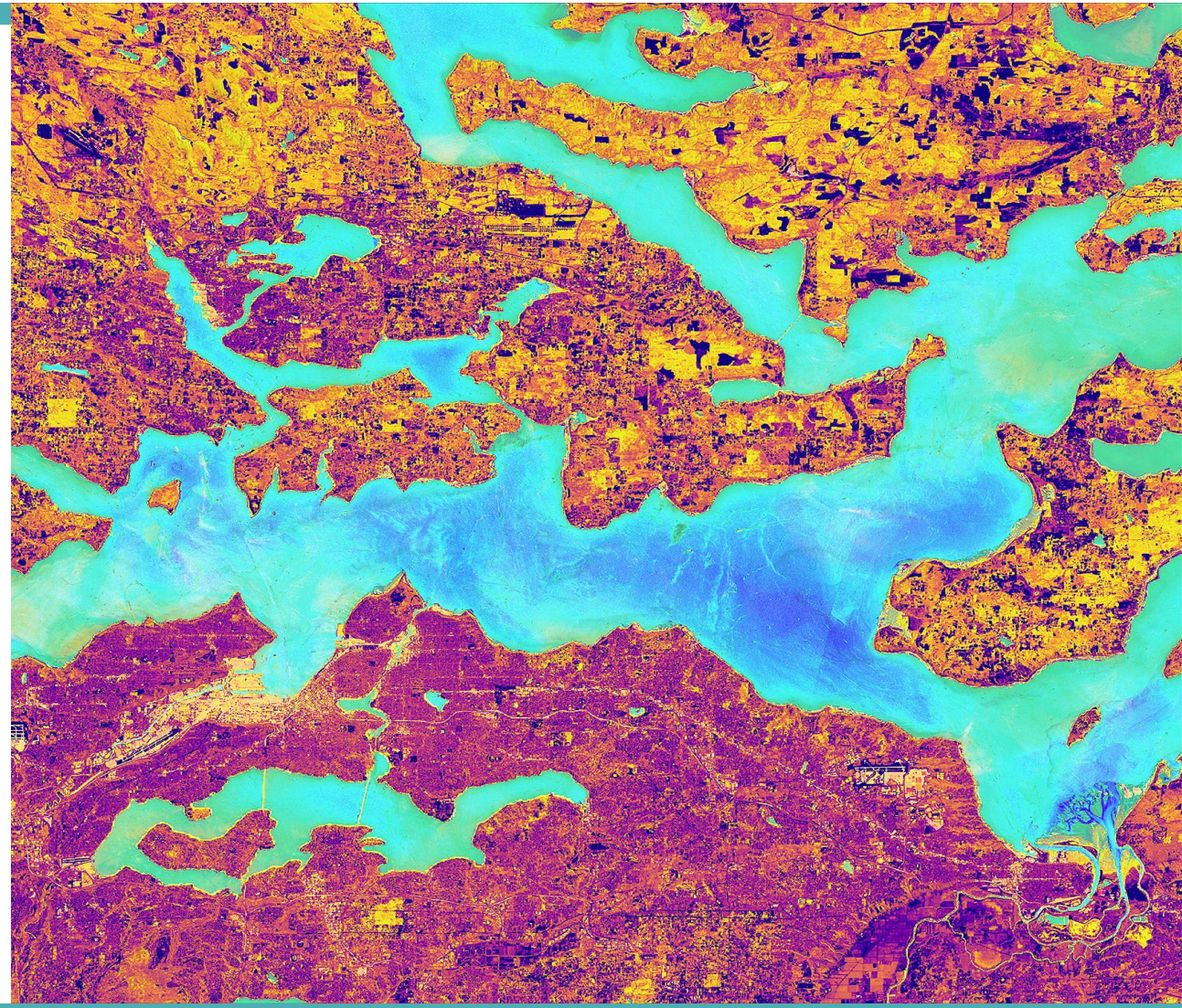


Bull Kelp – *Nereocystis luetkeana*

- Ecologically & culturally critical algae species in the Puget Sound
- Forms floating canopies visible from remotely sensed imagery
- Peak canopy extent in Puget Sound is mid-July to early September
- Sensitive to changes in temperature, nutrient depletion, & trophic cascades

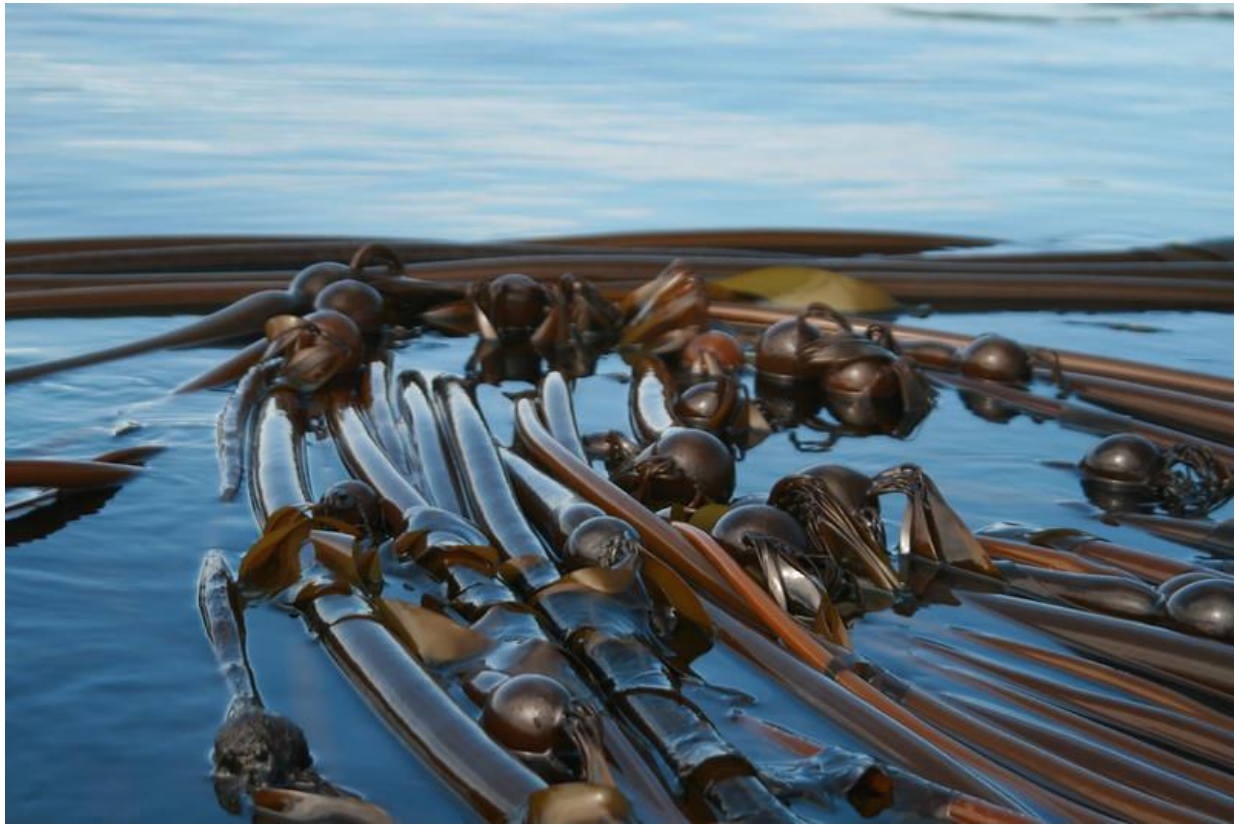


Image Credit: Peggy Foreman/NOAA Fisheries West Coast

Community Concerns

Decline of bull kelp in Puget Sound

Reduction in ecological and cultural services

Gaps in local research on bull kelp abundance

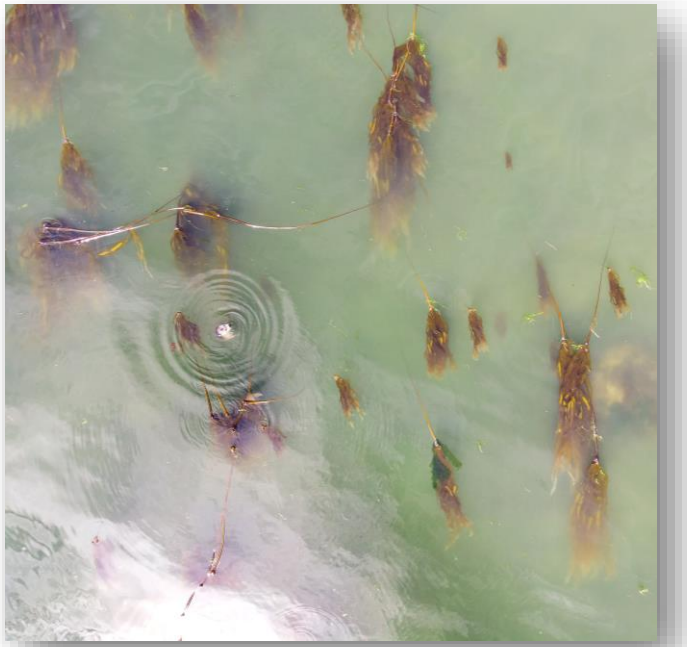


Image Credits: Hannah Gabrielson (left), Mike Hitchner (middle), Jennifer Stock/NOAA/CBNMS (right)

Partners

- Port of Seattle
- Washington State Department of Natural Resources

Image Credit: Mike Hitchner/DEVELOP Team

Objectives

1. Explore feasibility of satellites for mapping bull kelp extent in the Central Puget Sound

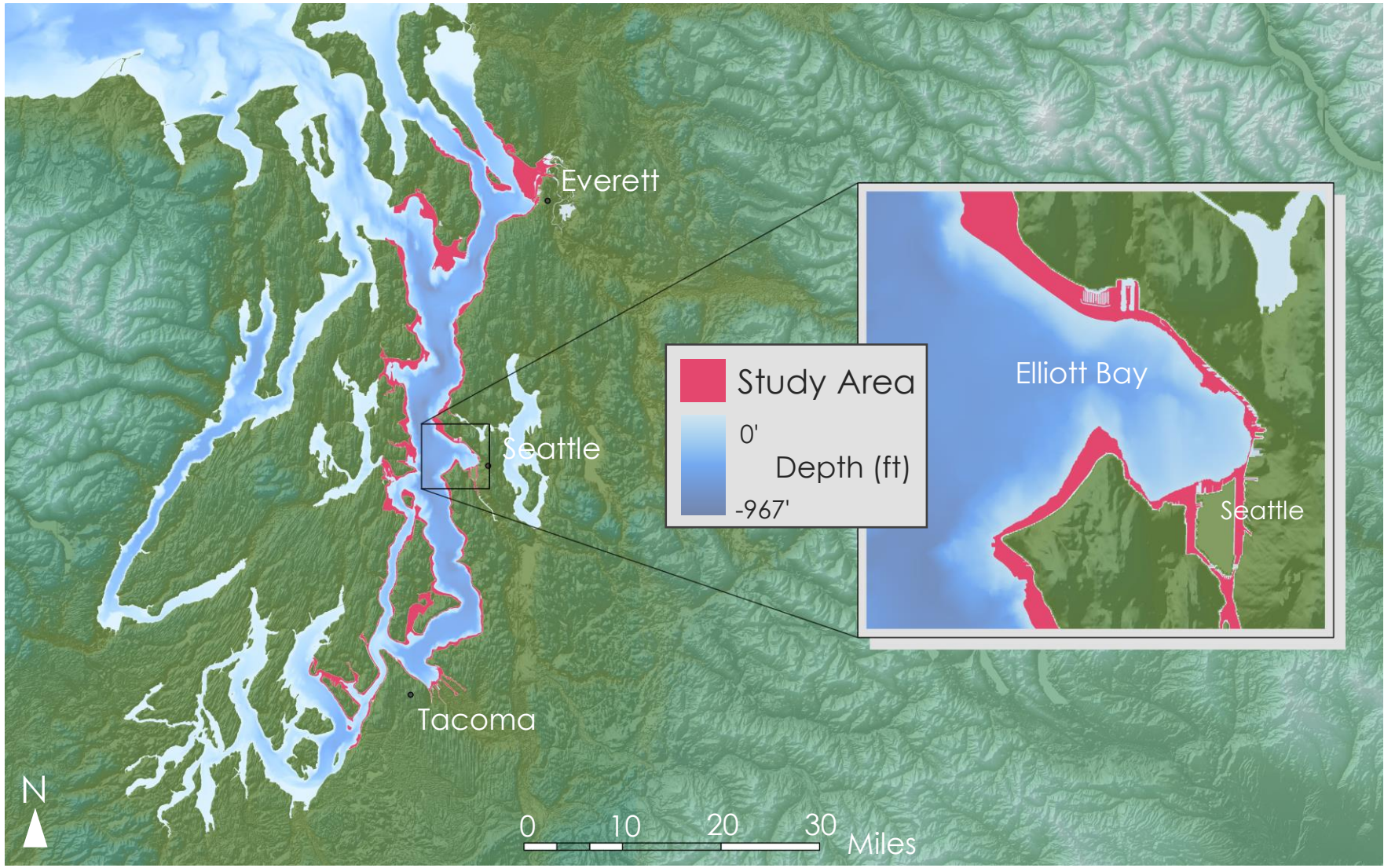
2. If feasible, produce map of 2021 bull kelp extent

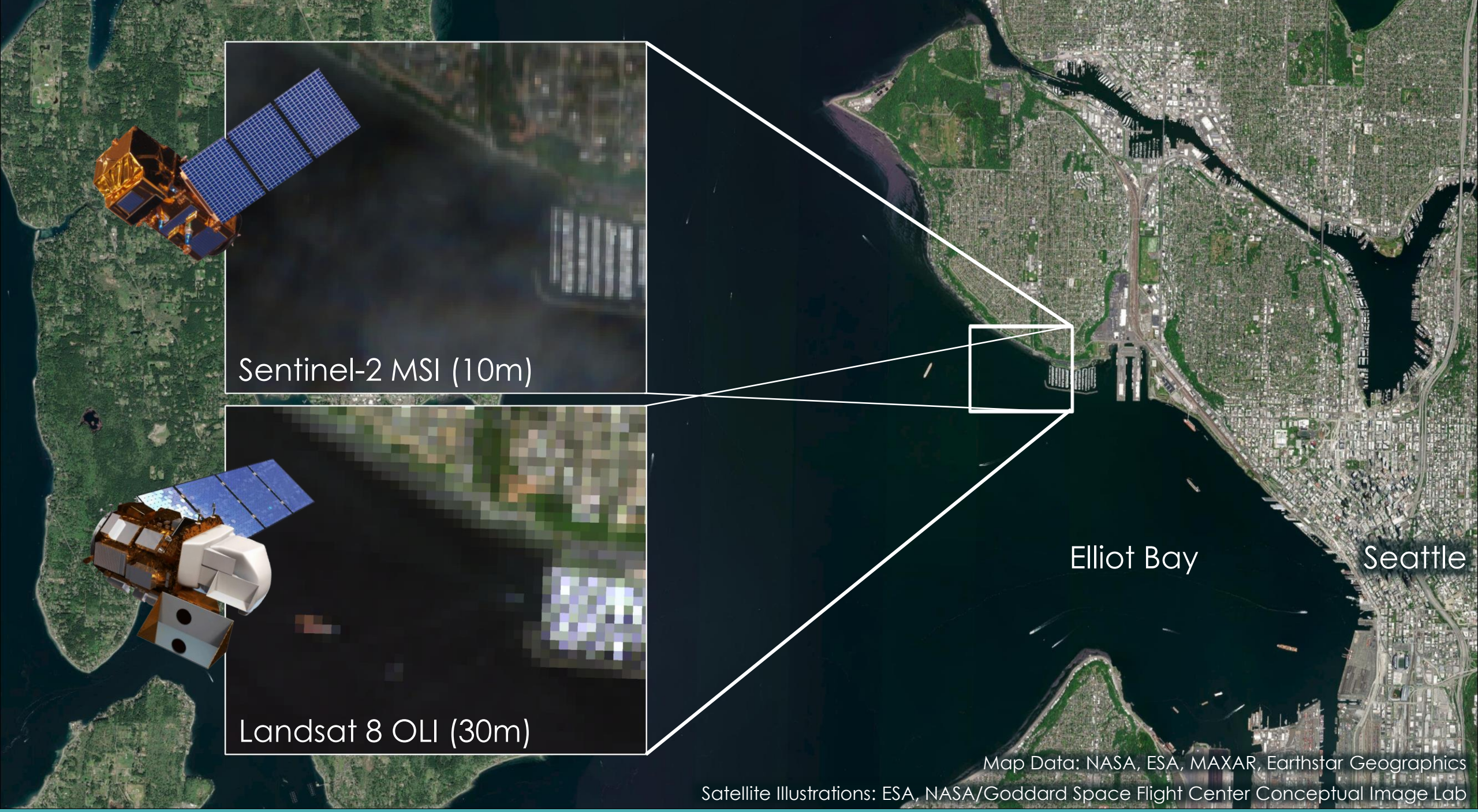
3. If feasible, analyze changes in bull kelp extent by creating time series maps from 2011 – 2021

Image Credit: Hannah Gabrielson

Study Area

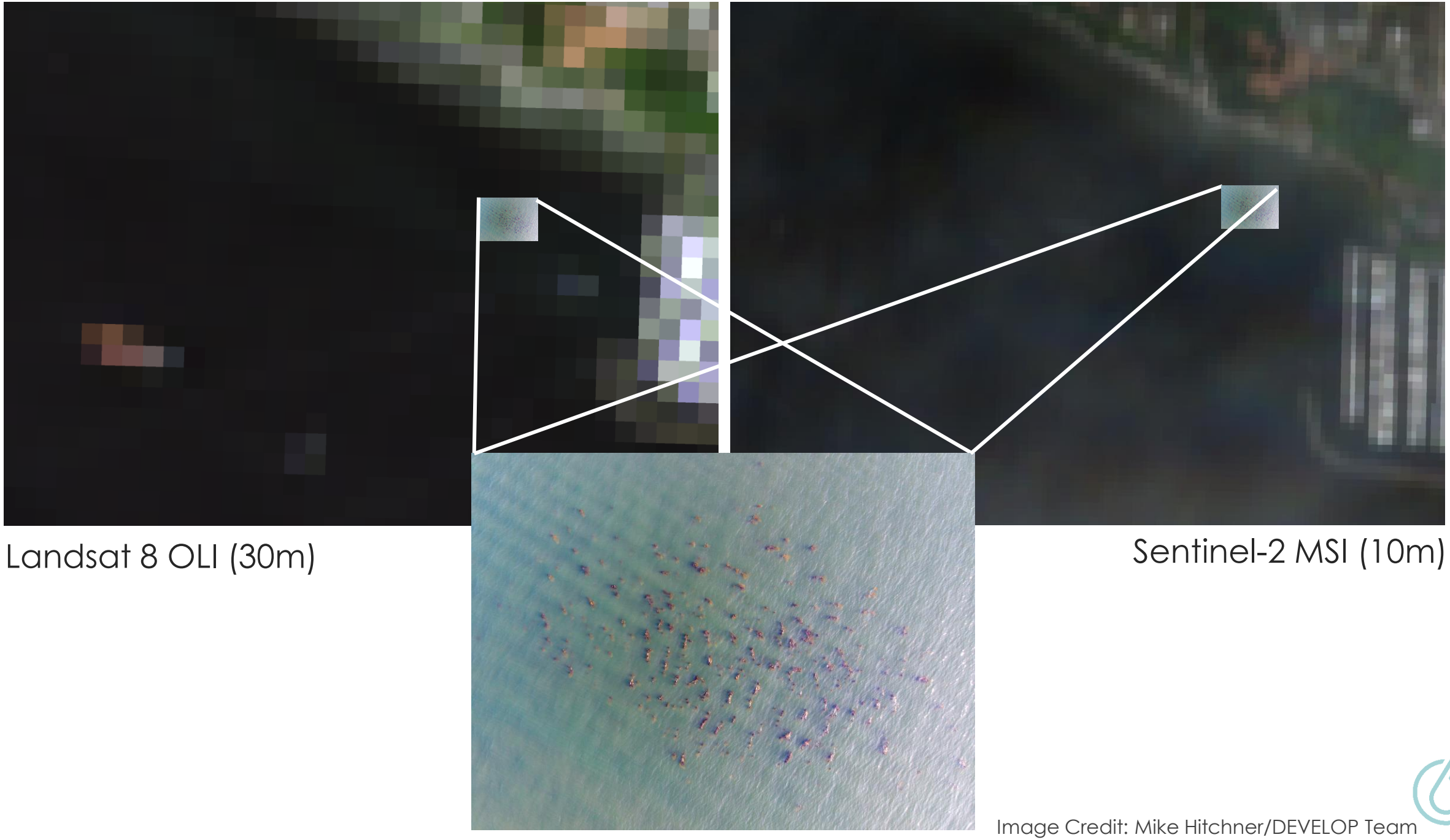
- **Location:** Central Puget Sound, Washington
  - Elliott Bay
- **Study Period:** 2011 – 2021
  - Peak kelp extent: July 15 to Sep 15
- **Spatial bounds defined using:**
  - Coastal buffer
  - Bathymetry selection
  - Mask of above-water obstructions





Map Data: NASA, ESA, MAXAR, Earthstar Geographics

Satellite Illustrations: ESA, NASA/Goddard Space Flight Center Conceptual Image Lab



Landsat 8 OLI (30m)

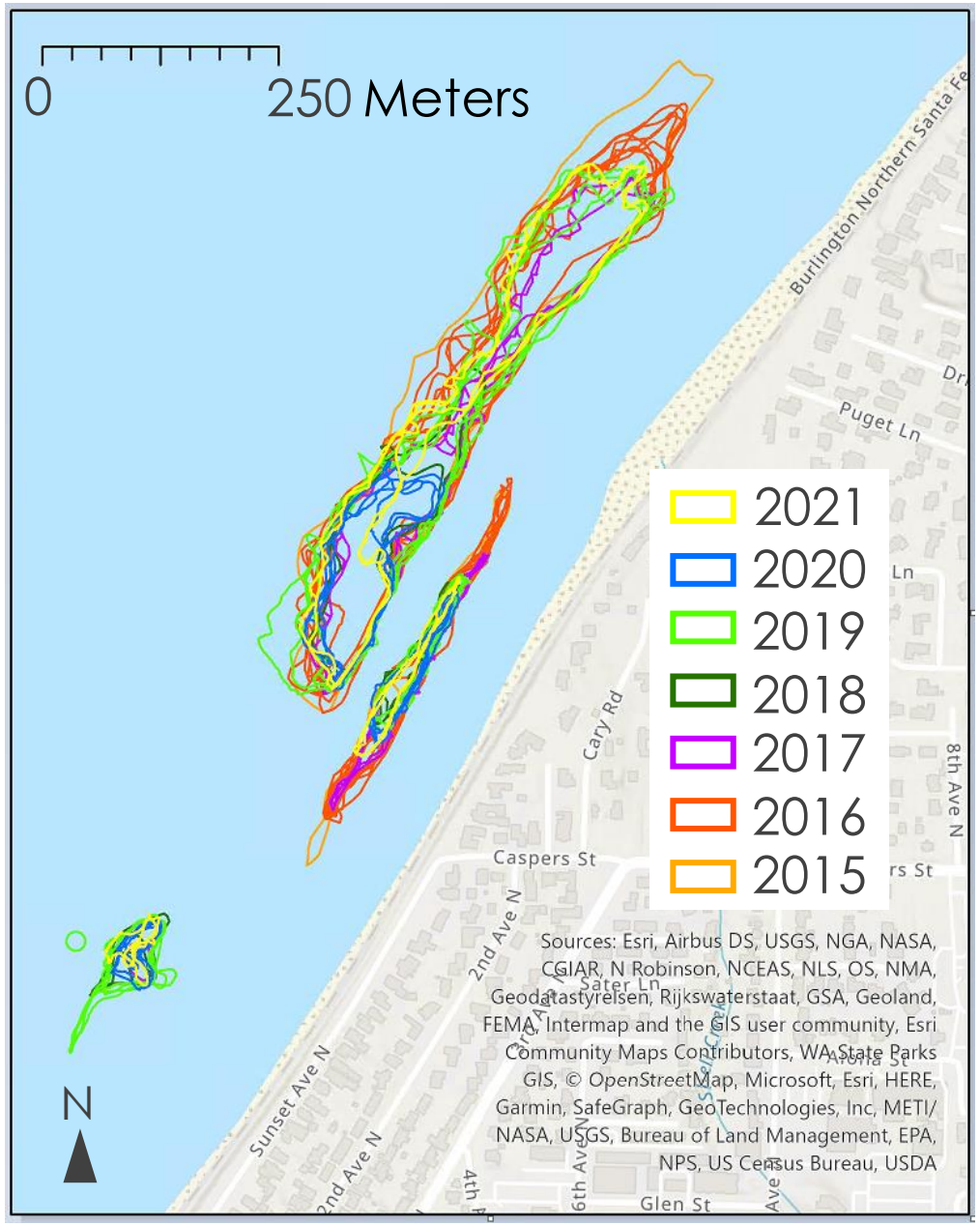
Sentinel-2 MSI (10m)

Image Credit: Mike Hitchner/DEVELOP Team

Additional Data

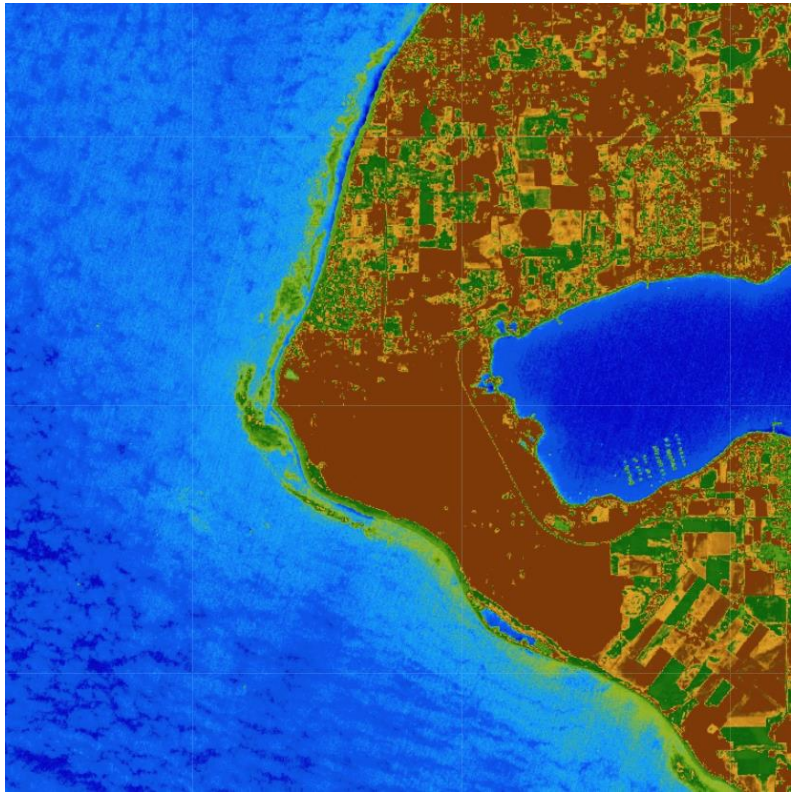
- Elliott Bay Coastal Kelp Transects
  - Puget Sound Restoration Fund
  - 2021
- Annual Kelp Extents
  - Northwest Straits Commission
  - 2015 – 2021
- NOAA Tides and Currents

Annual Kelp Extents



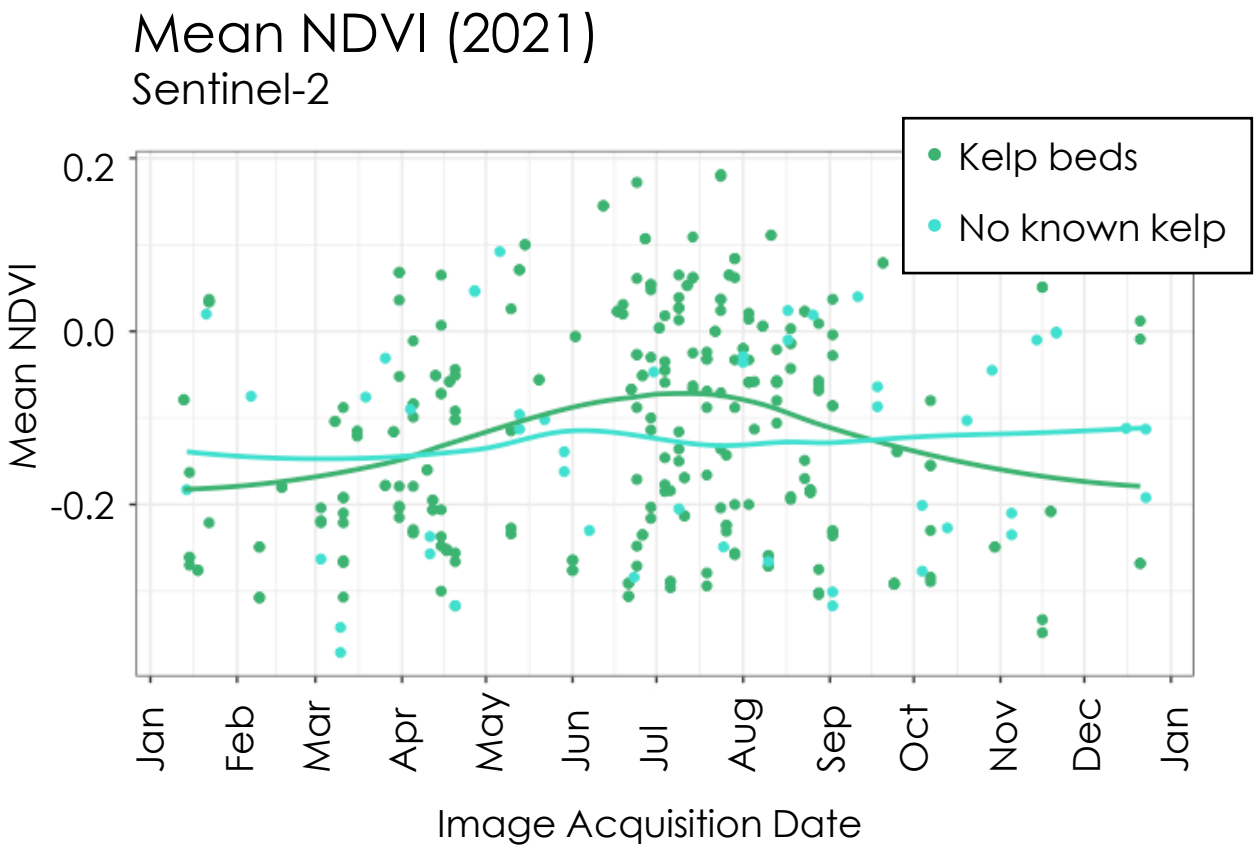
Methodology: Spectral Indices

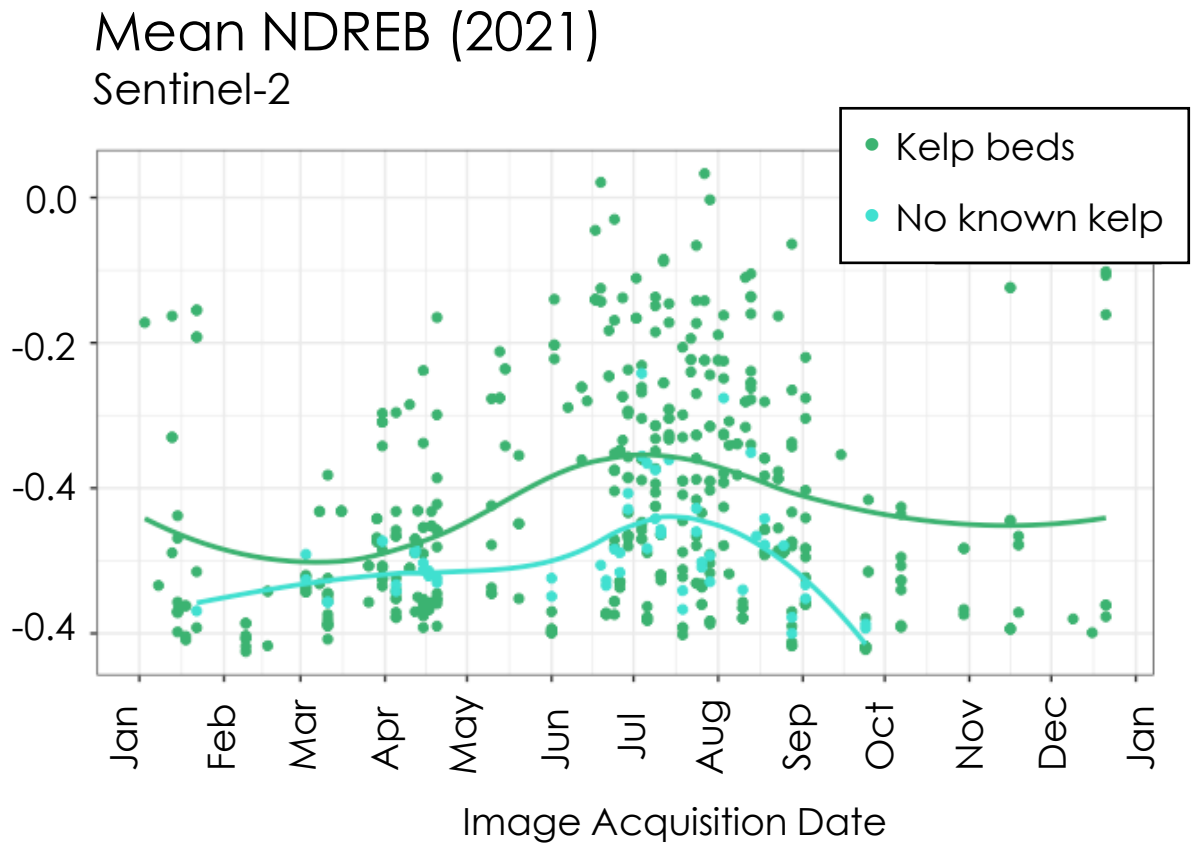
Normalized Difference Vegetation Index (NDVI)



Normalized Difference Red-Edge Blue (NDREB)

Data Exploration: Spectral Indices





Methodology: Bed Size

Bed size in surveyed kelp beds was broken down into 3 quantiles: small, medium, large

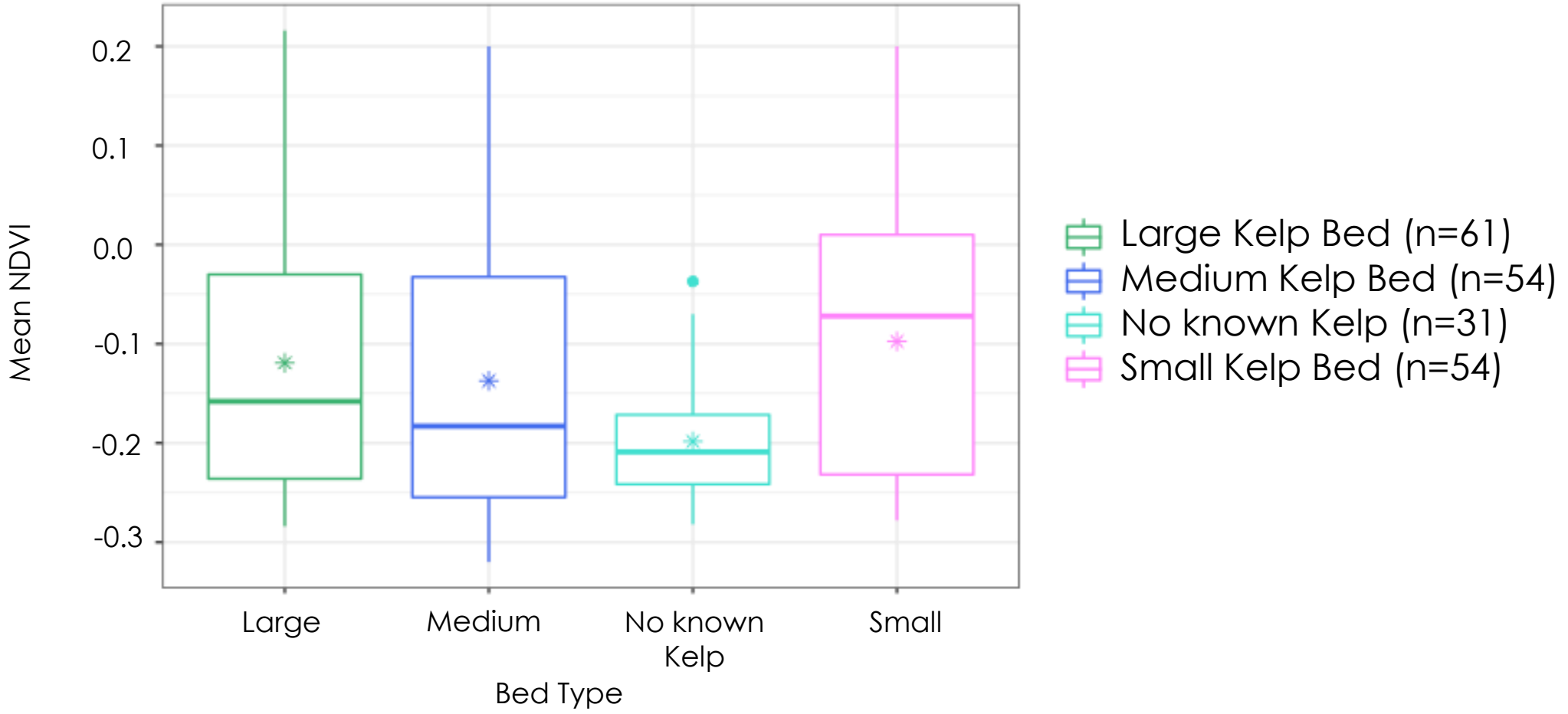
Summer growing season NDVI of each patch size was plotted against areas with no known kelp to see if patch size impacted the NDVI signal.

Growing Season Bed Size Information (2020)

Patch Type	Number of Beds	Size Range (acres)	Number of mean NDVI/NDREB values
Small	4	0.33-0.63	54
Medium	4	0.64-2.03	54
Large	13	2.9-112.7	61

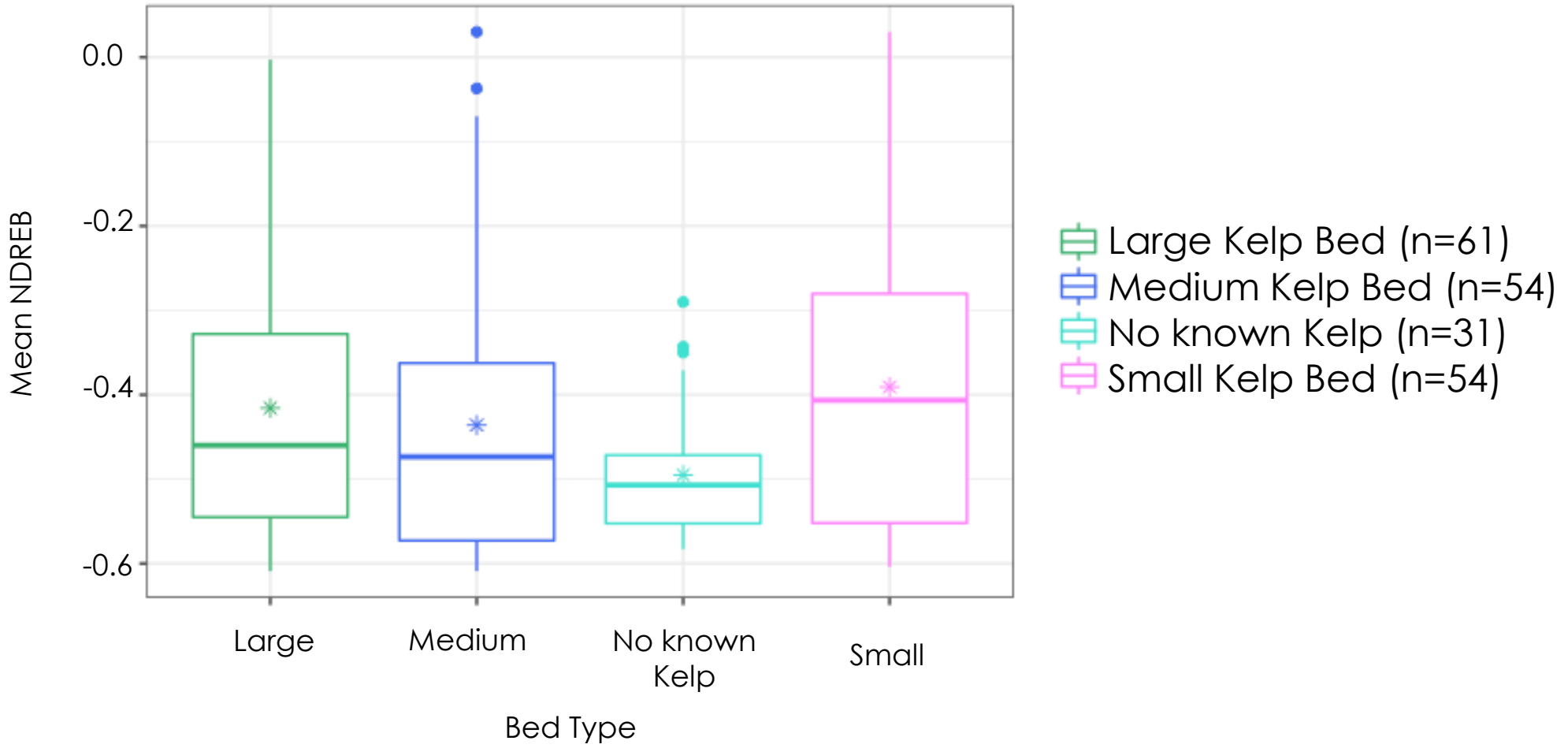
Data Exploration: Bed Size – NDVI

Growing Season NDVI by Bed Type (2020)
Sentinel-2

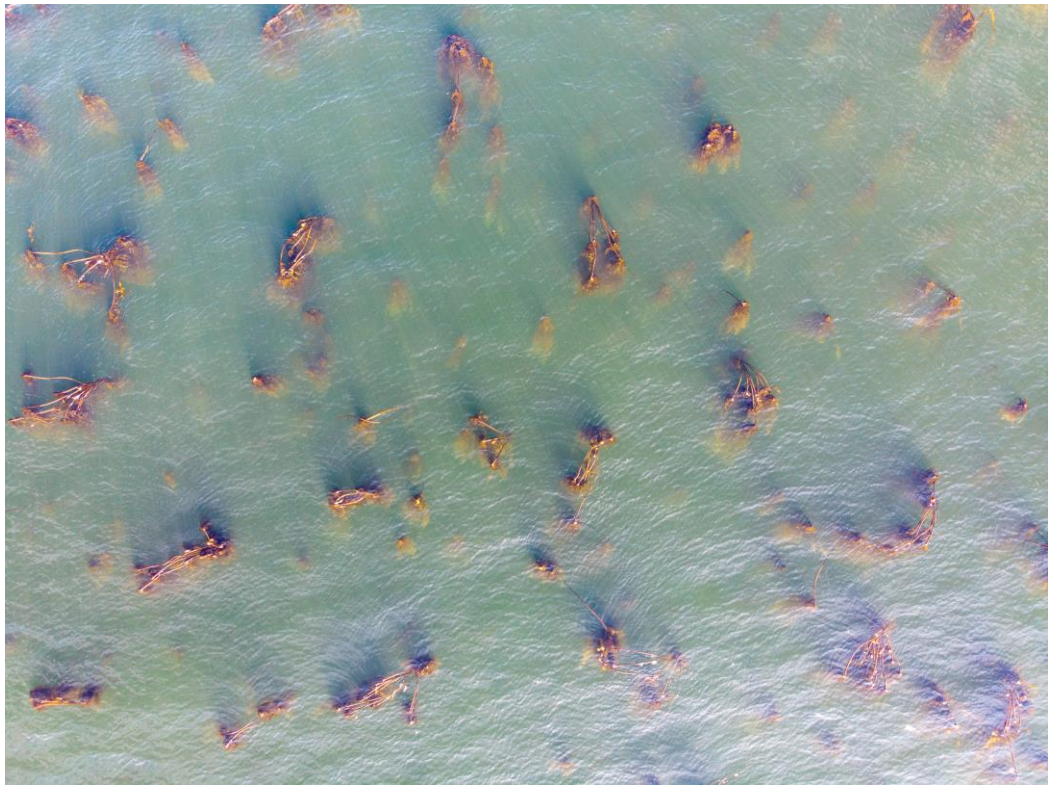


Data Exploration: Bed Size – NDREB

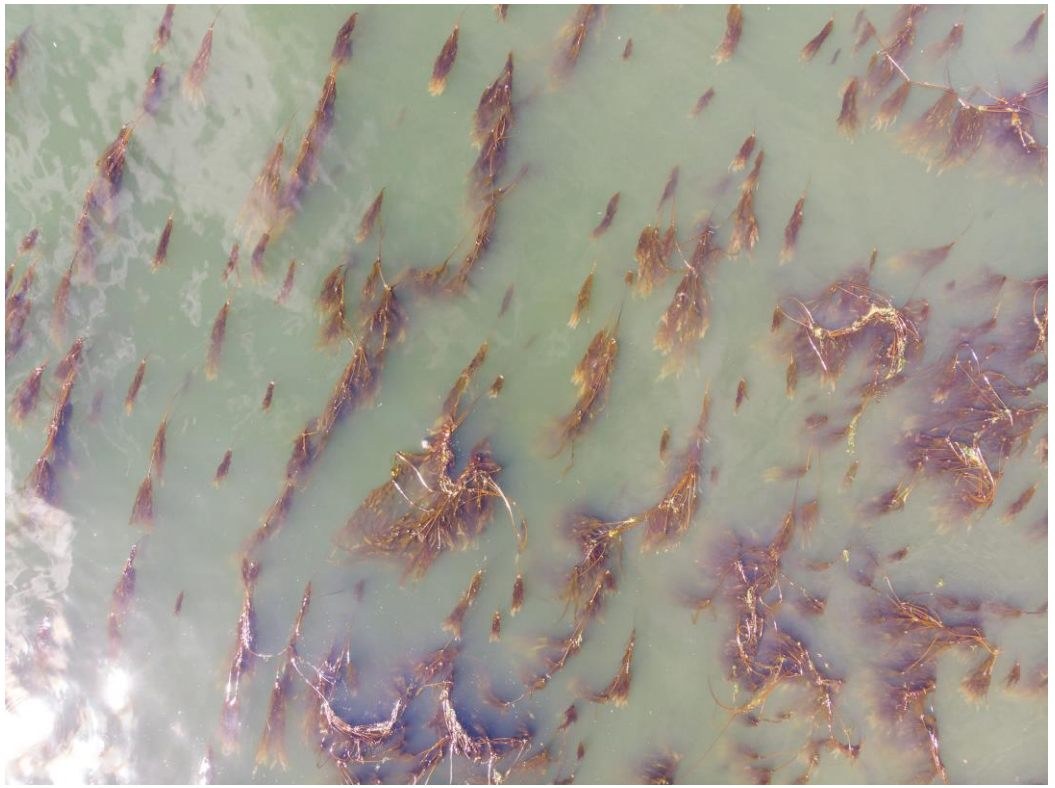
Growing Season NDREB by Bed Type (2020)
Sentinel-2



What do kelp beds look like at different tides?



+9.71 ft (MLLW)

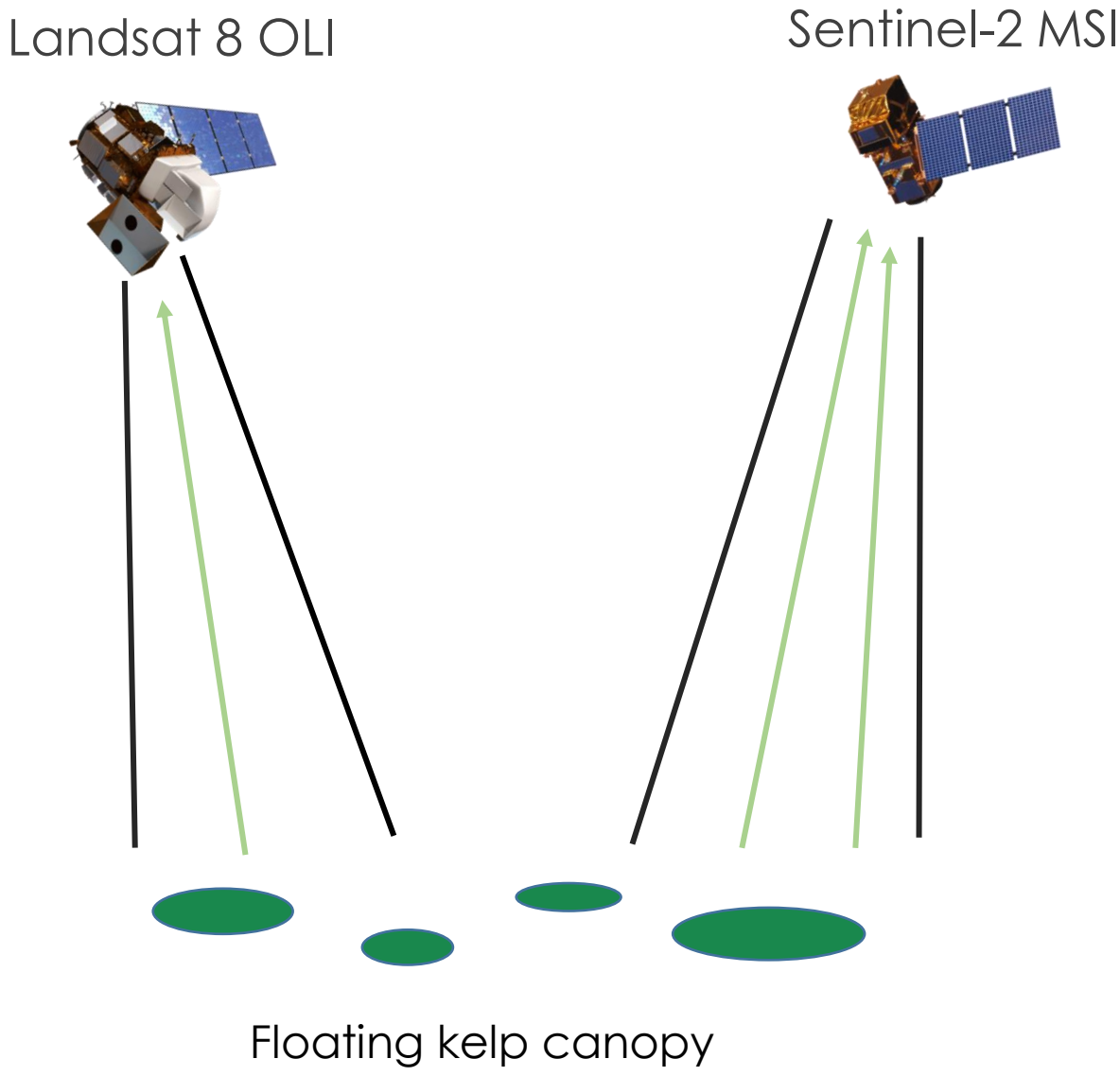


-3.98 ft (MLLW)

Image Credit: Mike Hitchner/DEVELOP Team

Methodology

Summer imagery
2016 – 2021



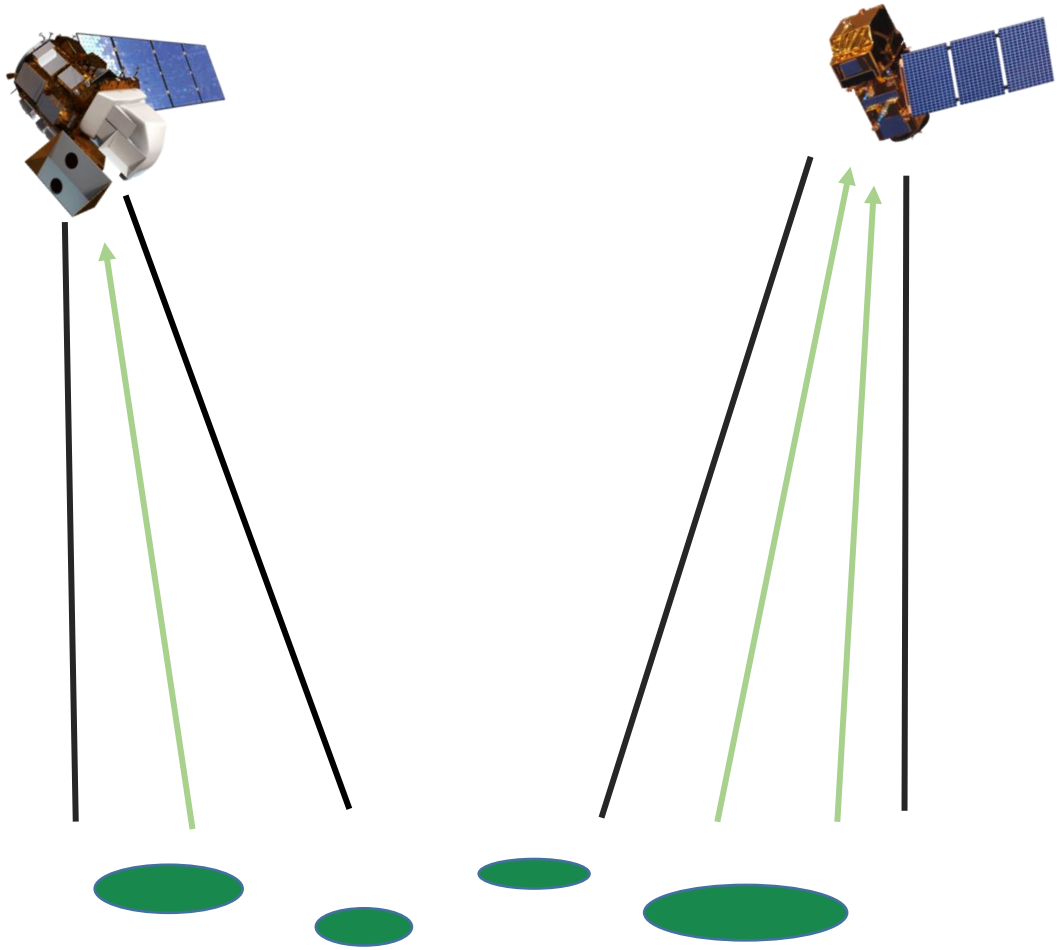
Methodology

Summer imagery
2016 – 2021

Clouds

Landsat 8 OLI

Sentinel-2 MSI



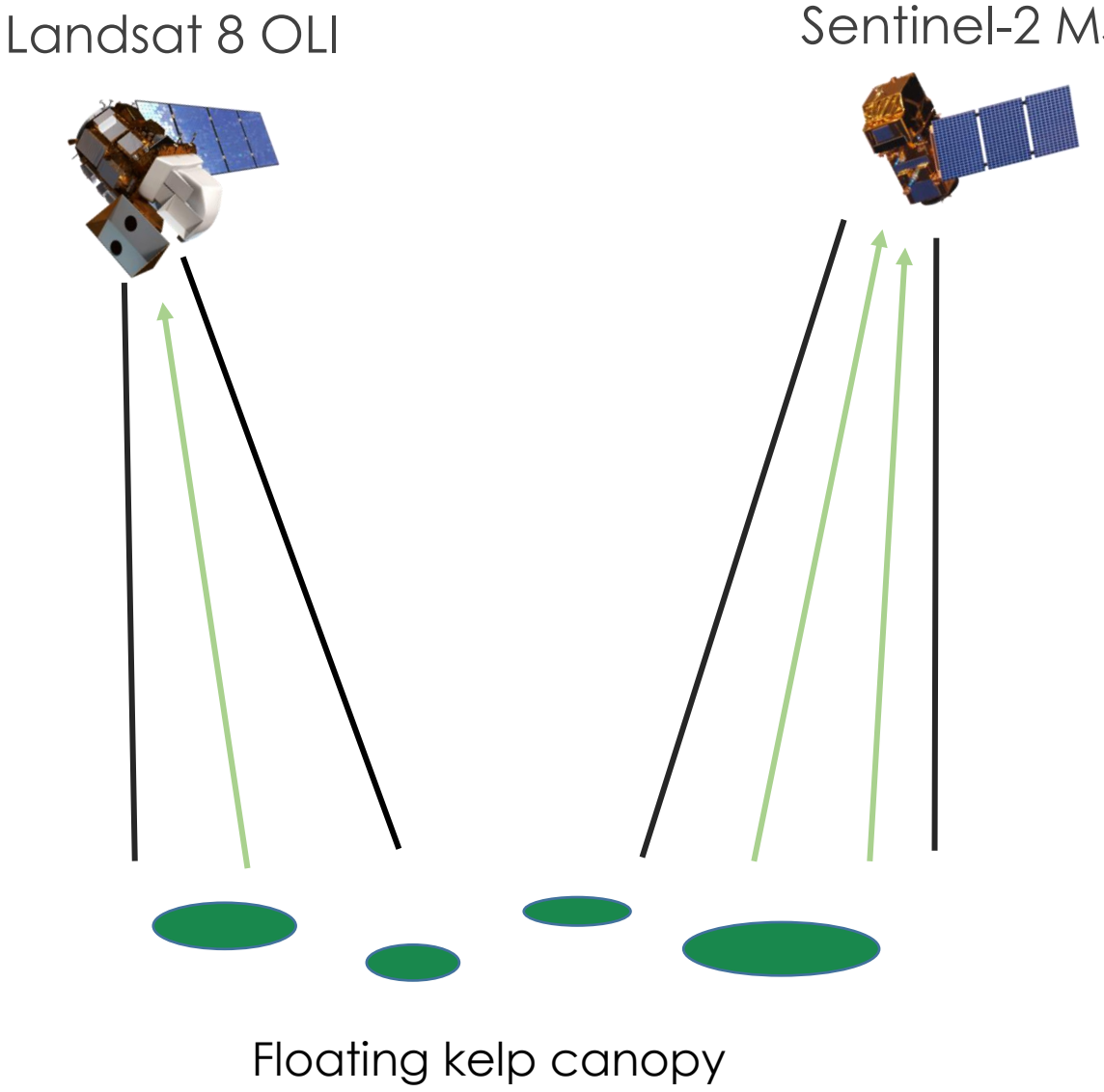
Floating kelp canopy

Methodology

Summer imagery
2016 – 2021

Cloud filter

Tidal heights



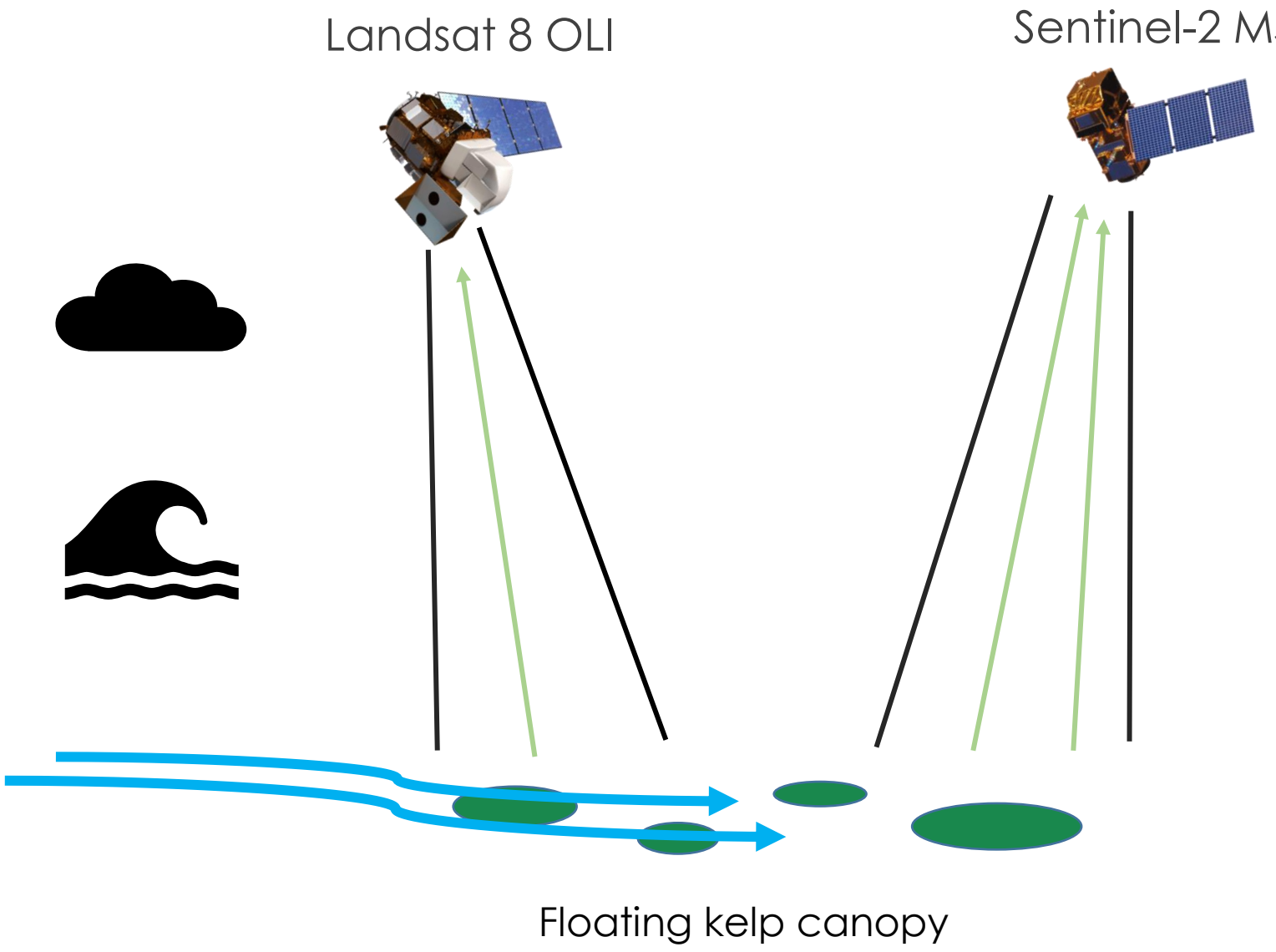
Methodology

Summer imagery
2016 – 2021

Cloud filter

Tidal height filter

Currents



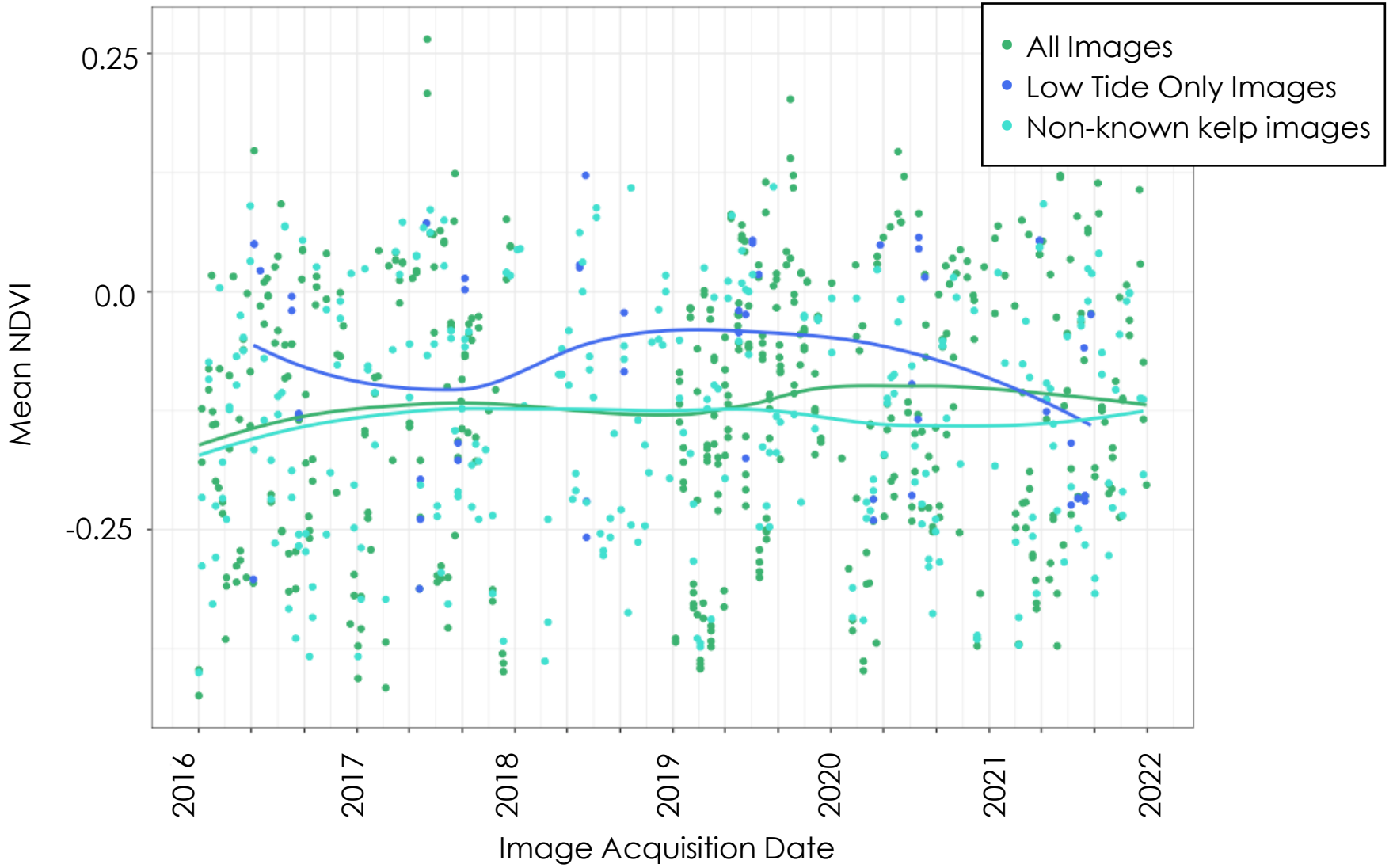
Methodology: Tide Filtering

Imagery Filter	Landsat 8	Sentinel-2
Cloud Cover < 30%	109	158
Captured during peak extent (June 15 – September 15)	32	63
Captured within +/- 1 hour of a low tide	11	18
Low tide height between –6ft and 1ft	6	10

Average number of images per year

Data Exploration: Tide Filtering – Landsat 8

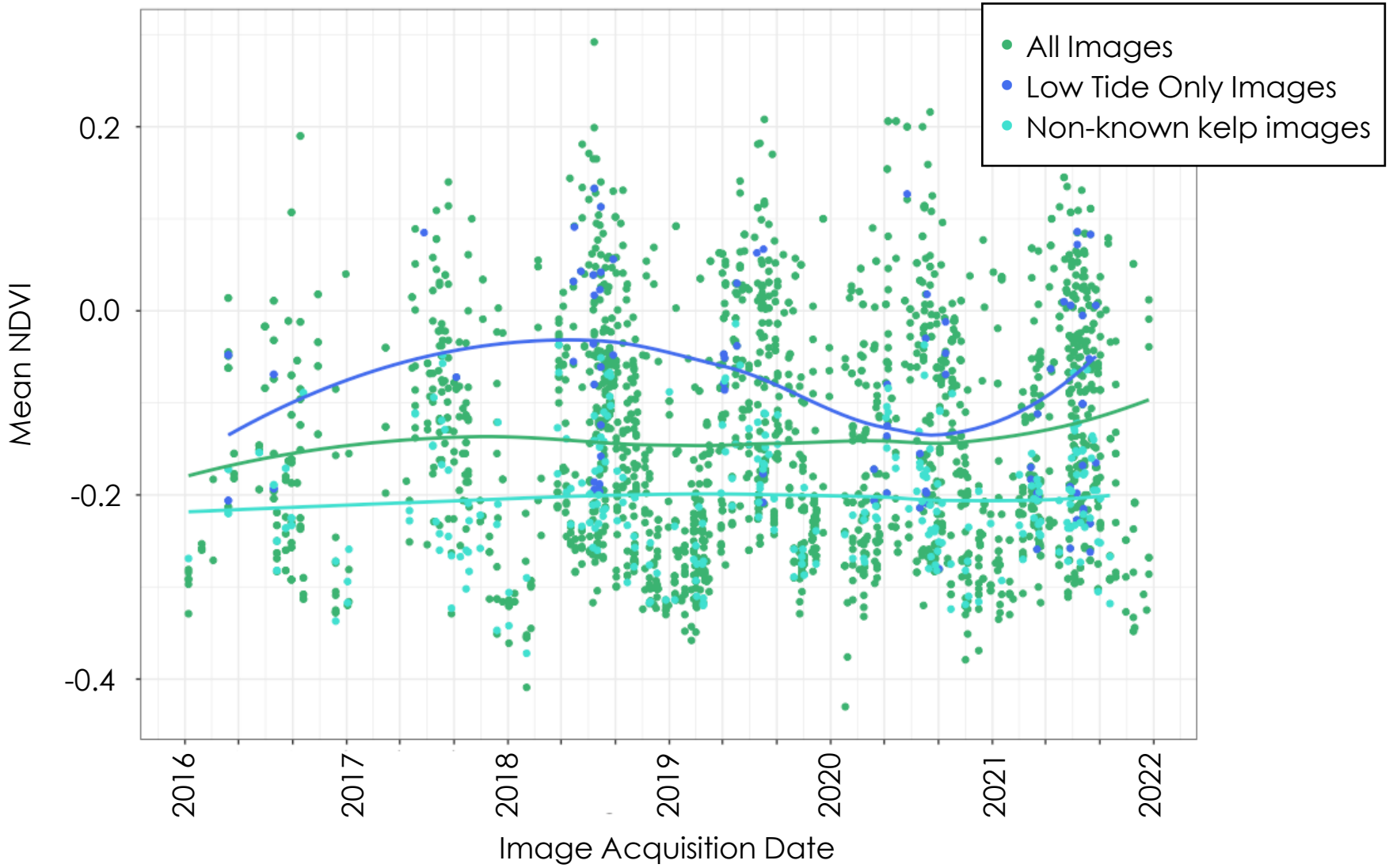
Interannual Variability in Mean NDVI for All Images vs. Low Tide Images (2016 – 2021)
Landsat 8



Data Exploration: Tide Filtering – Sentinel-2

Interannual Variability in Mean NDVI for All Images vs. Low Tide Images (2016 – 2021)

Sentinel-2

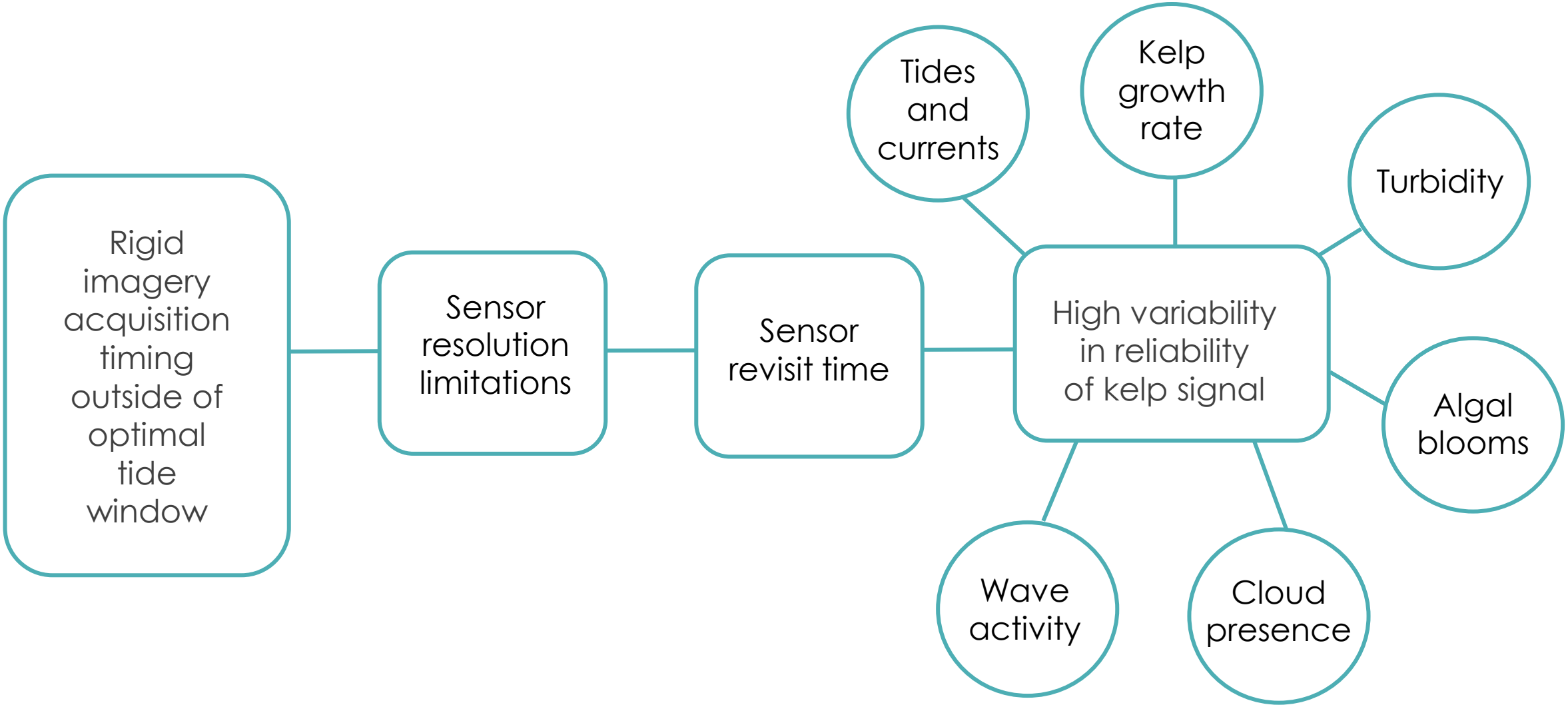


Results

- No clear difference detected between areas of kelp and no known kelp
- No clear difference between bed sizes
- Tides influence kelp detection

Image Credit: Mike Hitchner/DEVELOP Team

Limitations, Errors, & Uncertainties



The Takeaways

- Classification may be useful
- Tidal filters important for kelp detection
- Challenges of monitoring nearshore ecosystems
- Remote sensing for kelp monitoring is a time-intensive, multi-step process that requires calibration against other datasets

Image Credit: Mike Hitchner/DEVELOP Team

Future Work

- Use of object-based kelp classification using NDVI and NDREB
- Exploration of Multiple Endmember Spectral Mixture Analysis (MESMA)
- Puget Sound Kelp Vital Sign
- The Port of Seattle and Seattle Aquarium collaboration
- WA DNR aerial kelp surveys
- Many smaller non-profits and NGOs are involved in monitoring and restoring kelp

Image Credit: Hannah Gabrielson

ACKNOWLEDGEMENTS

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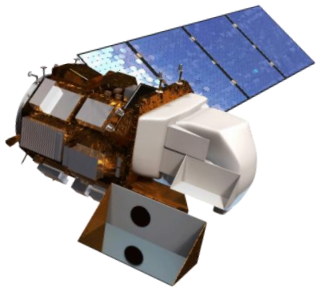
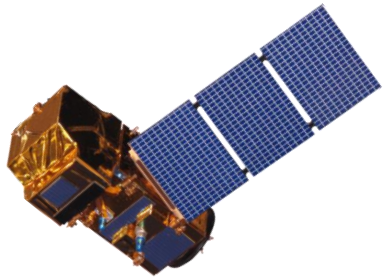
Additional Slides

Methodology: Overview of Classification



Landsat 8 OLI



Sentinel-2 MSI

Filter out high tides

Apply cloud mask and NDVI threshold

Train model

Kelp extent maps

Assess accuracy

R

Google Earth Engine

ArcGIS Pro

Image Credit: NASA/Goddard Space Flight Center Conceptual Image Lab