Kelp Forest Monitoring in Washington State: challenges and opportunities

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WA DNR Nearshore Habitat Program

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Kelps of Puget Sound

Washington: a kelp forest biodiversity hotspot

- 22 species of kelp

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- Two canopy-forming species

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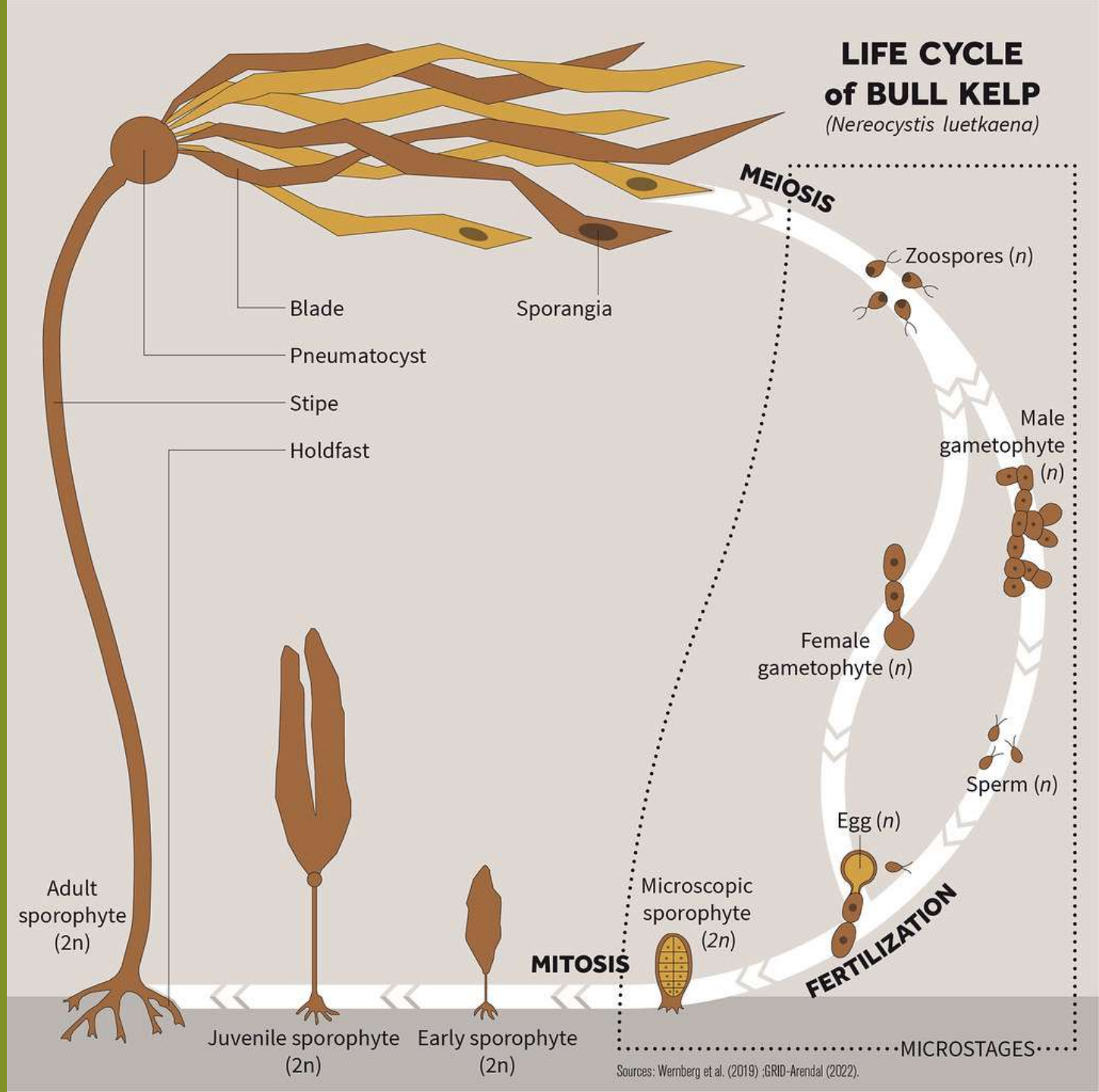
Bull Kelp Life Cycle

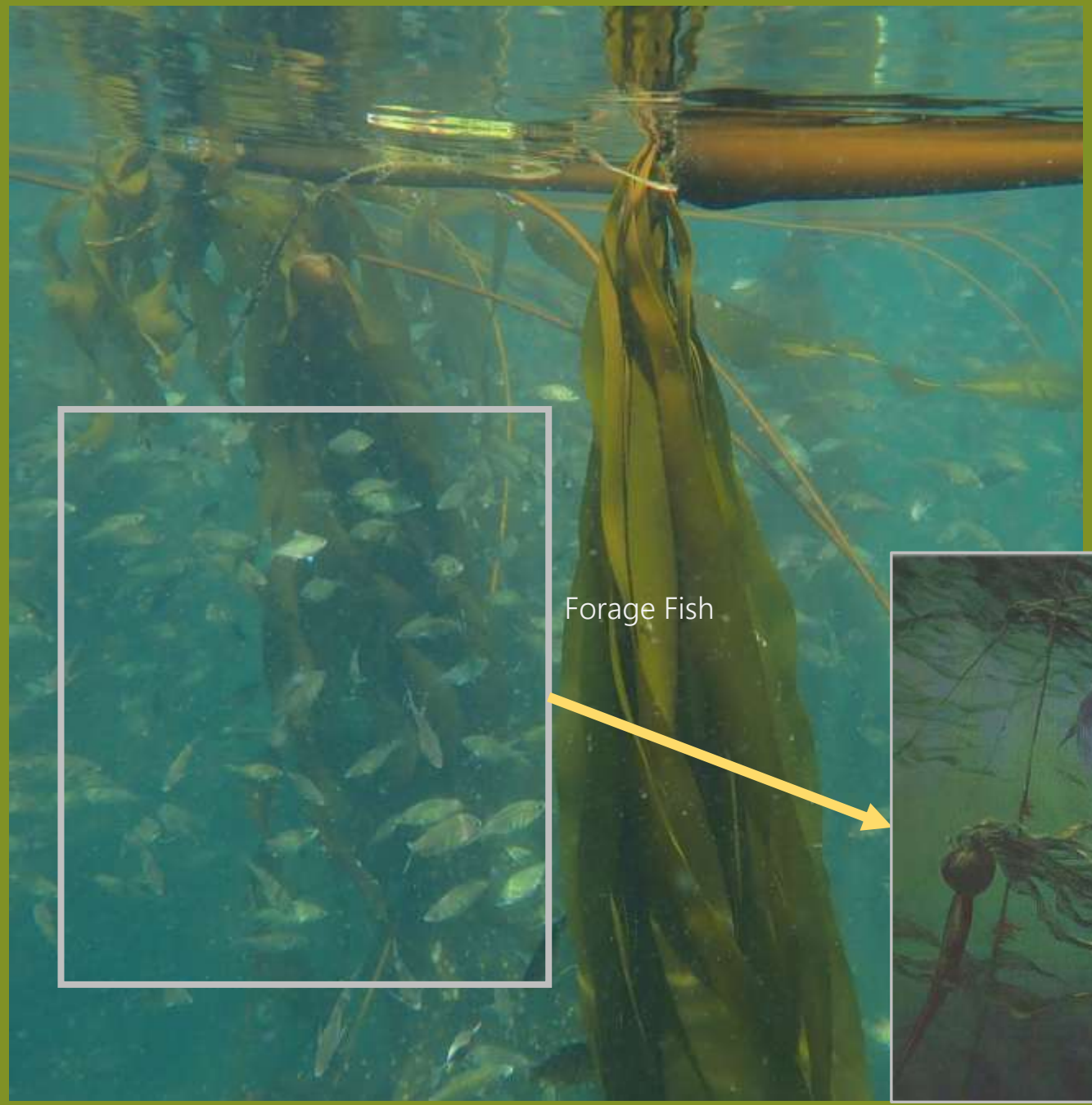
- Primarily annual
- Two stages:
  - Sporophyte (large)
  - Gametophyte (microscopic)



KELP

Critical habitat

Primary production



Forage Fish

Widespread interest in kelp - and concern

Mission:
Manage, sustain, and protect the health and productivity of Washington's kelp forests and seagrass meadows to meet the needs of present and future generations.

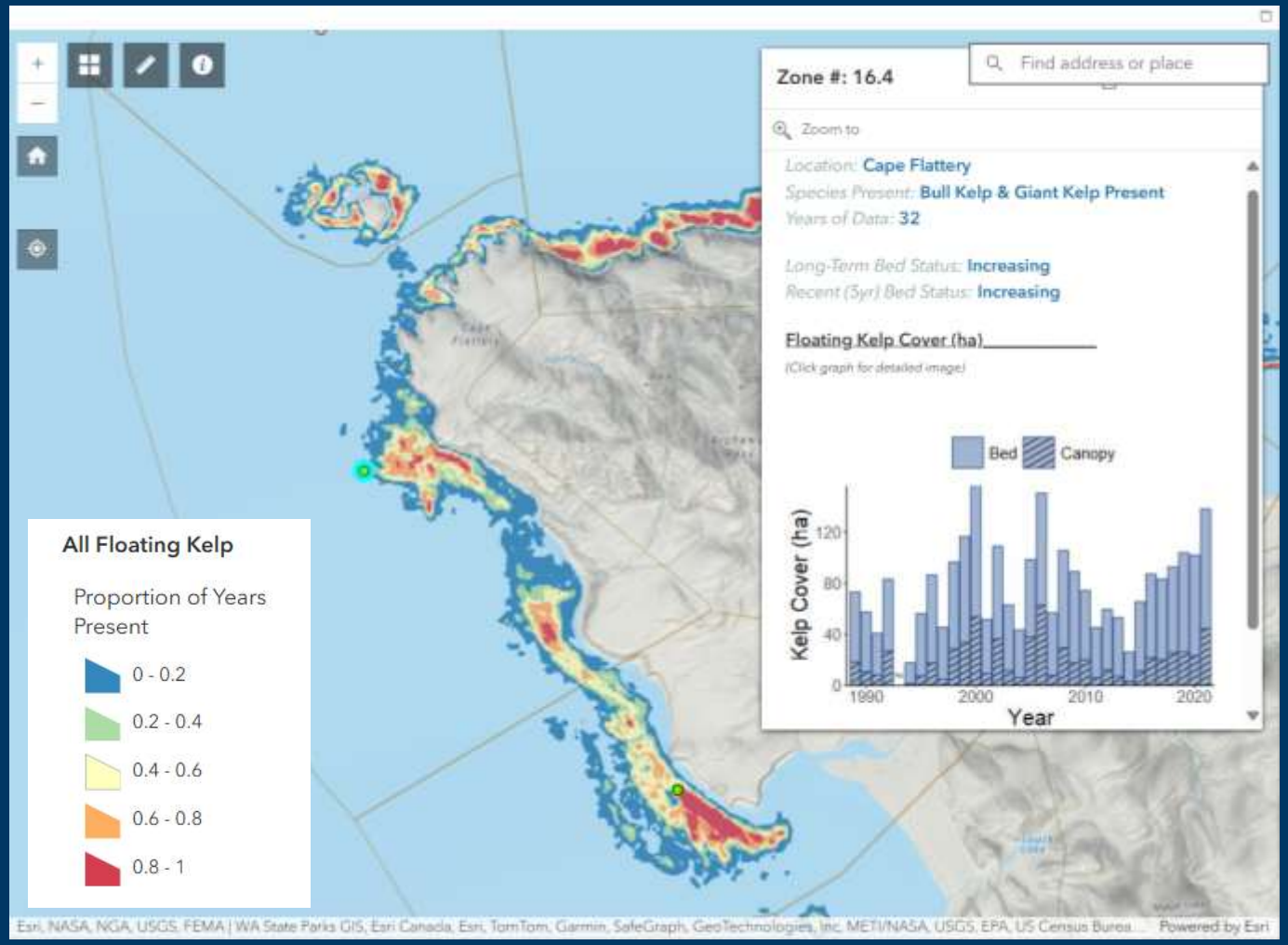
Outline

- Kelp canopy surveys
- Floating kelp status & trends: Vital Sign Indicator
- Kelp resilience and loss study

Kelp Forests WA

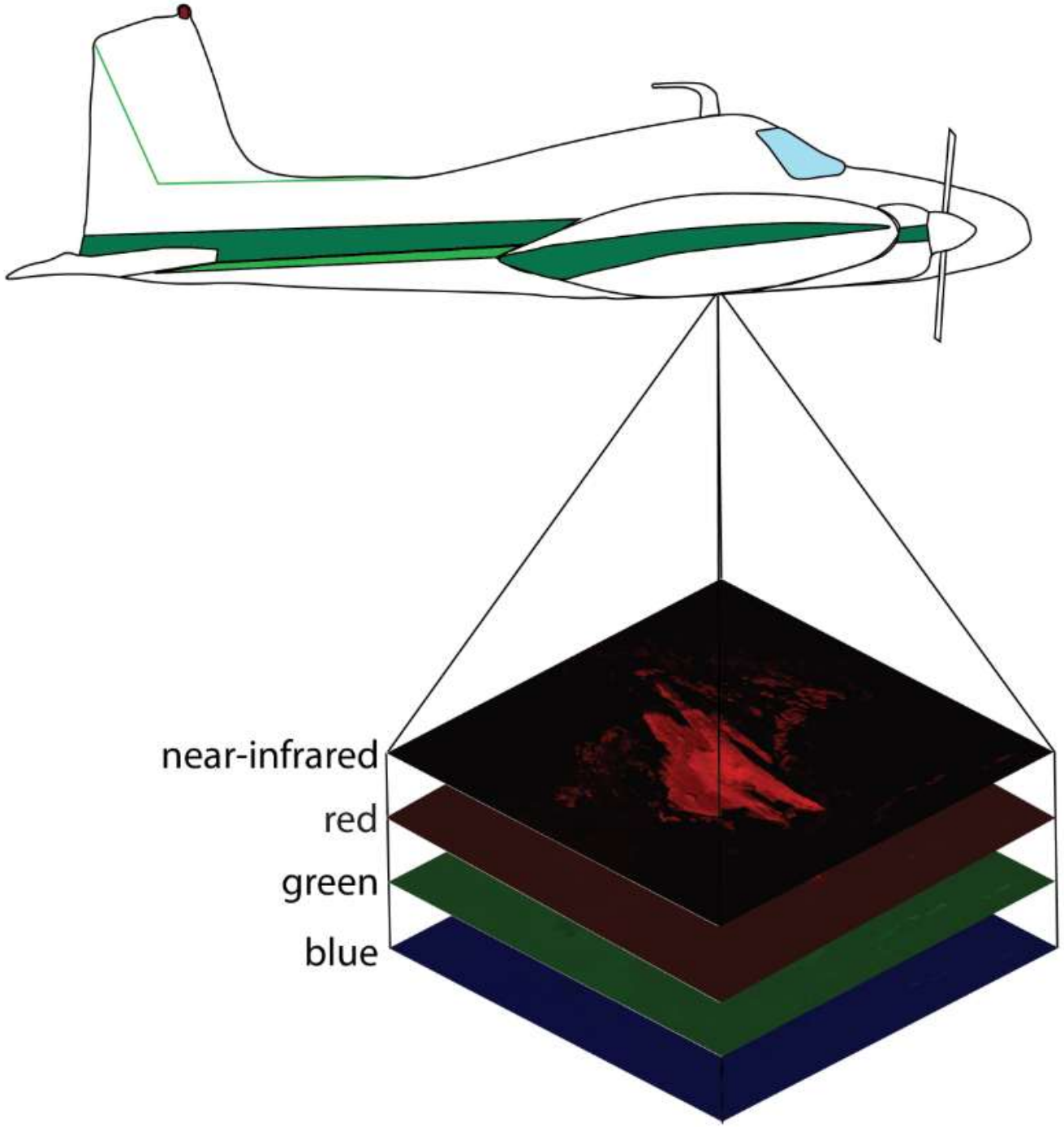
Fixed-wing aircraft imagery

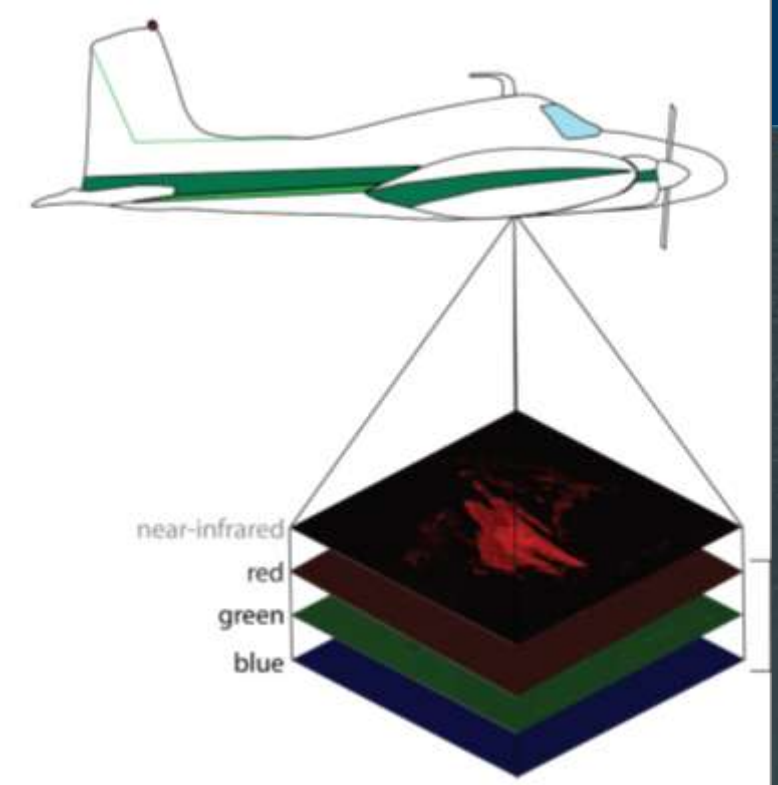
- Long-term monitoring
- Variability and persistence
- Change over time



Fixed-wing aircraft imagery

- High-resolution imagery
  - Started 2022
  - Large-scale monitoring
    - ~760,000 acres/year
  - 6-inch resolution
  - 4 spectral bands
    - Near-infrared
    - Red
    - Green
    - Blue




near-infrared
red
green
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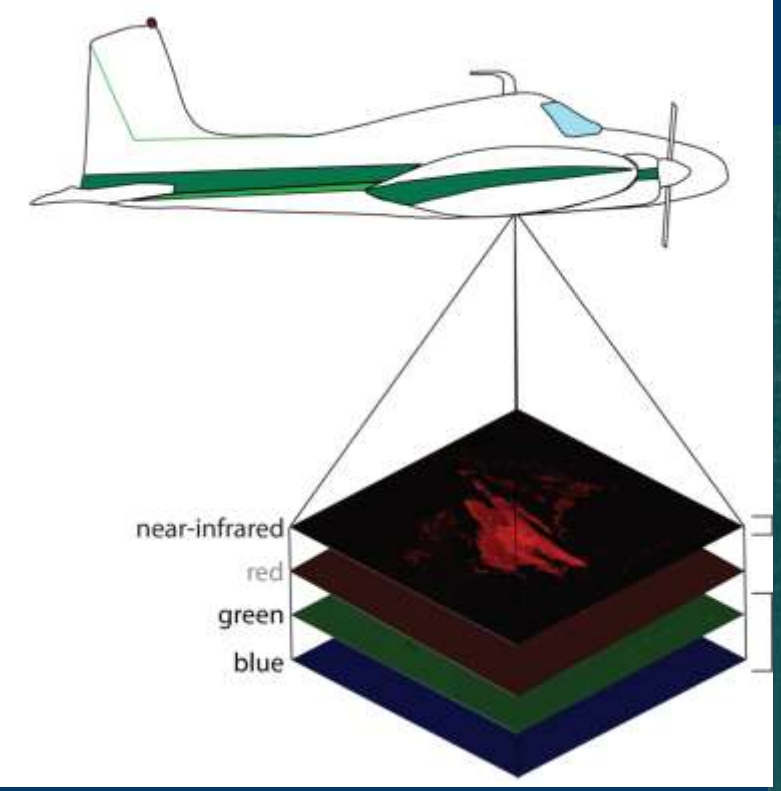
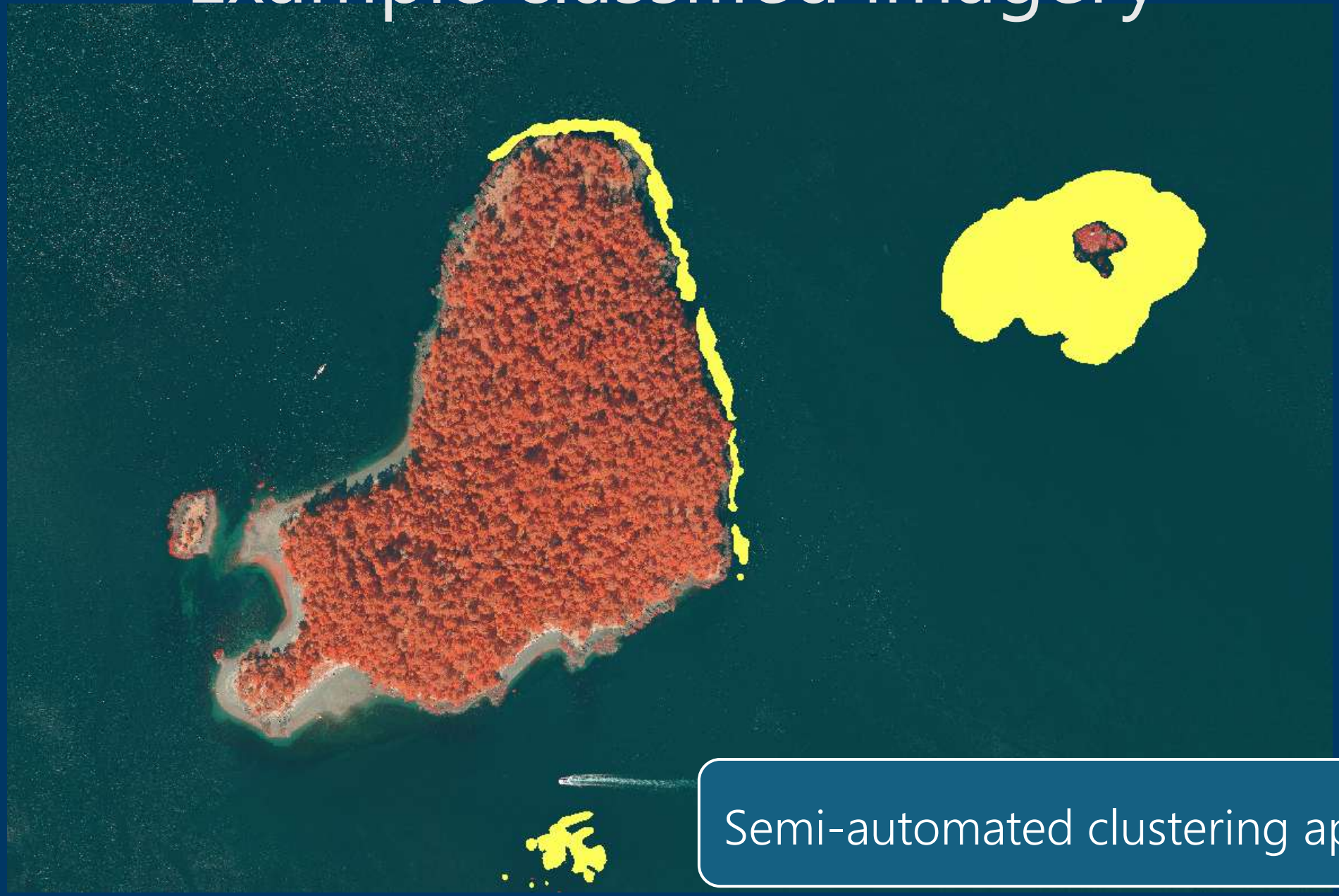
Turn Island


near-infrared
red
green
blue


Turn Island
No legend

Example classified imagery

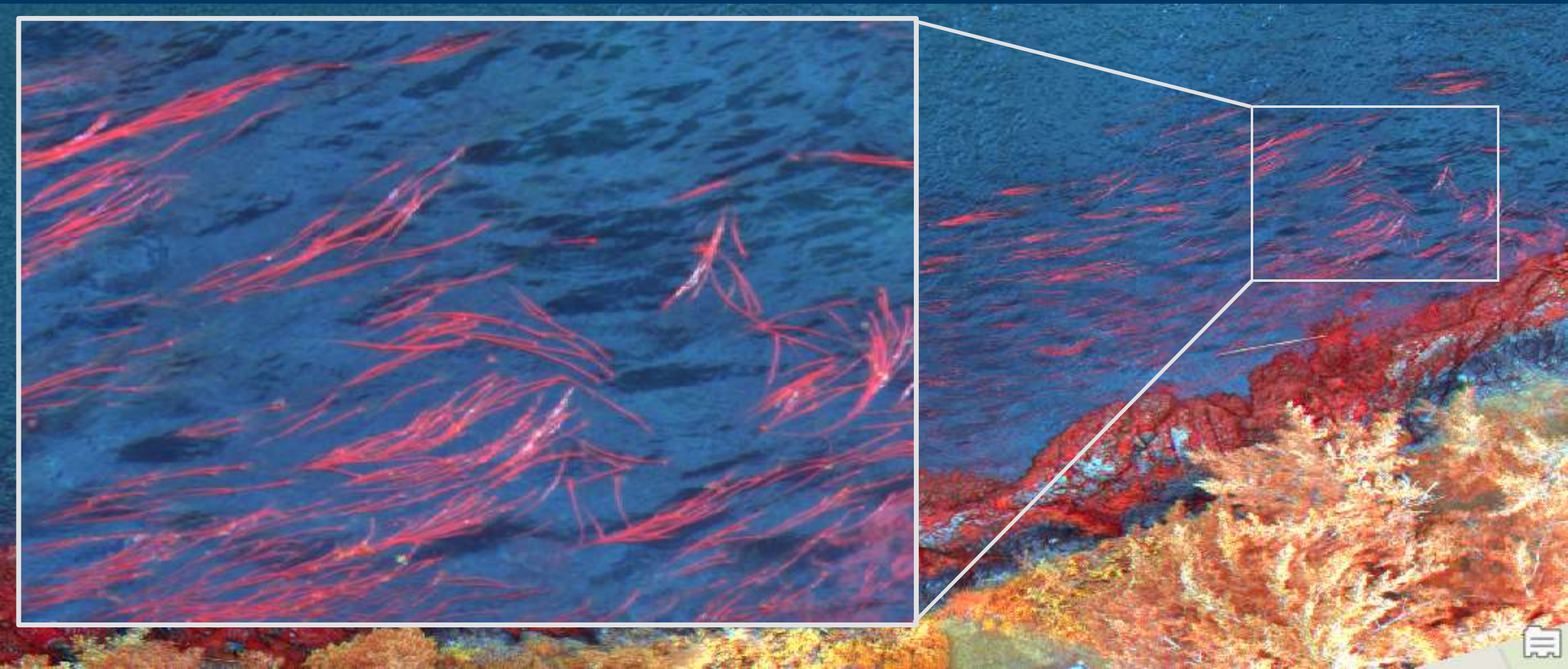


Semi-automated clustering approach

UAS imagery classification

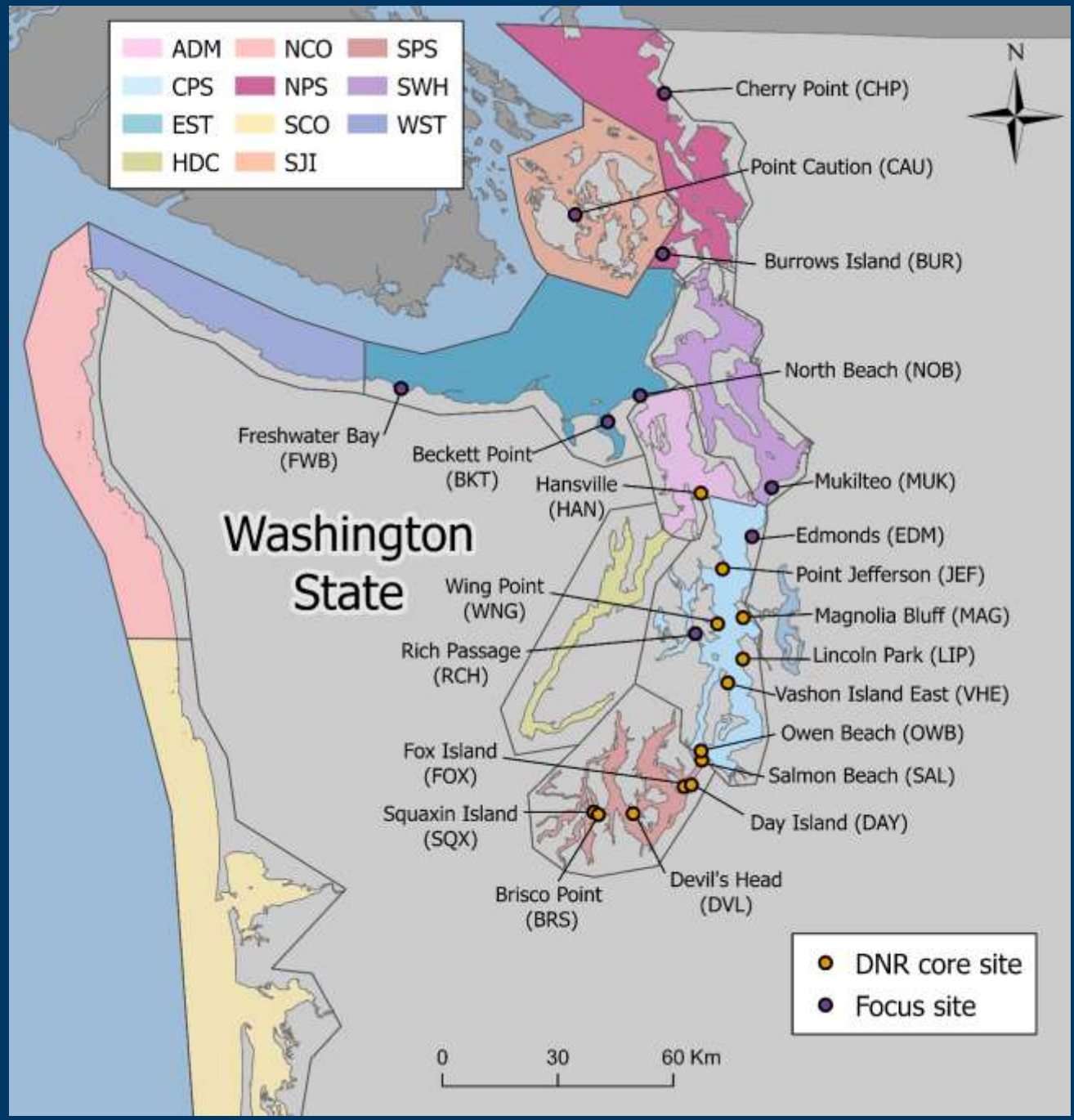
- Site-level monitoring
- Super-fine resolution
  - ~3-inch
  - Multi-spectral imagery

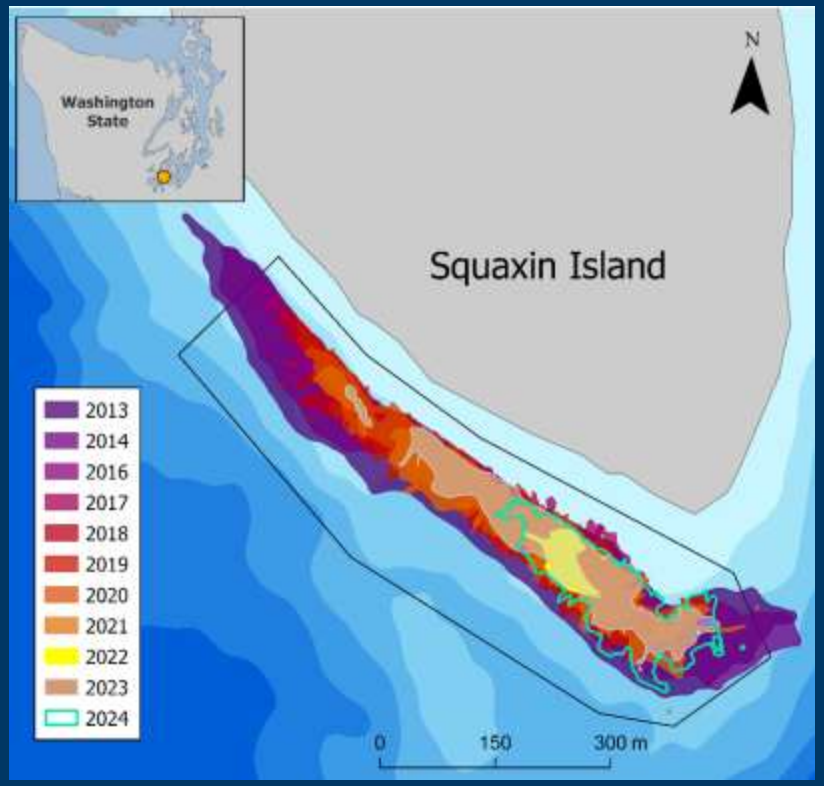
UAS imagery classification



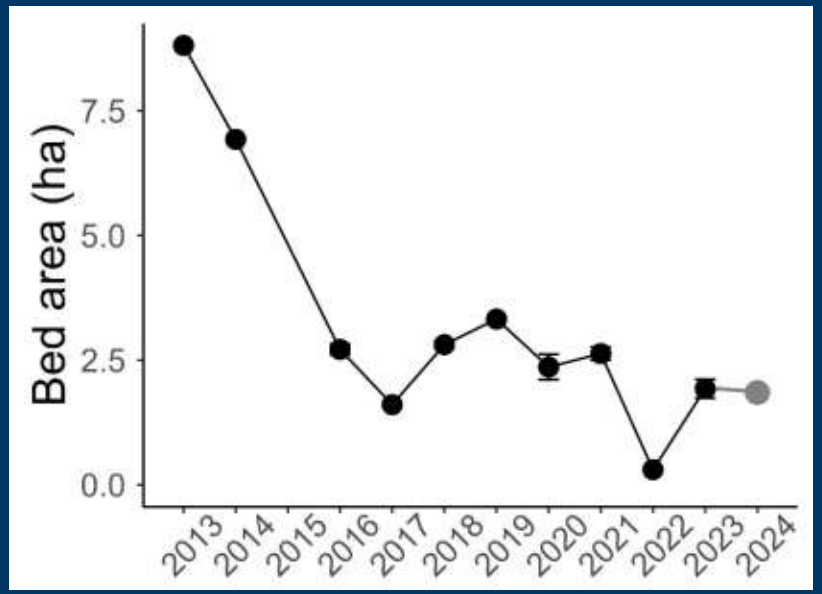
DNR Kelp Kayak

- Annual monitoring
- Bed area, depth, density
- 13 core sites





- Variable trends
  - 5 sites with total loss
  - 1 site declining*
  - 6 sites with no trend
- Losses prevalent
- Local refugia



Status and Trends – Floating Kelp Indicator

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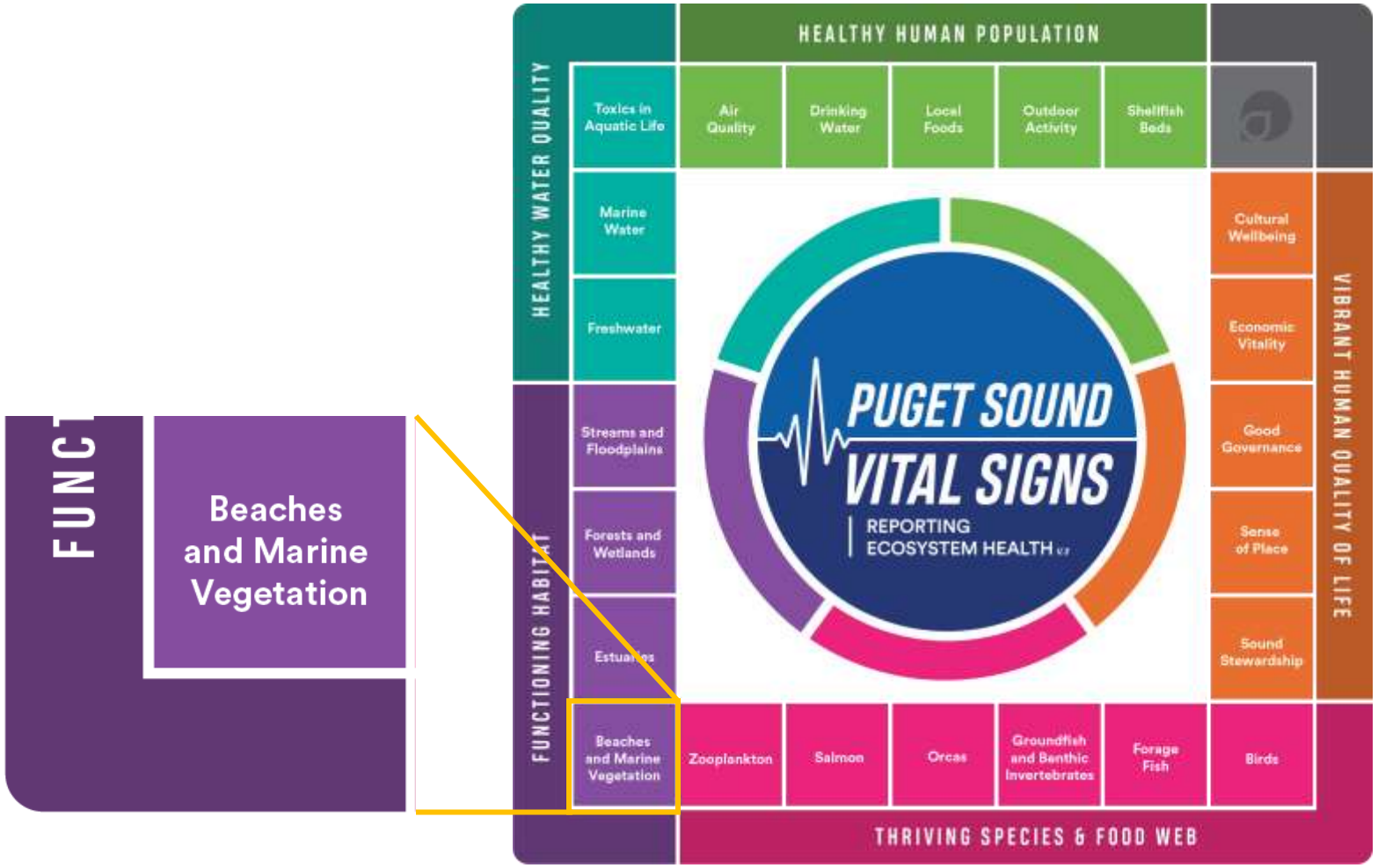


Kelp Forests WA

Status and Trends – Floating Kelp Indicator

Kelp Forests WA

Marine Agronomics

Northwest Straits COMMISSION

Washington Department of FISH & WILDLIFE

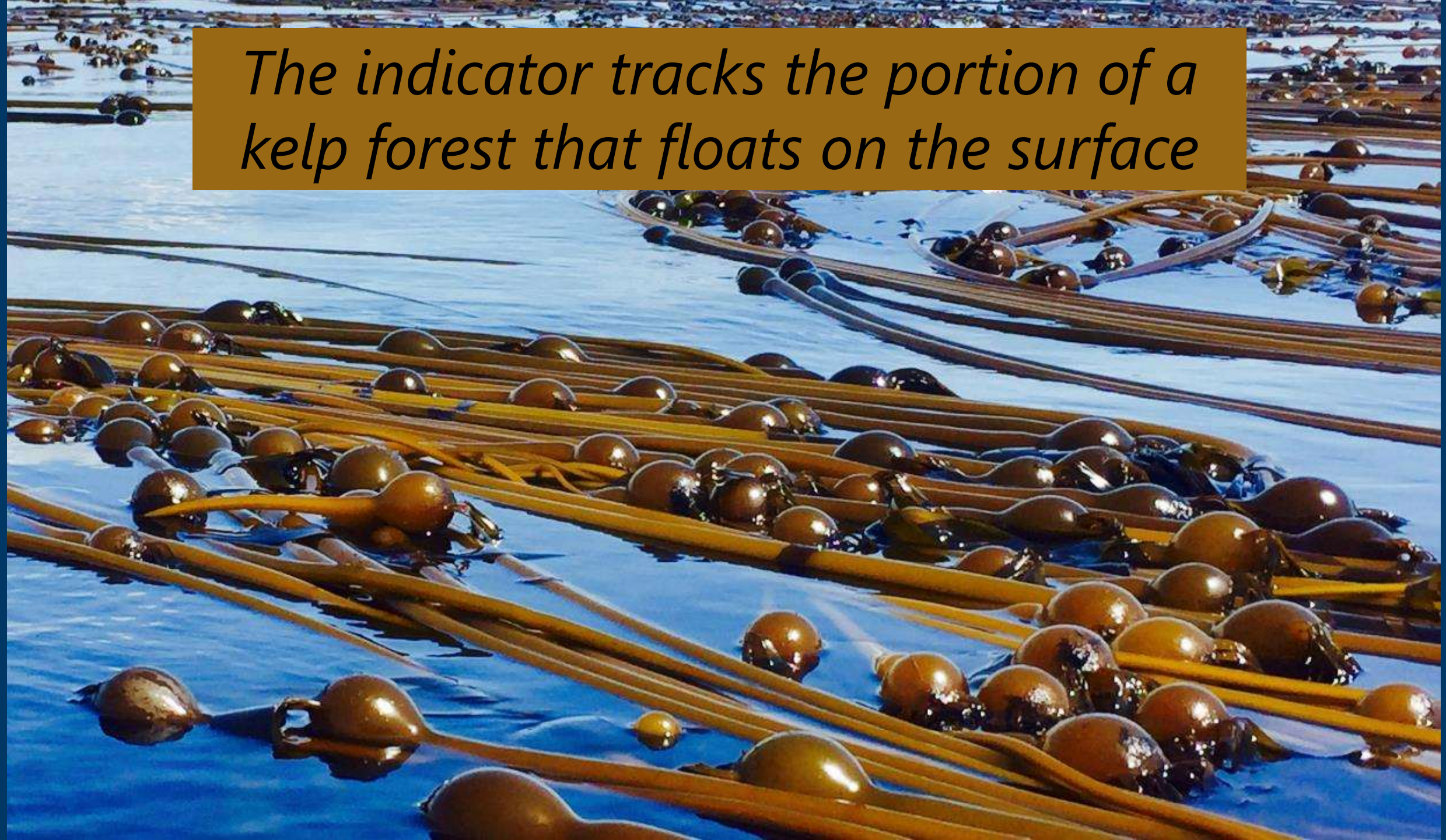
Sea Grant WASHINGTON

SAMISH INDIAN NATION

Developing the Floating Kelp Indicator

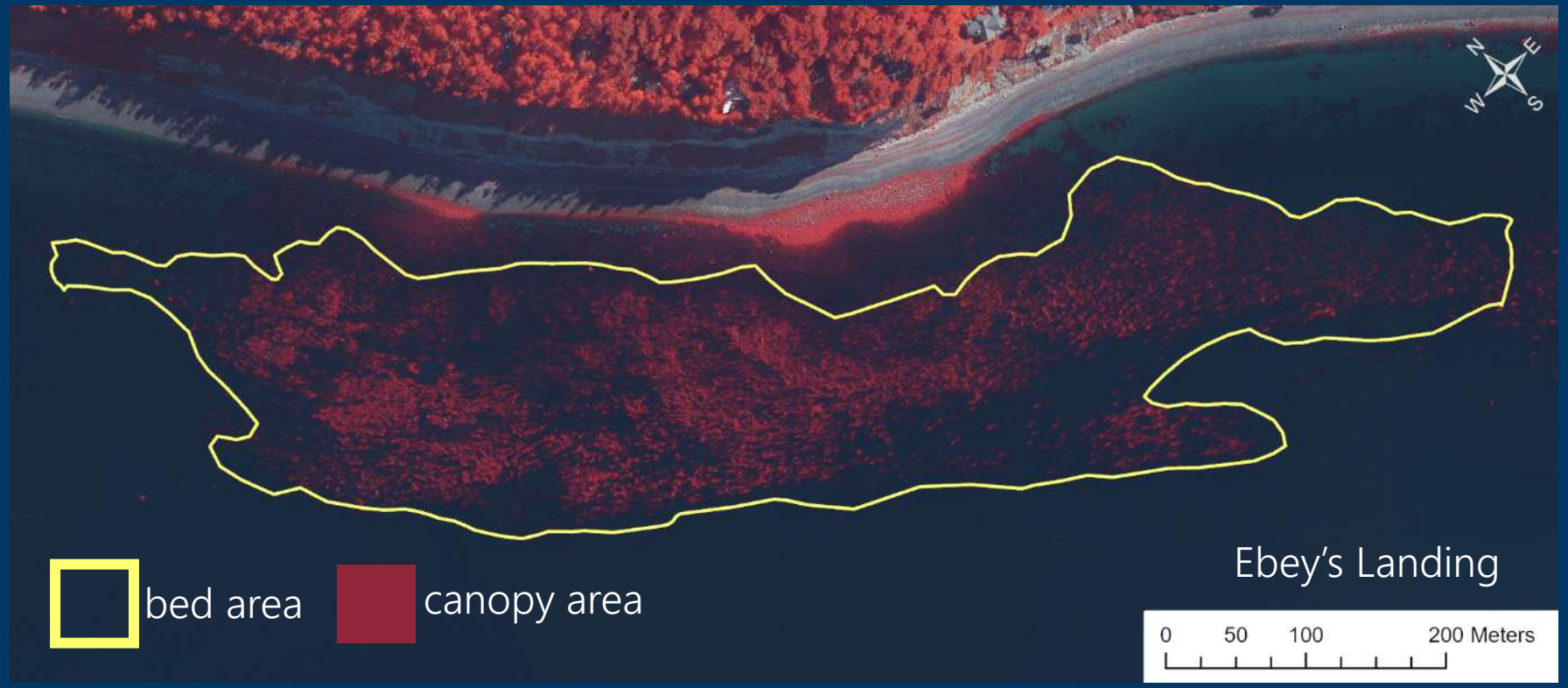
We wanted an indicator that could…

- Leverage existing data
- Incorporate multiple ways of knowing
- Have a high-level summary, but ability to drill down into detail
- Be highly collaborative and persist over time



The indicator tracks the portion of a kelp forest that floats on the surface

The primary statewide metric is floating kelp bed area



The "bed" is defined as the area encompassing kelp tissues floating on the water surface and small gaps between adjacent individuals.

Indicator assesses long-term trends in bed area at 175 locations

Long-term trends

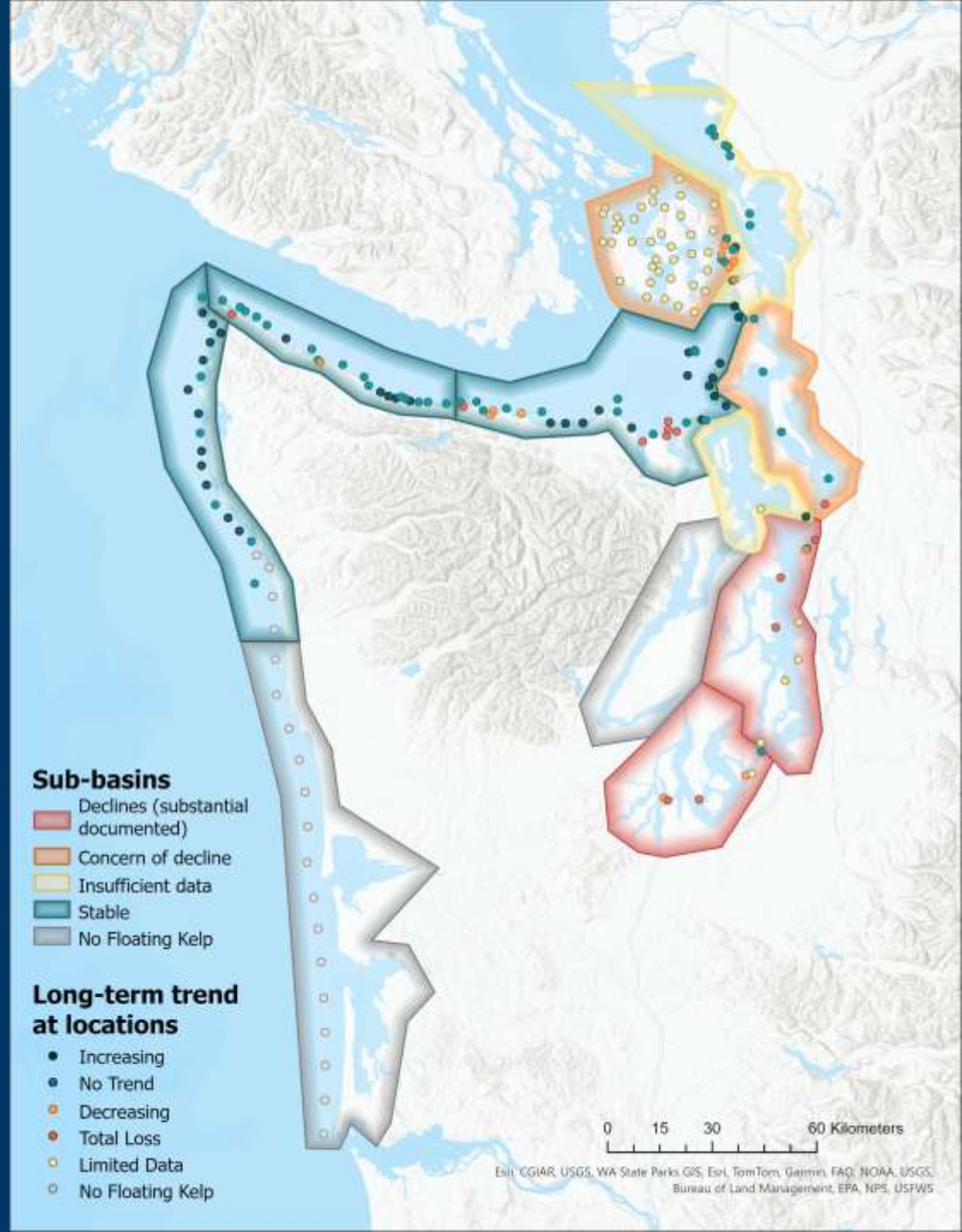
- Increasing
- No Trend
- Decreasing
- Total loss
- Limited data
- No floating kelp

Sub-basin status provides a rapid summary of the state of knowledge.

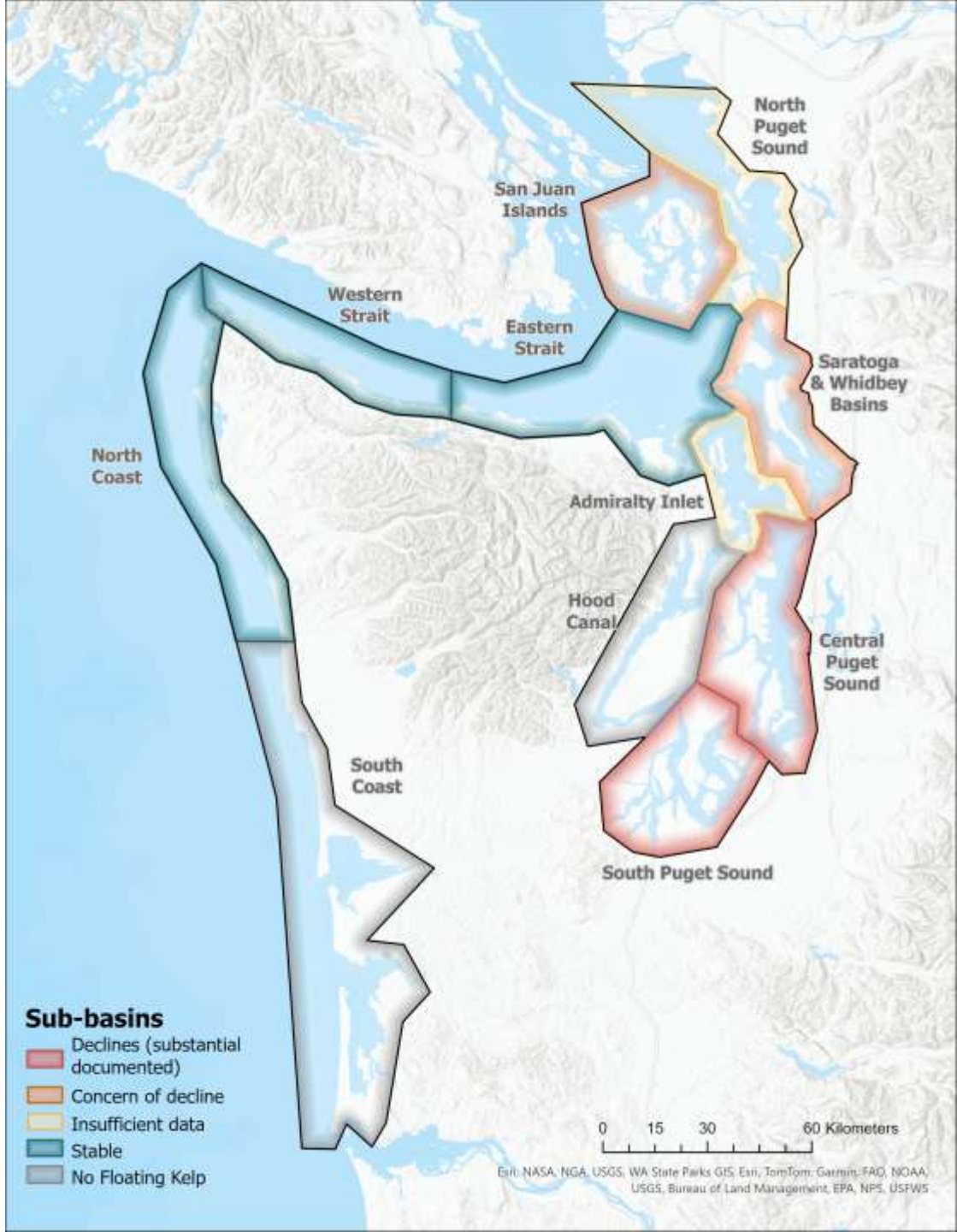
Sub-basin status

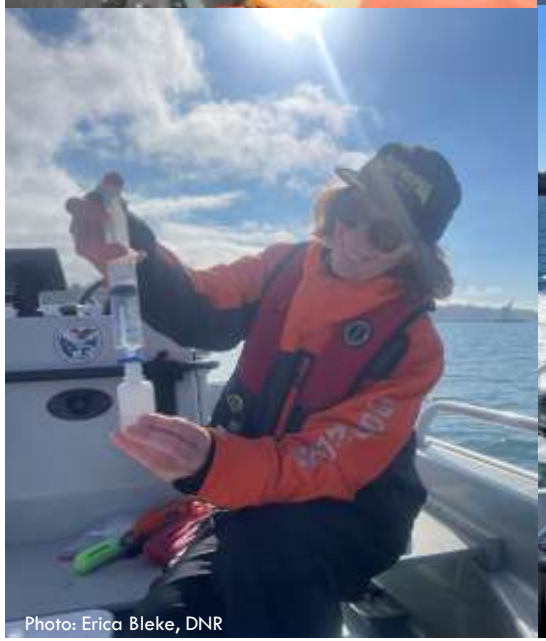
- Stable
- Concern of decline
- Decline (substantial)
- Insufficient data
- No floating kelp

Quantitative trends are woven together with other ways of knowing to determine sub-basin status.



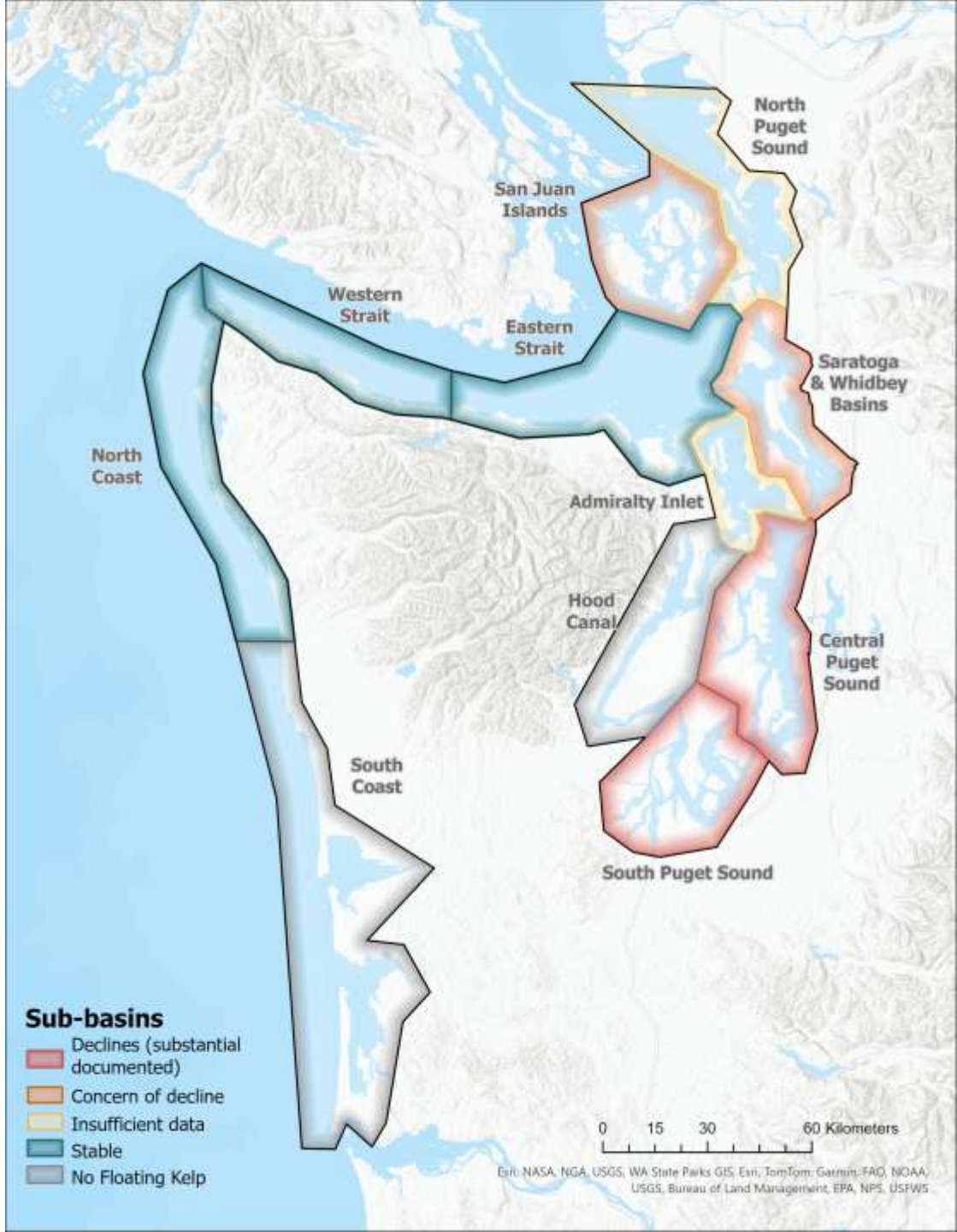
Why is bull kelp stable in some areas and declining in others?





Bull kelp resilience and loss study

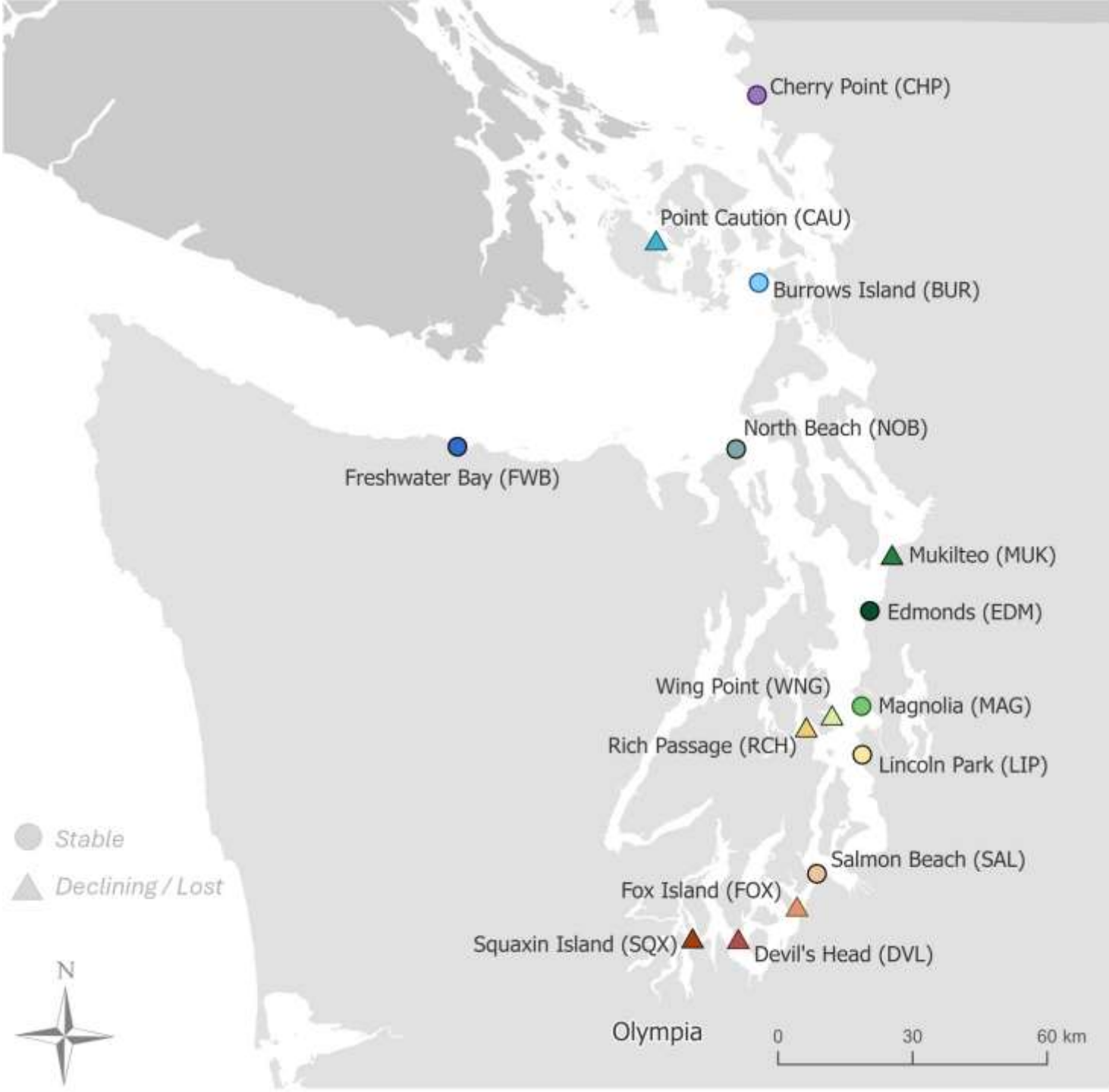
HSIL-funded



Bull kelp resilience and loss study

Sampling methods

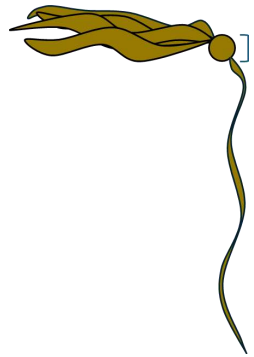
- Environmental data
  - Monthly and continuous sampling
- Benthic community surveys
- Kelp canopy extent, condition, and performance

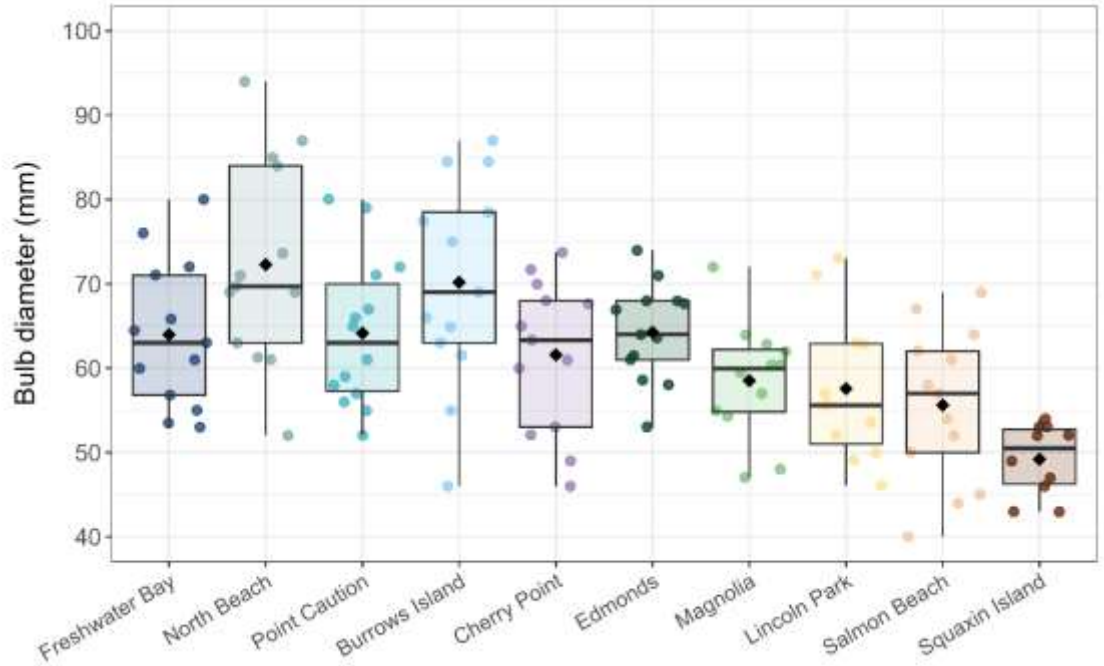


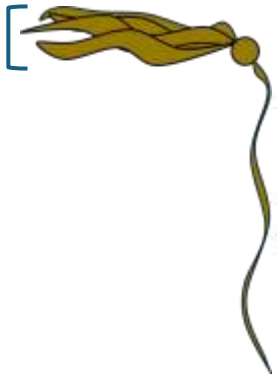
Bull kelp resilience and loss study

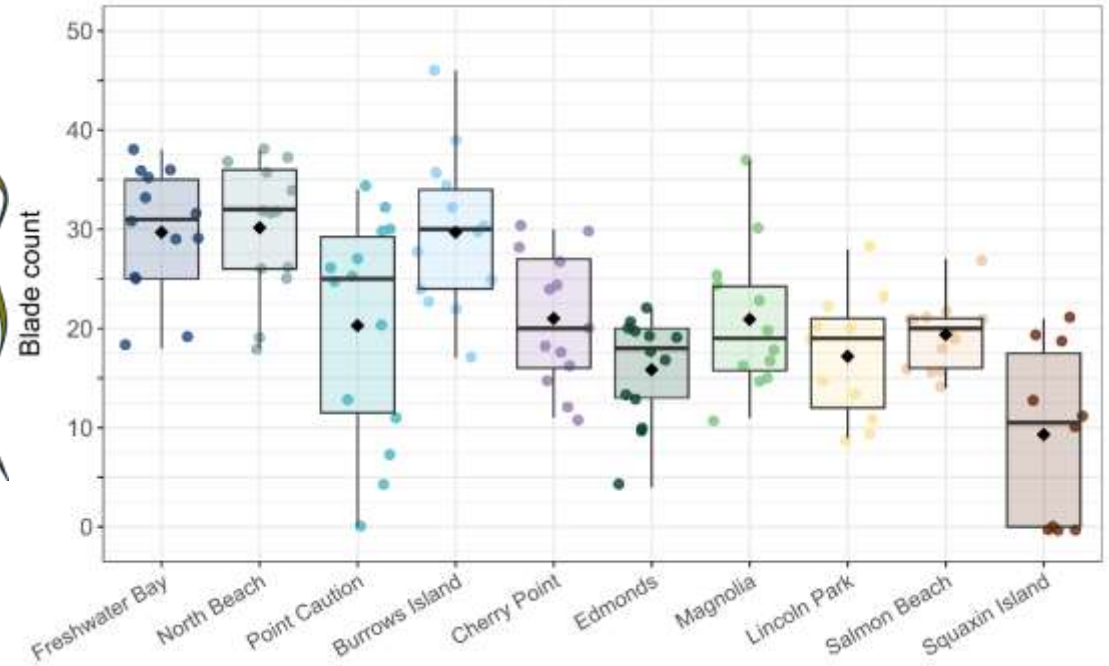
Results

- Sporophyte size decreases from oceanic to estuarine waters







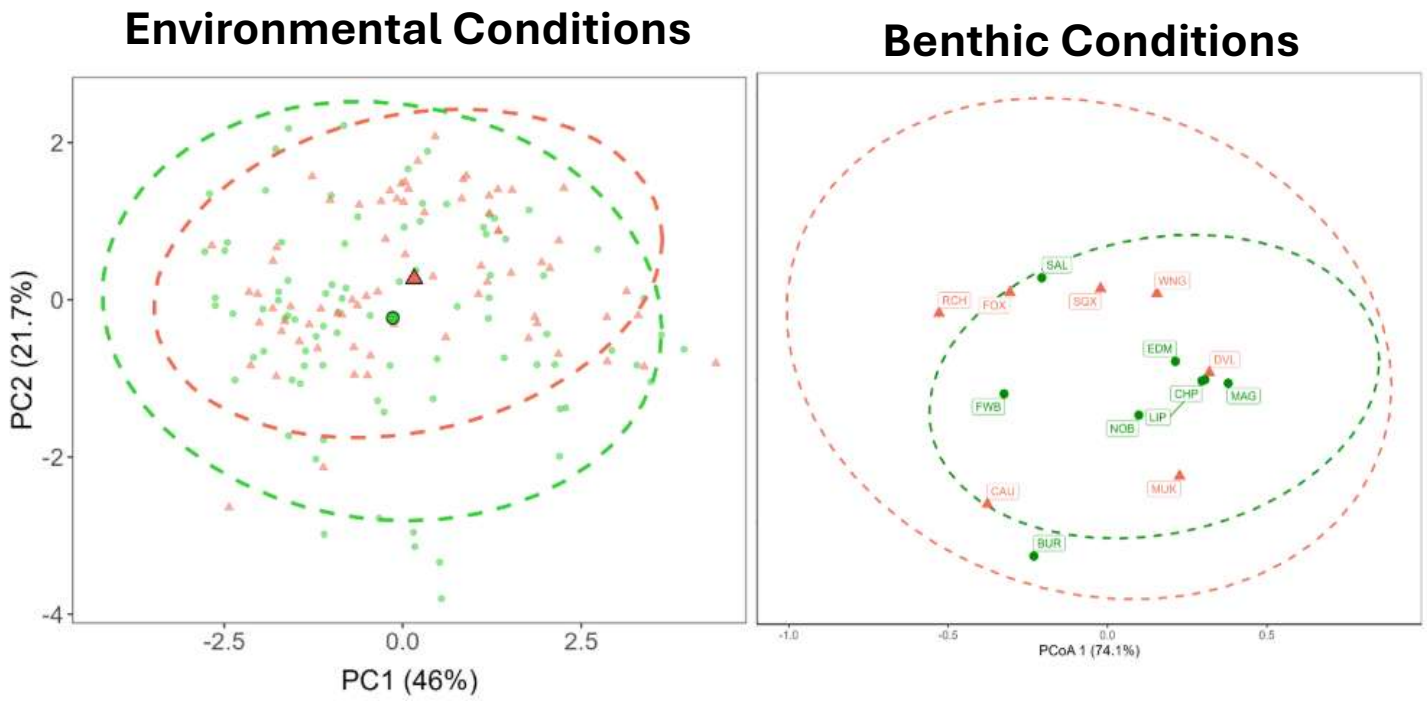


Bull kelp resilience and loss study

Results

- Bull kelp are found across a range of environmental and benthic conditions

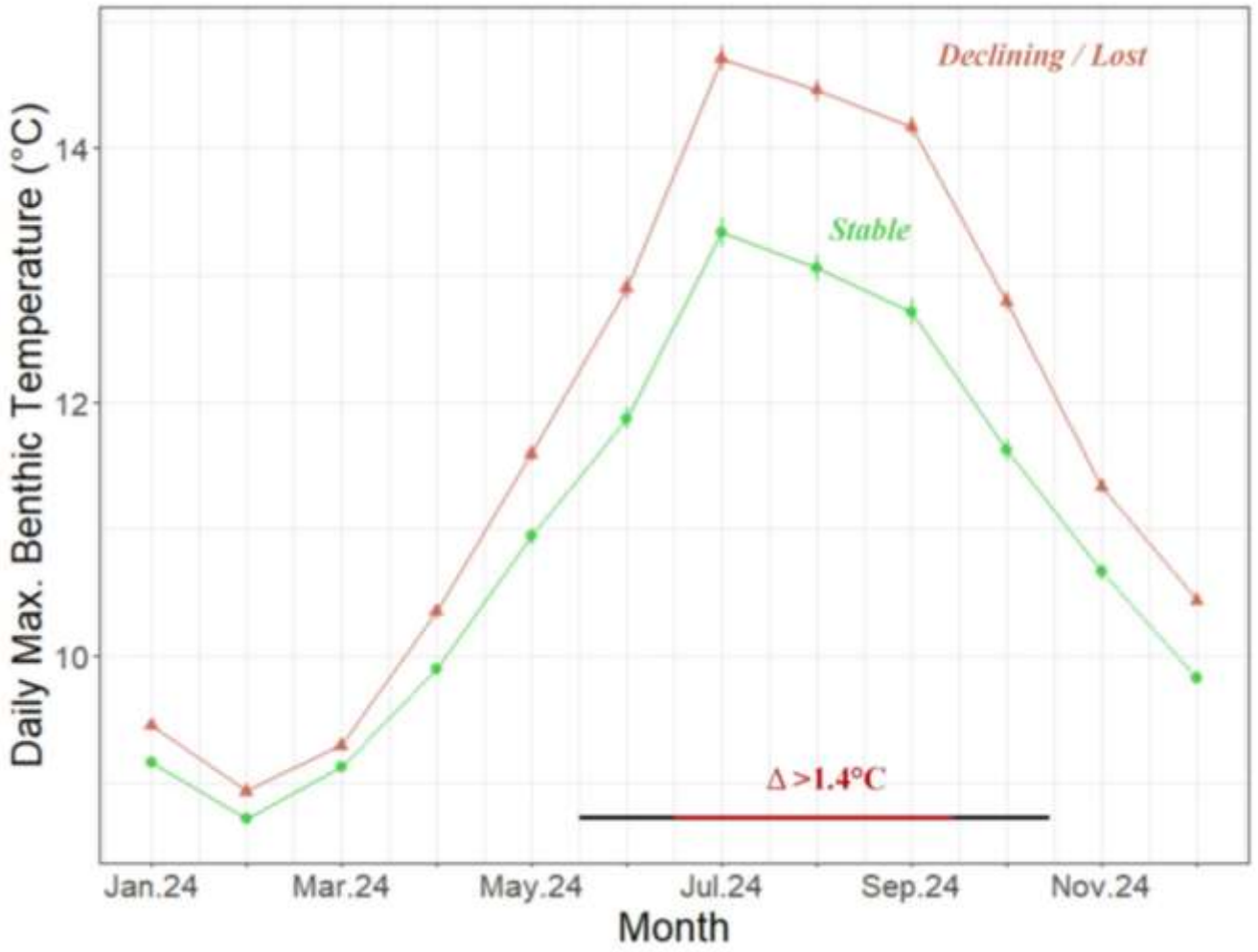
- No one stressor can explain losses
  - Spatial and temporal trends can provide clues about specific drivers



Bull kelp resilience and loss study

Results

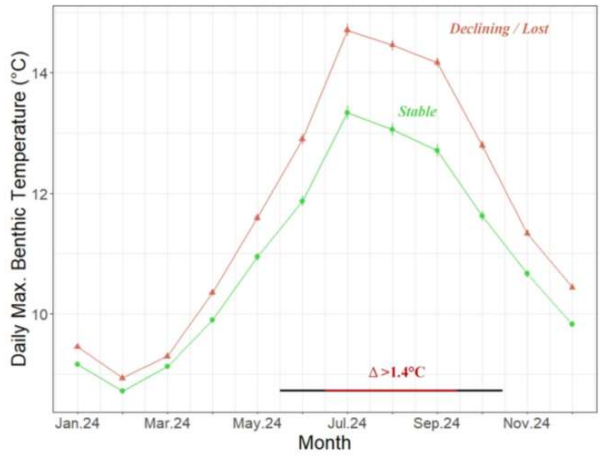
- Water temperature
  - Declining/lost sites had warmer summer temperatures
  - BUT kelp does persist at some warm sites

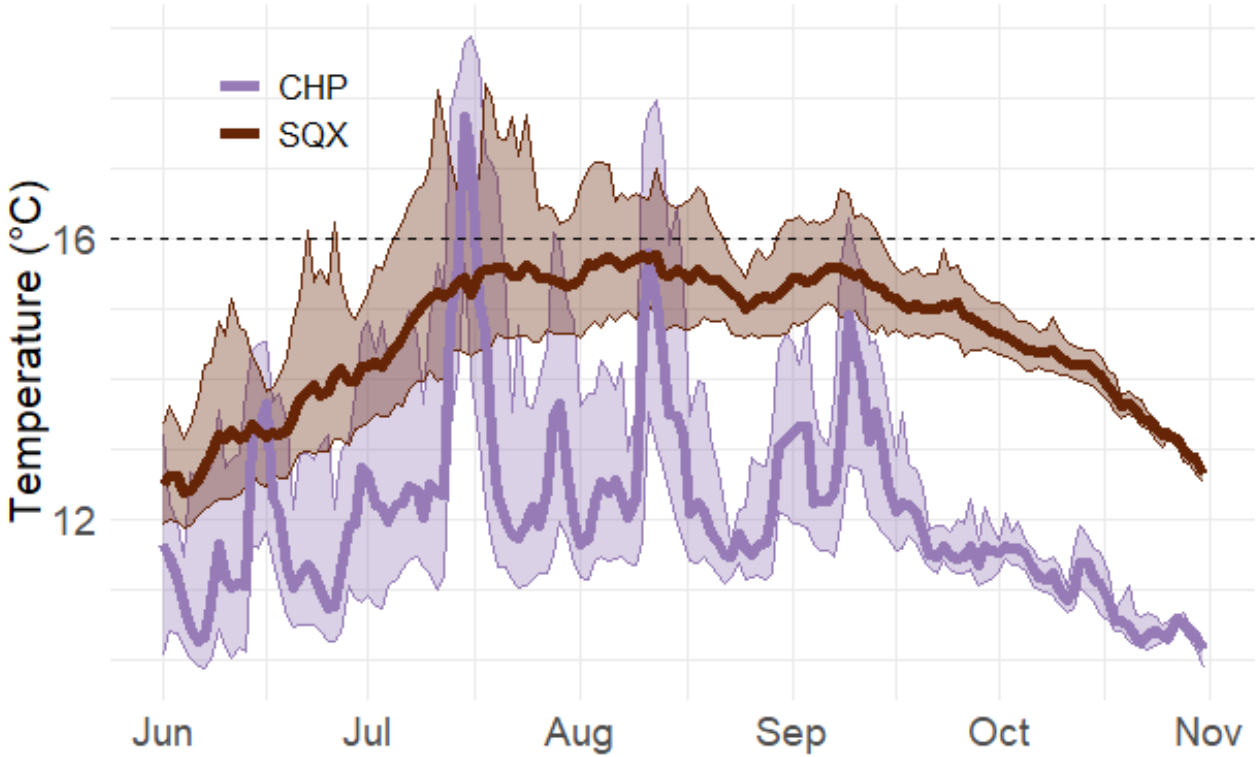


Bull kelp resilience and loss study

Results

- Water temperature
  - Declining/lost sites had warmer summer temperatures
  - BUT kelp does persist at some warm sites
  - Maximum temperature is only part of the story

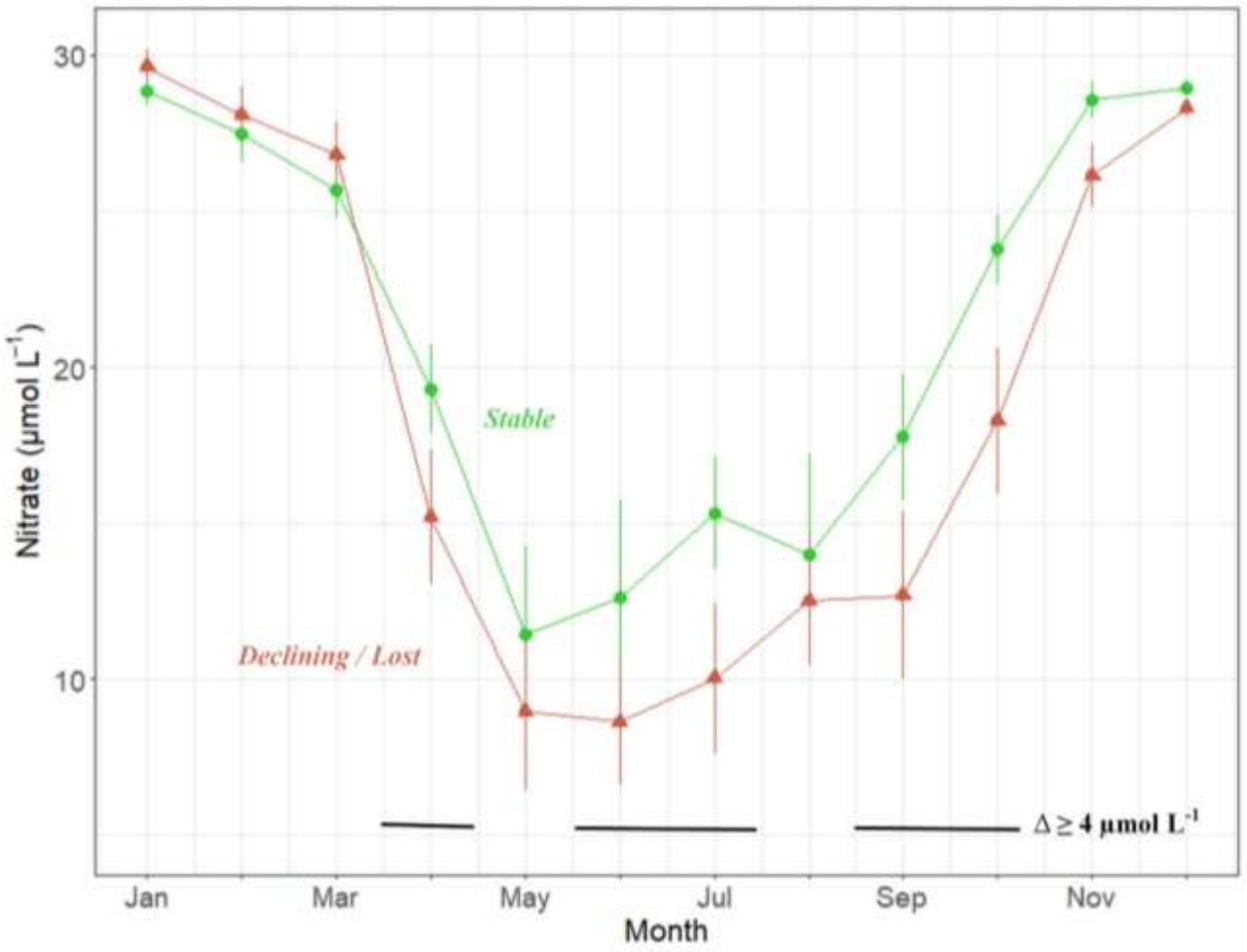




Bull kelp resilience and loss study

Results

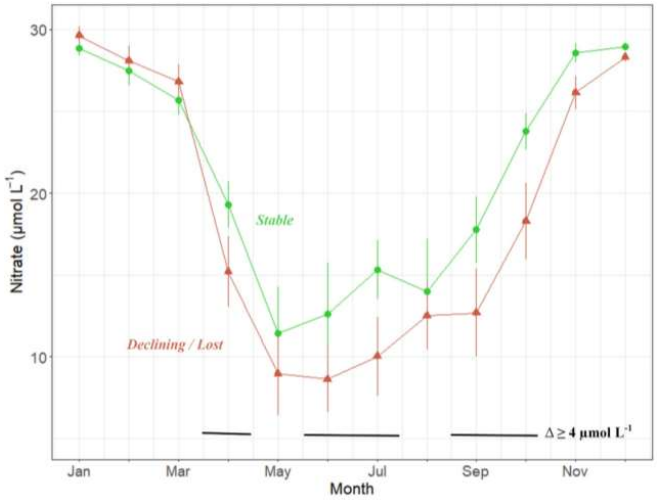
- Nitrate concentration
  - Declining/Lost sites had lower summer nitrate concentrations
  - BUT kelp does persist at some low-nutrient sites

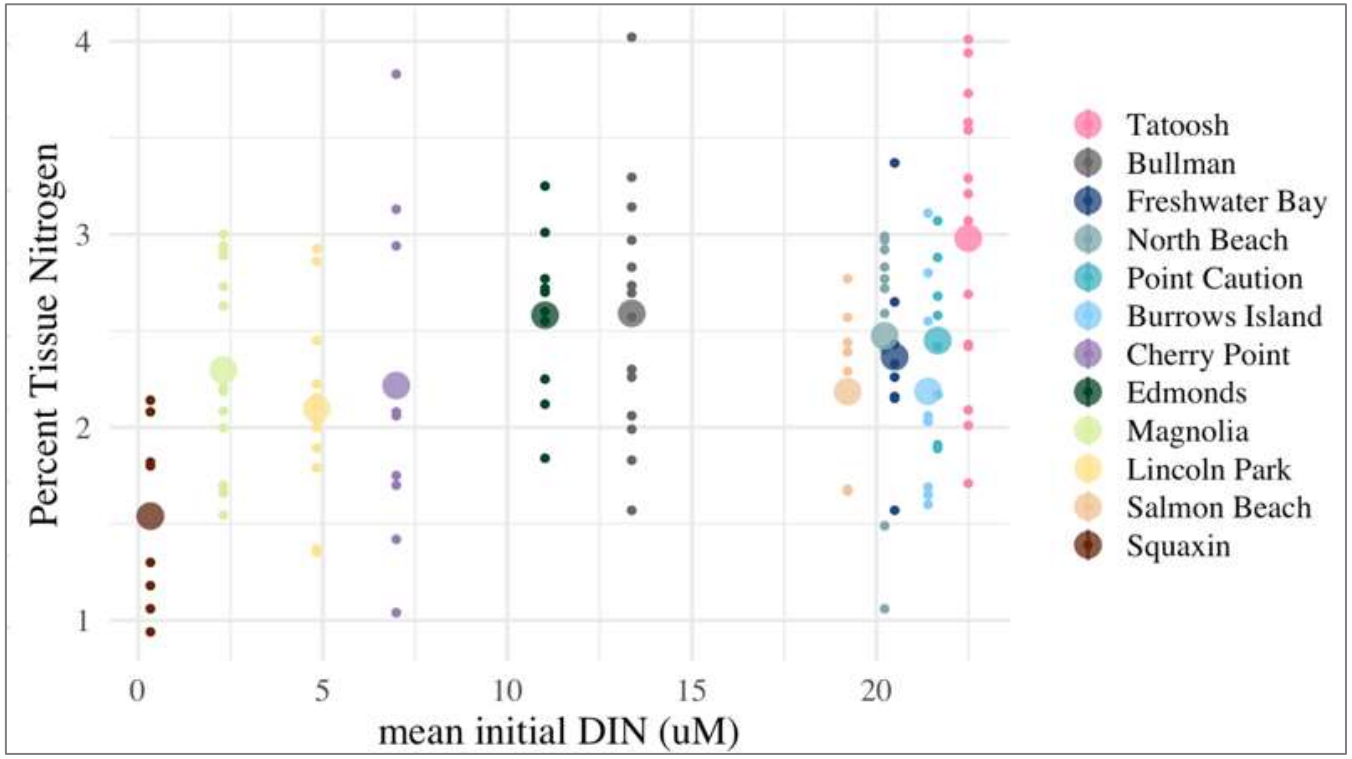


Bull kelp resilience and loss study

Results

- Nitrate concentration
  - Declining/Lost sites had lower summer nitrate concentrations
  - Kelp does persist at some low-nutrient sites
  - Tissue nitrogen is correlated with seawater nitrate concentration

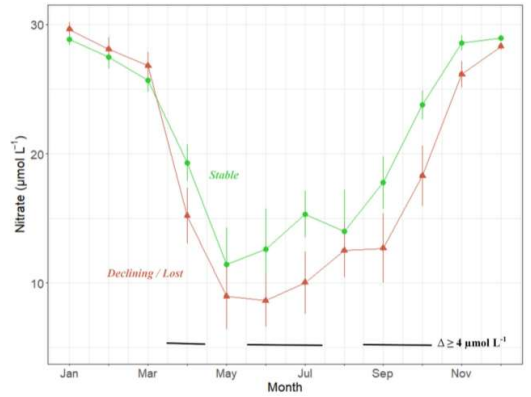


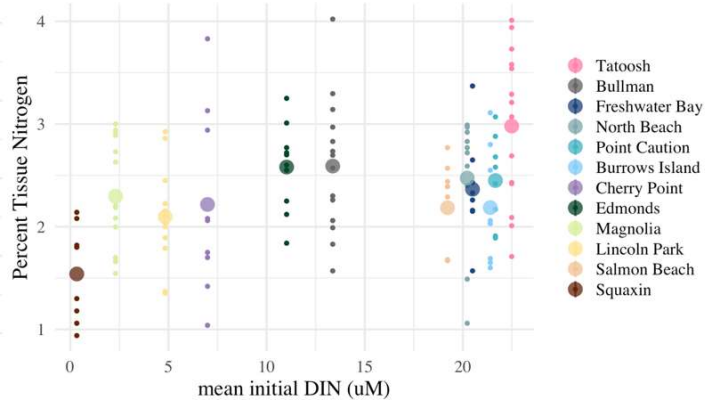


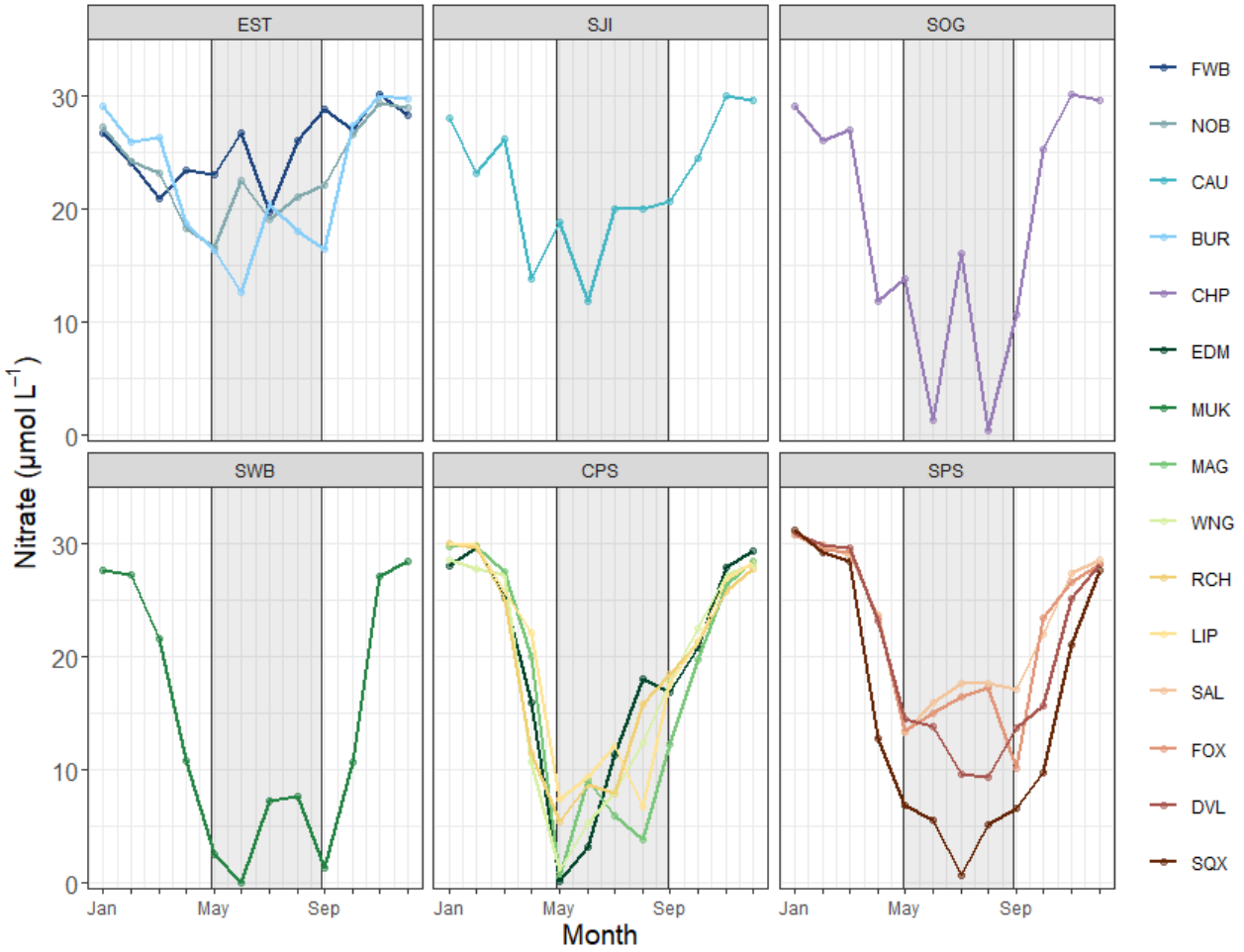
Bull kelp resilience and loss study

Results

- Nitrate concentration
  - Declining/Lost sites had lower summer nitrate concentrations
  - Kelp does persist at some low-nutrient sites
  - Tissue nitrogen is correlated with seawater nitrate concentration
  - Ongoing questions about temporal thresholds

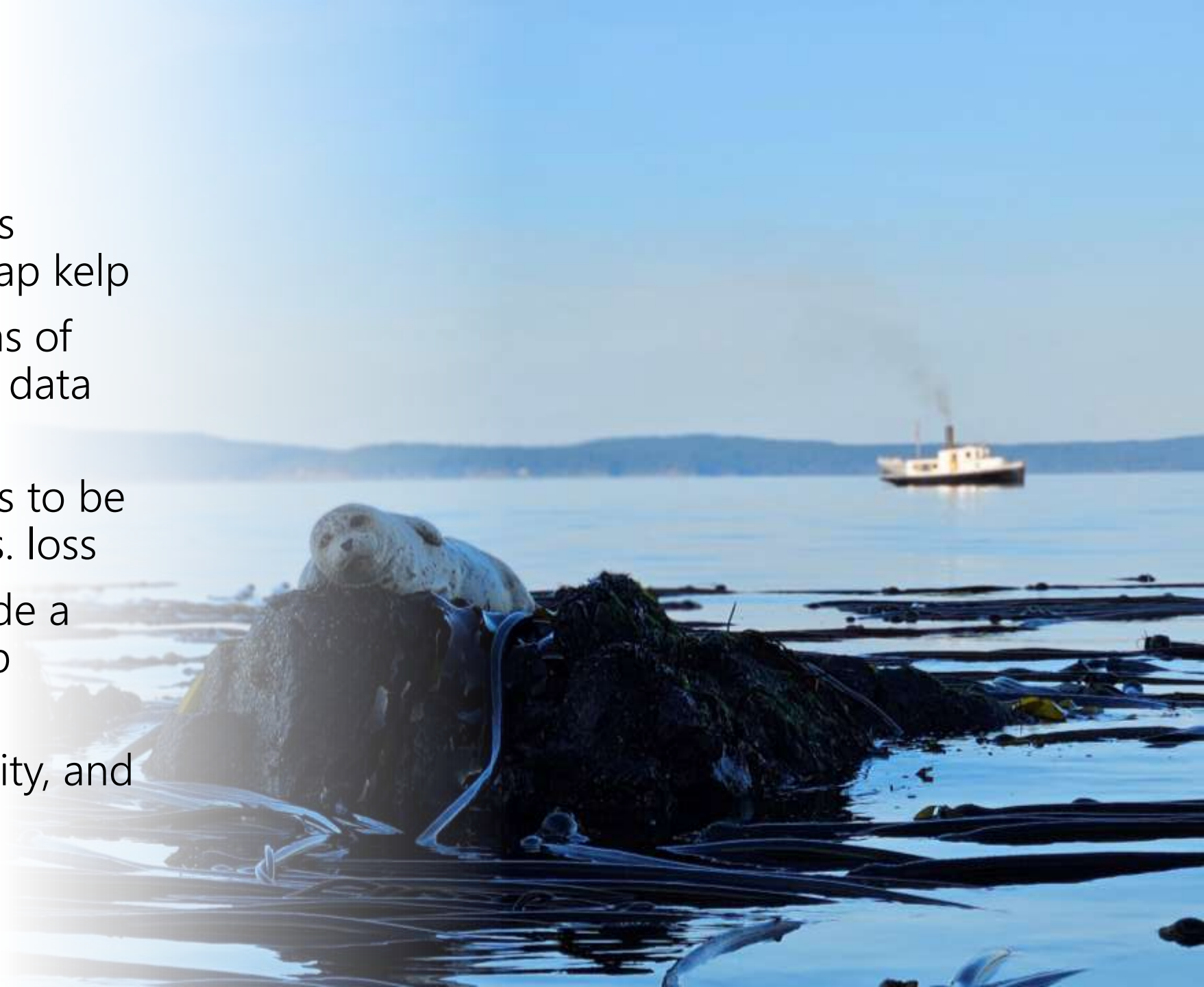






In summary…

- Multiple survey methods needed to accurately map kelp
- Indicator highlights areas of stability, loss, and major data gaps
- No single stressor seems to be driving kelp resilience vs. loss
- Local refugia may provide a reprieve for floating kelp
- Other factors: genetics, plasticity, spore availability, and other human impacts



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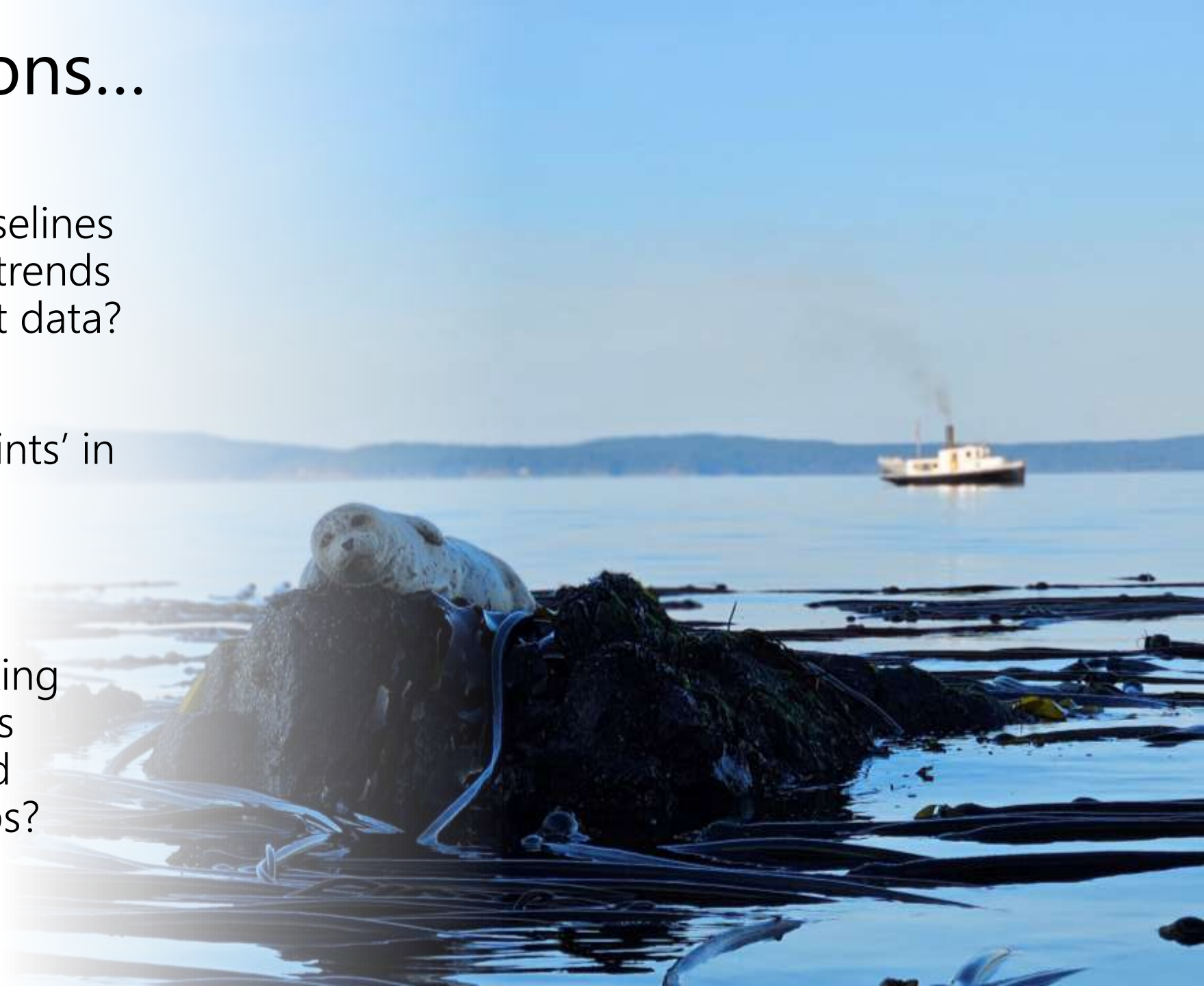
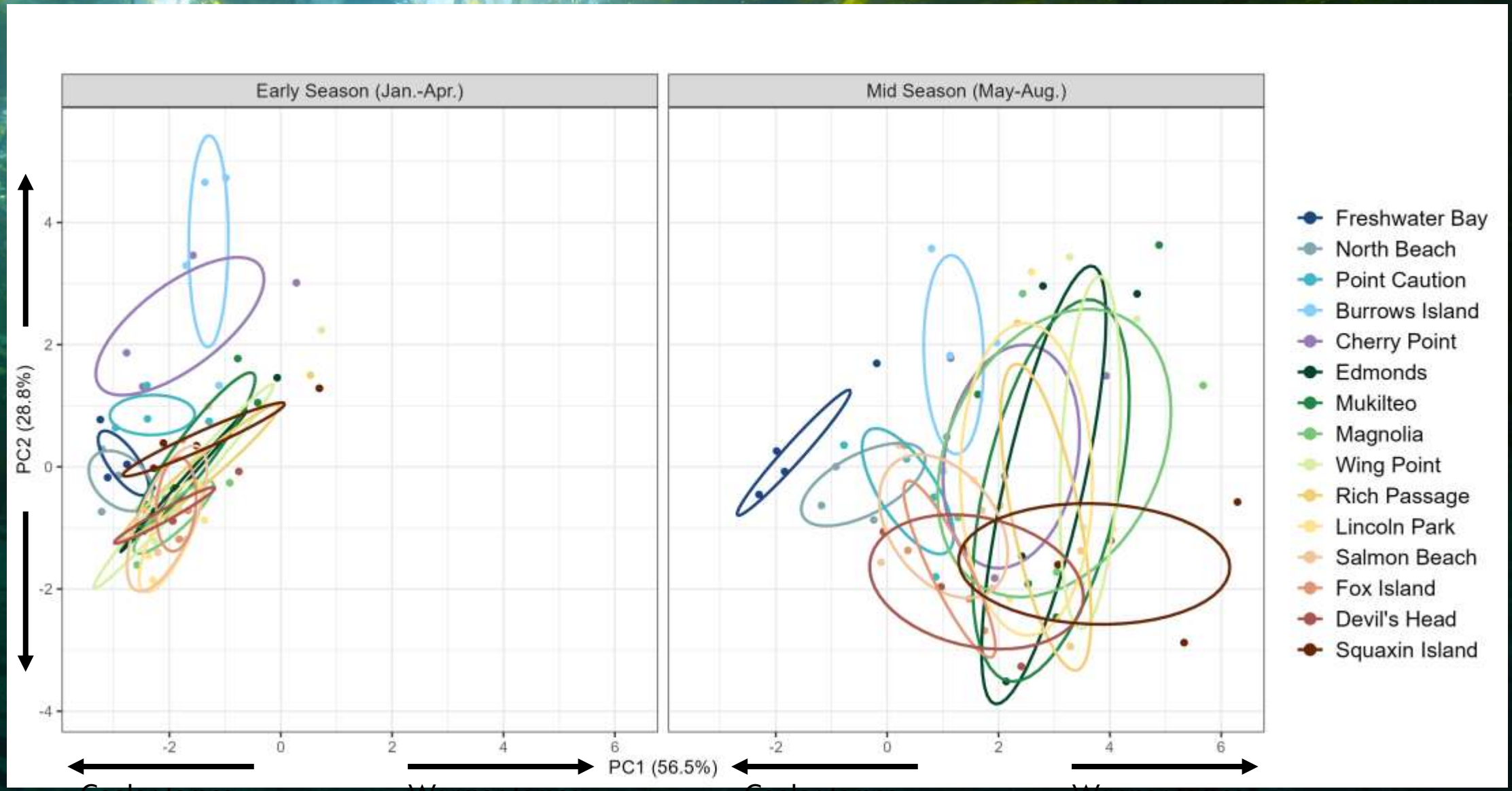
Next big questions…

- How can we develop baselines and quantify status and trends for areas with insufficient data?
- Where are the ‘pinch points’ in canopy kelp life cycle persistence?
- If there’s no single ‘smoking gun’ how can we address stressors and understand dynamics of canopy kelps?



Site environment: differences varied seasonally

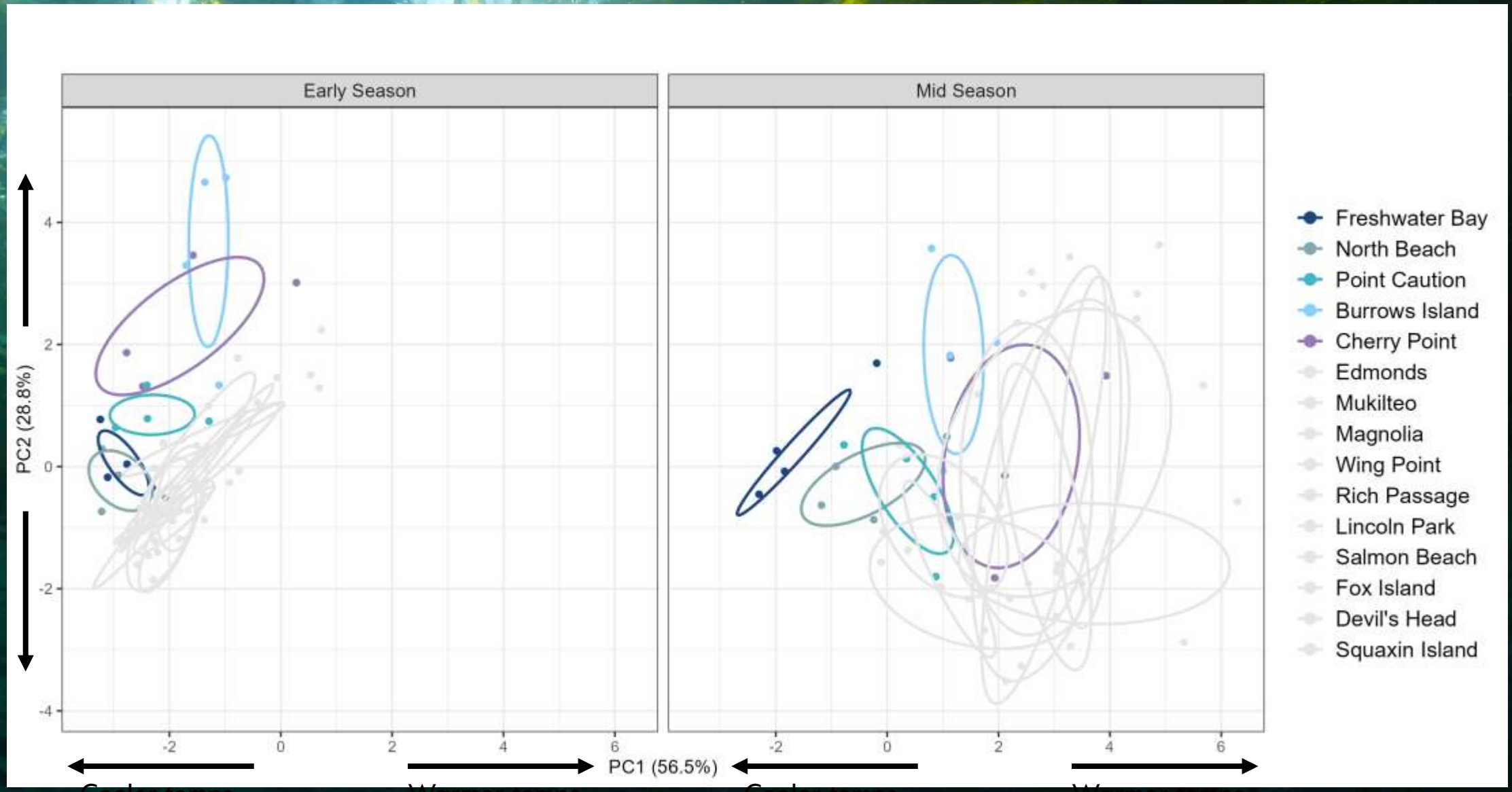


Sites closest to the ocean

Murkier waters

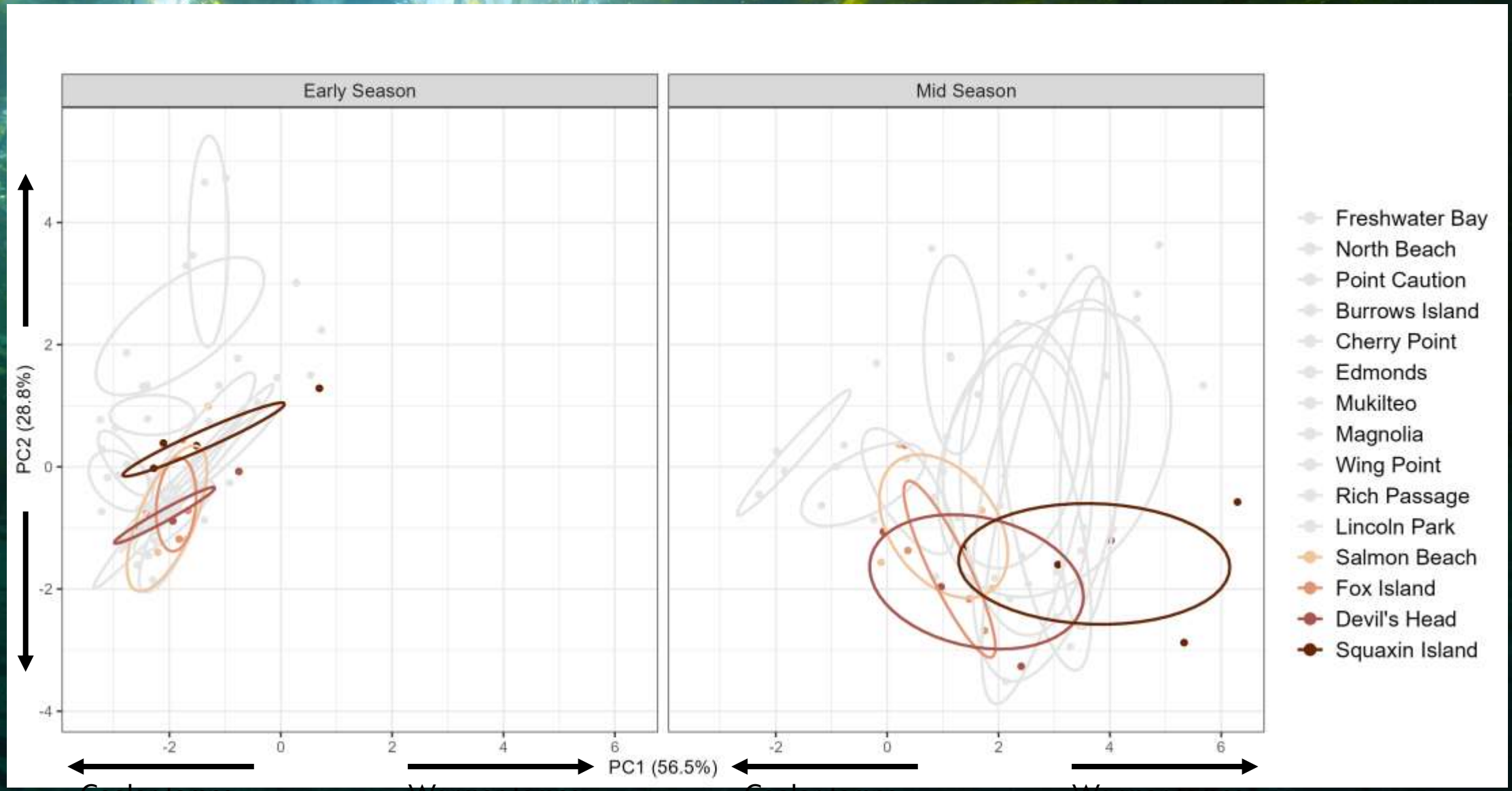
Water clarity

Clearer waters



Water temperature

Sites furthest from the ocean



Murkier waters

Water clarity

Clearer waters

Cooler temps

Warmer temps

Cooler temps

Warmer temps

Water temperature

Environmental data collection

Monthly water sampling (discrete):

- CTD casts
- Secchi depths
- Light attenuation
- TSS and POM
- Nutrients

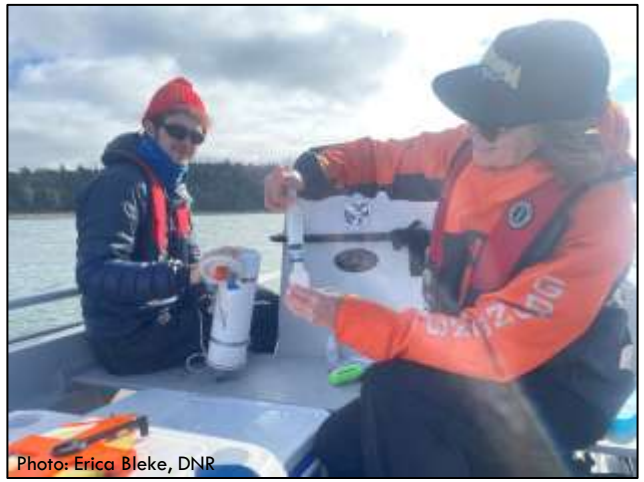


Photo: Erica Bleke, DNR


Photo: Erica Bleke, DNR


Photo: Erica Bleke, DNR

Benthic loggers (continuous):

- Temperature
- PAR (light)
- Depth (pressure)
- Conductivity (salinity)

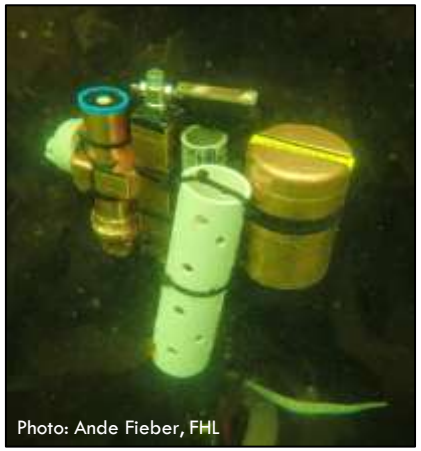
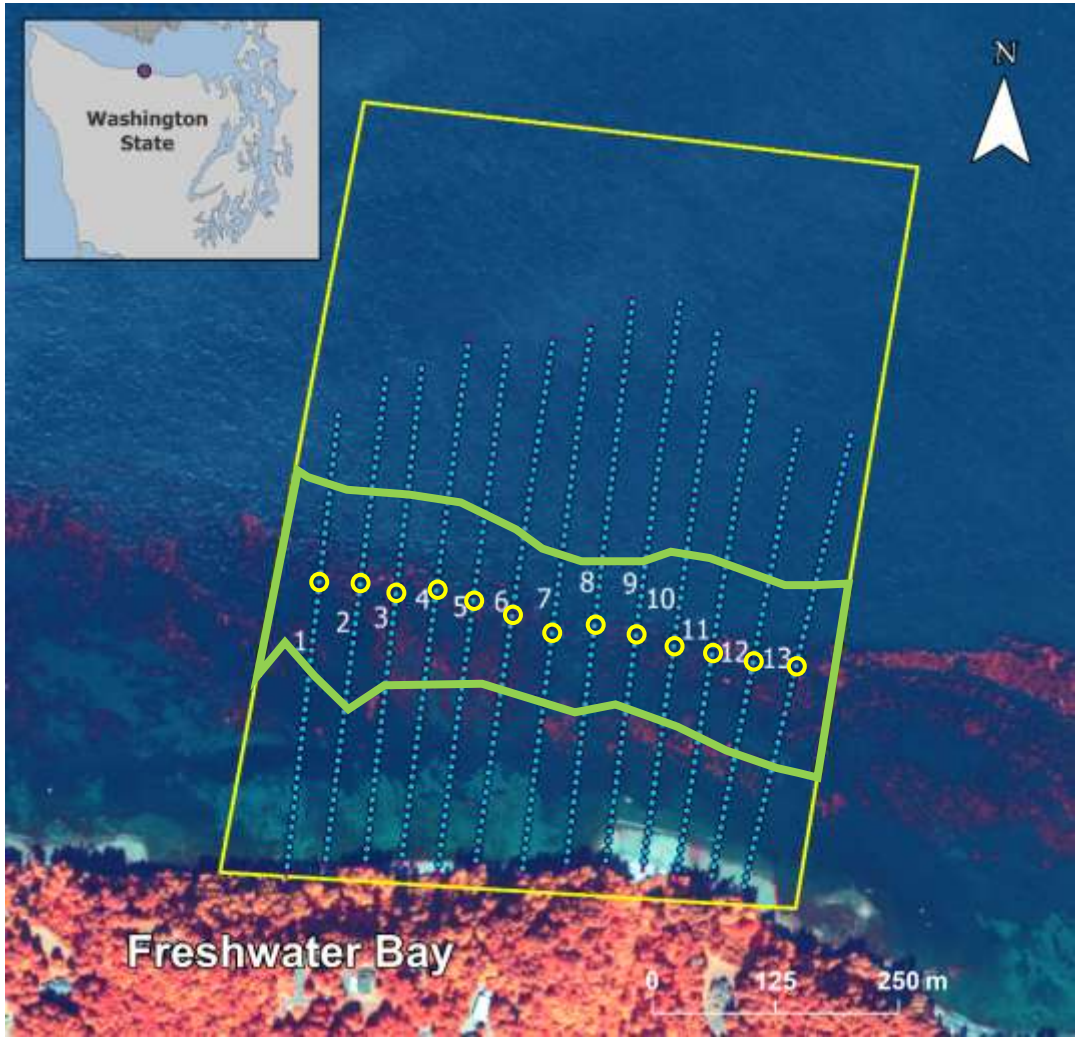
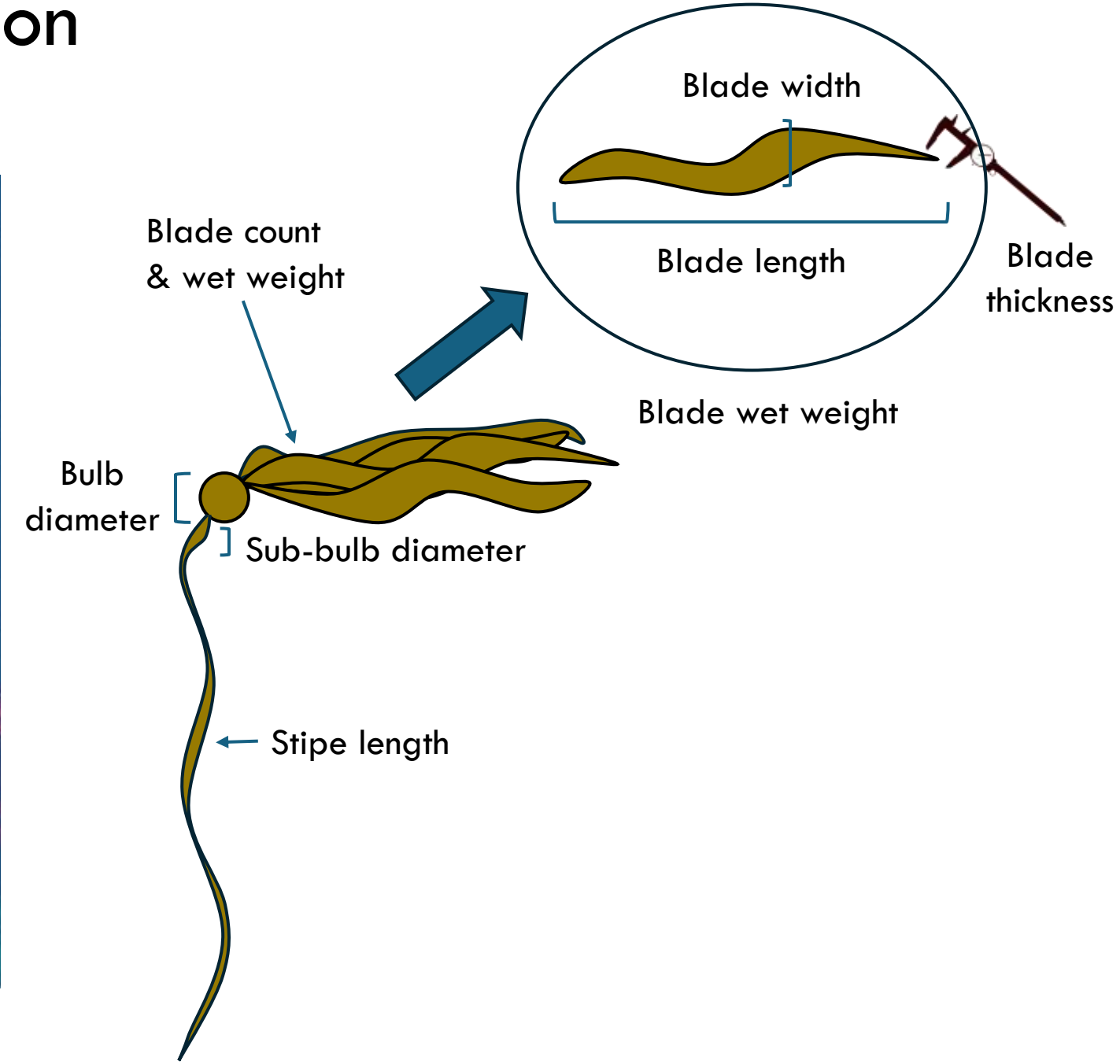


Photo: Ande Fieber, FHL

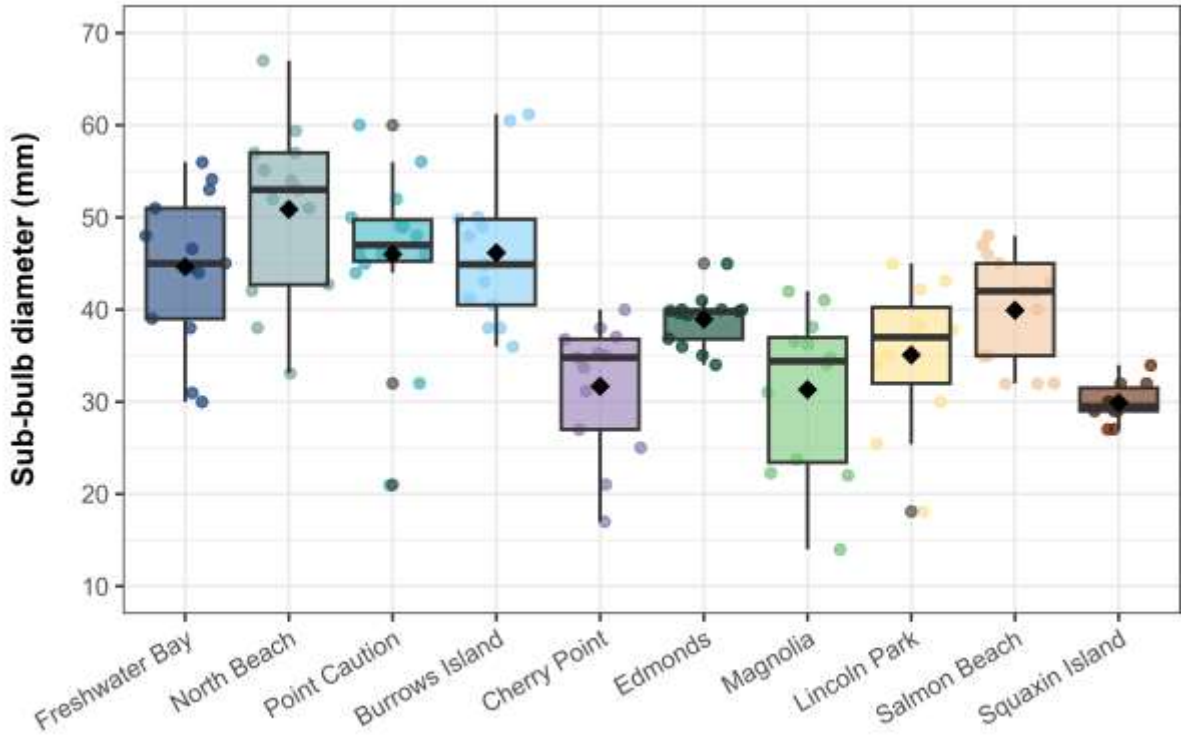
Sporophyte data collection

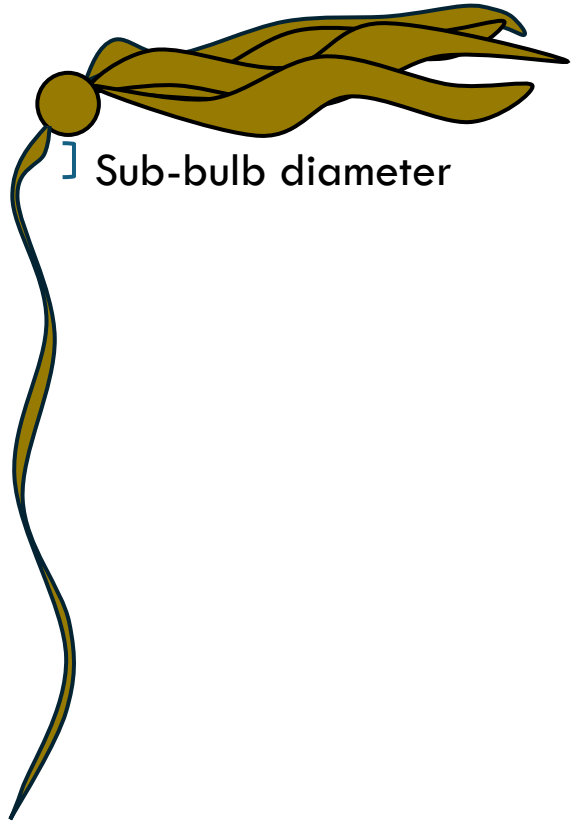


Map: Julia Ledbetter, DNR

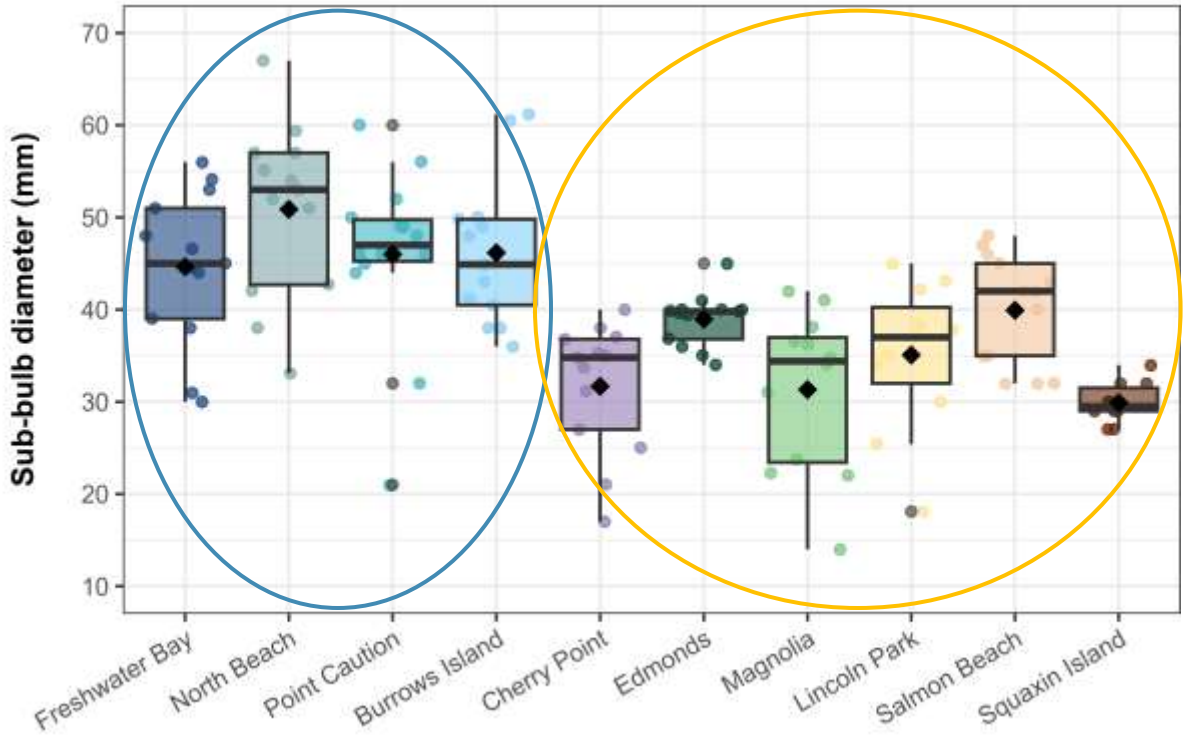


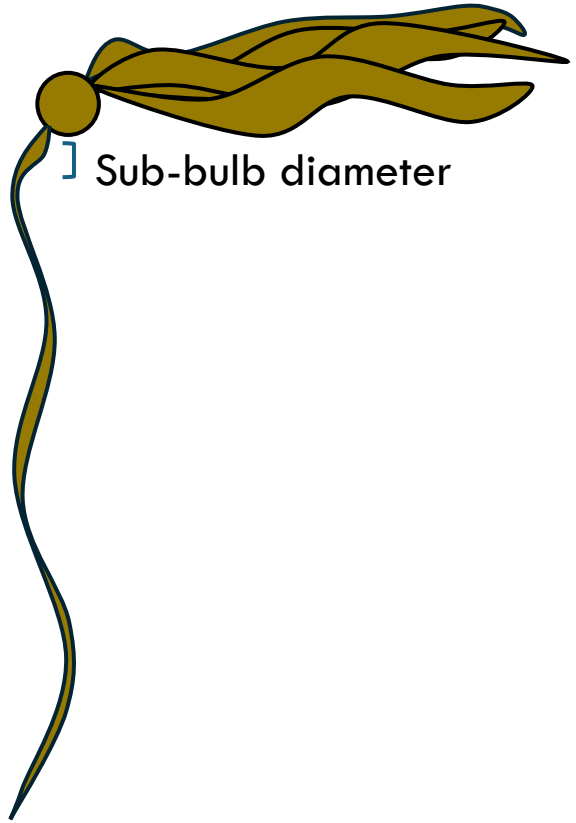
Nereocystis morphometrics: sub-bulb diameter



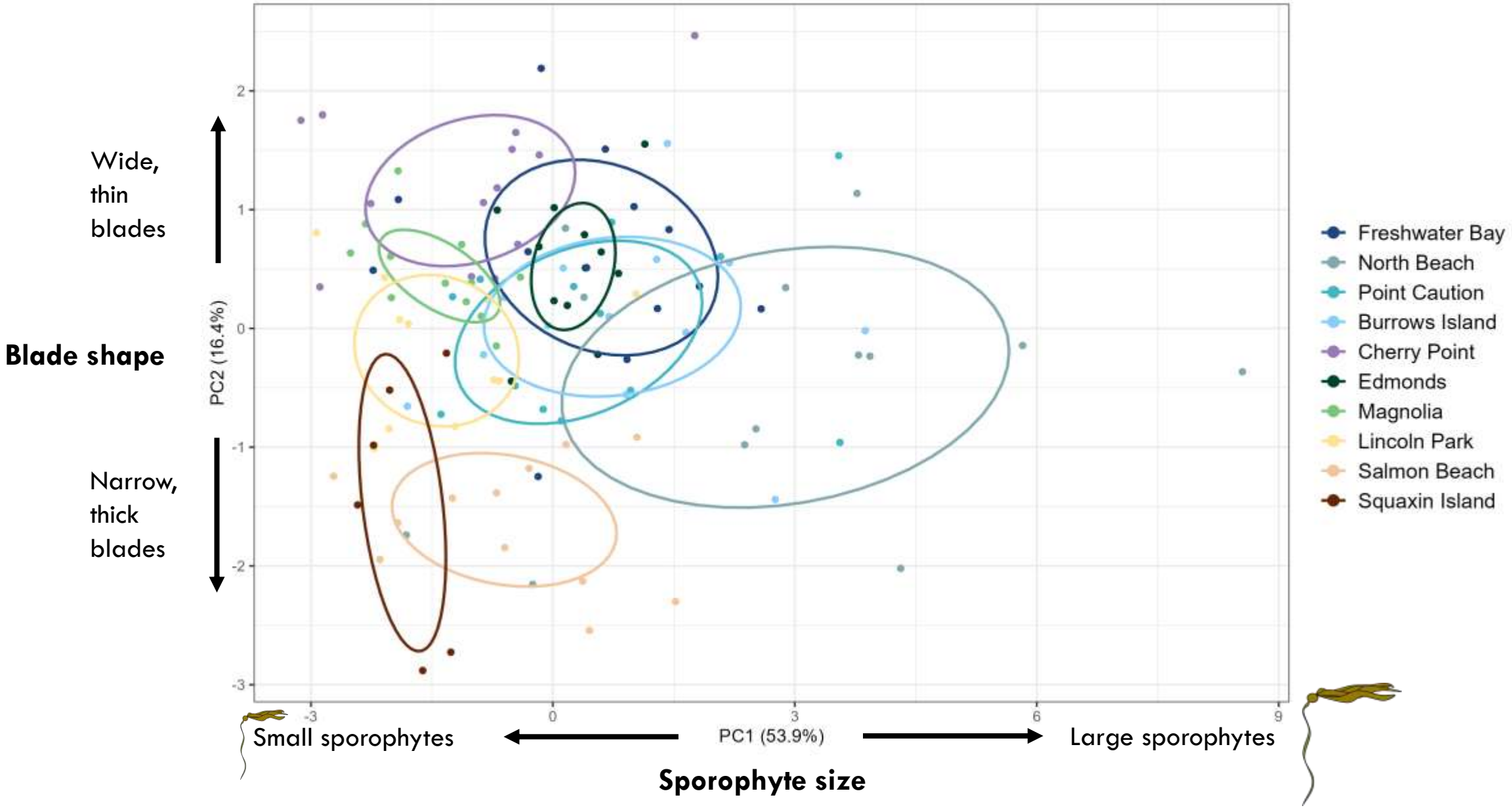


Nereocystis morphometrics: sub-bulb diameter

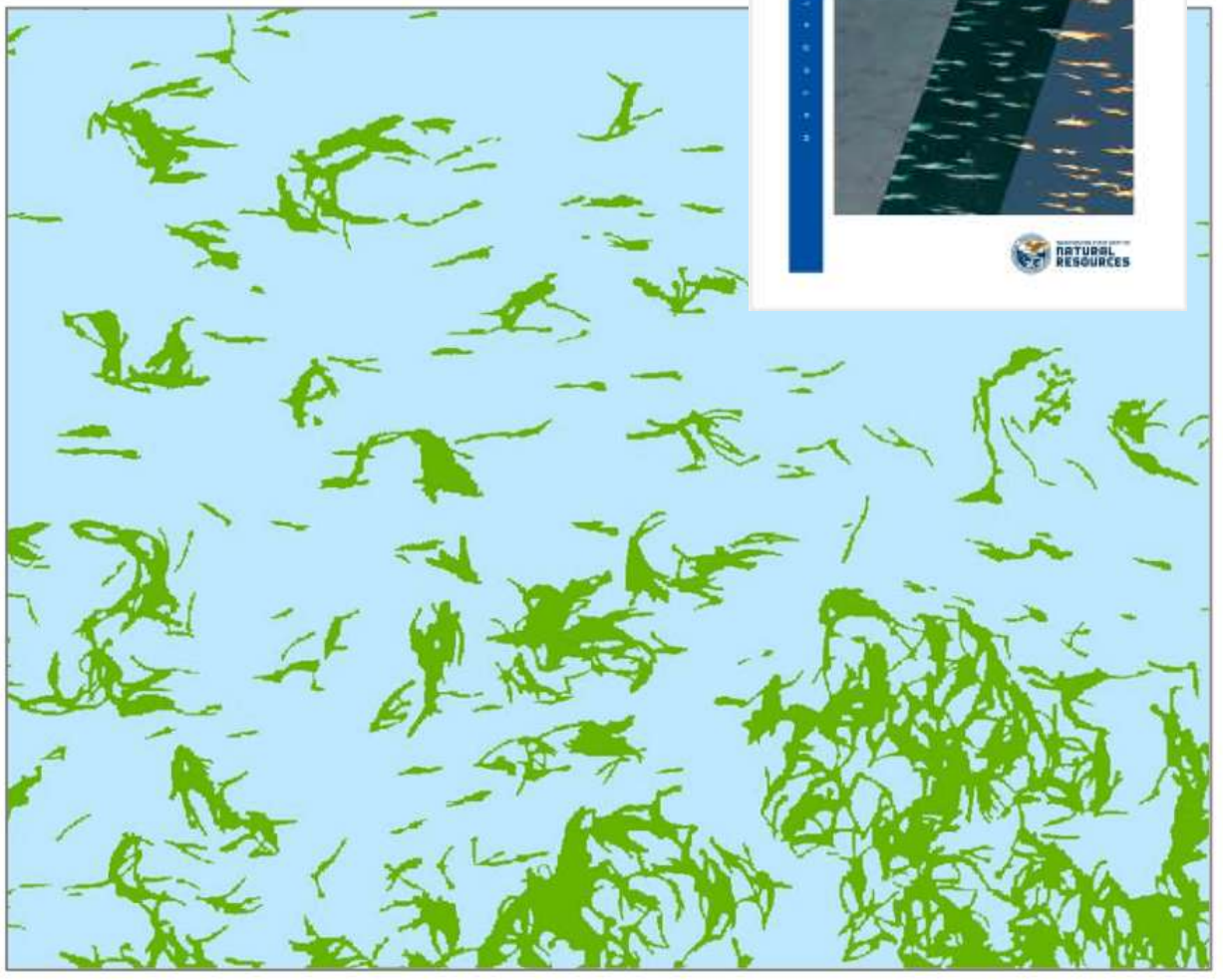




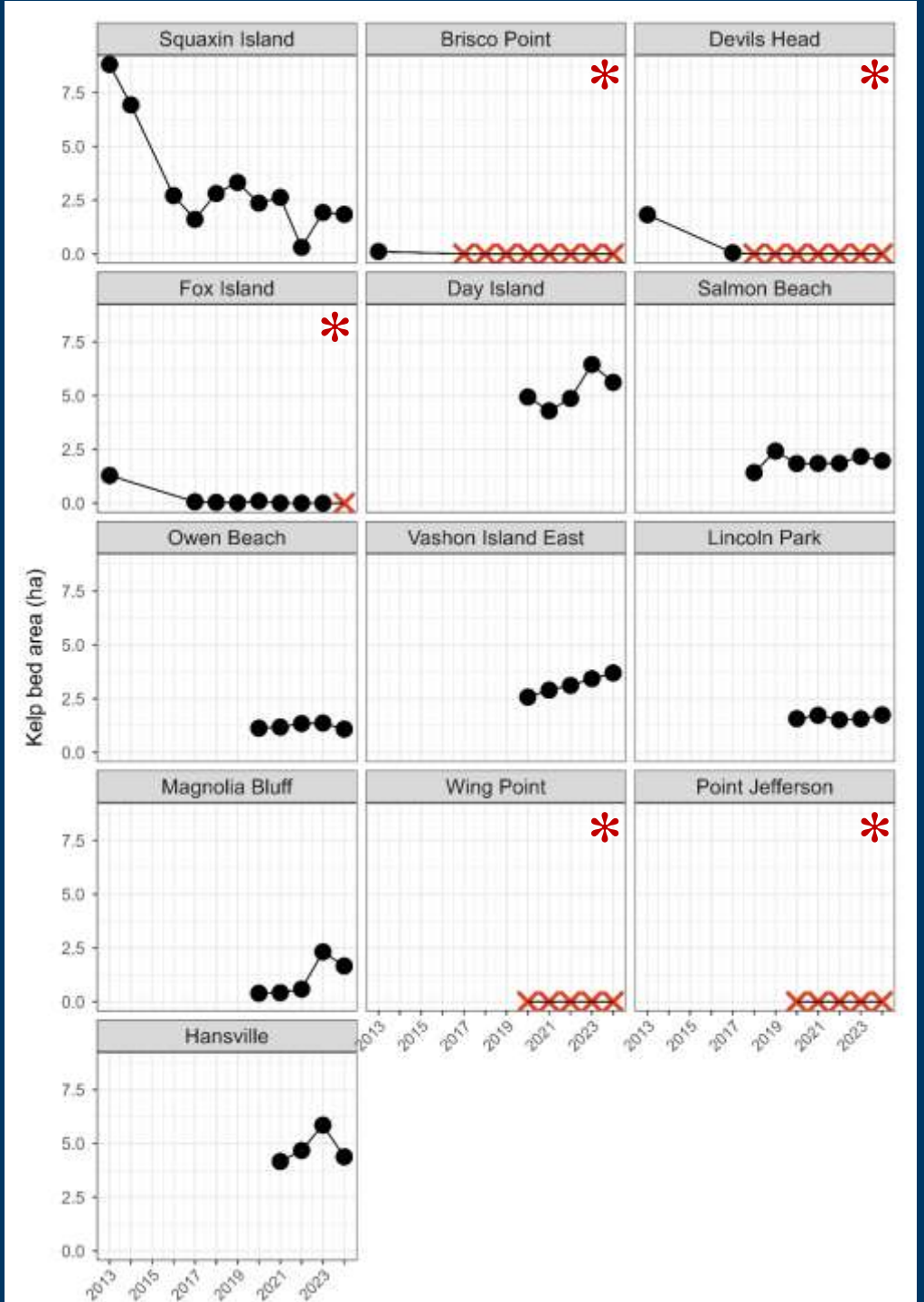
Nereocystis morphometrics: plant size and blade shape



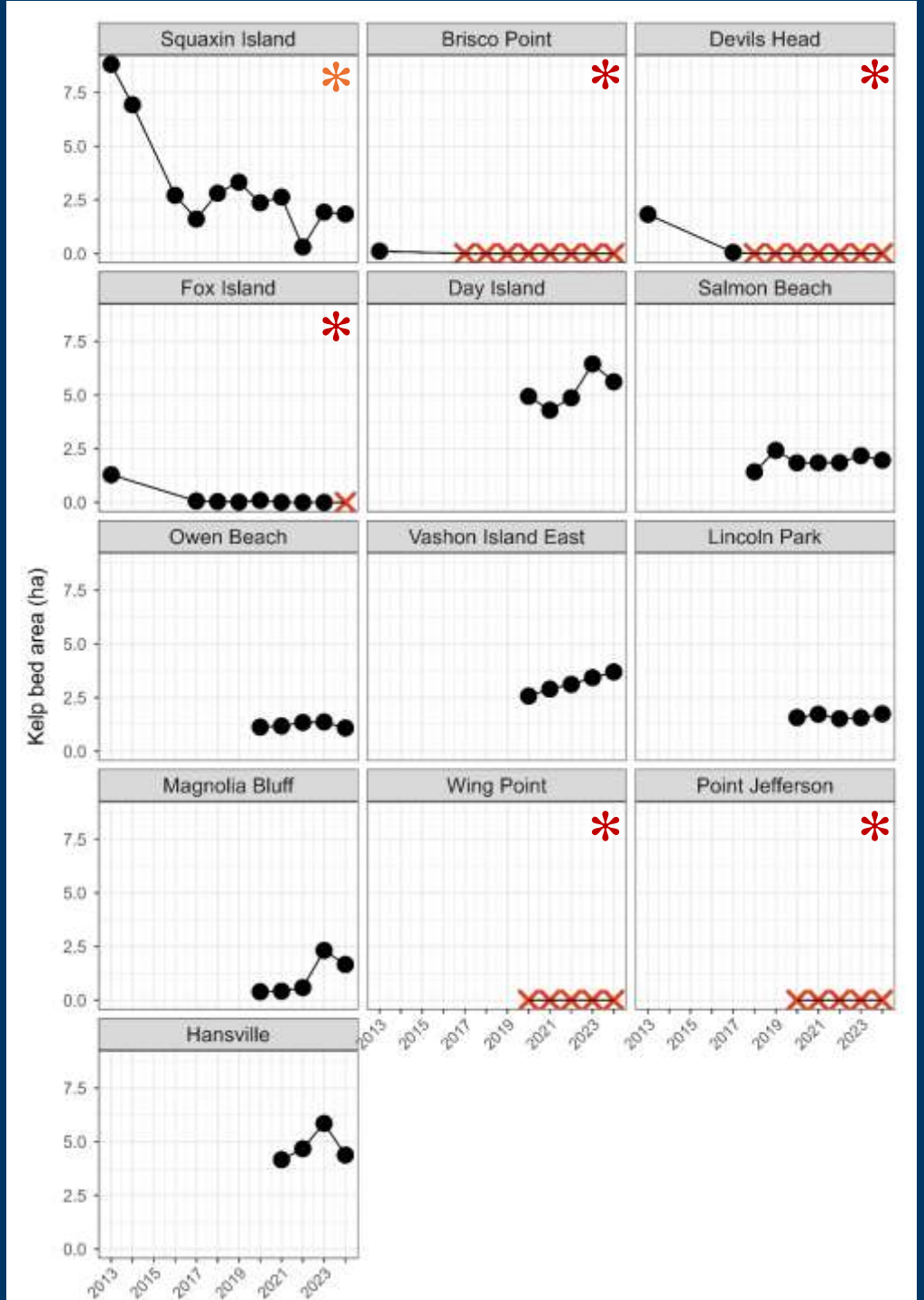
UAS imagery classification



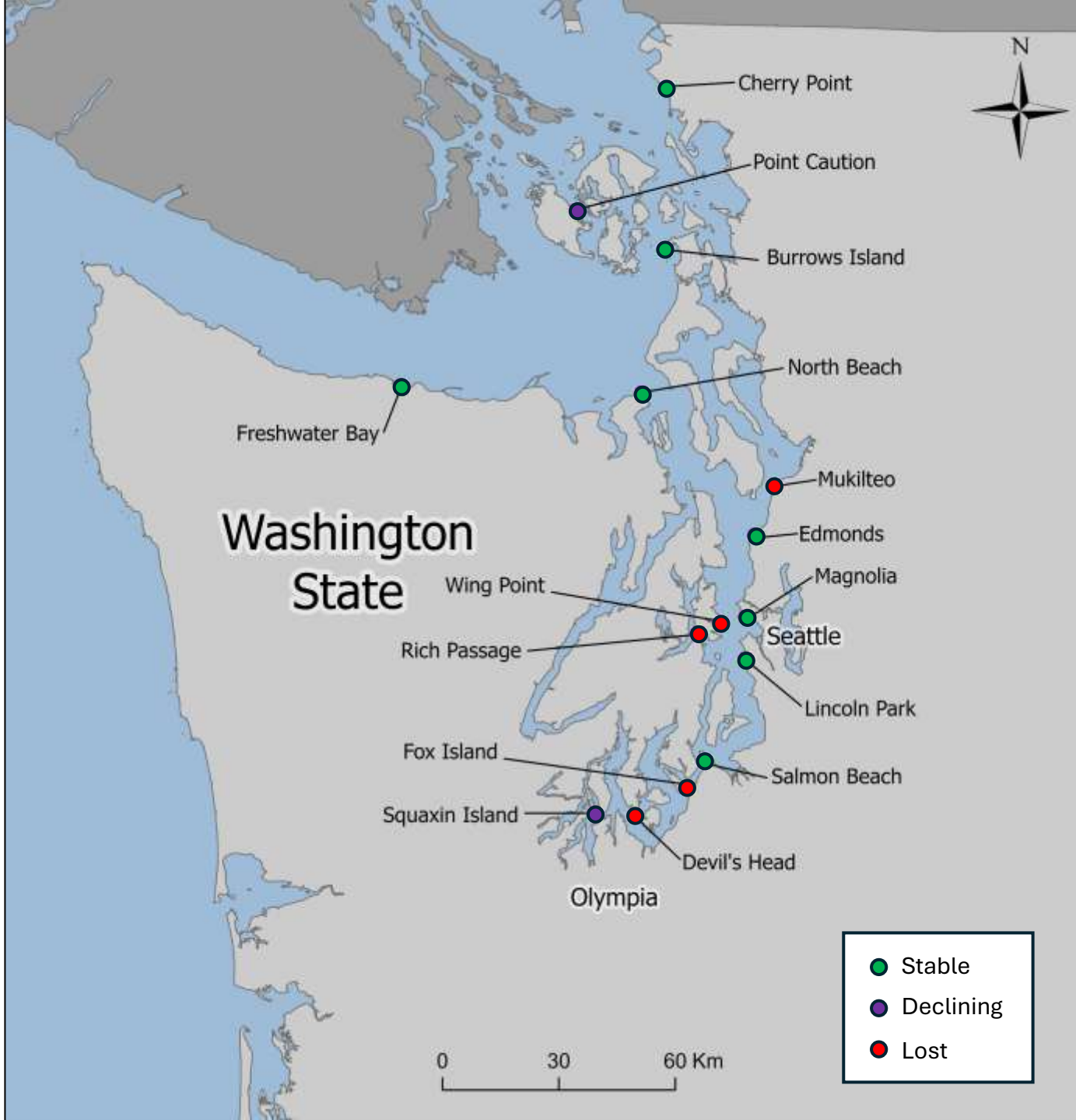
BNDVI threshold-based classification

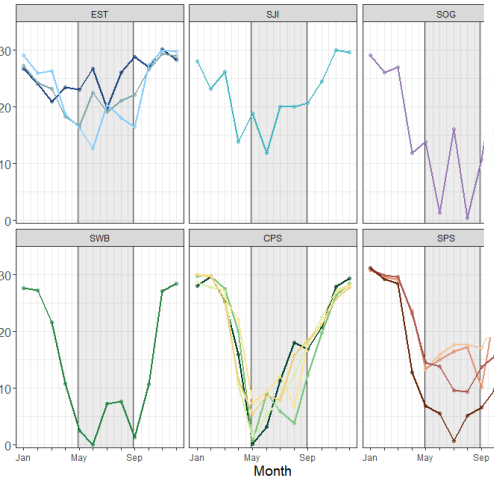


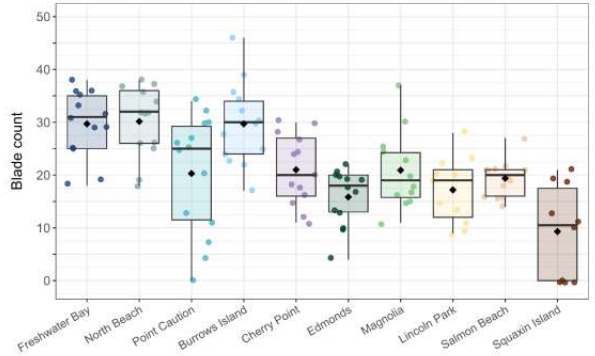
- 5 sites with total loss

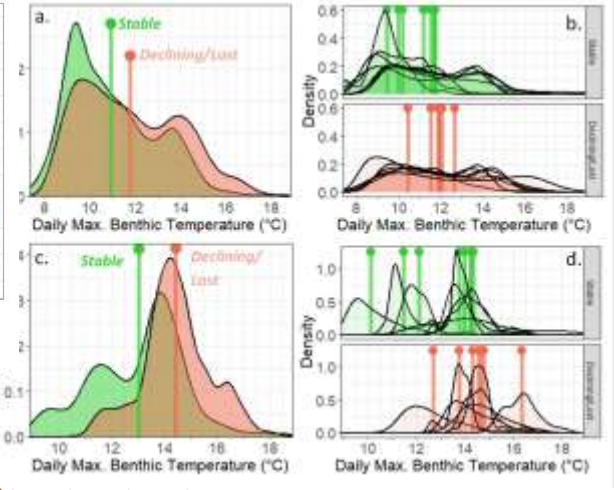


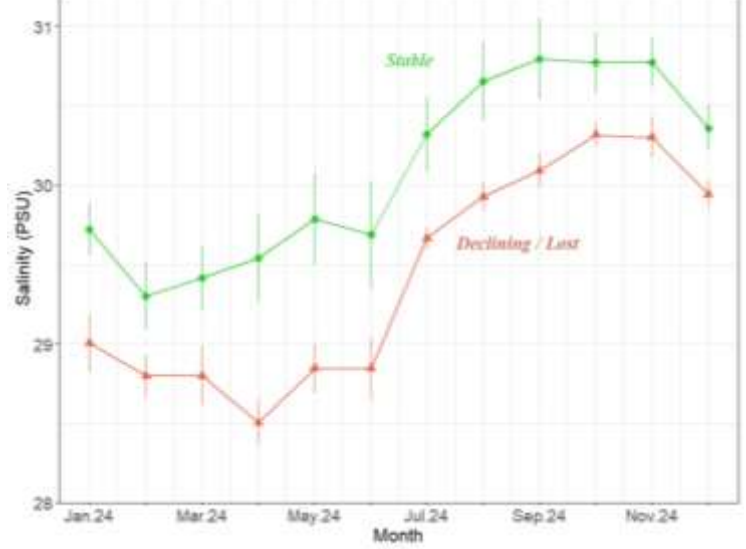
- 5 sites with total loss
- 1 site declining*

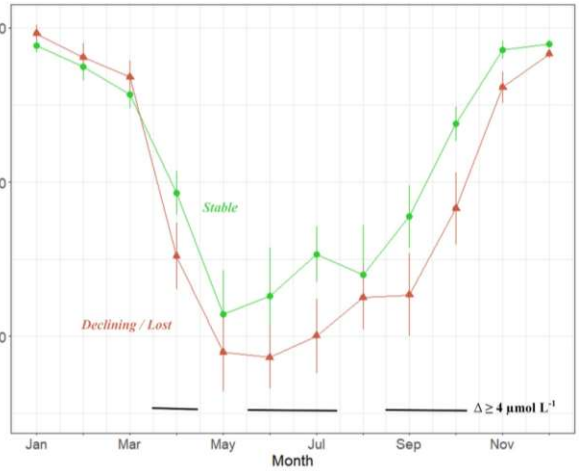

N
Cherry Point
Point Caution
Burrows Island
North Beach
Freshwater Bay
Mukilteo
Washington State
Edmonds
Magnolia
Wing Point
Seattle
Rich Passage
Lincoln Park
Fox Island
Salmon Beach
Squaxin Island
Devil's Head
Olympia
Stable
Declining
Lost
0
30
60 Km

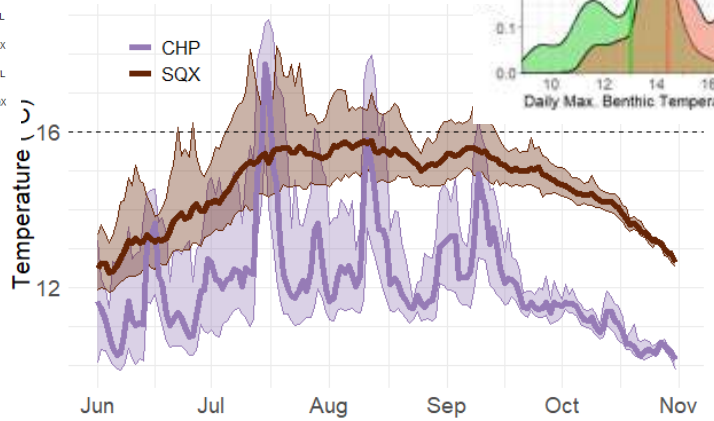

EST
SJI
SOG
SWB
CPS
SPS
Jan
May
Sep
Month

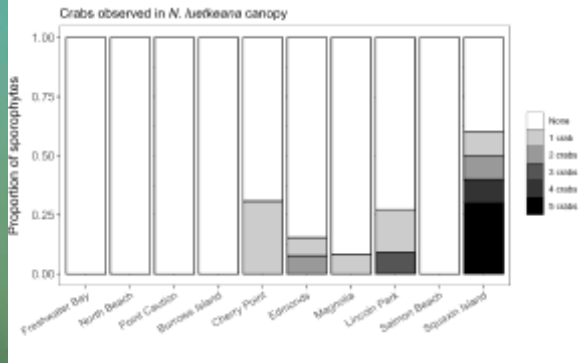

Blade count
Freshwater Bay
North Beach
Point Caution
Burrows Island
Cherry Point
Edmonds
Magnolia
Lincoln Park
Salmon Beach
Squaxin Island

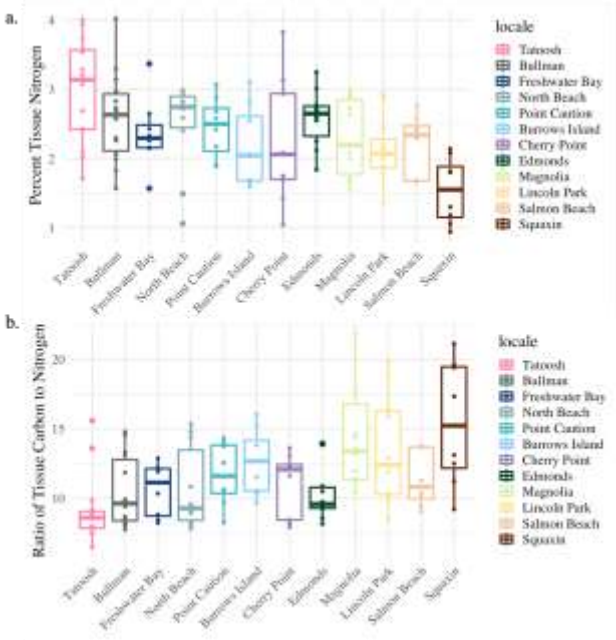

a.
Stable
Declining/Lost
b.
c.
d.
Density
Daily Max. Benthic Temperature (°C)

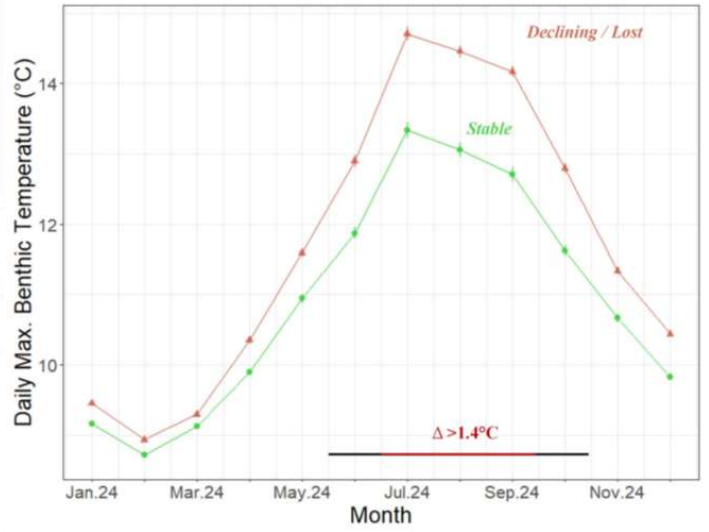

Stable
Declining / Lost
Salinity (PSU)
Jan.24
Mar.24
May.24
Jul.24
Sep.24
Nov.24
Month

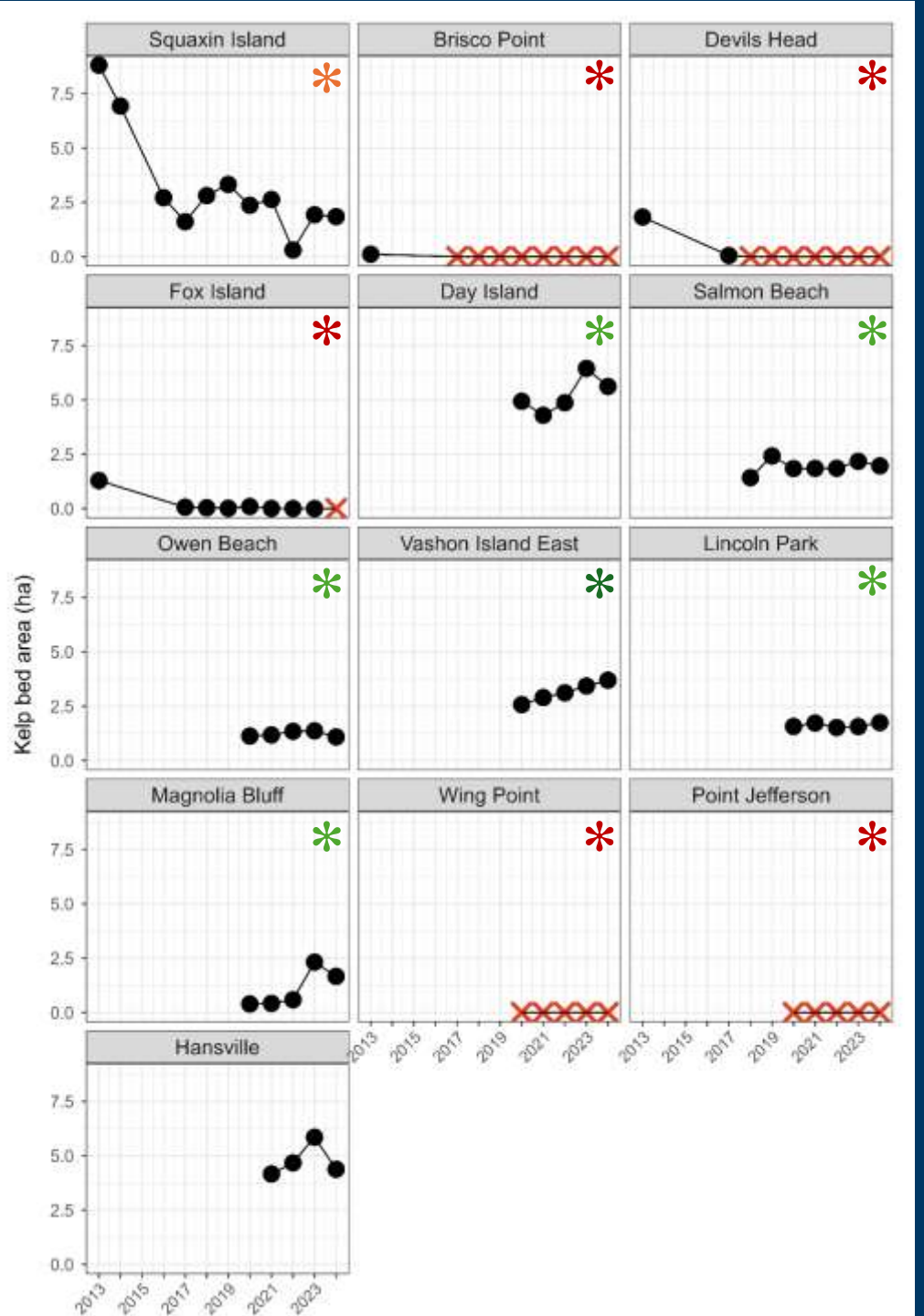

Stable
Declining / Lost
Δ ≥ 4 µmol L⁻¹
Jan
Mar
May
Jul
Sep
Nov
Month


CHP
SQX
Temperature (°C)
16
12
Jun
Jul
Aug
Sep
Oct
Nov


Crabs observed in N. luetkeana canopy
Proportion of sporophytes
Freshwater Bay
North Beach
Point Caution
Burrows Island
Cherry Point
Edmonds
Magnolia
Lincoln Park
Salmon Beach
Squaxin Island

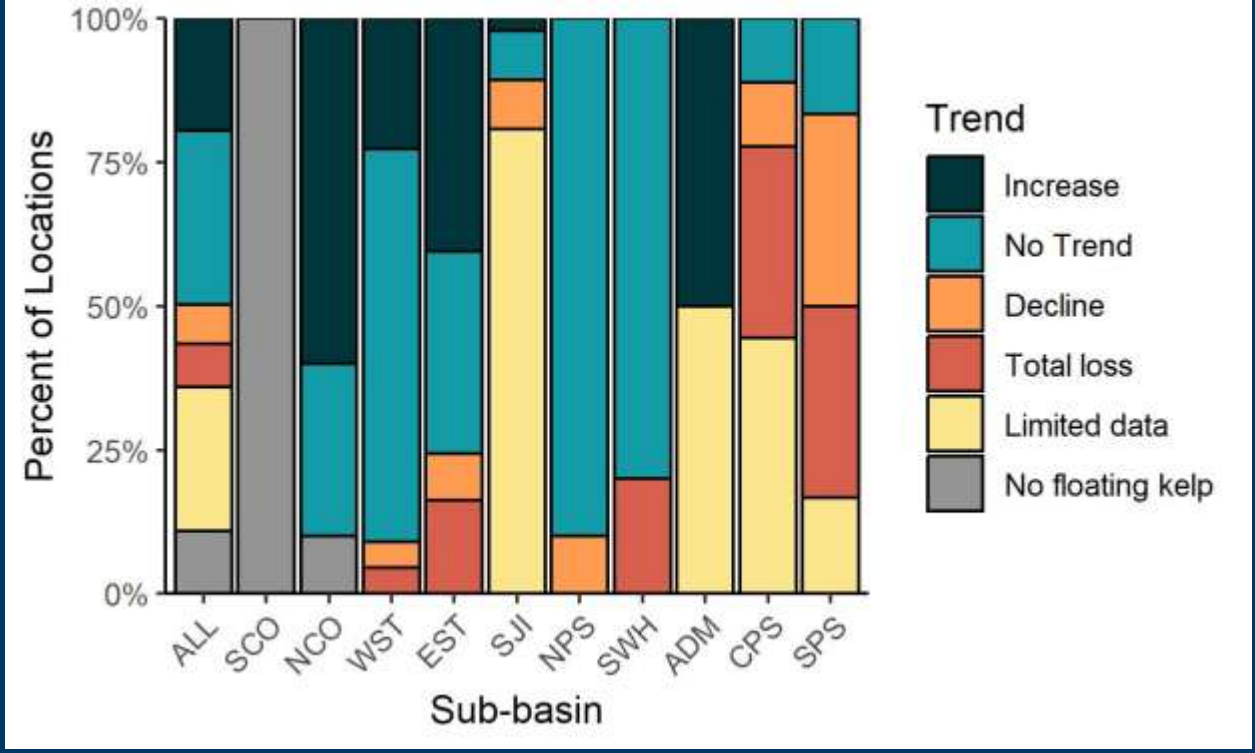

a.
Percent Tissue Nitrogen
b.
Ratio of Tissue Carbon to Nitrogen
locale
Tatoosh
Bullman
Freshwater Bay
North Beach
Point Caution
Burrows Island
Cherry Point
Edmonds
Magnolia
Lincoln Park
Salmon Beach
Squaxin


Declining / Lost
Stable
Δ >1.4°C
Daily Max. Benthic Temperature (°C)
Jan.24
Mar.24
May.24
Jul.24
Sep.24
Nov.24
Month

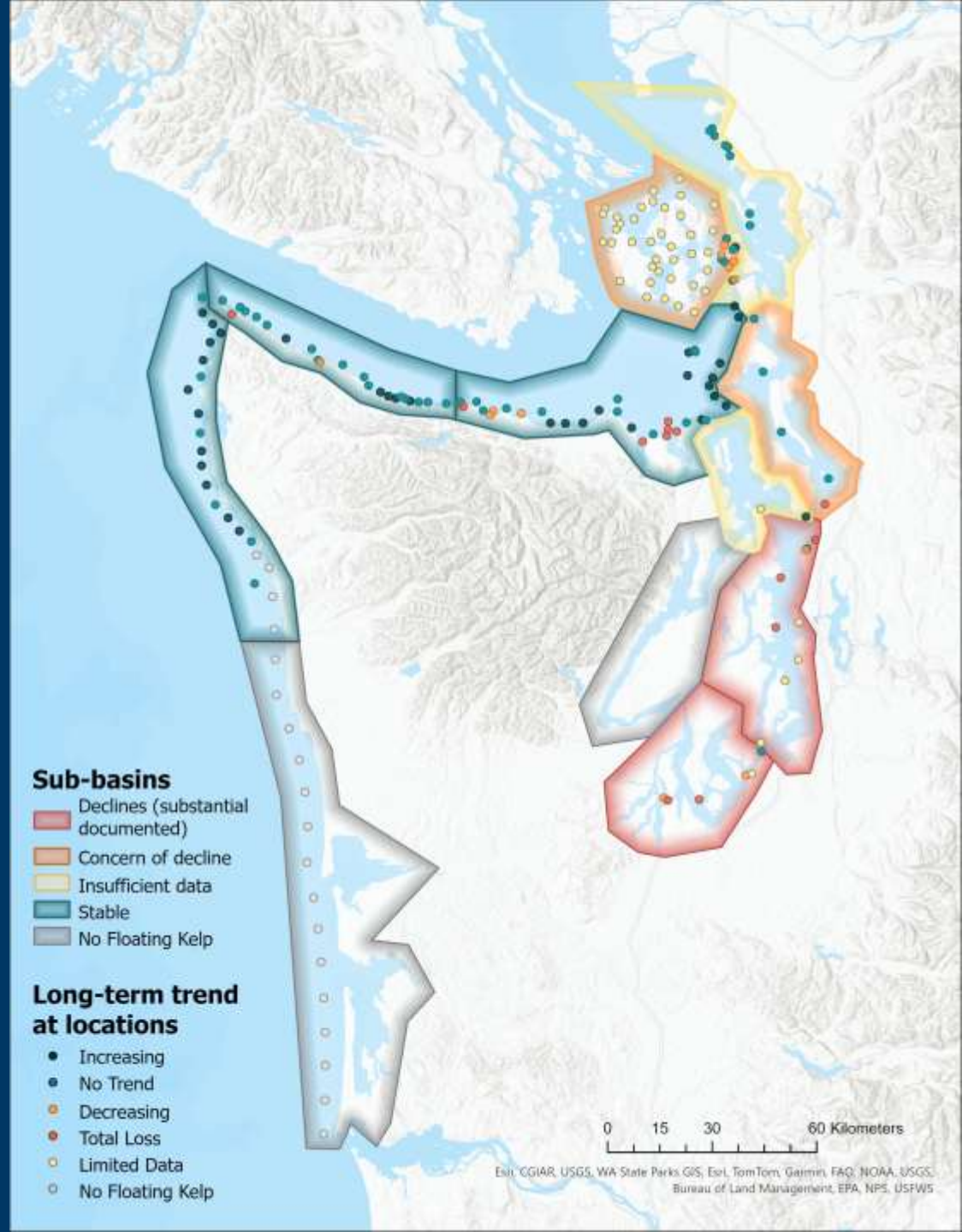


- Losses prevalent
- Local refugia

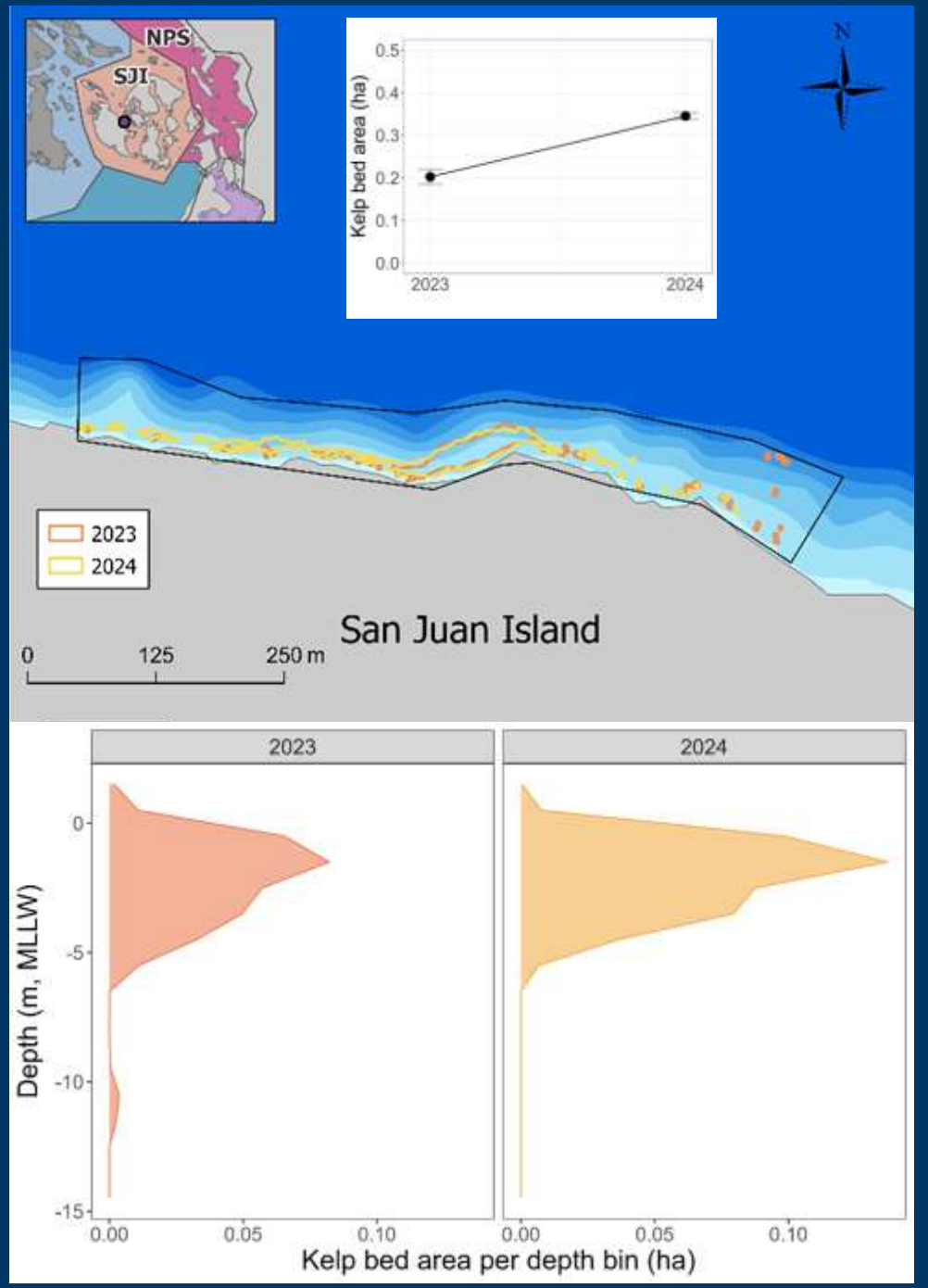
Indicator assesses long-term trends in bed area at 175 locations



The percent of locations with different trends provides insight into sub-basin status.



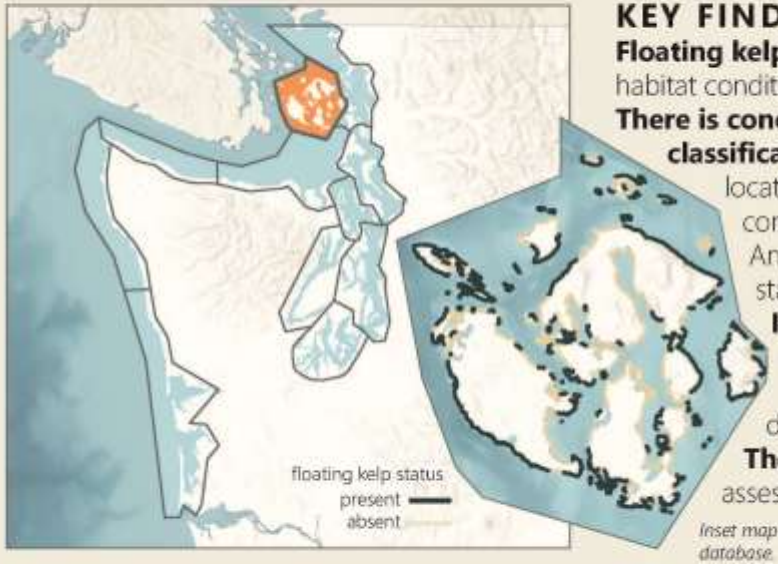
Point Caution



SUB-BASIN: SAN JUAN ISLANDS (SJI)

report | interactive map | website

SUBBASIN STATUS ASSESSMENT: CONCERN OF DECLINE



Inset map shows the distribution of floating kelp in this sub-basin according to the most recent surveys, based on the linear extent database.

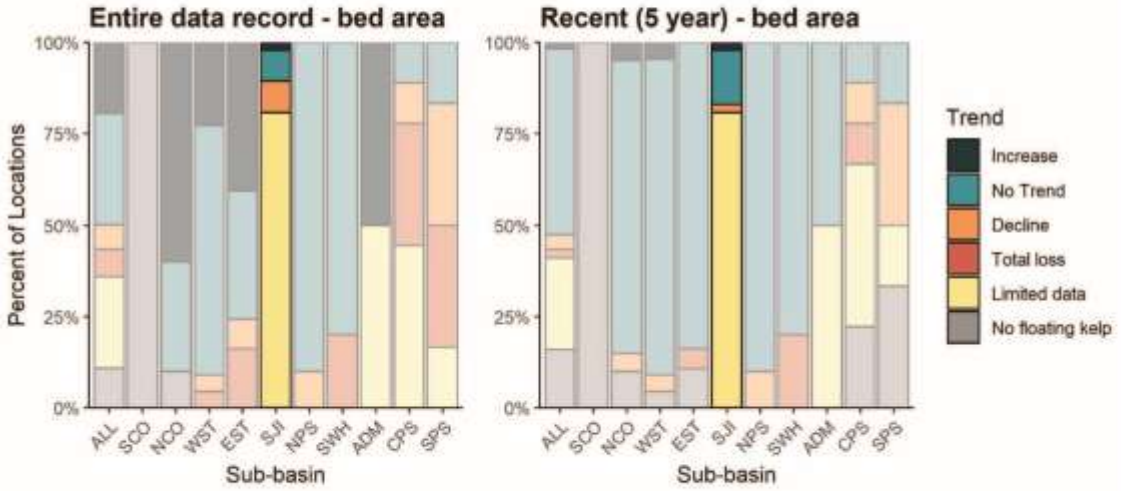
KEY FINDINGS:

Floating kelp is abundant along the shorelines of the San Juan Islands where appropriate habitat conditions exist. One species occurs here, bull kelp (*Nereocystis luetkeana*).

There is concern of declines in the sub-basin, yet data limitations preclude definitive classification. Virtually all nearshore areas have been surveyed more thavn once, but most locations have data limitations that don't allow for trends assessment (the imagery wasn't controlled for tides or currents, which are known to impact the amount of visible canopy). Annual surveys from 2011-2022 around Cypress Island (4.5% of the resource) indicate stability in total abundance, as well as within most locations.

Indigenous Scientific Knowledge (ISK) gathered by the Samish Indian Nation suggests multiple areas of decline in floating kelp canopies over decades. Other studies conducted at smaller spatial scales within the sub-basin suggest kelp area decline. One area of concern is San Juan Channel, on eastern San Juan Island.

The priority is to collect sufficient survey information to support a robust assessment.

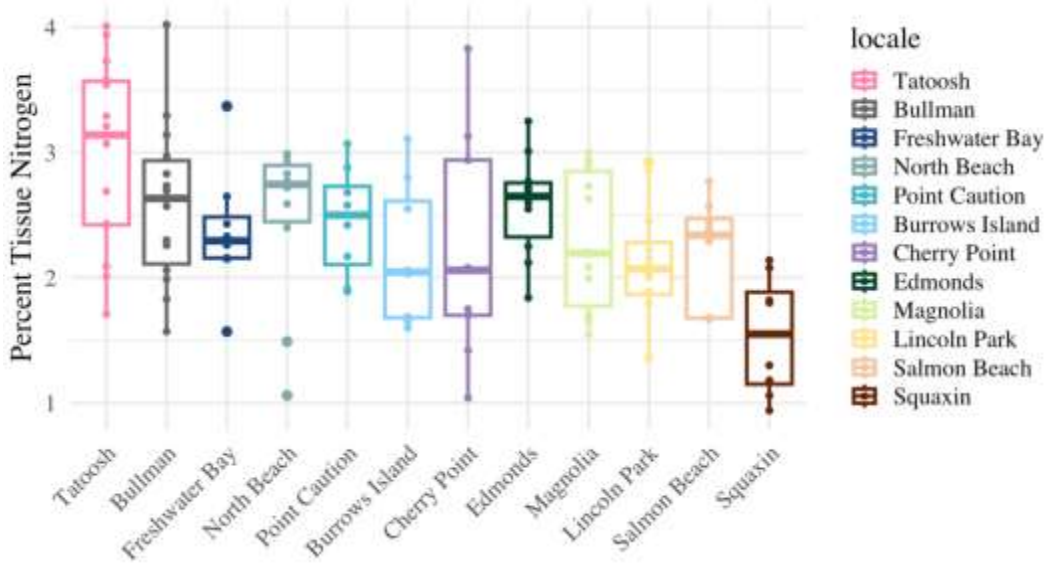


The bar charts show the count of locations by trend category for two time periods (lVong-term on left, recent on right). Within each chart, the left-most bar includes all locations in WA state (all). Subsequent bars correspond to individual sub-basins, sorted spatially from coast (left) to innermost basin (right). The colors for this sub-basin are vibrant (others are muted).

SUB-BASIN DETAILS

number of locations monitored in indicator		47
count of entire data record trends at locations	increasing	1
	no trend	4
	decreasing	4
	total loss	0
	limited data	38
	no floating kelp	0
% of shoreline monitored in indicator		99.5 %
% of shoreline units with floating kelp present		51.7 %

Percent shoreline reported on and percent floating kelp presence values are derived from the floating kelp linear extent database. This assessment includes updates through 2023.



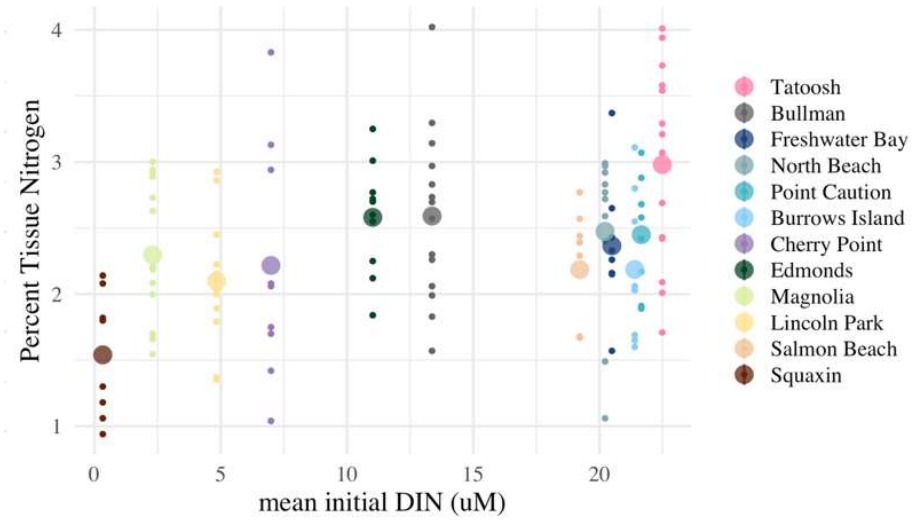
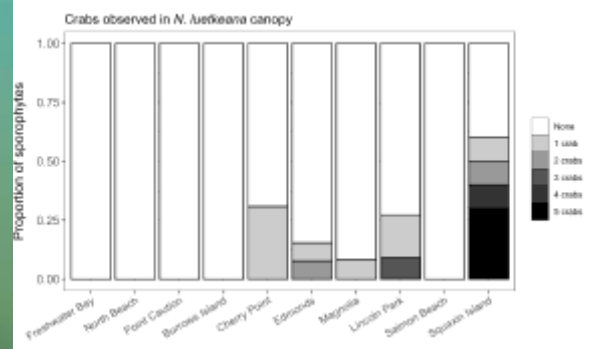


Figure 5-10. The rate of carbon fixation as a function of the uptake of nitrate by bull kelp blades throughout the incubation (coefficient = 0.146, p = 0.013), and b. the relationship between percent tissue nitrogen and mean DIN concentration in μM at the beginning of the incubation (coefficient, 0.025, p = 0.040, n = 7-14) The large circle represents the mean value at each site; small circles are individual kelp measurements. Colors follow Figure 5-1. Both analyses are linear mixed effects models with site as a random effect.


Crabs observed in N. luetkeana canopy
Proportion of sporophytes
1.00
0.75
0.50
0.25
0.00
Freshwater Bay
North Beach
Point Gardiner
Burrows Island
Cherry Point
Edmonds
Magnolia
Lincoln Park
Salmon Beach
Squaxin Island
None
1 crab
2 crabs
3 crabs
4 crabs
5 crabs