PUGET SOUND KELP CONSERVATION & RECOVERY PLAN

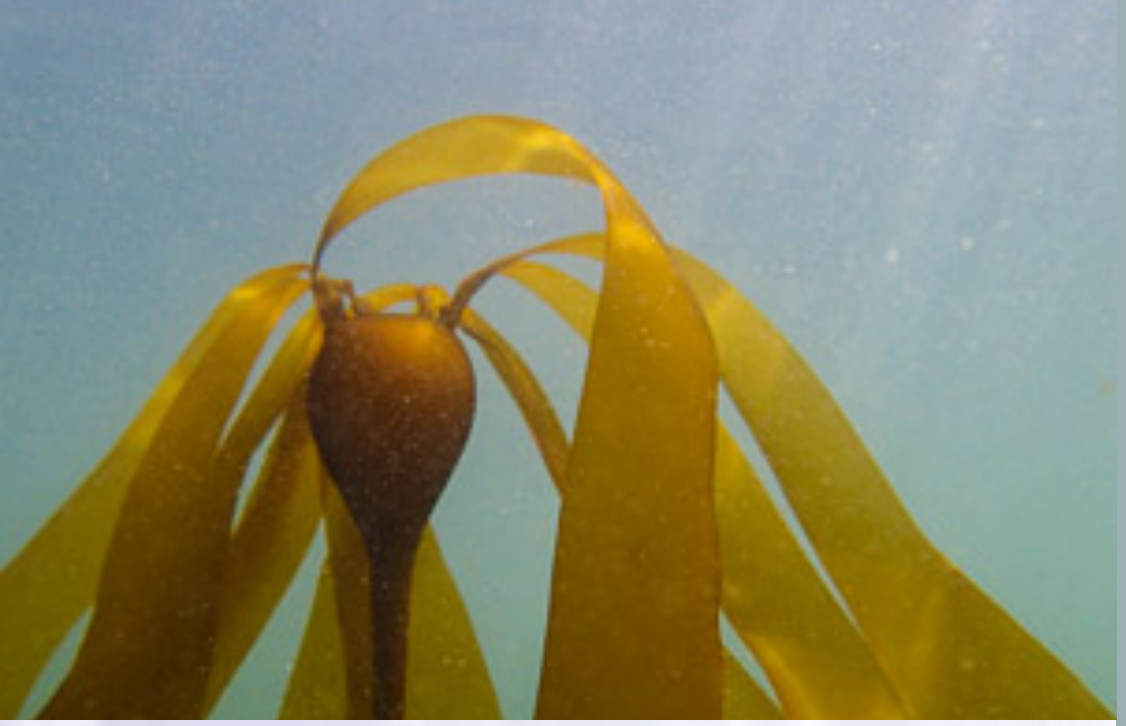
Knowledge Review

Max Calloway

Year 2, Workshop 1

2/28/19

Photo courtesy: NOAA Archives



WHAT IS KELP?

"Brown" seaweed

Order: Laminariales

Photo Courtesy: M. Calloway, PSRF, Fitzgerald Marine Preserve

FOUNDATION SPECIES & ECOSYSTEM ENGINEER

Foundation functions:

- Food
- Habitat
- Refuge & Nursery
- Alters food web interactions

Alters physical environment

- Light
- Water movement

CRITICAL FISH HABITAT

- Nurseries for Juvenile rockfish and salmon
- Important refuge & spawning ground for forage fish
- High quality feeding grounds for adult salmon and rockfish

Adult Chinook salmon foraging in a kelp bed. Artwork used with permission of the Pacific Salmon Foundation

KELP LIFECYCLE

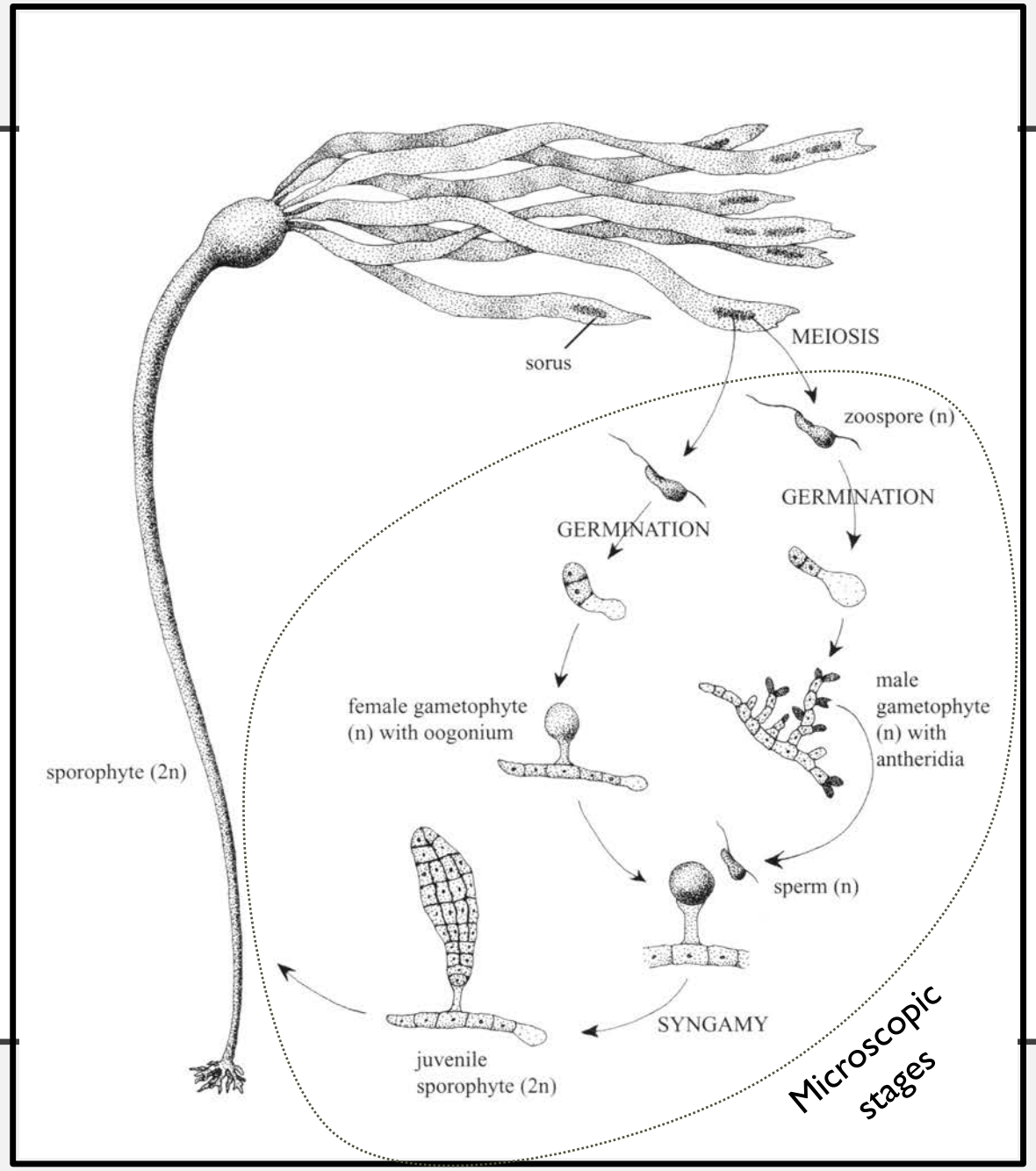


Photo Courtesy: Mondragon and Mondragon 2003

WHAT KELP NEEDS

Hard Substrate

- Bedrock, boulders, cobble, pebbles

Light

- Shade tolerant species
- 1% of total sunlight for microscopic stages (spores, gametophytes)
- 7% - 10% for adult plants (sporophytes)

Nutrients

- Needs food nutrients (nitrogen most important) + trace elements

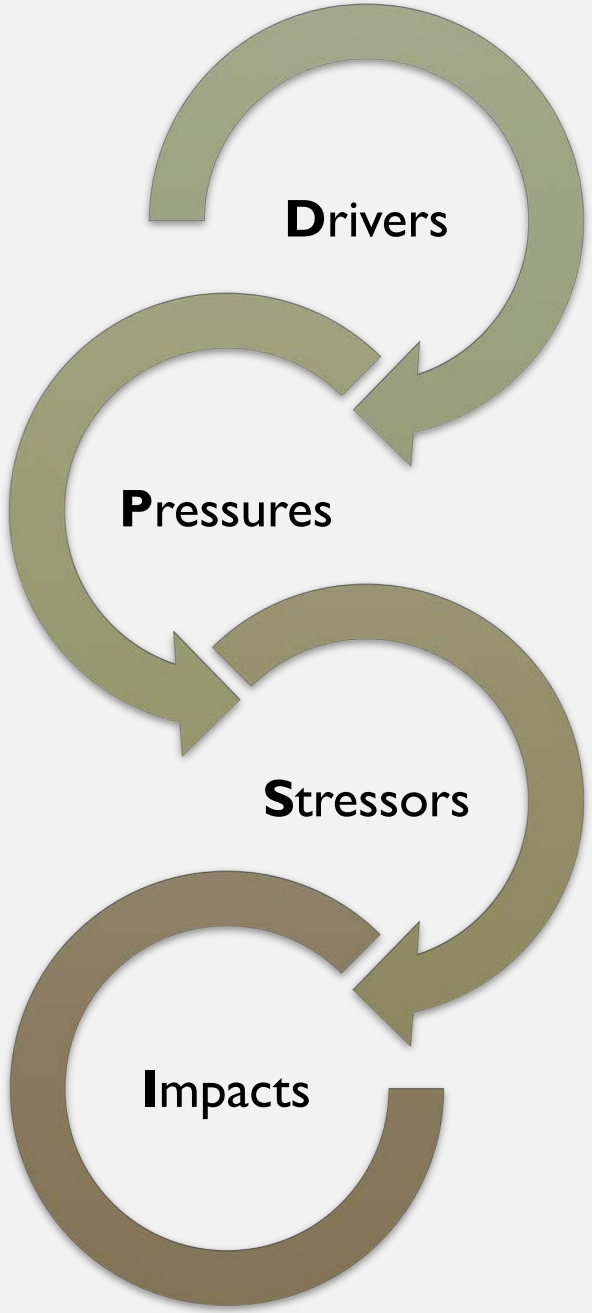
Temperature

- Happiest in 5 – 14 °C
- Stress at ~15 – 16 °C (59 – 61 °F); Mortality at ~17 – 20 °C (63 - 68 °F)

PUGET SOUND STRESSORS

Photo Courtesy: WA-DNR

HUMAN IMPACTS



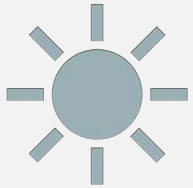
- Population Growth
- Economic Needs

- Overfishing
- Land use-changes
- Shoreline armoring
- Increased emissions
- Climate change
- Pollution

- Physical
  - Light
  - Temperature
  - Salinity
  - Nutrients
  - Substrata- attachment
  - Sedimentation- smothering
  - Energy- wave, tidal
- Biological
  - Herbivory (Including Harvest)
  - Competition
  - Disease

- Decreased resilience & recruitment
- Mortality
- Loss of biodiversity
- Community changes

INFLUENCES ON KELP FITNESS



Physical

Temperature
Nutrients
Sediment
Waves

Biology

Competition
Grazing

Interactions

Unpredictable
Synergistic
Jump boundaries

WARMING OCEANS

Stress

Reduce resilience

Mortality

Decreased recovery

Disturbance

More frequent and intense heat waves & storms

SEDIMENT EFFECTS

- Reduces light reaching benthos
- Suspended sediments
  - Fine sediments can stick to floating spores
- Sediment accumulation
  - Blocks attachment of sores or smothers gametophytes and microscopic sporophytes
- Pollutants associated with sediment

NUTRIENT POLLUTION

- Alters competitive interactions between kelp and other seaweeds
- Example:
  - Rise of "turf" barrens composed of small, filamentous and other ephemeral species

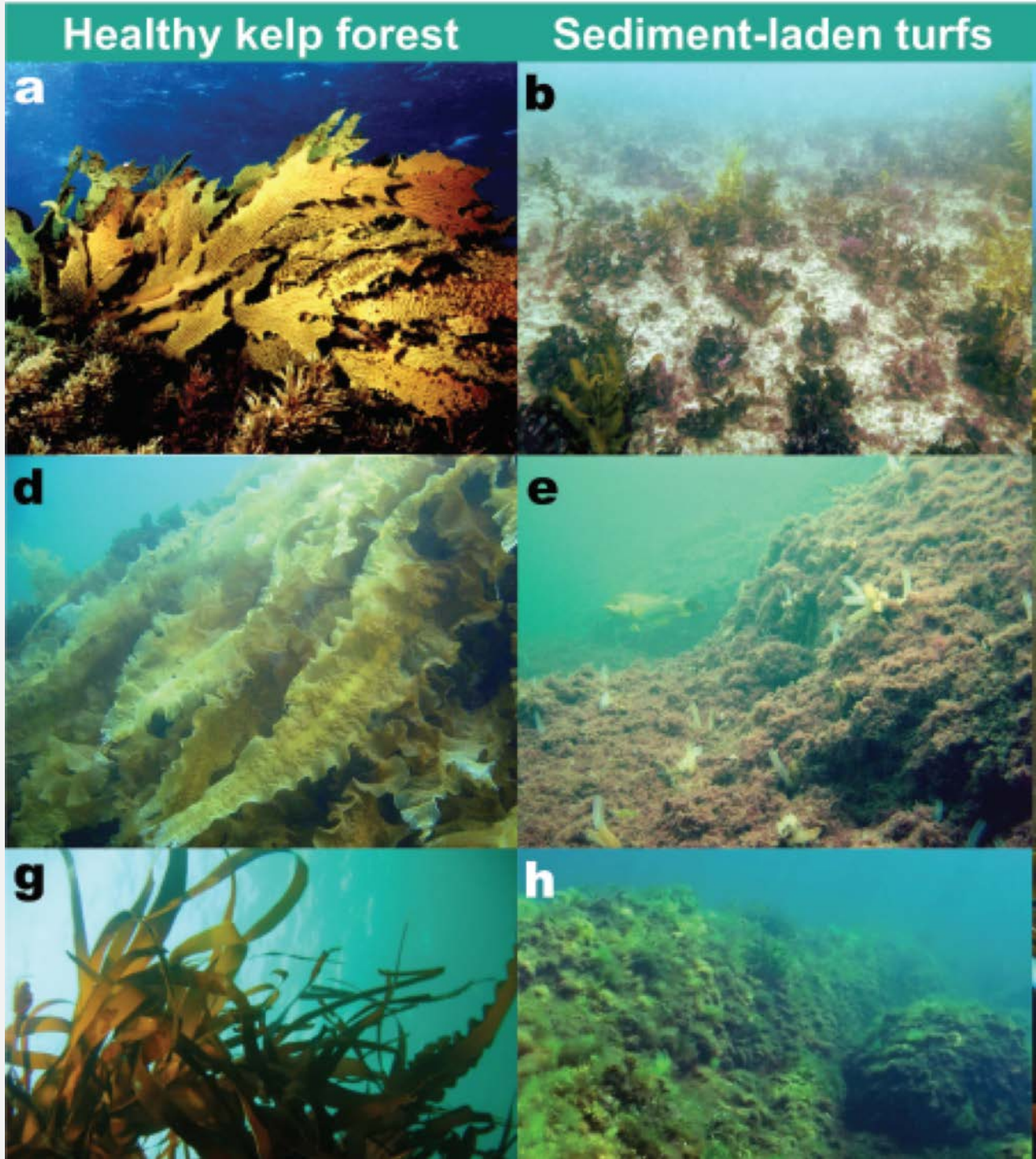


Image Source: Filbee-Dexter & Wernberg 2018, *BioScience*

COMPETITION BETWEEN SEAWEEDS

Light

- Floating canopies can block 90% of light
- Understories reduce >95%

Space

- Floating canopies only represent ~20% of total recruitment
- Scour

Invasive species

- Ex. *Sargassum muticum*.
- Known to block light to native species

Photo Courtesy: WA-DNR

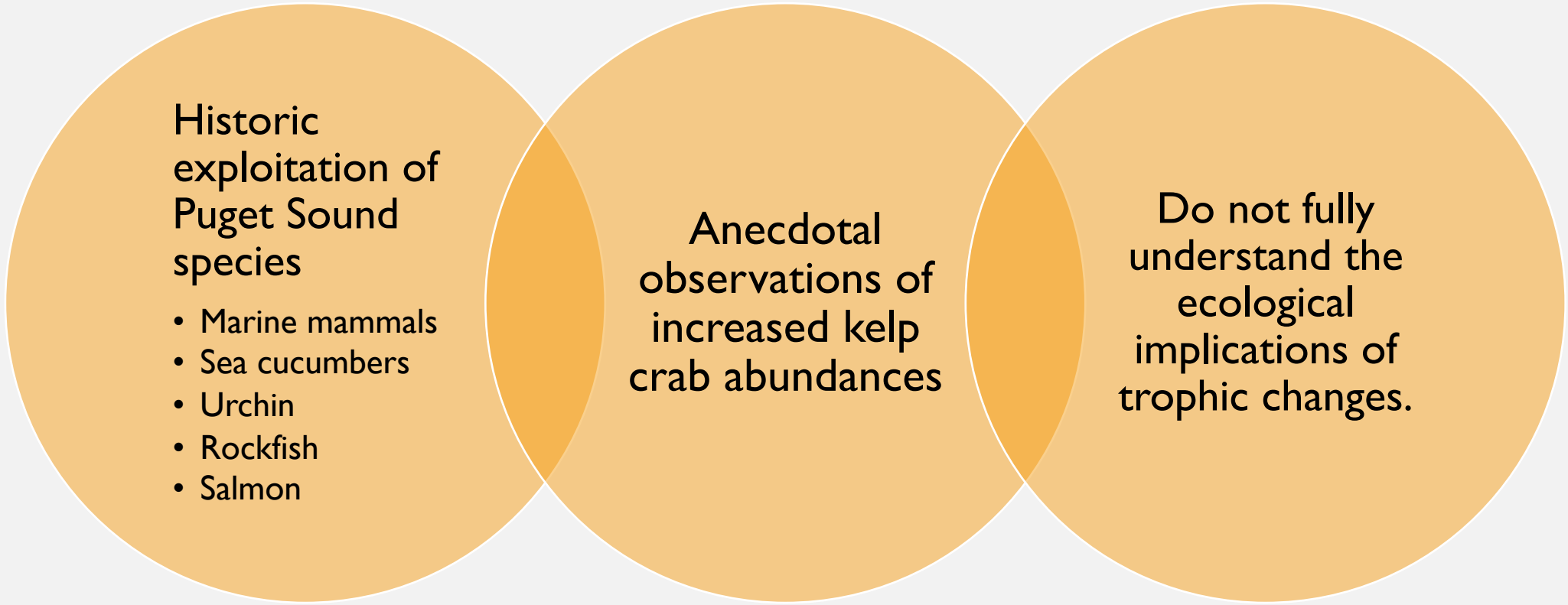
GRAZERS LOVE KELP

- Urchin barrens well documented
  - But not an issue for Puget Sound
    - Maybe San Juans
- Kelp crabs
  - Prefer Bull Kelp
- Small grazer impacts and connections to changes in food web not well known.

OVERFISHING LEADS TO GRAZER BARRENS

- Removal of apex predators
  - Sea otters
  - Rockfish
  - Seastars
  - Lobsters
- Increase in grazers
  - Urchin
  - Kelp Crab
  - Snails and other mesograzers

PUGET SOUND


Historic exploitation of Puget Sound species
• Marine mammals
• Sea cucumbers
• Urchin
• Rockfish
• Salmon
Anecdotal observations of increased kelp crab abundances
Do not fully understand the ecological implications of trophic changes.

NEREOCYSTIS IN PUGET SOUND

Distributions and Trends

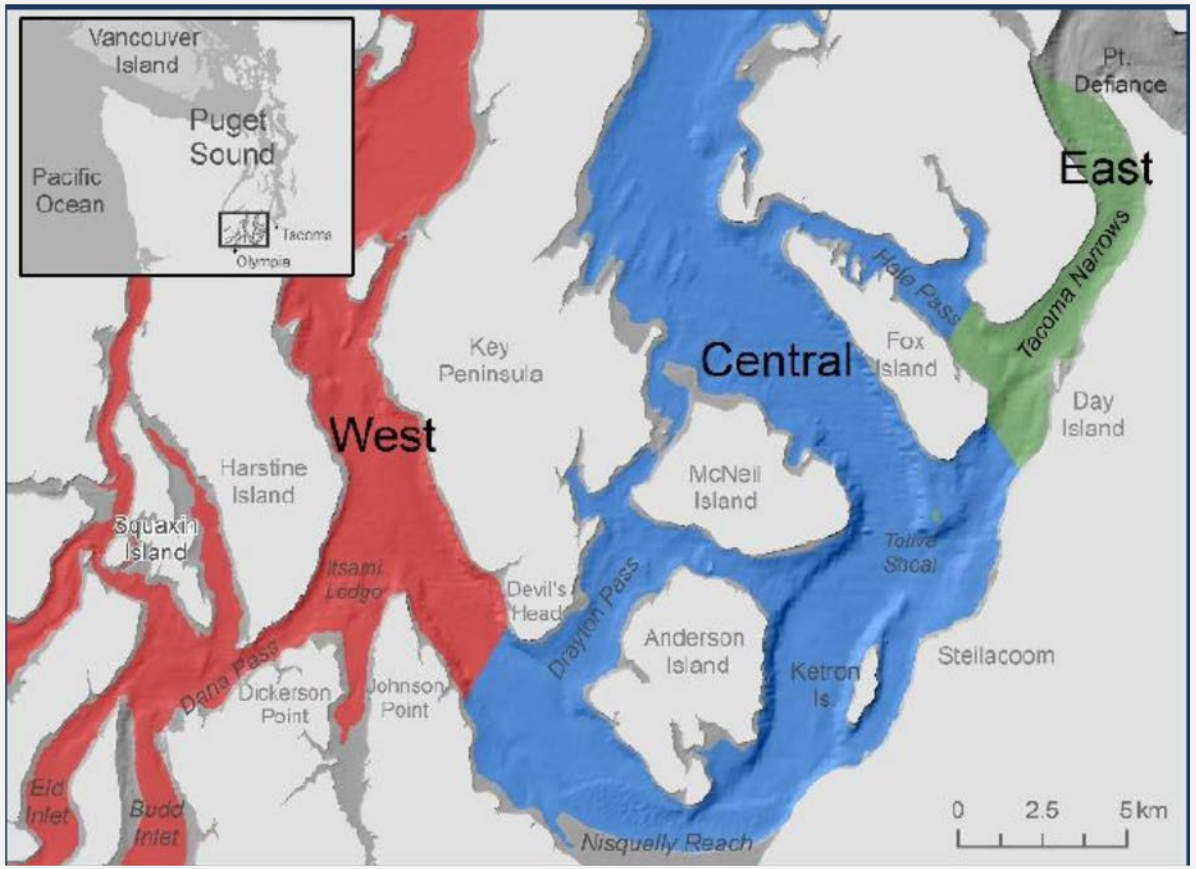
Photo Courtesy: M. Calloway

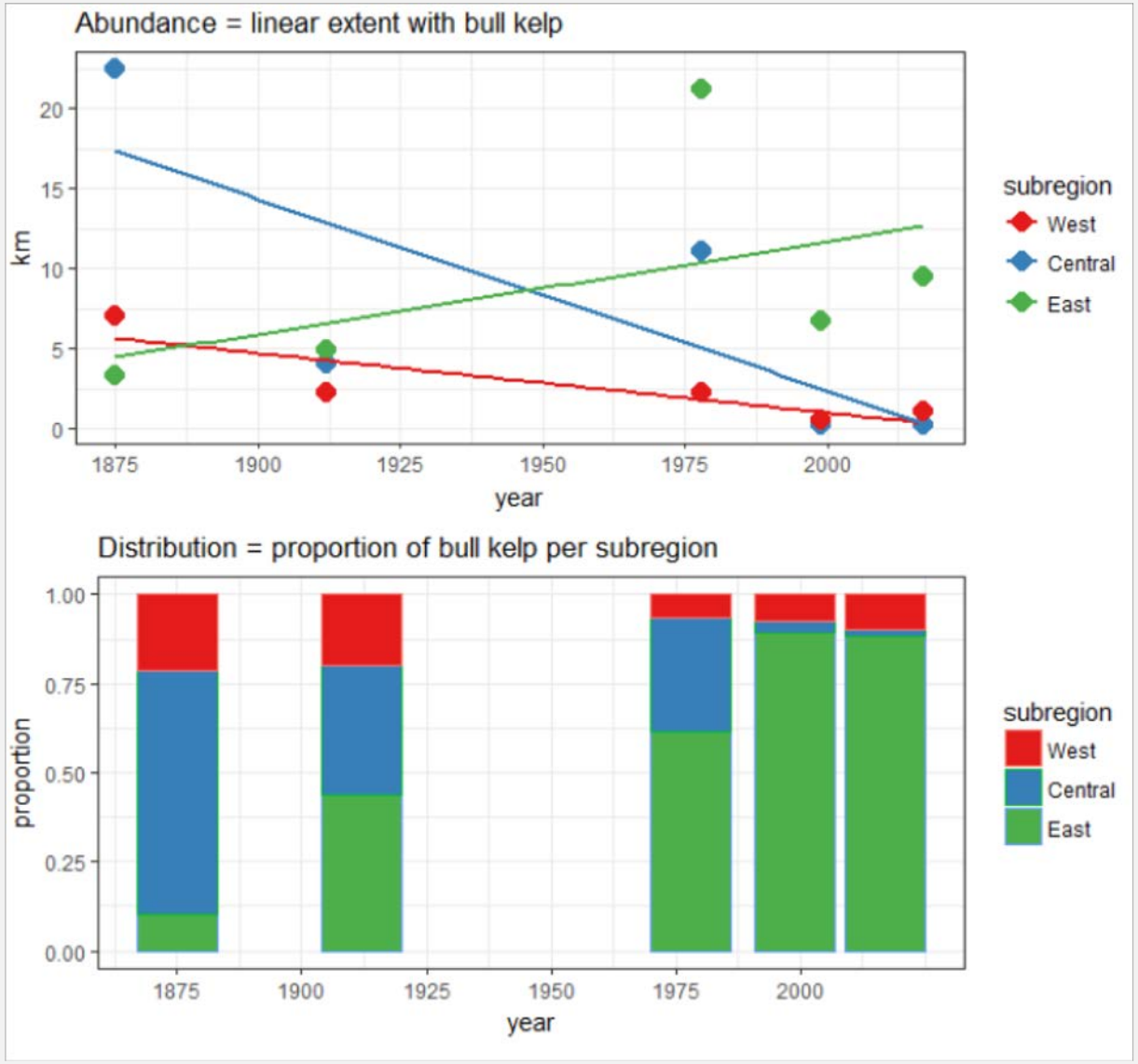
NEREOCYSTIS CANOPY

- Spotty survey data for floating canopies since the 1800's being compiled by DNR
  - South sound done, working on central
- MRC kelp mapping
- Towed underwater video

Photo Courtesy: M. Calloway

SOUTH SOUND NEREOCYSTIS CANOPIES





- 67% decrease in linear extent between 1873 & 2017
  - 99% decline in central, 85% decrease in west, East stable

Berry, Dowty, Mumford & Christiaen, in prep.

BAINBRIDGE ISLAND NEREOCYSTIS

- Red and blue indicate historic floating canopies.
- *Nereocystis* canopy totally gone in 2015.

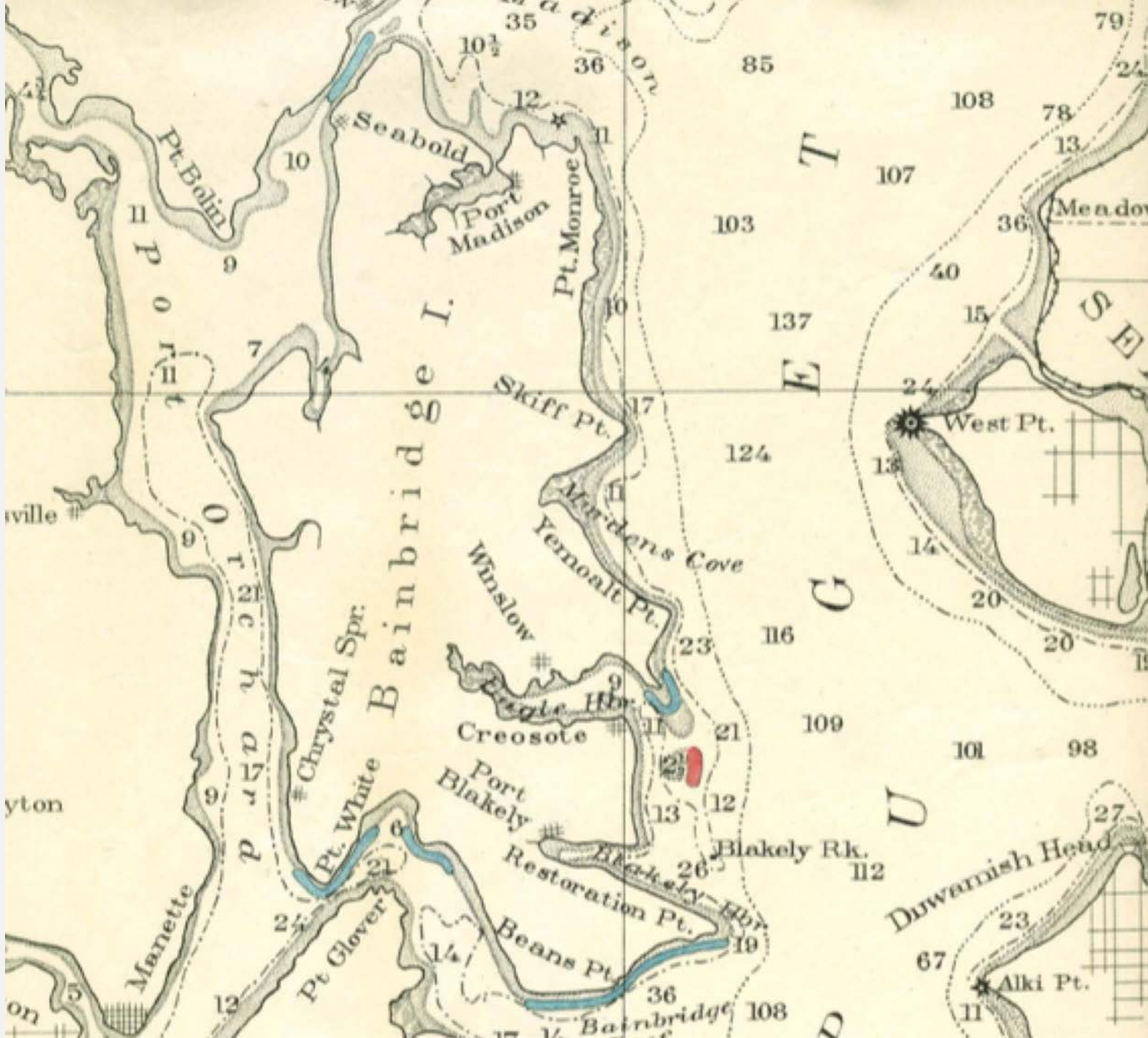
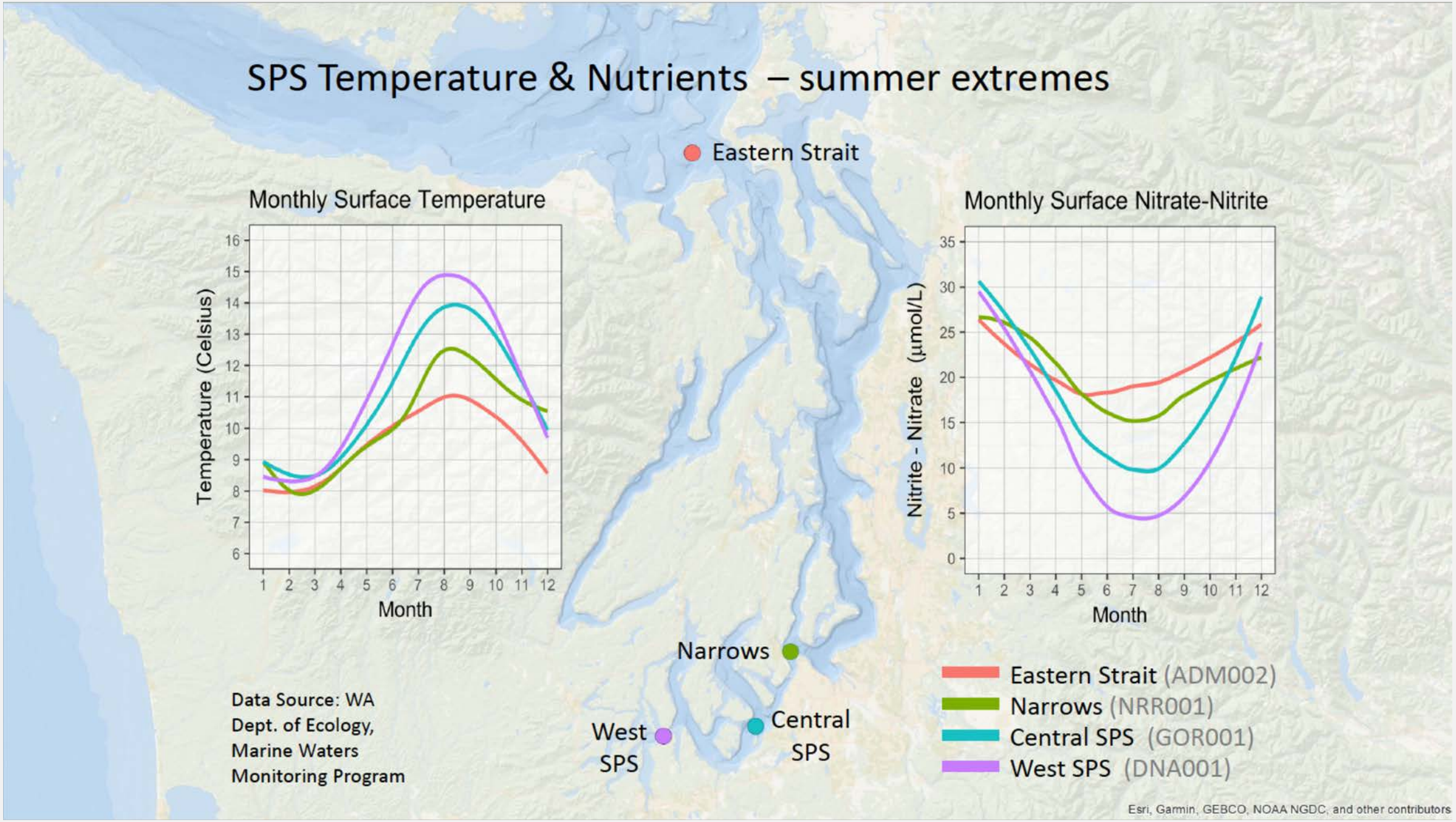


Photo Courtesy: PSRF

SPS Temperature & Nutrients – summer extremes



Slide courtesy of: Helen Berry, *WA-DNR*, 2018

RESTORATION EFFORTS

Nile Creek Enhancement Society

2014: Modified aquaculture techniques used to grow artificial kelp bed on submerged lines

Puget Sound Restoration Fund

2016 – 2017

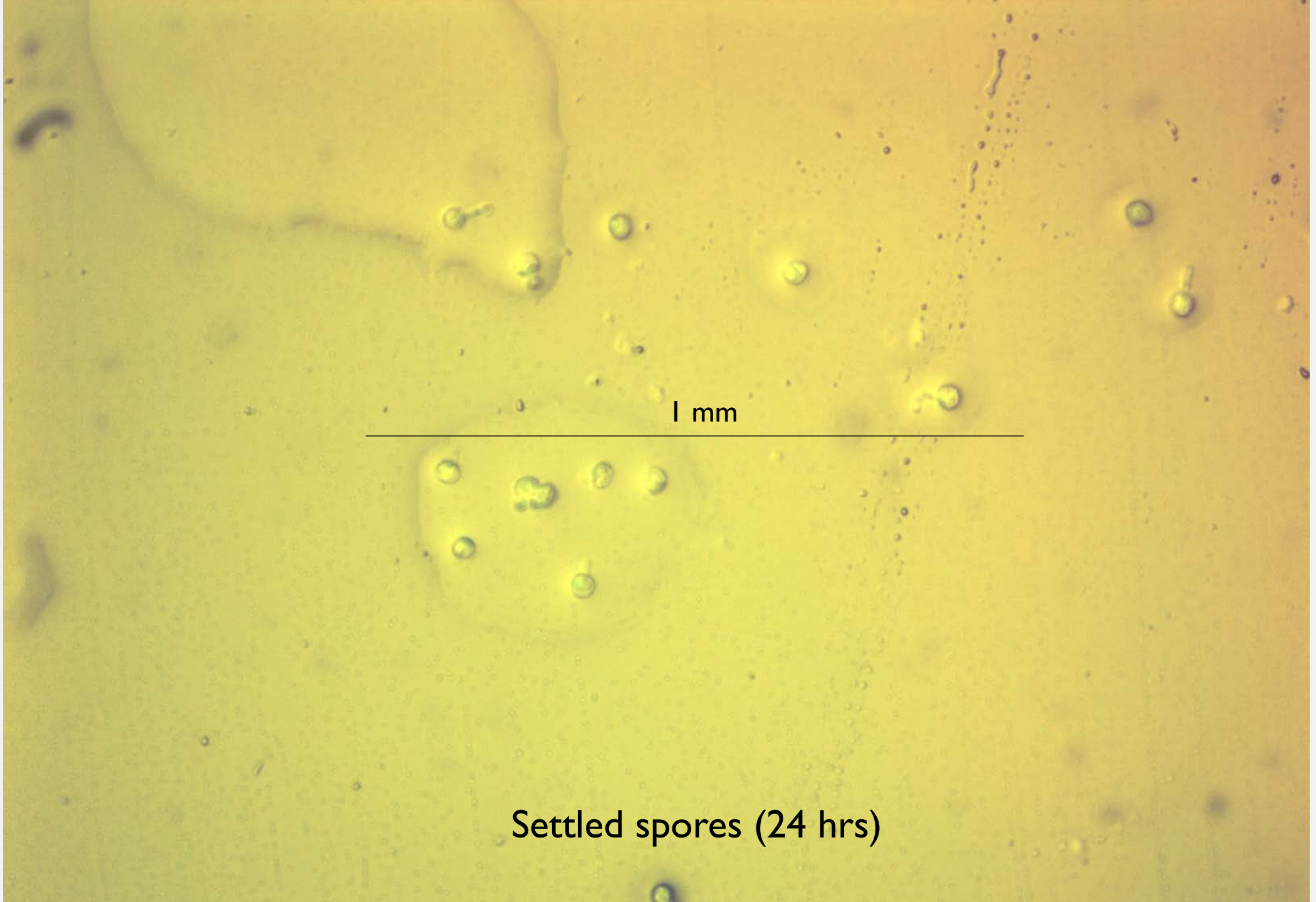
- Optimal outplant timing trials

2019 – 2021

- First attempts at canopy restoration
- Seaweed succession investigation

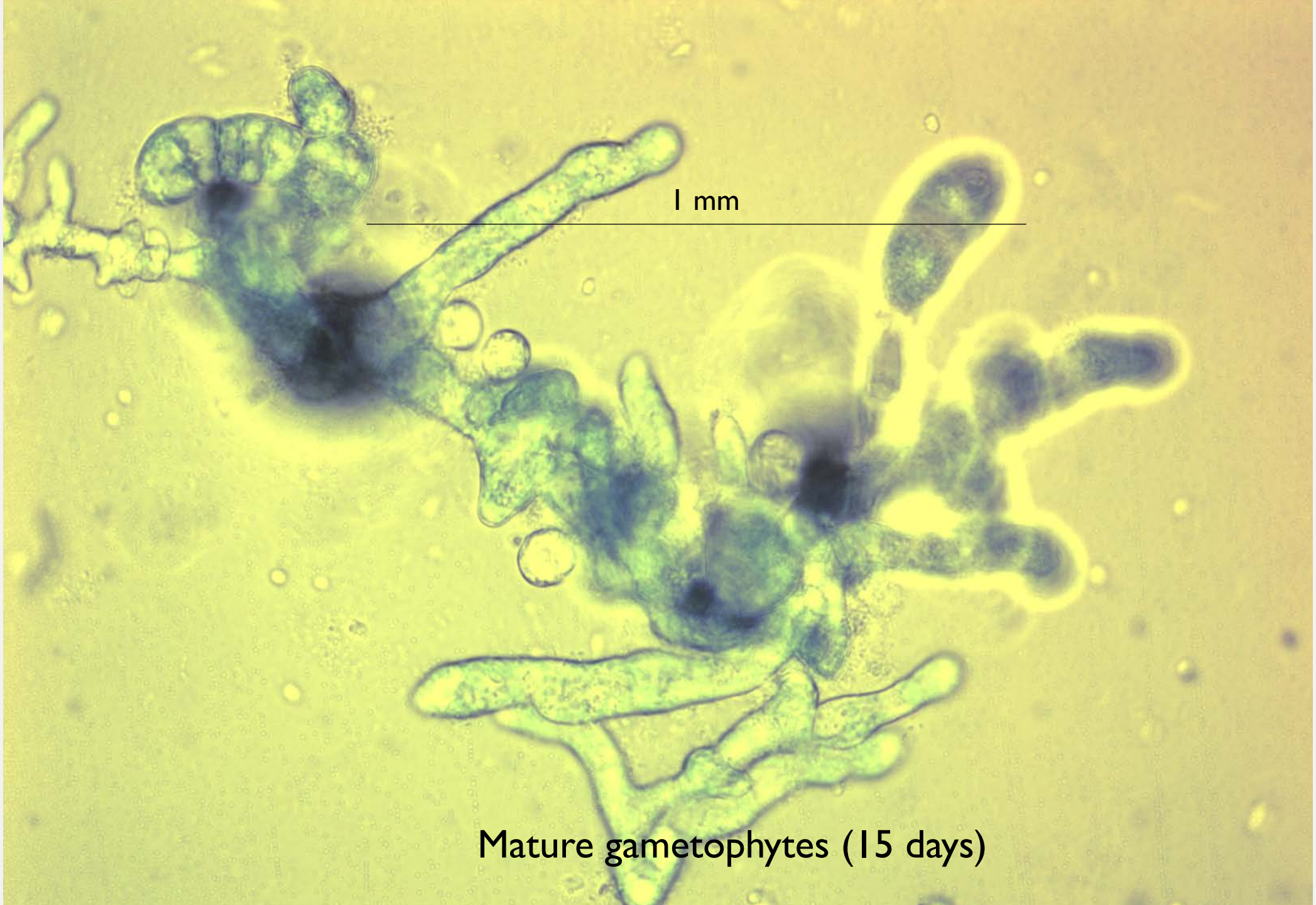
QUESTIONS?

MAX@RESTORATIONFUND.ORG

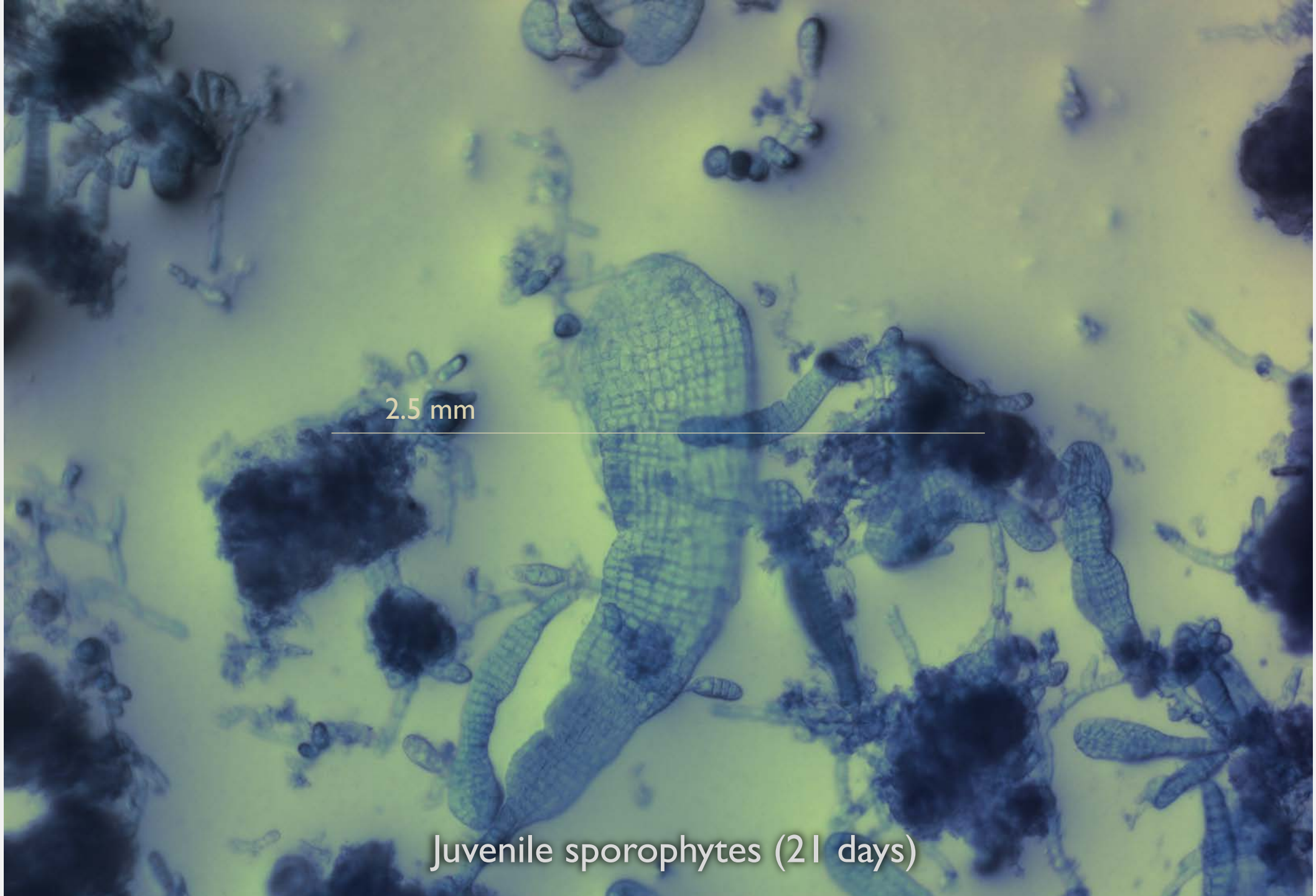


Settled spores (24 hrs)

New gametophytes (8 days)

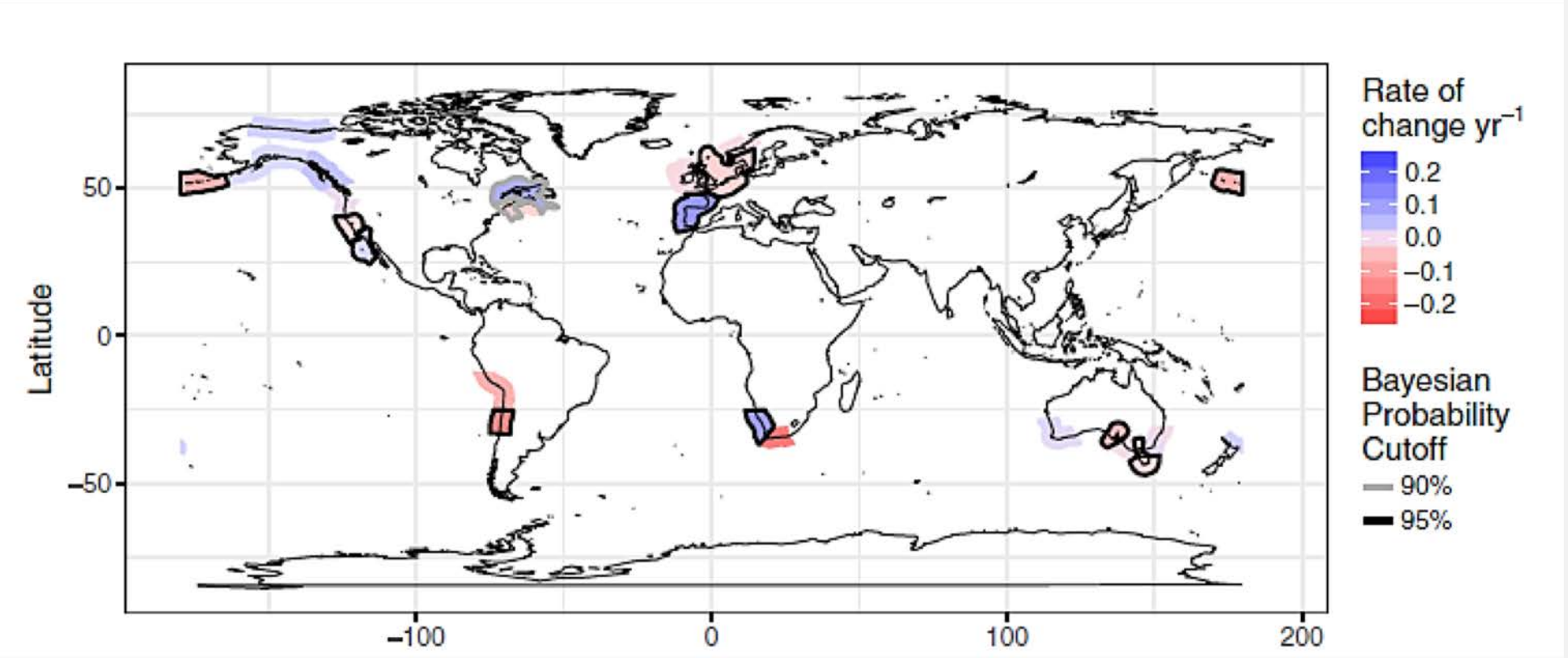


Mature gametophytes (15 days)



Juvenile sporophytes (21 days)

GLOBAL TRENDS



- 1/3 declining, 1/3 no change*, 1/3 increasing
- Local conditions important
- No data for Puget Sound

Image Source: Krumhansl et al., 2016, *Proc Natl Acad Sci U S A*

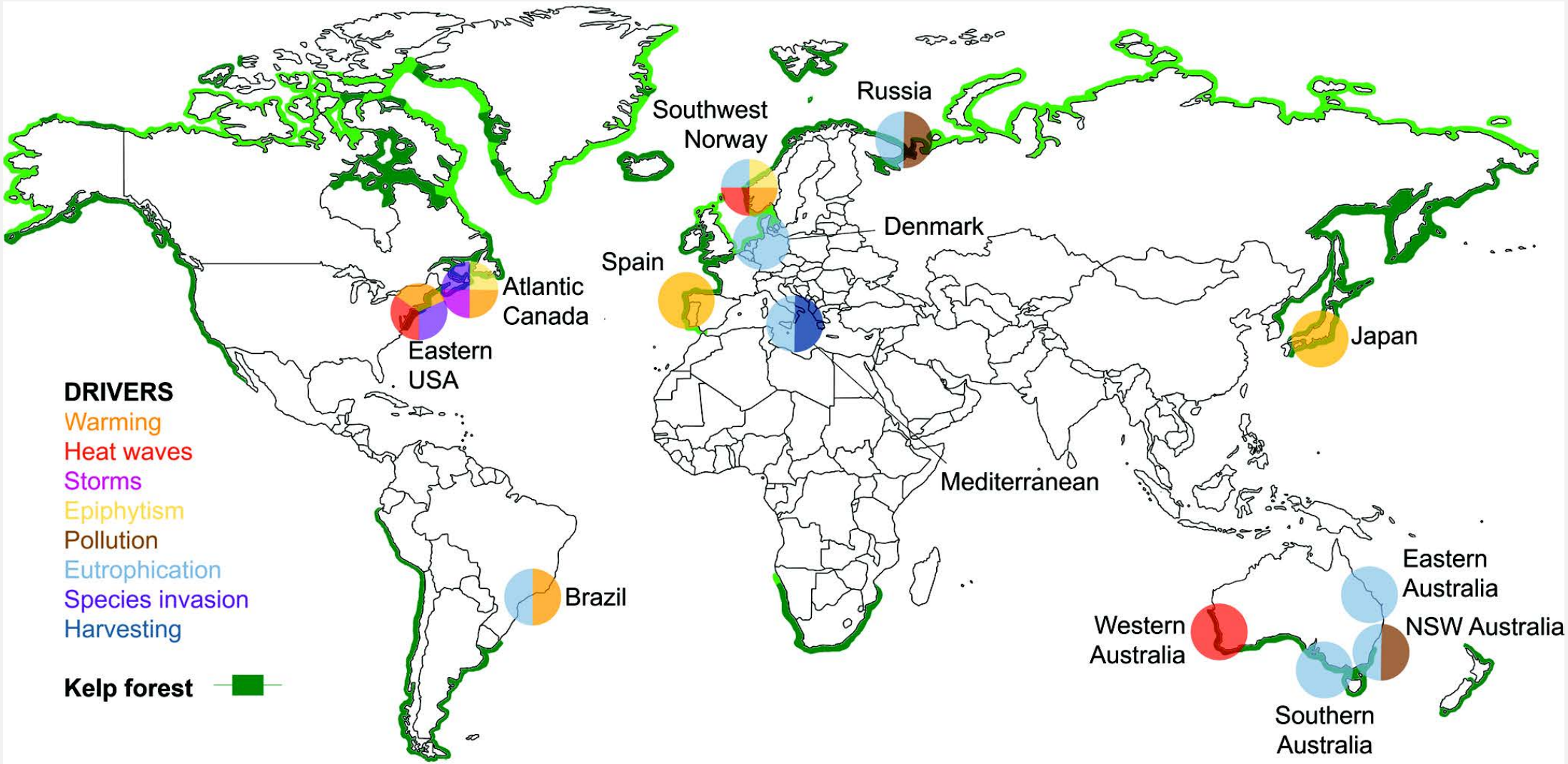
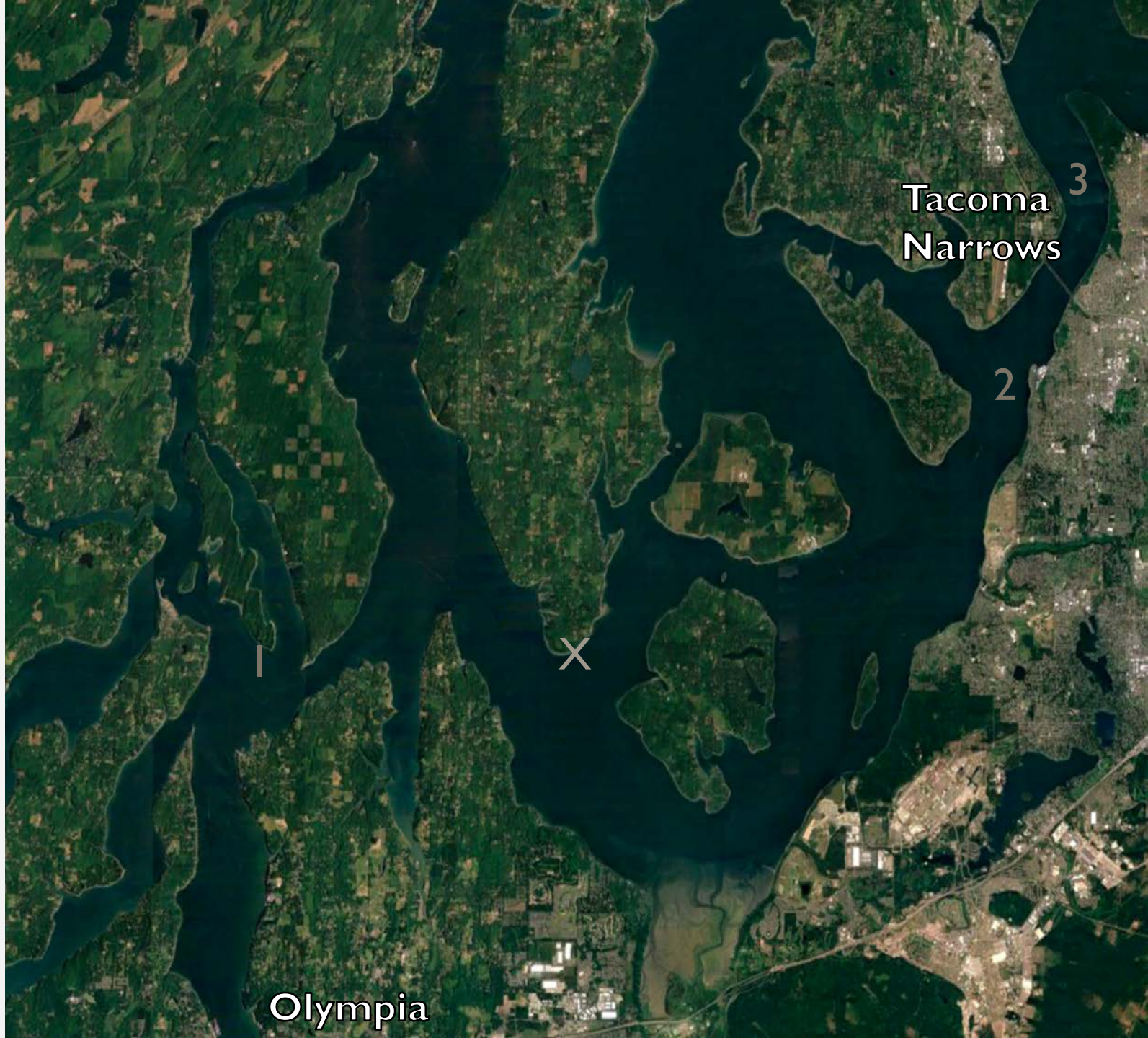


Image Source: Filbee-Dexter & Wernberg 2018, *BioScience*

SOUTH PUGET SOUND

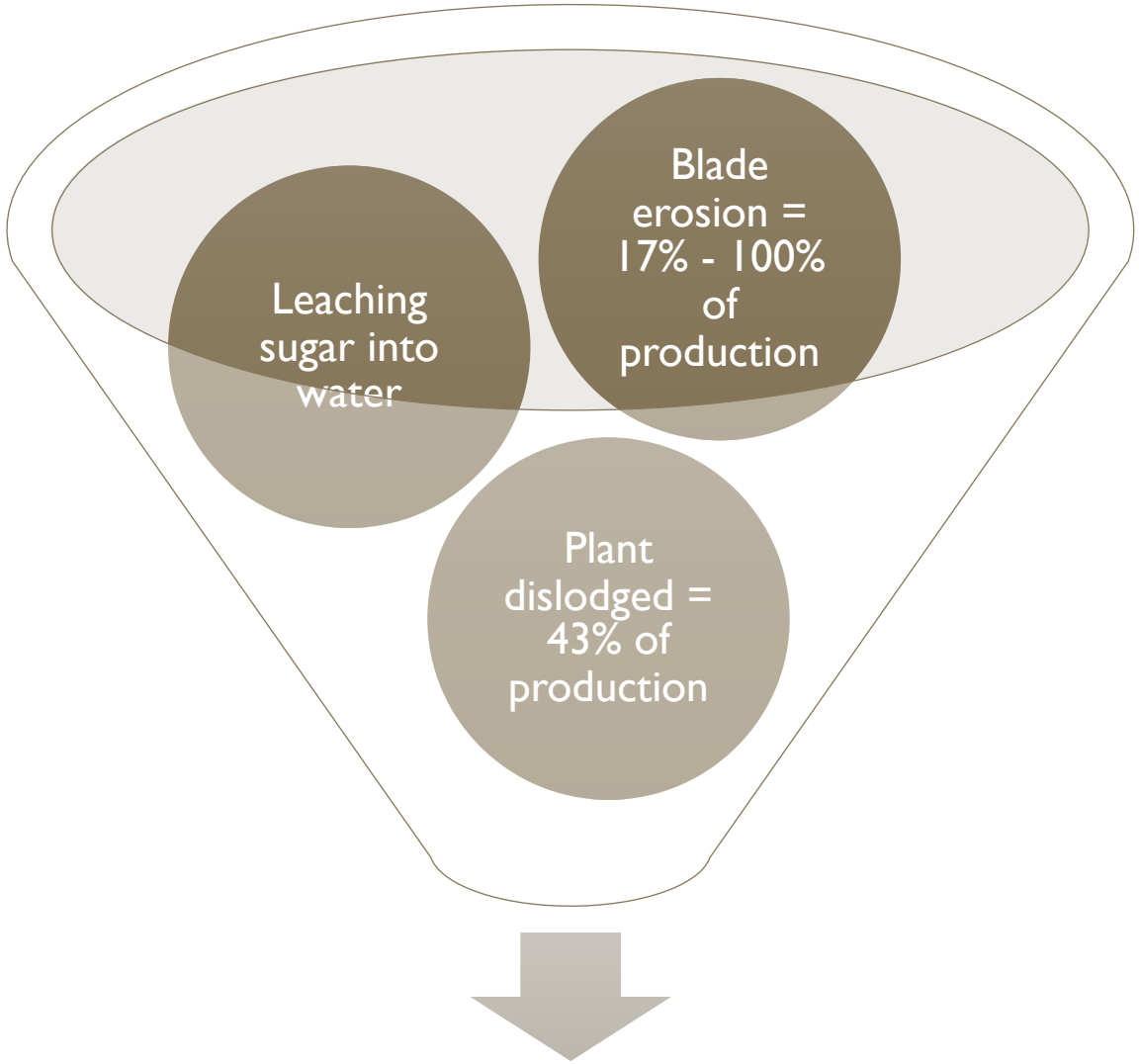
1. Tucksel Point, Squaxin Island
2. Day Island
3. Salmon Beach

X. Devil's Head




Harmful Algal Bloom
2011
El Niño
2015 - Present
"Warm Blob"
2014 - Present
Purple Urchin Boom
2014 - Present
Seastar Wasting Disease
2013
Decimation
of Kelp Forest

DETRITUS AND WRACK PROVIDE FOOD

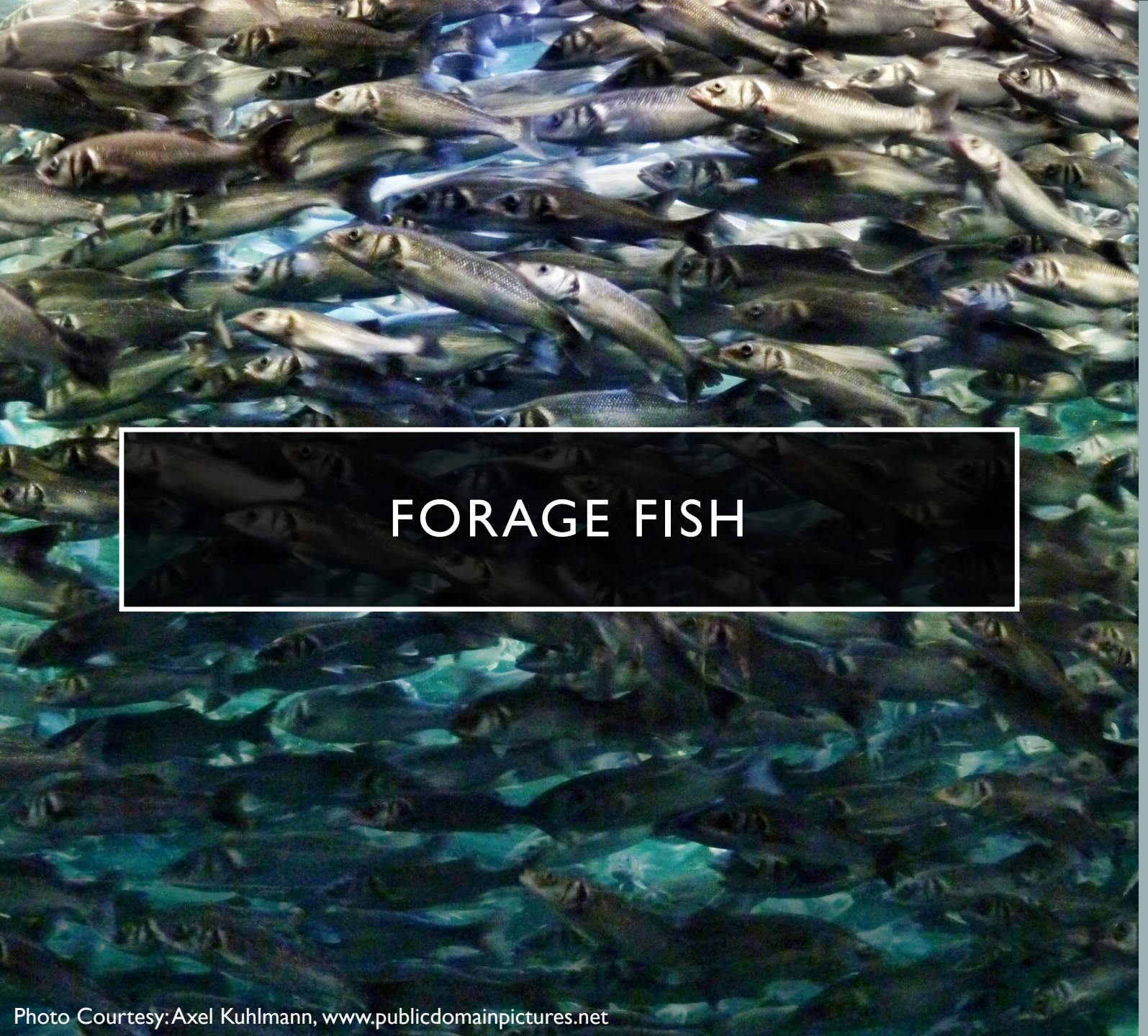


More food locally and exported to deep water and shoreline habitats

MORE INVERTEBRATES GROWING FASTER

- Invertebrate abundances > 500,000 per m^2
  - ~5x higher than abundances in seagrass and fucoid habitats
- Same effect even without a floating canopy
- Mussels grow 2-4x faster
- Barnacles grow 5x faster

Miller et al. 2018, *Proceedings B*
Duggins et al., 1989, *Science*
Photo Courtesy: NOAA



FORAGE FISH

Photo Courtesy: Axel Kuhlmann, www.publicdomainpictures.net

Herring, sand lance, surf smelt

Planktivorous

- Calanoid copepods
- Megalops
- Barnacle larvae

Herring require macrophytes for spawn

All species use nearshore for spawning

Penttila 2007, *Puget Sound Nearshore Partnership*
Tribble 2000, University of Washington Masters Thesis

ROCKFISH NURSERIES

Photo Courtesy: Clark Anderson/Aquaimages, Wikimedia Commons

- YOY rockfish often most abundant finfish encountered during surveys in kelp forests
- Juveniles hide in canopy and migrate down to understory and then to deep water habitats
- Helps avoid predation from large con-specifics and other predators
- Kelp detritus transported to continental shelves likely important in promoting deep water benthic food webs

Singer 1985, *Fishery Bulletin*
Love et al. 1990, *Experimental Biology of Fishes*
Tolimieri et al. 2016, NOAA NMFS WCR

SALMON USE KELP AS REFUGE

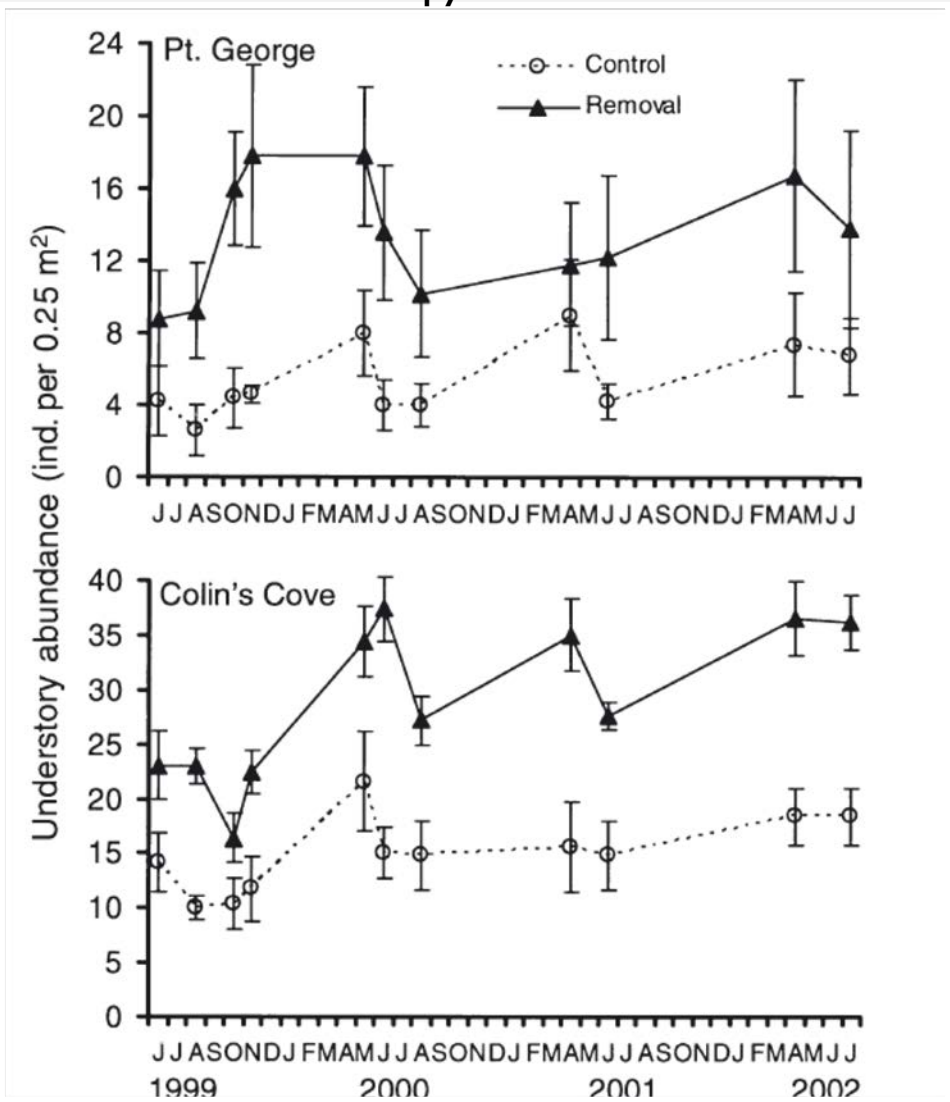
- Puget Sound juvenile outmigration and nearshore rearing period coincides with peak kelp productivity.
  - Early growth critical.
- Juveniles will leave areas with inadequate foraging opportunities.
- Juvenile coho observed to prefer floating kelp forests in the Strait of Juan de Fuca.
- Juvenile salmon observed around the edges of overwater structures in urban waters.

Shaffer 2003, WDFW, Georgia Basin/Puget Sound Research Conference
Toft et al. 2007 *North American Journal of Fisheries Management*
Photo Courtesy: NOAA

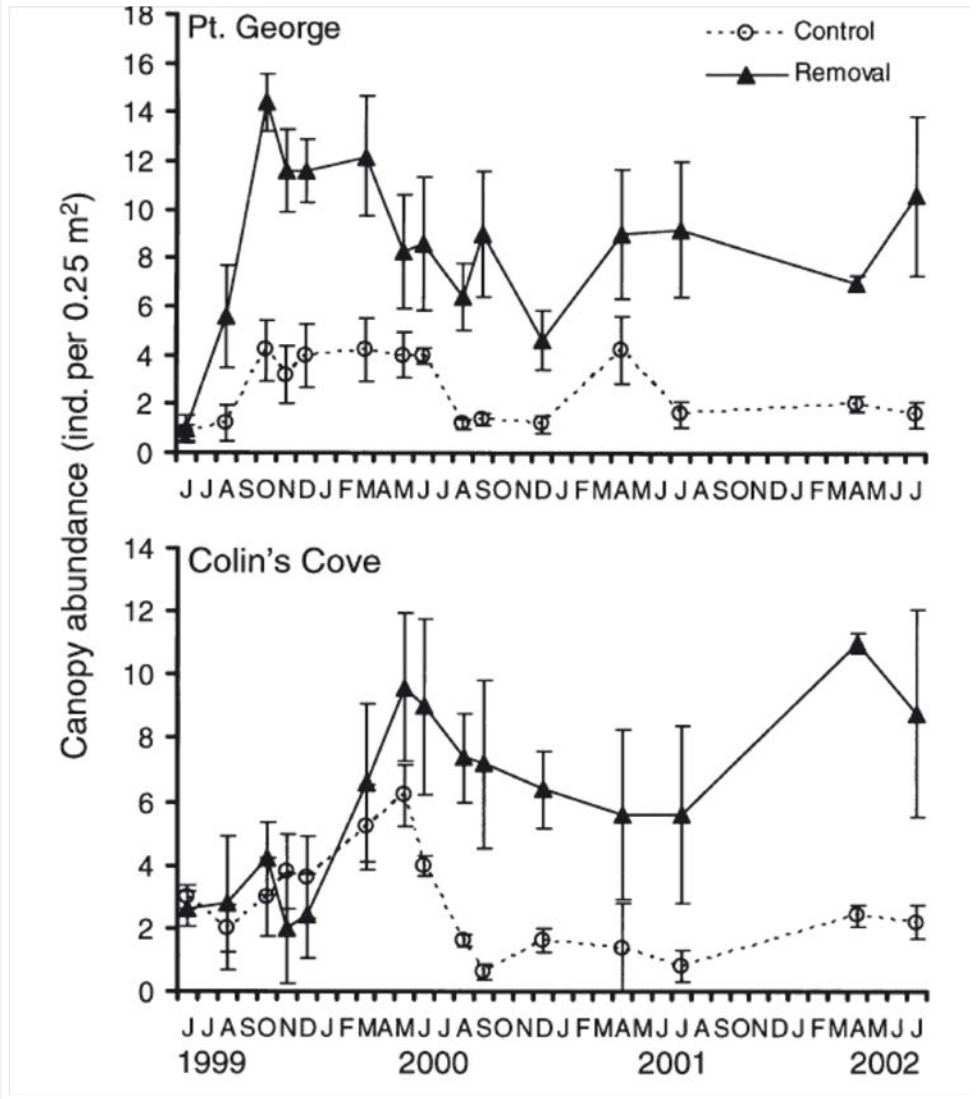
SARAGASSUM IN PUGET SOUND

- Removal experiments in the San Juans

Canopy abundance



Understory abundance



Britton-Simmons, 2004, *Marine Ecology Progress Series*