

The Perfect Storm: Multiple Stressors Push Kelp Forest Beyond Tipping Point

Conservation Series

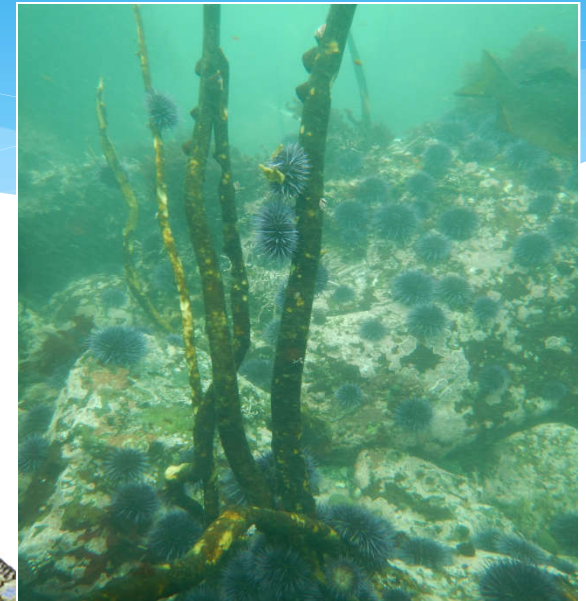
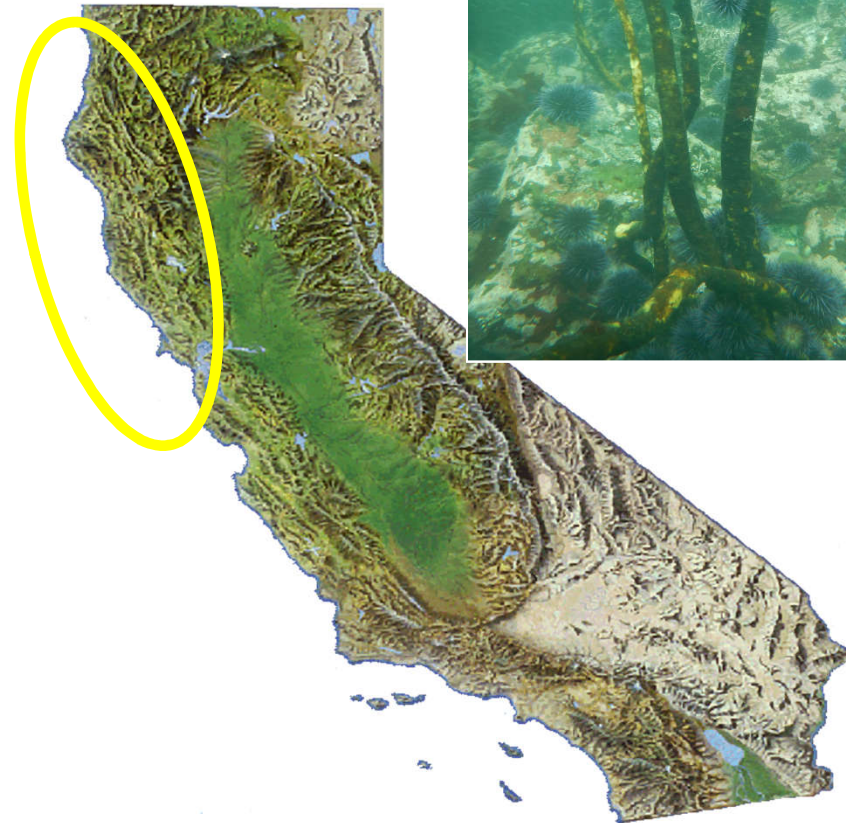
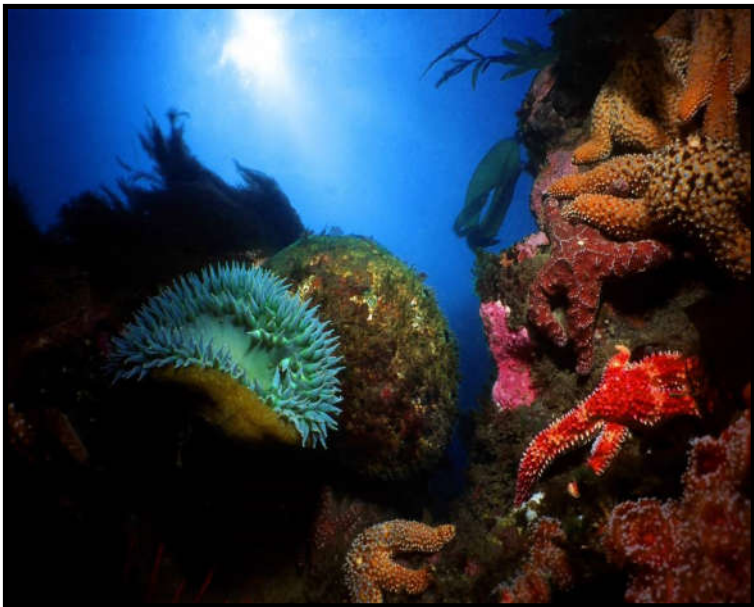
Science Inst. CDFW

July 18, 2019

Dr. Laura Rogers-Bennett



Northern California Kelp Forests at Tipping Point to Alternative Stable State

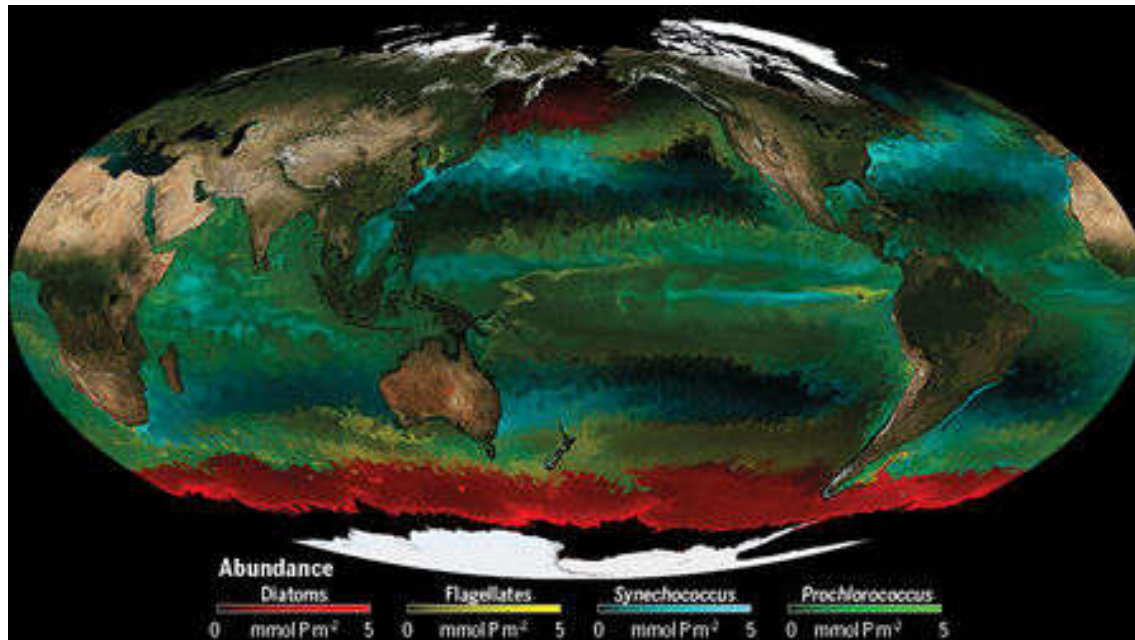


Today's Talk Outline

- * Kelp and algae are cool
- * Kelp forests provide services to humans
- * Kelp is vulnerable to stressors like ocean warming
- * Sea urchins are cool
- * Sea urchins gobble up Kelp forests
- * Kelp is in trouble in northern California !
- * What we can do for our iconic Kelp forest ecosystems ?
 - * Microclimates and kelp oases
 - * Urchinomics business model

Algae produce 50+% of Earth's Oxygen

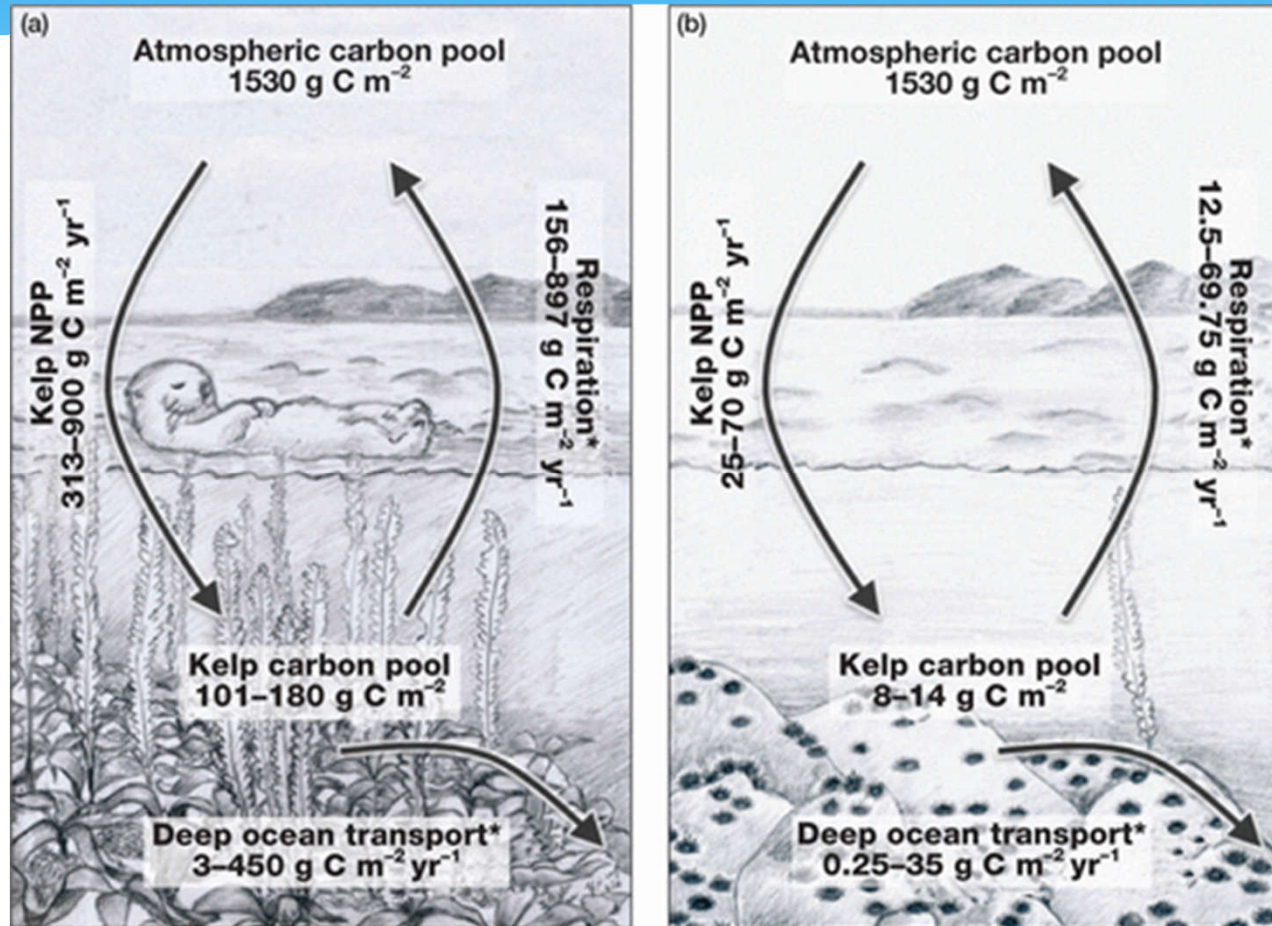
Prochlorococcus produces 5% by itself. 10^{27} cells (octillion) or 20,000 cells per drop SW



Dr. Penny Chisholm discovered it in 1988



Carbon Sequestration



Wilmers et al. 2012 *Frontiers in Ecology and the Environment*

New Species Kelp: Golden V

Aureophycus aleuticus



Kelp 7 feet long from Aleutians Discovered by Mandy Lindeberg **in 2008 !**

Kelp Ecosystem Services

- * Kelp Harvest
- * Fisheries
- * EcoTourism (Ramirez-Valdez et al. 2017)
- * Cultural Value (Salomon et al. 2015)
- * Shoreline Protection (Arkema et al. 2013)
- * Blue Carbon (Wilmers et al. 2012)



Kelp Harvester - Photo K. Karr

Kelp Forests are Ecosystem Engineers

- * Provide food and shelter
- * Provide kelp subsidies deep
- * Structure subtidal community



Kelp Carbon Particulate

Feehan, Grauman-Boss, Strathmann, Dethier and Duggins 2018

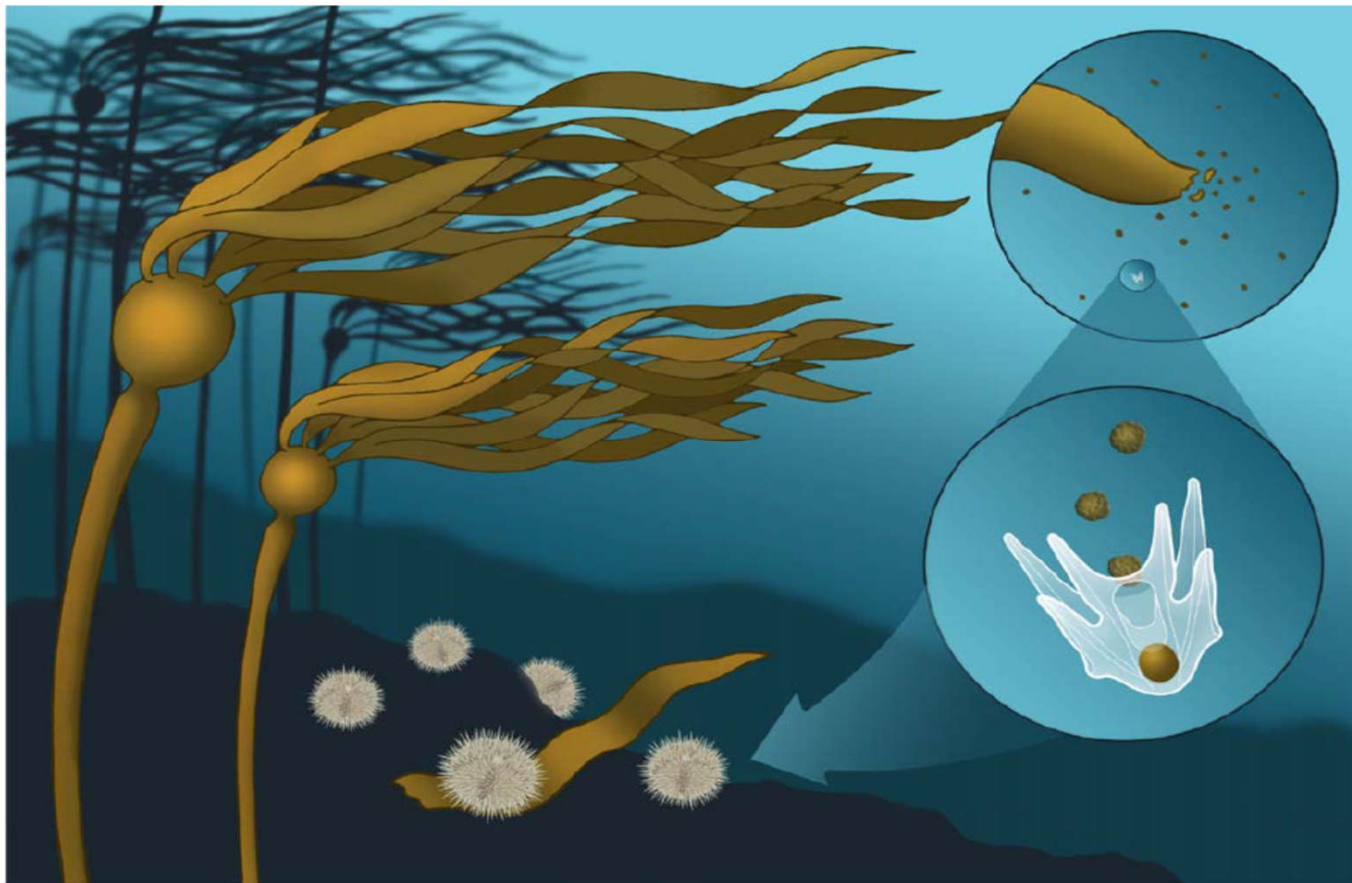


Figure A. Dingeldein

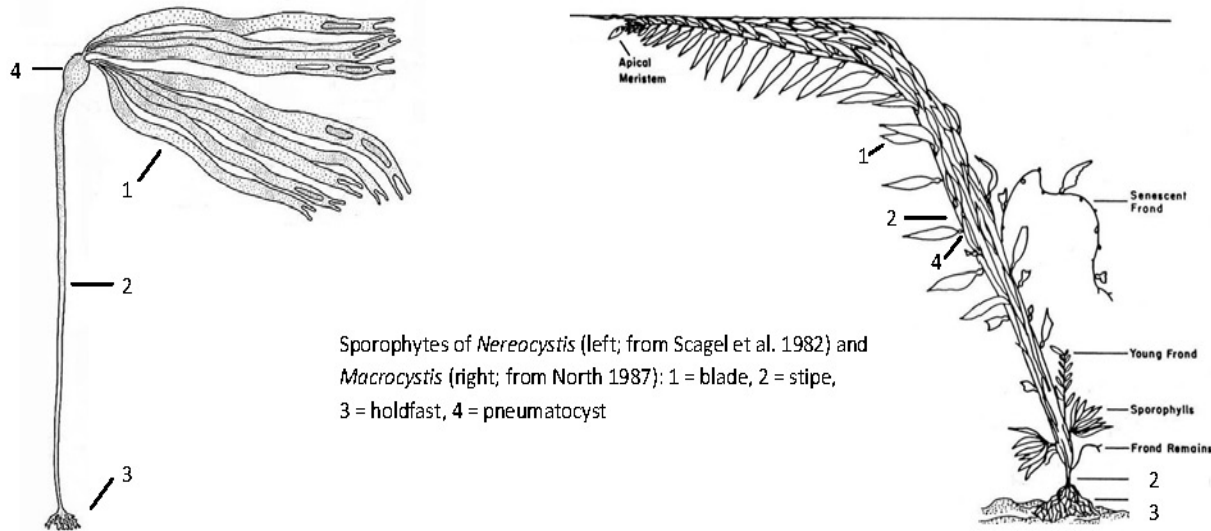
Deep Habitat Kelp Subsidies

45m depth



Filbee-Dexter 2014 Aquatic Biol. Britton-Simmons et al. 2009 Aquatic Biol.

Bull Kelp and Giant Kelp



- One of the fastest growing organisms on earth
- Growth rate of 2 feet per day
- Rich in elements
- **Bull Kelp is an annual and Giant Kelp is perennial**

Ecosystem Multiple States

- * Alternative States (Lewontin 1969)
- * Productive and unproductive communities (Sutherland 1974, May 1977)
- * Tipping Points / Thresholds
- * Non-linear dynamics lead to abrupt shifts
- * Kelp Forest and Urchin Barrens
- * Barrens dominated by urchin and coralline algae

Kelp loss threatens fisheries and the ecosystem

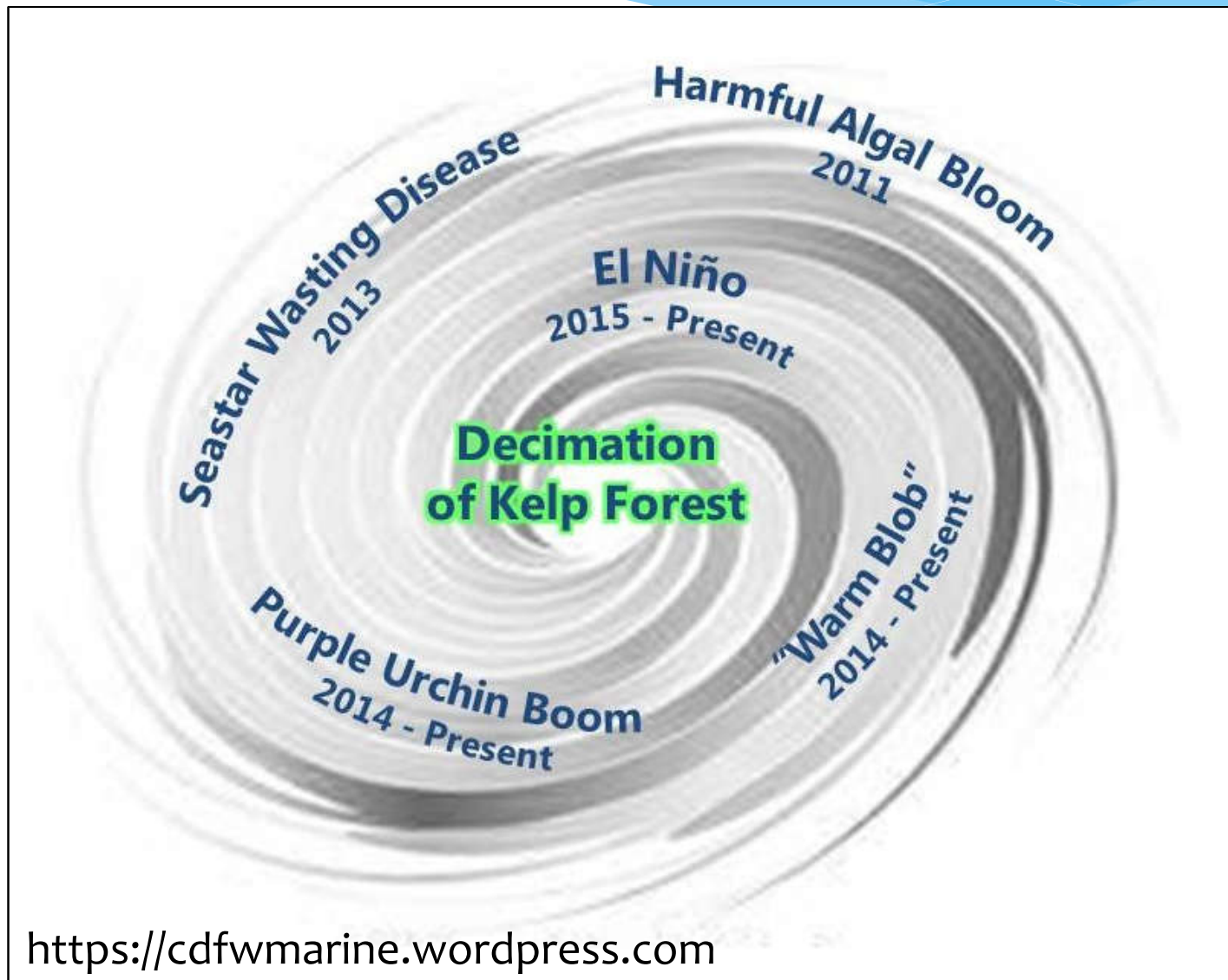


L. Rogers-Bennett (CDFW)



A. Weltz (CDFW)

“The Perfect Storm”



The Perfect Storm: Kelp Decline

- * Sea Star Wasting Disease (2013)
- * Persistent Warm Water (2014 -)
- * Purple Urchin Explosion (2014 -)



“The Perfect Storm”: Series of Large-Scale Stressors

* KELP FOREST DECLINE

- * SEA STAR WASTING DISEASE (2013)
- * PURPLE URCHIN EXPLOSION (2014 -)
- * PERSISTENT WARM WATER (2014 -)

CDFW Ecosystem Monitoring 1999-2018

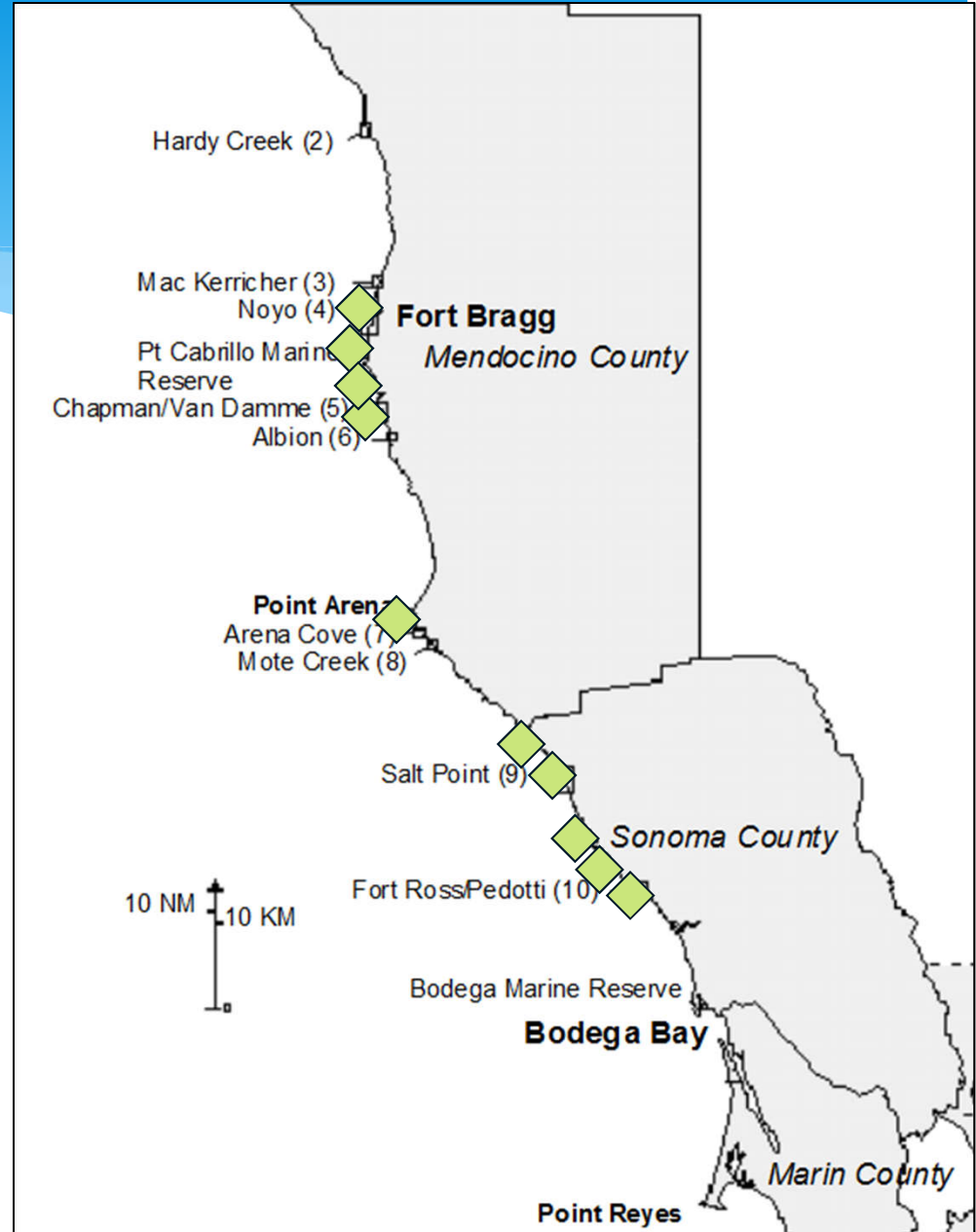
**Northern California
At a Tipping Point?**

**Dramatic Subtidal
Community Structure Shifts
to Urchin Barrens**



Long-term 20yr Monitoring Sites

- Ecosystem surveys
- Inverts, algae, substrate
- 10 fished sites
- 2 unfished sites
- 36 transects / site
- 60m² / transect
- 3-year survey cycle



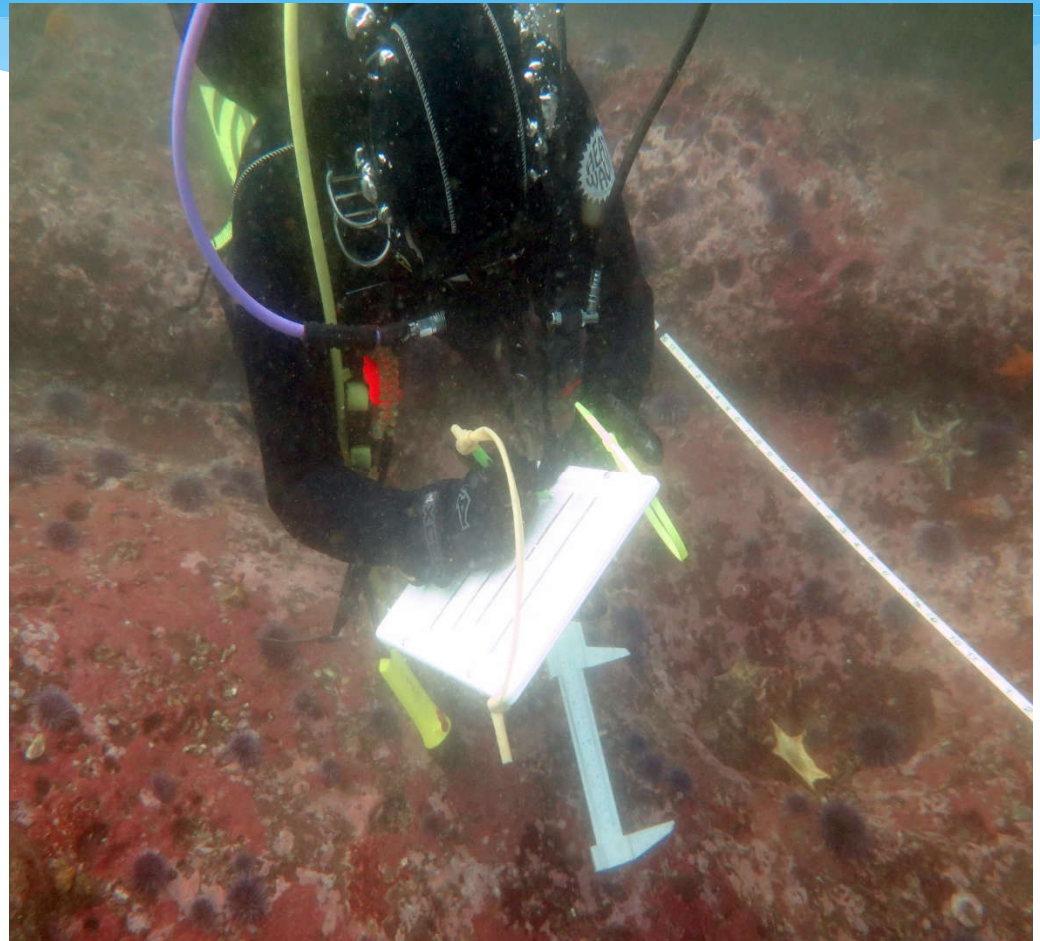
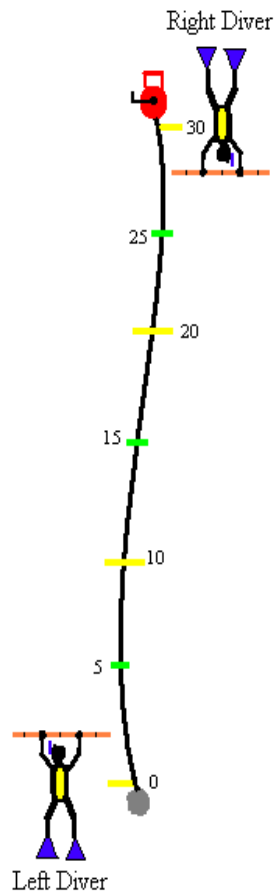
Sea Star Wasting Disease 2013

Hewson et al. 2016,18; Harvell et al. 2019 Densovirus



Photo A. Maguire

Subtidal density surveys 30m x 2m

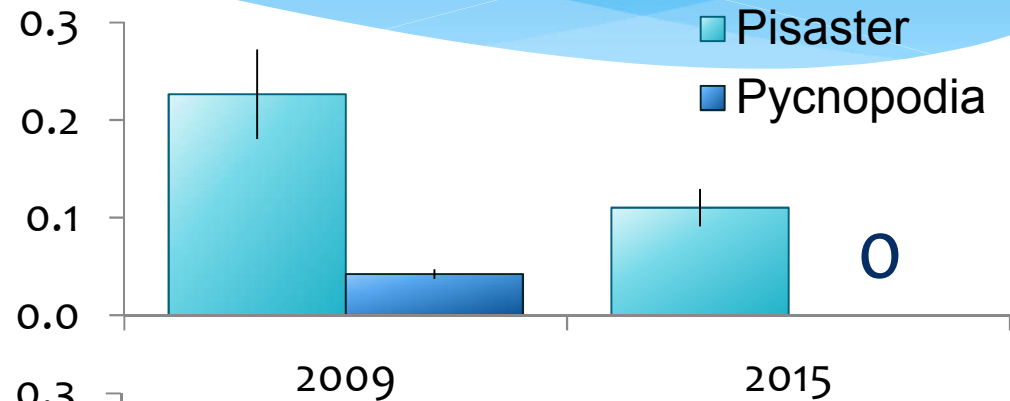


Graphic A. Lauermann

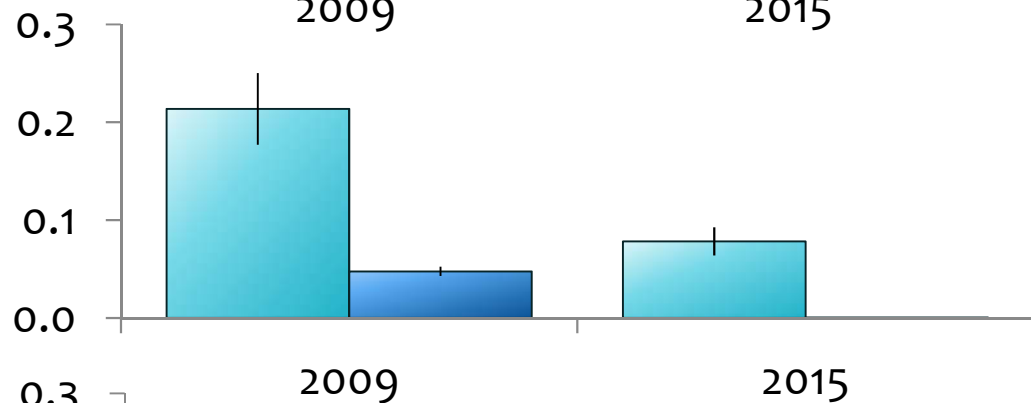
Photo A. Maguire

Seastar Densities 2009-2015

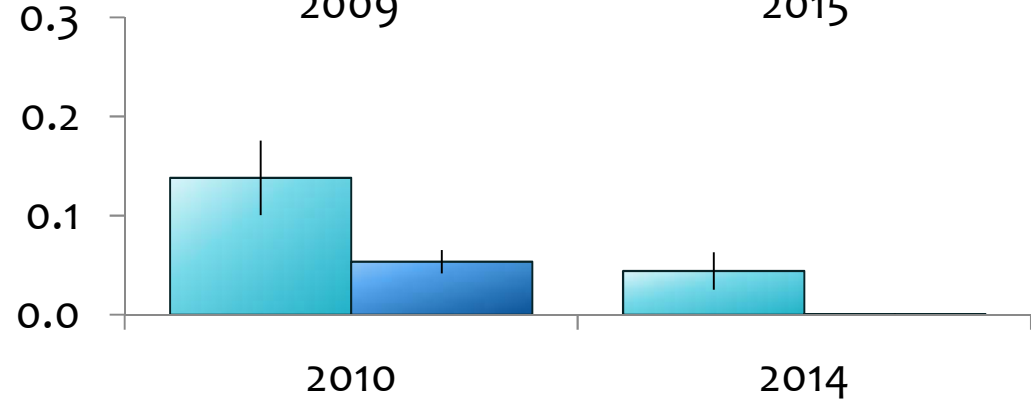
Fort Ross



Timber Cove



Point Arena



Unprecedented Large-Scale Purple Sea Urchin Explosion in 2015



> 60x historic densities in N. California

Reports of high urchin numbers from Central California to Washington State

Photo A. Maguire

The Native Purple Sea Urchin is Amazing

- * can degrow
- * can absorb dissolved organics

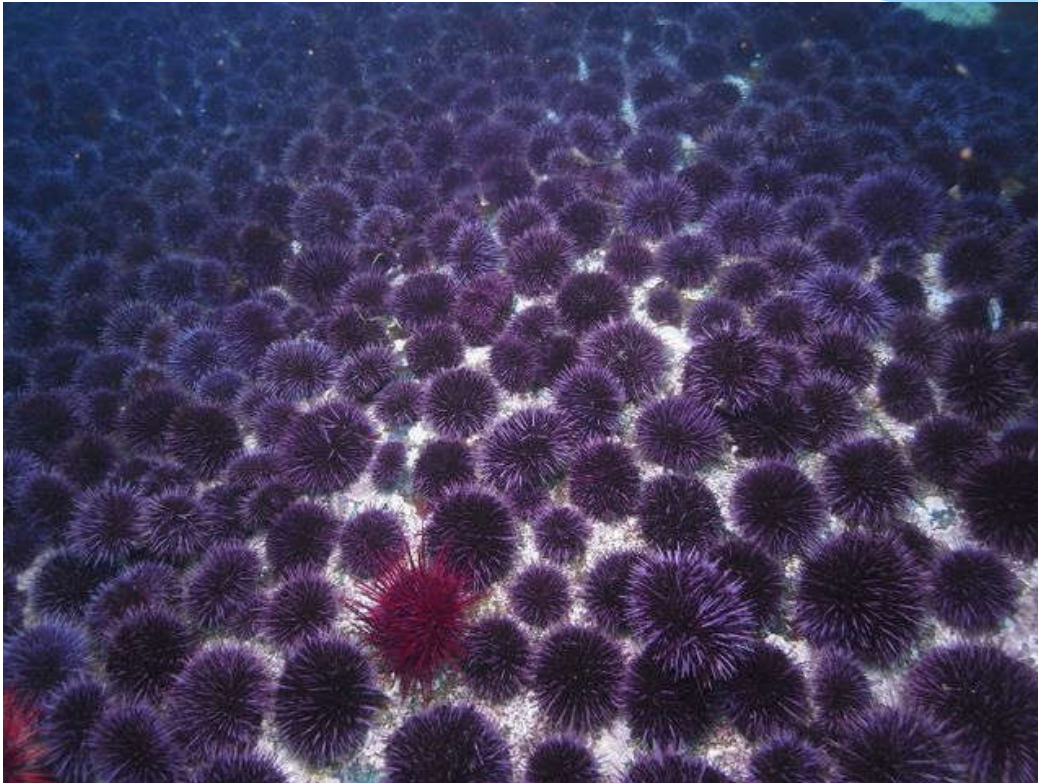
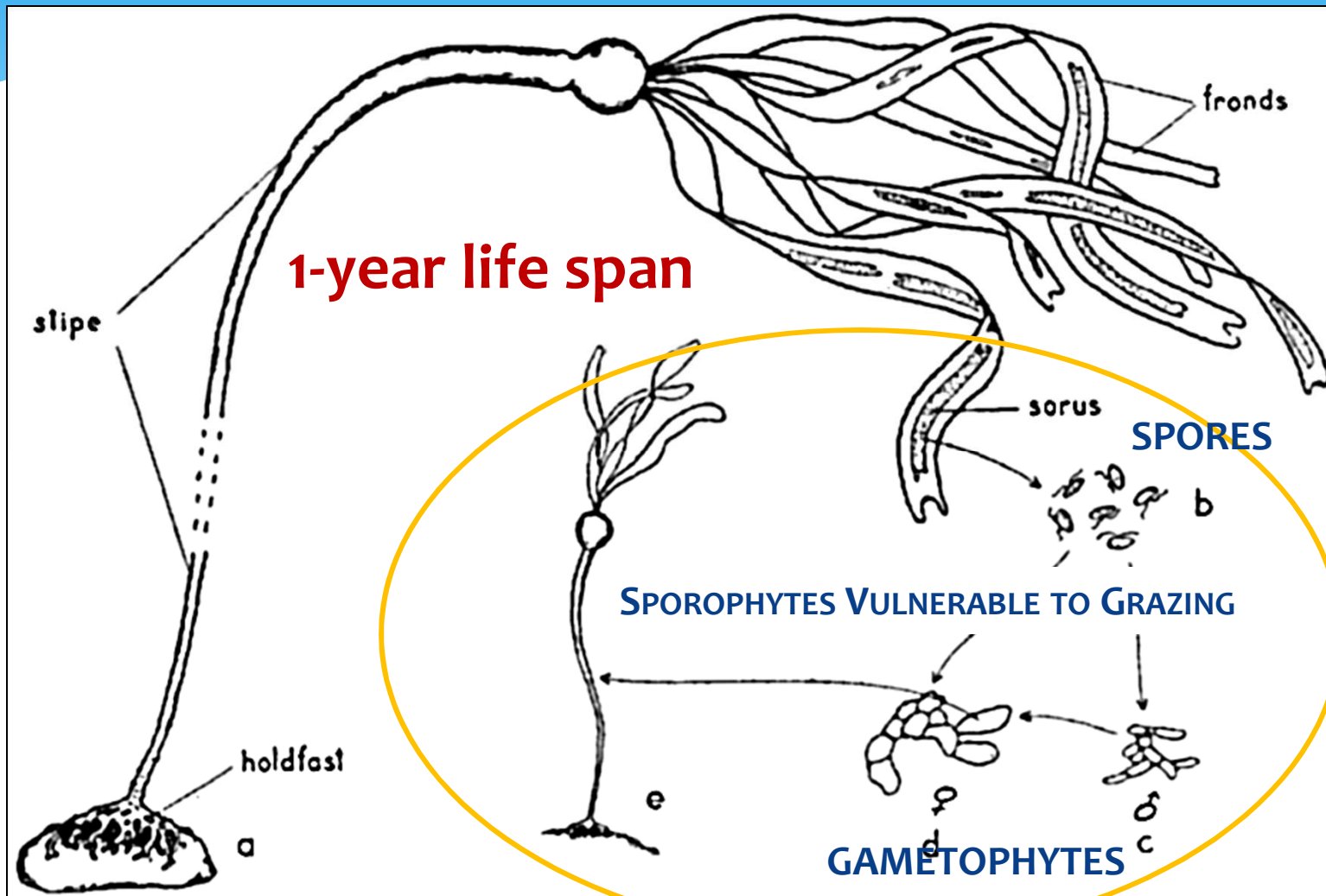
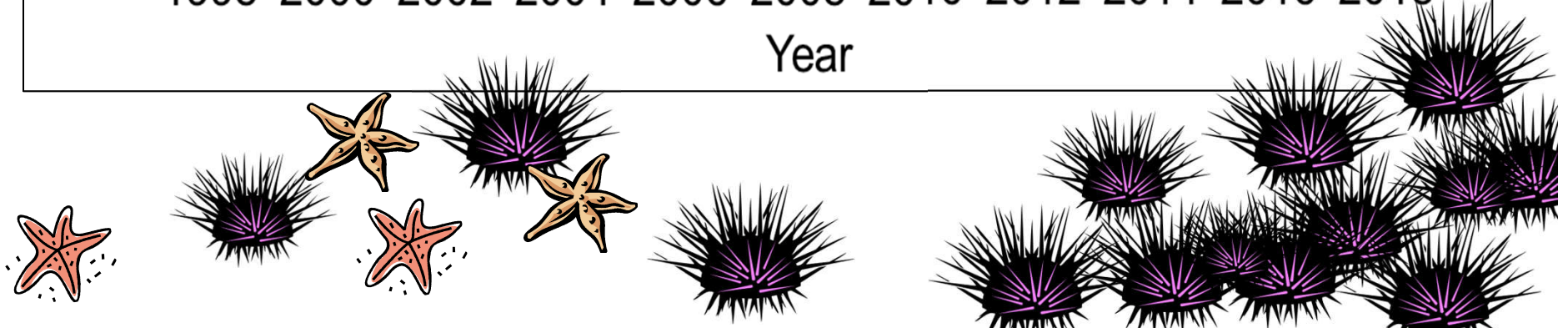
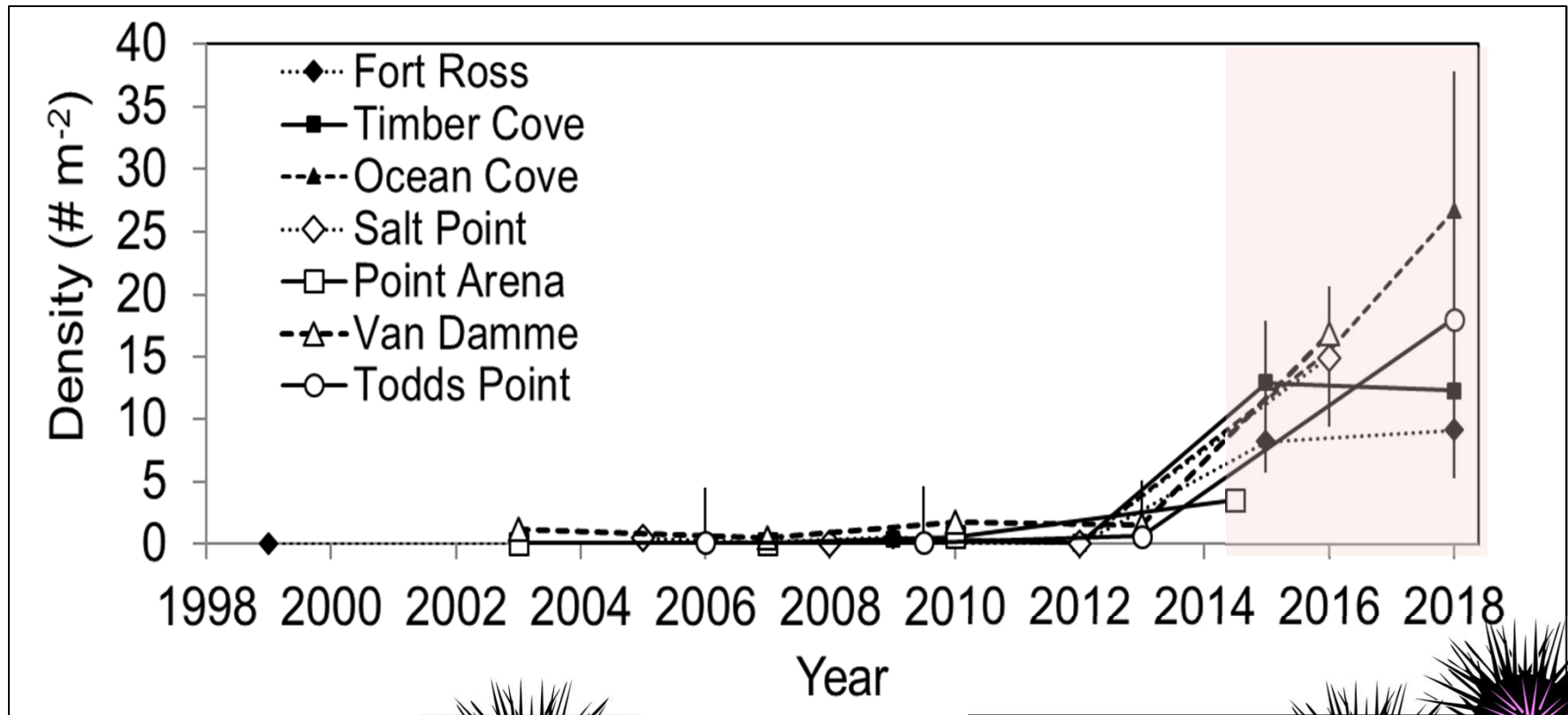


Photo L. Lee

Bull Kelp Life Cycle

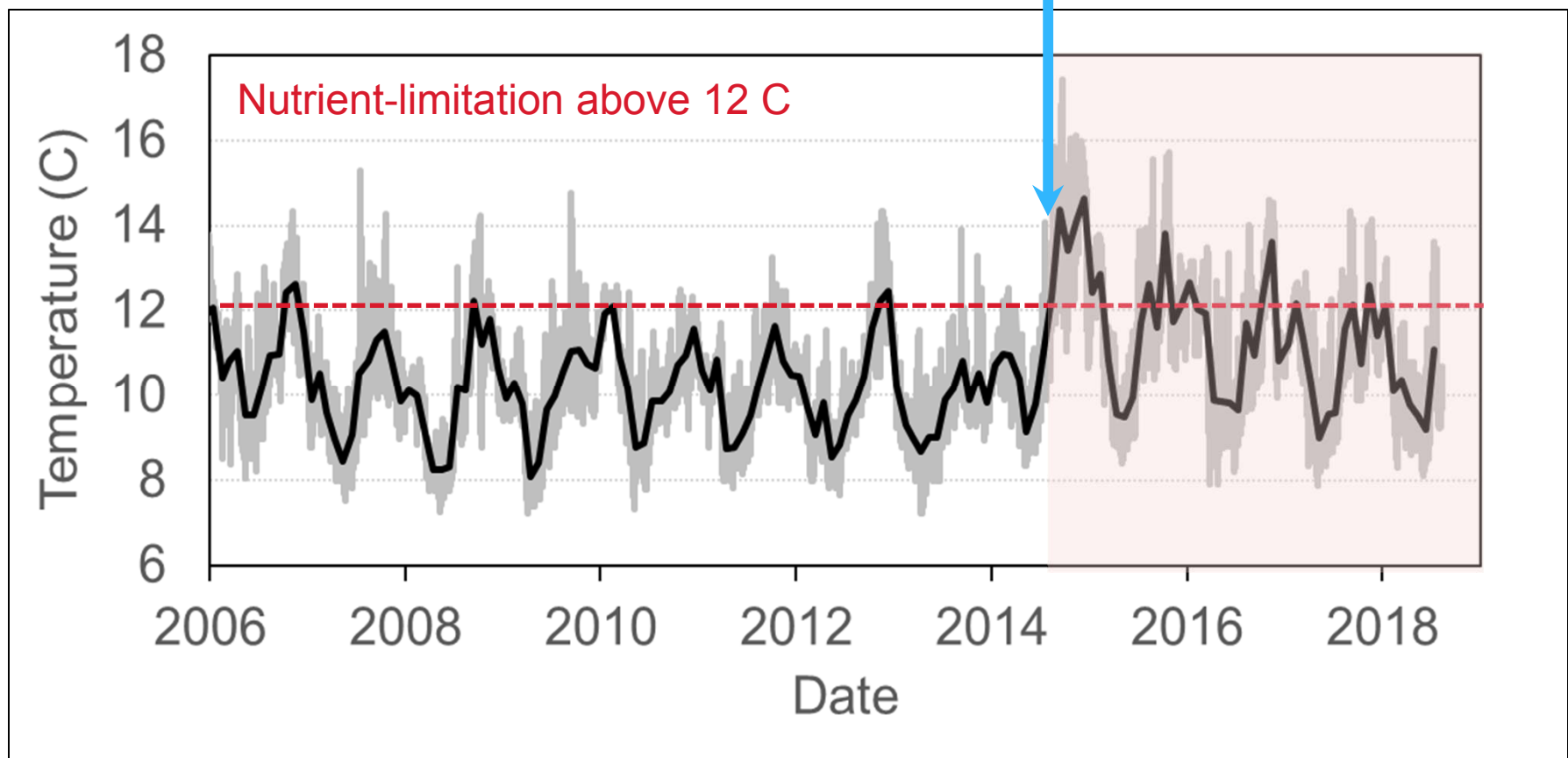


Rapid Increase in Purple Urchin Densities



Persistent Warm Ocean Conditions

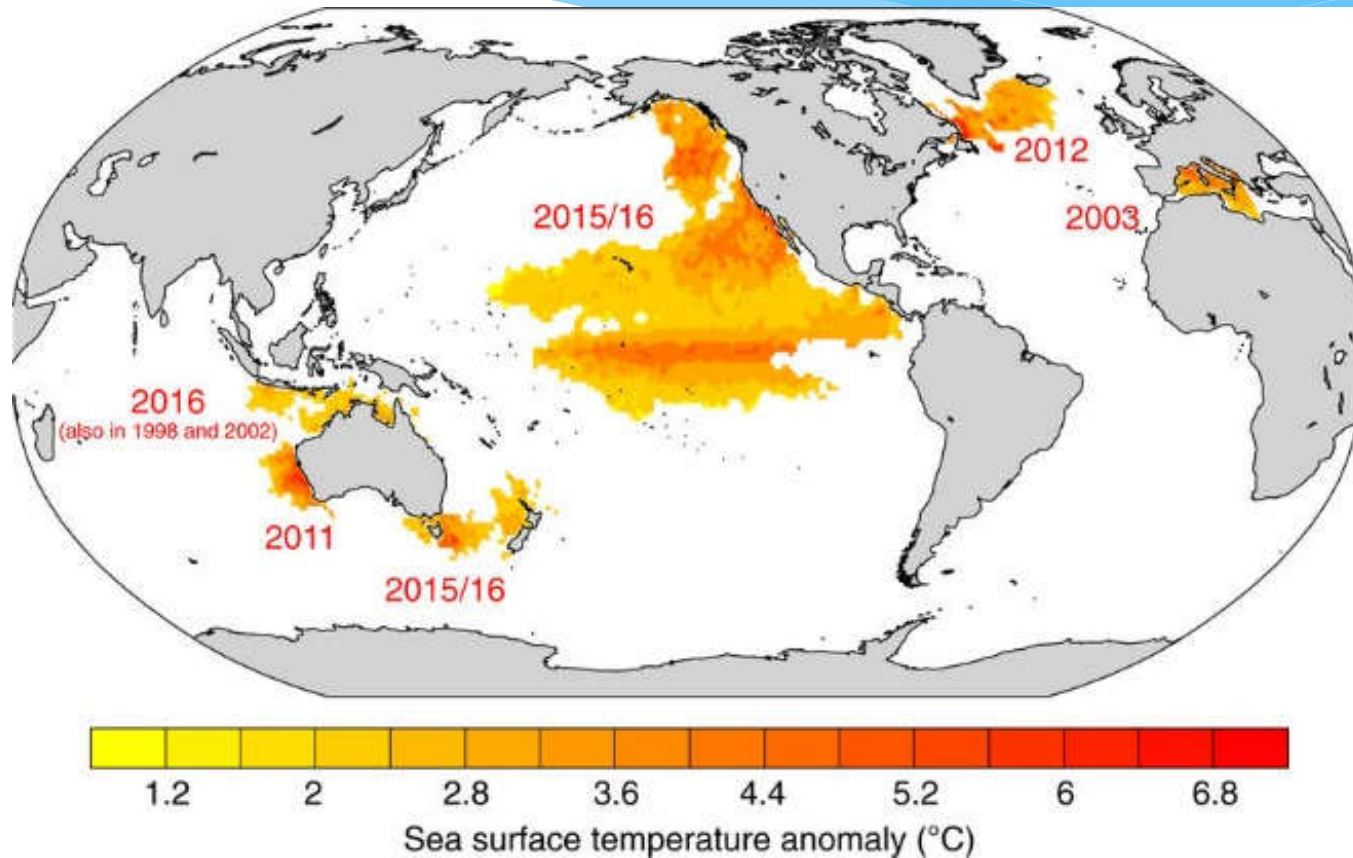
Bull kelp
recruitment failure



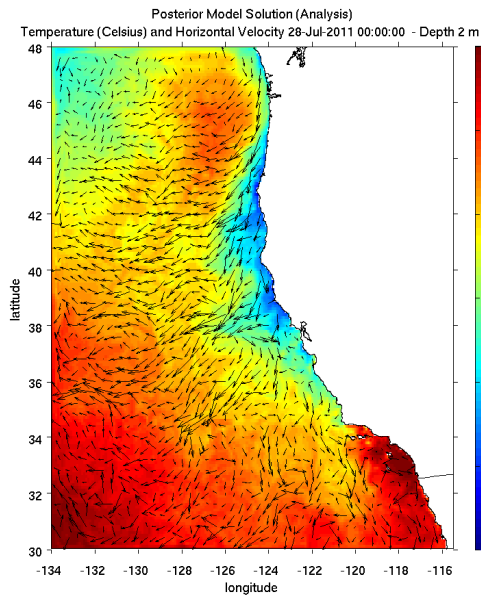
Subtidal nearshore water temperature (10m depth)

Extreme Marine Heat Wave

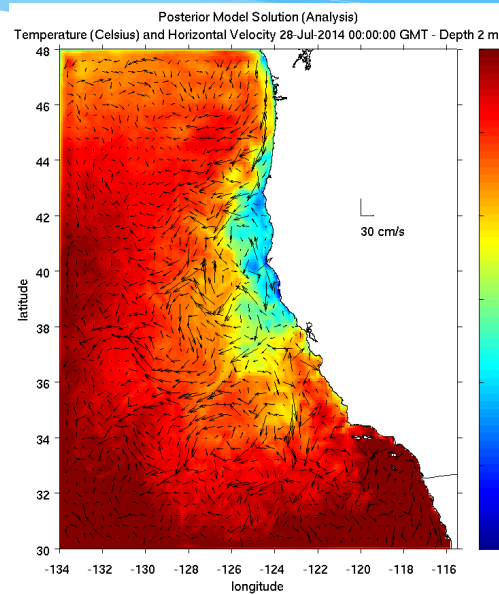
Frölicher and Laufkötter 2018



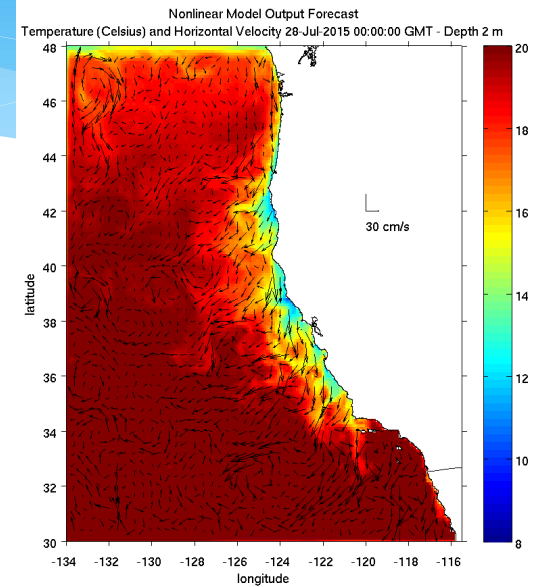
Underlying Stressor Warm Water Conditions



- * July 28, 2011
- * Normal Year



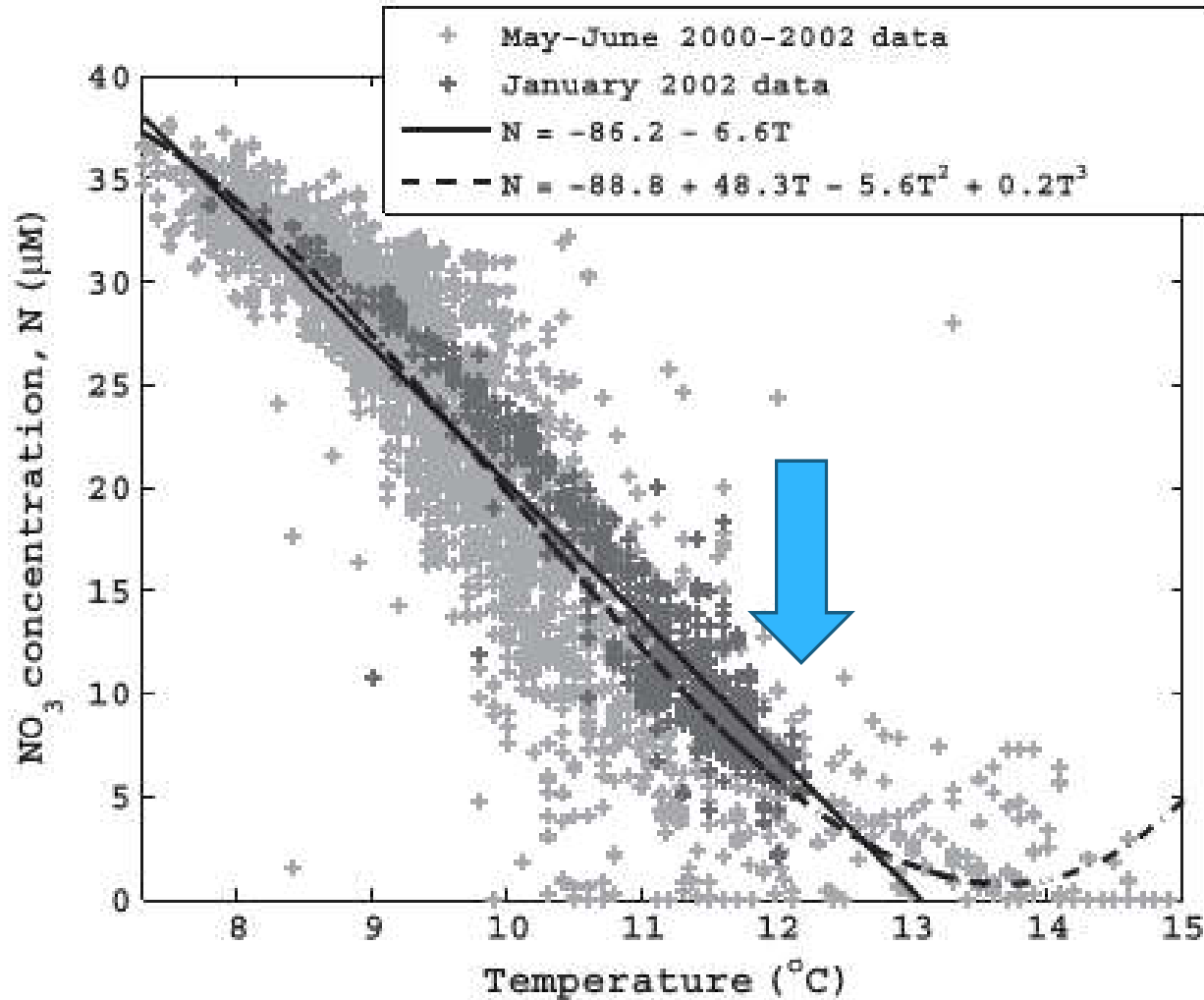
- * July 28, 2014
- * “Warm Blob” Nick Bond
- * Gulf Alaska



- * July 28, 2015
- * Very Strong El Niño
- * Godzilla El Niño

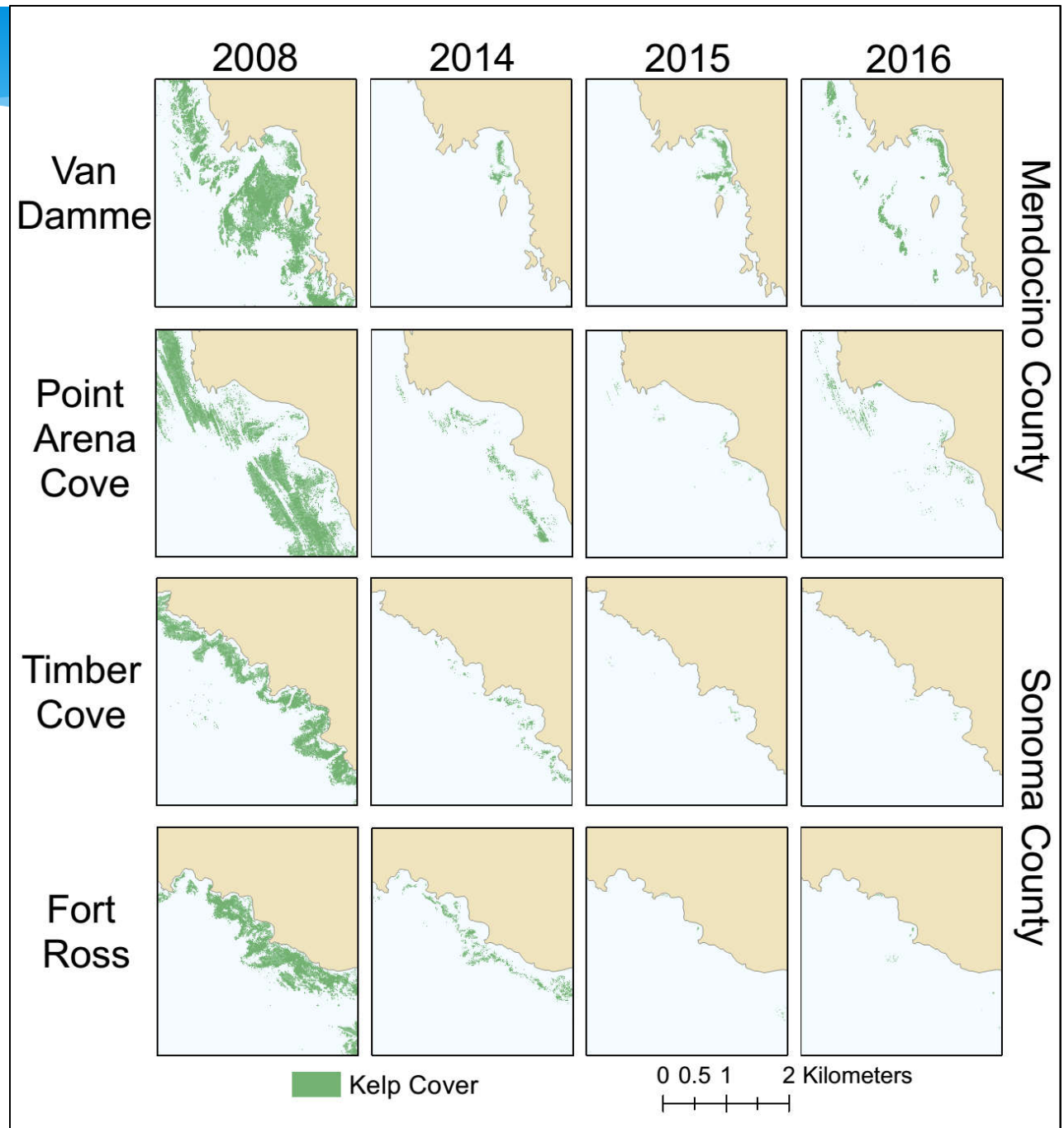
http://oceanmodeling.ucsc.edu/ccsnrt/webplots/latest/latest_SST.png

Bodega Bay Coast: Warm Water = Low Nutrients



Aerial Kelp Surveys (CDFW)

< 5% kelp canopy in Sonoma and Mendocino since 2014



Kelp Deforestation

- * Appears to be increasing worldwide (Steneck et al. 2002)
- * Fishing pressures on herbivore predators, pollution and ocean warming may be enhancing deforestation
- * Unfortunately sea urchin roe is of poor quality in urchin barrens reducing fishing
- * Deforestation impacts species diversity (Graham 2004)

Subtidal Algal Impacts in 2018



Bare Rock

Urchins are eating through the
Crustose coralline algae

Starving Conditions in Northern California



A. Maguire

Red Abalone Health Assessment

Creel surveys

Sonoma, Mendocino, and Humboldt

Spring 2016 and 2017

~6,000 abalone inspected



> 25% of abalone shrunken at key fishery locations

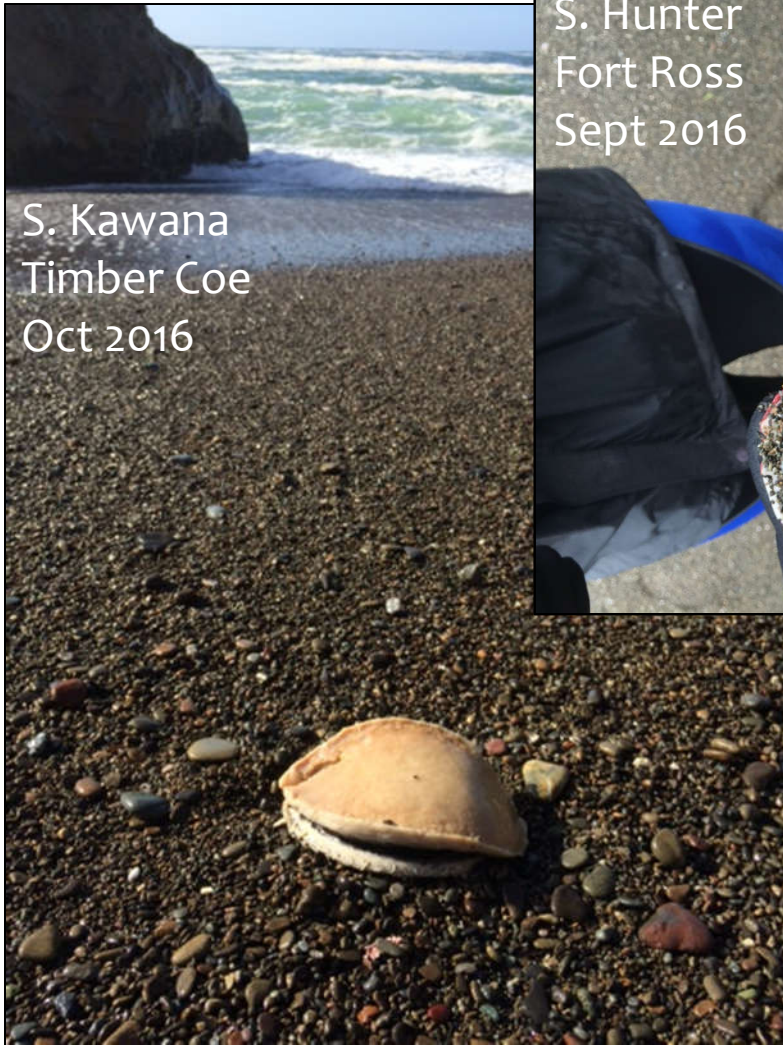
Body Shrinkage
Score 0

Body Shrinkage
Score 1

Body Shrinkage
Score 2

Body Shrinkage
Score 3

Large swells dislodge dying abalone





2017-18 Abalone Density Data

Index Site (Sonoma-SC or Mendocino-MC)	Past Density (ab/m ²) (year sampled)	2017-2018 Density (ab/m ²)	% Decline In Density
Fort Ross (SC)	0.44 (2015)	0.08 (2018)	81%
Timber Cove (SC)	0.38 (2015)	0.21 (2018)	60%
Ocean Cove (SC)	0.44 (2016)	0.11 (2018)	75%
Salt Point (SC)	0.38 (2016)	0.06 (2017)	84%
Sea Ranch (SC)	0.37(2012)	0.27 (2017)	27%
SONOMA AVERAGE	0.39	0.15	61%
Point Arena (MC)	0.66 (2014-15)	0.25 (2017)	62%
Van Damme (MC)	0.33 (2016)	0.15 (2018)	55%
Russian Gulch (MC)	0.60 (2014)	0.05 (2018)	92%
Caspar Cove (MC)	0.35 (2013)	0.01 (2018)	97%
Todd's Point (MC)	0.47 (2013)	0.16 (2018)	66%
MENDOCINO AVERAGE	0.49	0.13	73%
Overall Average	0.44	0.12*	72%

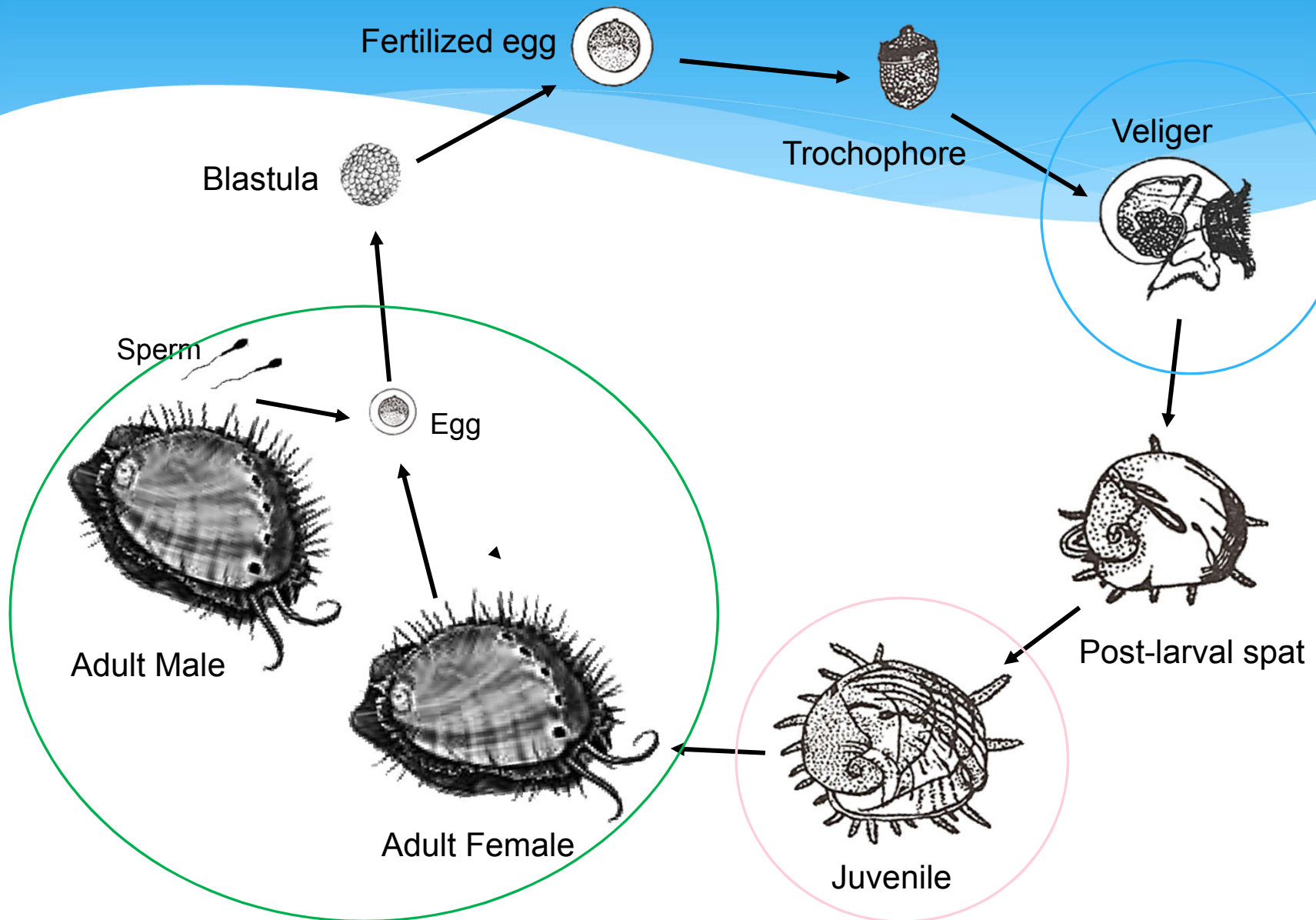
* The ARMP fishery closure is 0.30 abalone/m². The overall average, when including past densities as a proxy for sites not sampled in 2017, is 0.28.

Freshwater flows killed abalone 2019



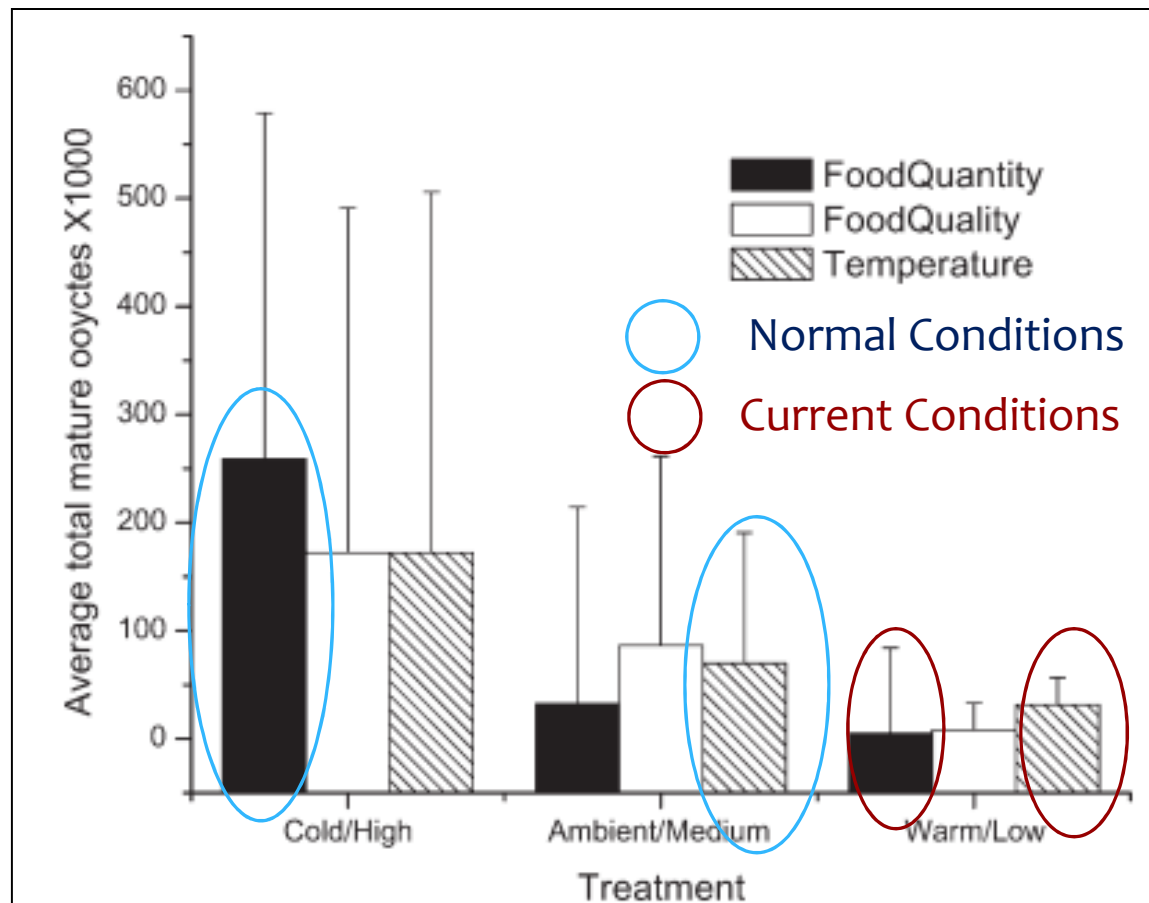
Photos Esquivel

Abalone Life Cycle



Abalone Reproduction

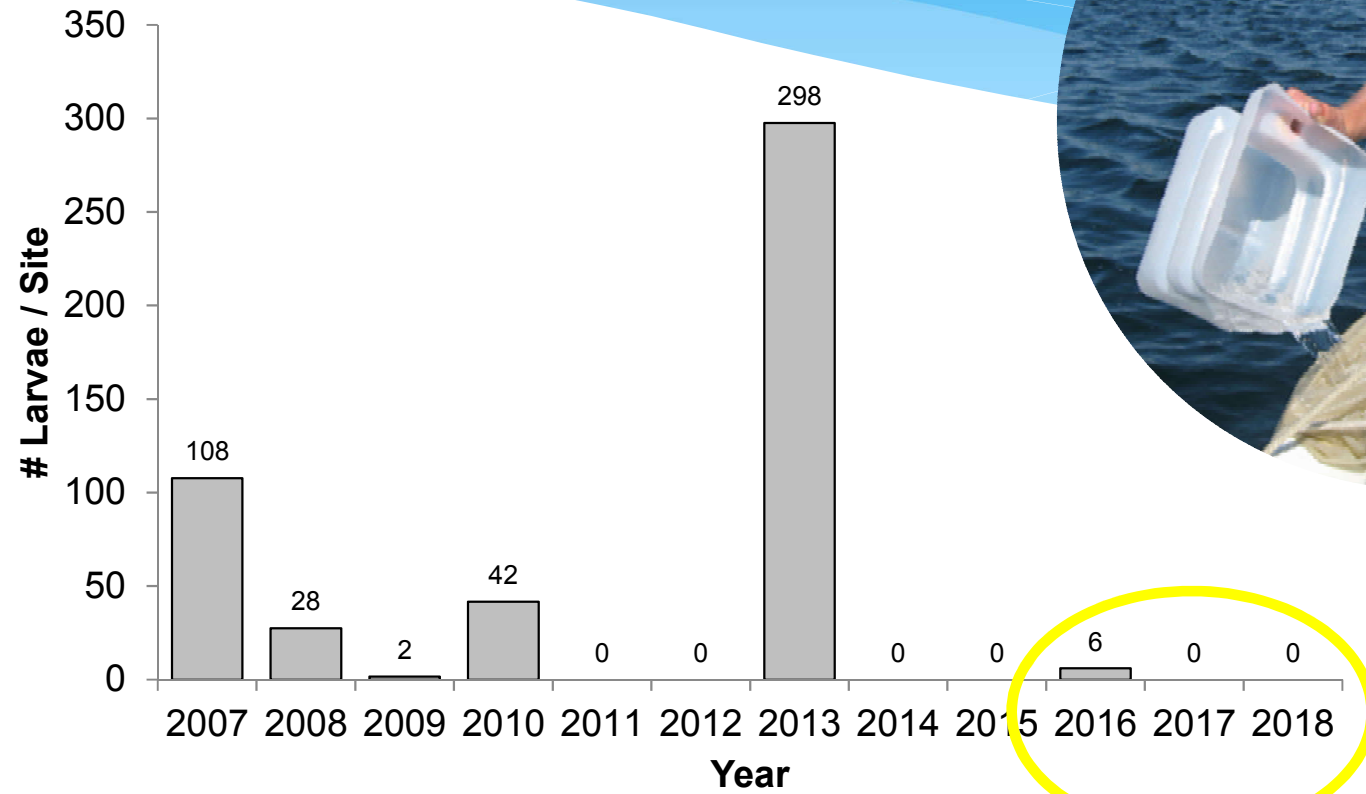
Low food quantity and warm temperatures greatly impacted oocyte production

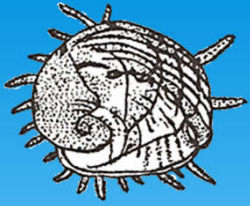


Rogers-Bennett *et al.* (2010)



Abalone Veligers: Plankton





Larvae and Newly Settled Abalone



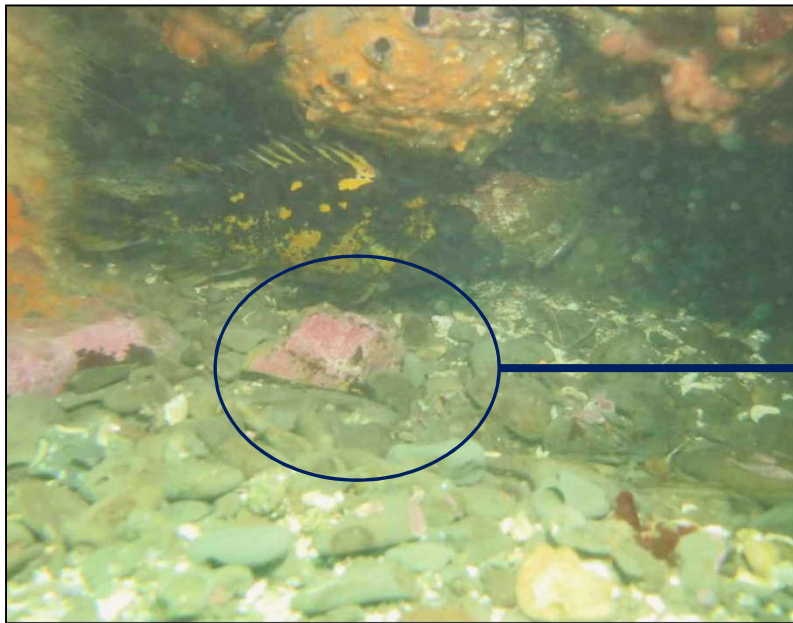
310 µm

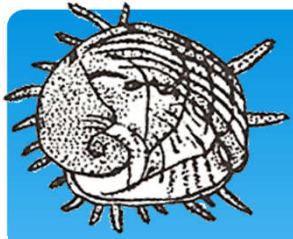


450 µm

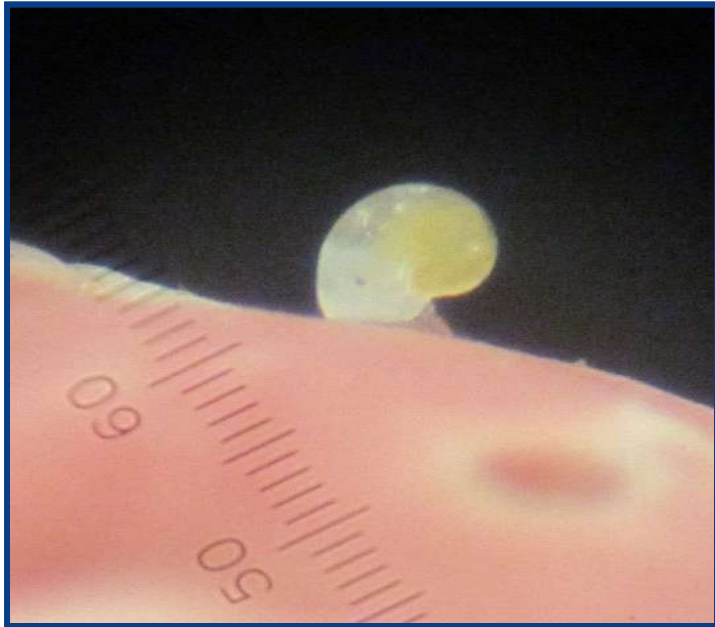


700 µm



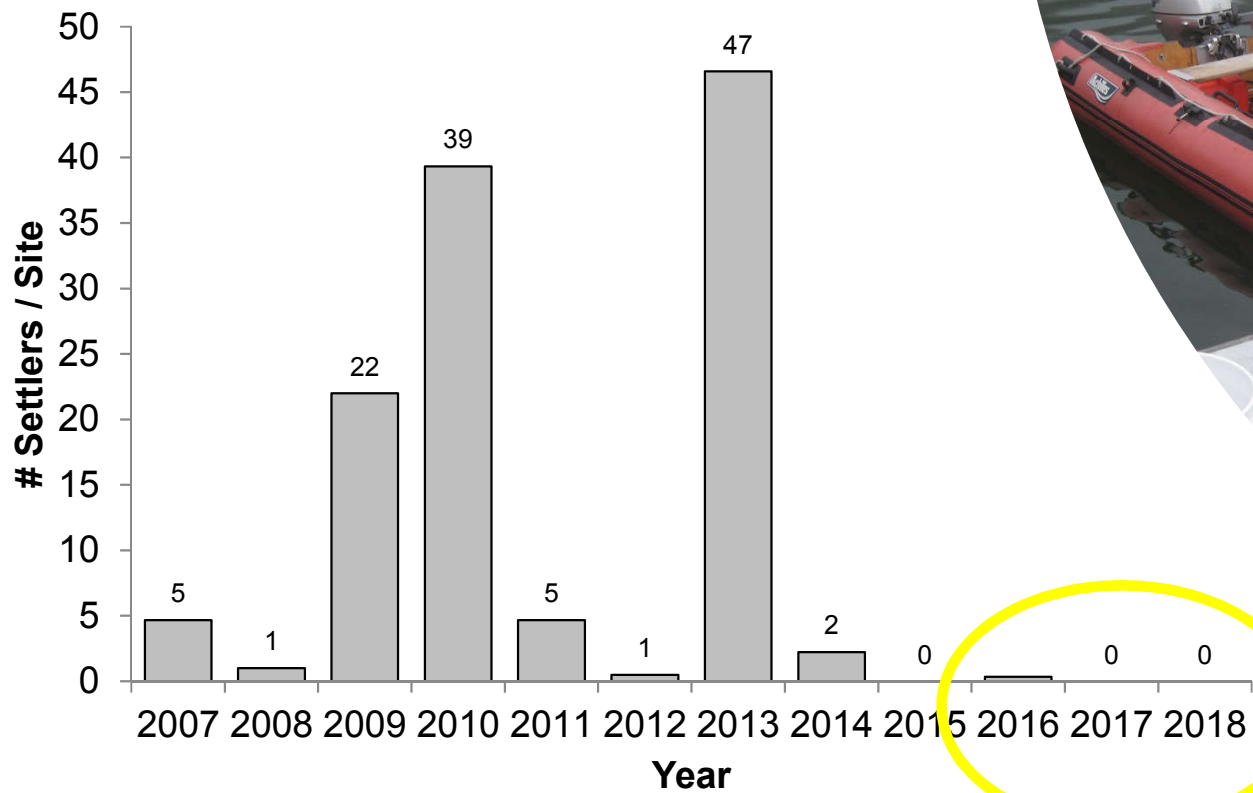


Coralline Covered Boulders





Newly Settled Abalone



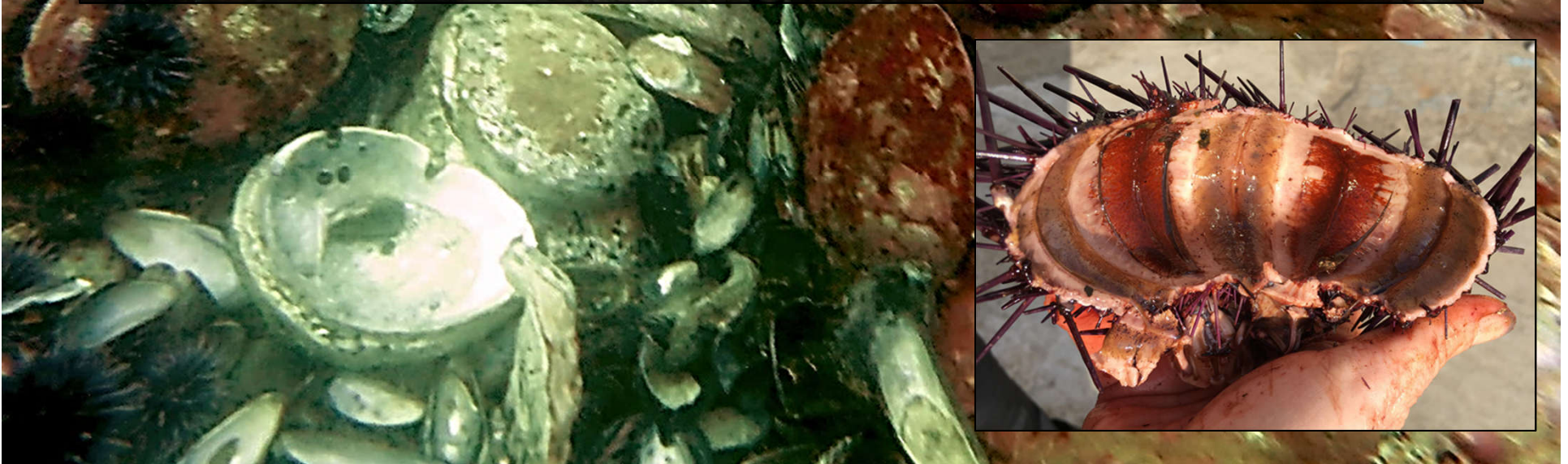
Economically Important Fisheries

- **Recreational Red Abalone**
~\$44 million dollars (non-market value)
- **Commercial Red Sea Urchin**
~\$3 million dollars (ex-vessel value)

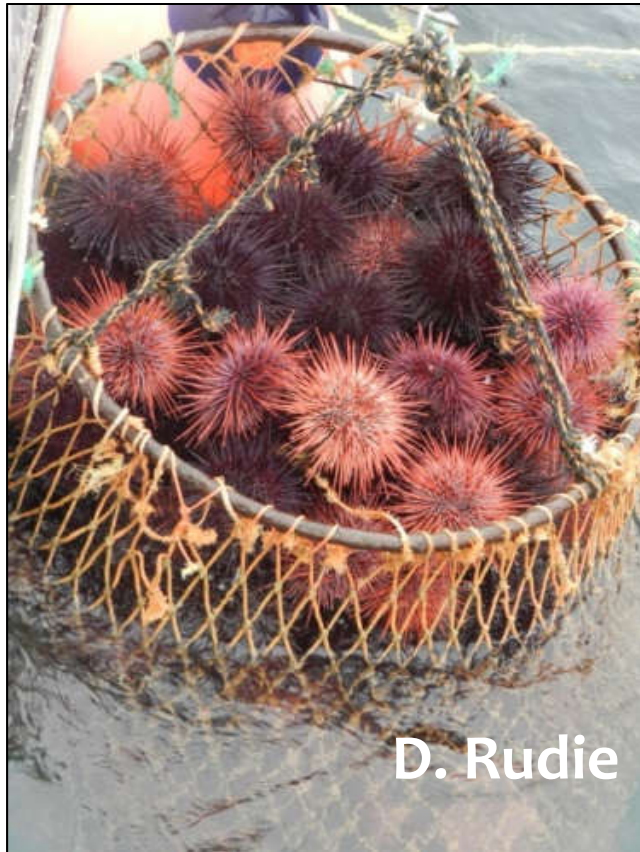


Impacts to Fisheries

- Red abalone fishery closure 2018
- Red urchin fishery
 - 80% decline in catch
 - Requested federal disaster relief



Poor Commercial Red Urchin Fishery Catch



D. Rudie



S. Osman LA Times

Kelp Deforestation

- * Increasing worldwide (Steneck et al. 2002)
- * Fishing pressures on herbivore predators, pollution and ocean warming may be enhancing deforestation
- * Unfortunately sea urchin roe is of poor quality in urchin barrens reducing fishing
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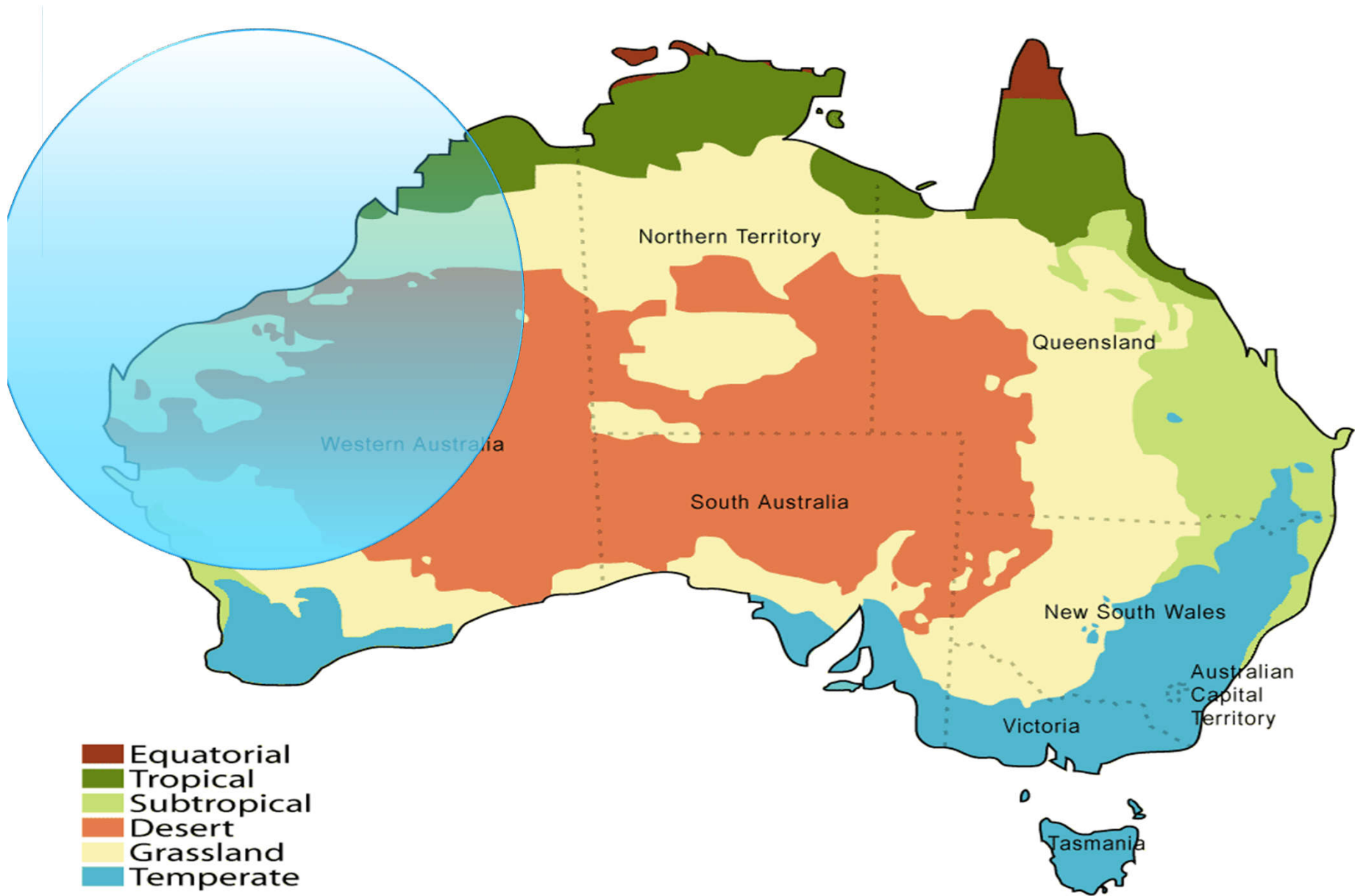
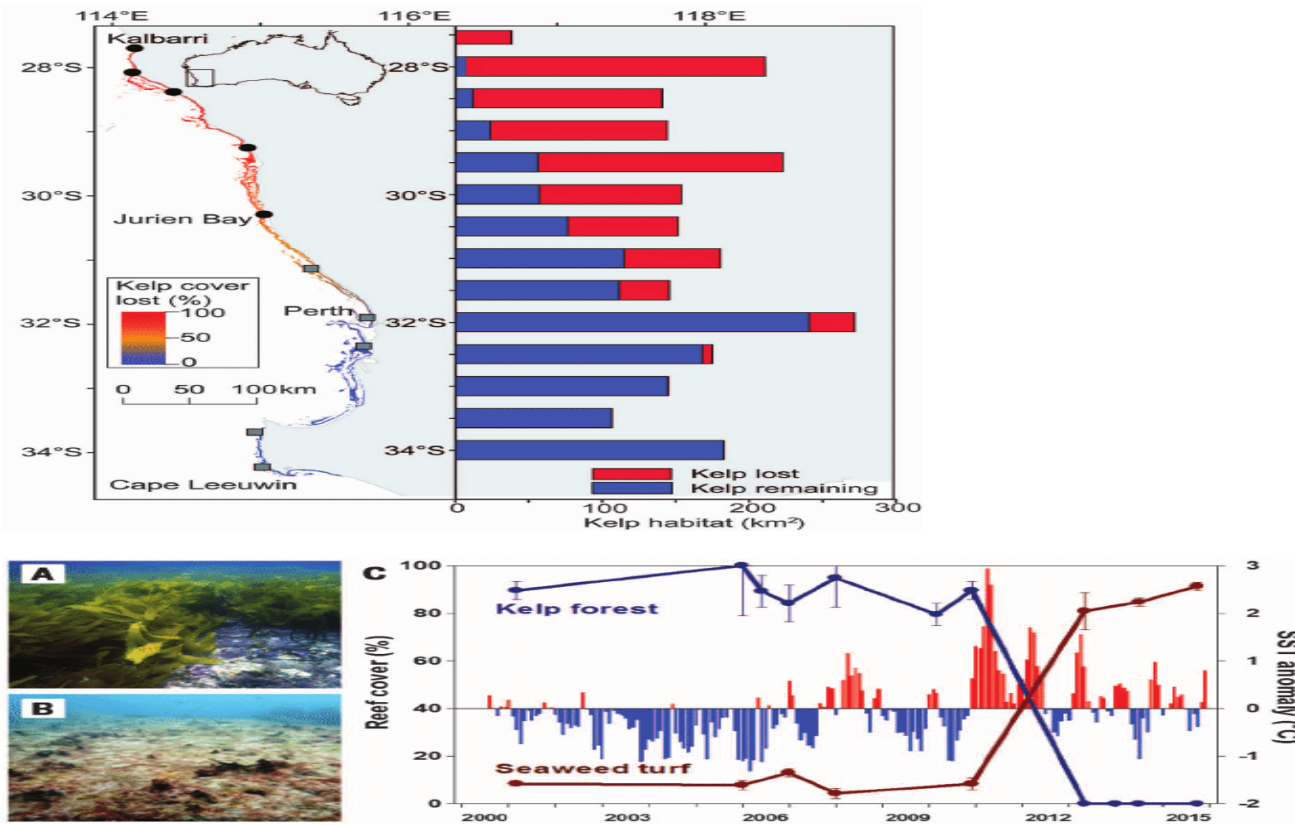


Fig. 3. Western Australia recreational abalone fishery closed.

Marine Heat Wave 2011

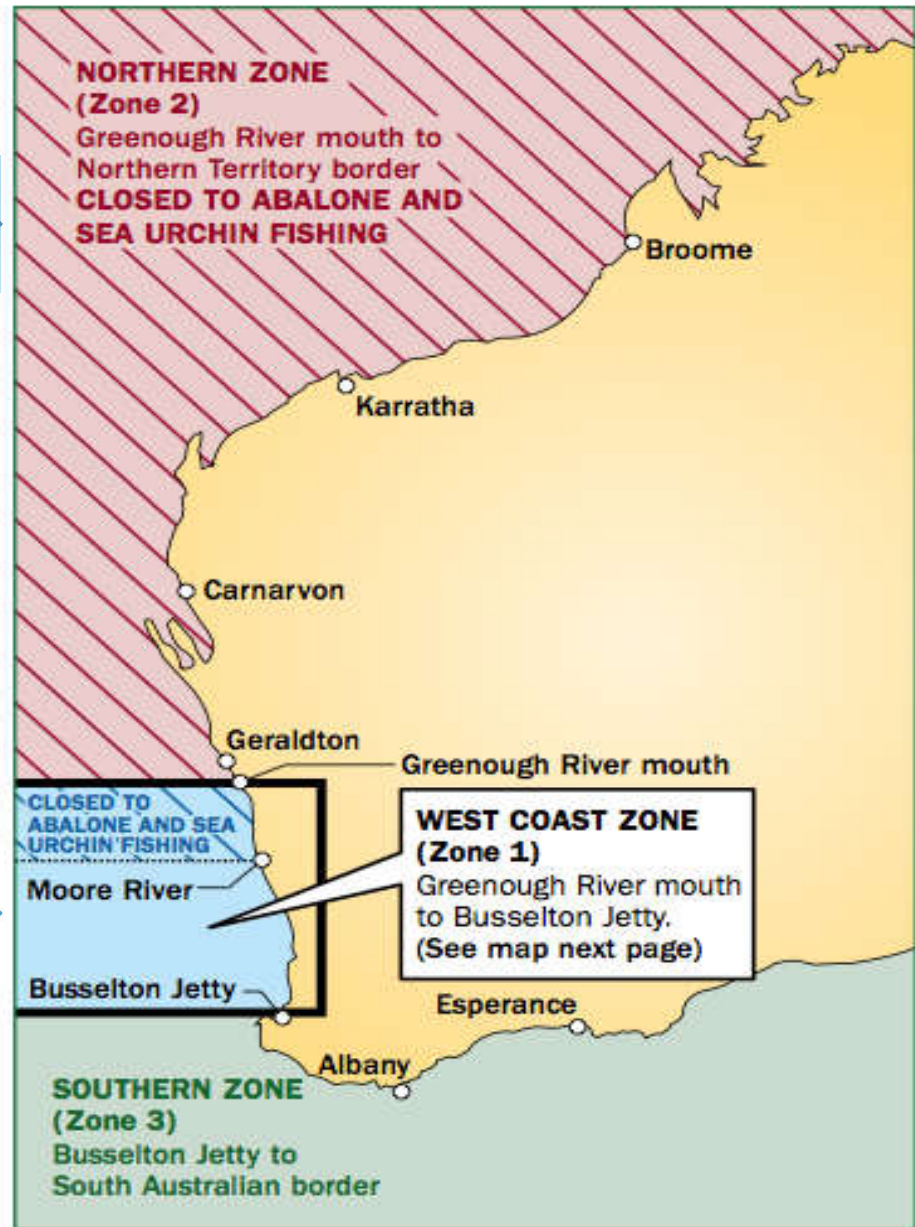
Kelp Deforestation Western Australia



Wernberg et al. 2016 Science 353: 169-172.

Total closure of abalone fishing due to 2011 heat wave

- from Moore River to the state's border with the Northern Territory
- Recreational
- Commercial



Slide T. Lazootin

Fig. 4. Map represents close up of recreational abalone fishery closures in Western Australia. All areas north of Moore River were closed in 2011 and remain closed.

Monterey Region

Status:

- * 2018 status sea otters N=3090
- * Reef Check indicates purple sea urchins moving in today
- * Coral street is now a sea urchin barrens



Photo US Fish and Wildlife Service

Kelp Forest Fisheries Are At Risk spreading in California

Status:

- * Purple urchin barrens
- * Poor red urchin and abalone fisheries
- * Potentially negative impacts to rockfish populations
- * Socioeconomic impacts to coastal communities



A. Maguire (CDFW)

Kelp Ecosystem & Landscape Partnership for Research on Resilience



- Broad partnership of stakeholders, scientists, and government agencies
- Focus on bull kelp forest ecosystem
 - Fill critical knowledge gaps
 - Assess recovery potential
 - Support rapid widespread kelp recovery by maintaining spore production along the coast
- Support commercial markets for purple urchins

KELPRR Workshop BML

April 2019

- * Kelp Recovery Action Plan
- * HELP THE KELP Campaign
- * Facebook
- * Website



Sheila Semans
Noyo Science Center



Dr. Cynthia Catton

Rietta Hohman Greater Farallones Assoc.

Charting the Path Forward

- Guidance document for collaborative kelp recovery
 - Research & Monitoring
 - Education & Outreach
 - Strategic Site Selection

Greater Farallones Assoc.

<https://farallones.org/wp-content/uploads/2019/06/Bull-Kelp-Recovery-Plan-2019.pdf>

Sonoma-Mendocino Bull Kelp Recovery Plan

For Greater Farallones National Marine Sanctuary
and California Department of Fish & Wildlife



April 2019

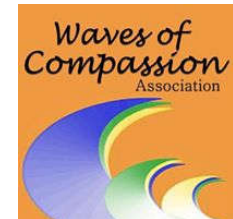
KELPRR Partnership



URCHINOMICS



NATIONAL MARINE
SANCTUARIES



Fortunate Farm



URCHINOMICS

- * Restorative Ranching
- * Solution Sea Urchin Harvest
- * Sea Urchin Ranching
- * Produce Quality Sustainable Seafood
- * Kelp and Ecosystem Restoration
- * Job creation

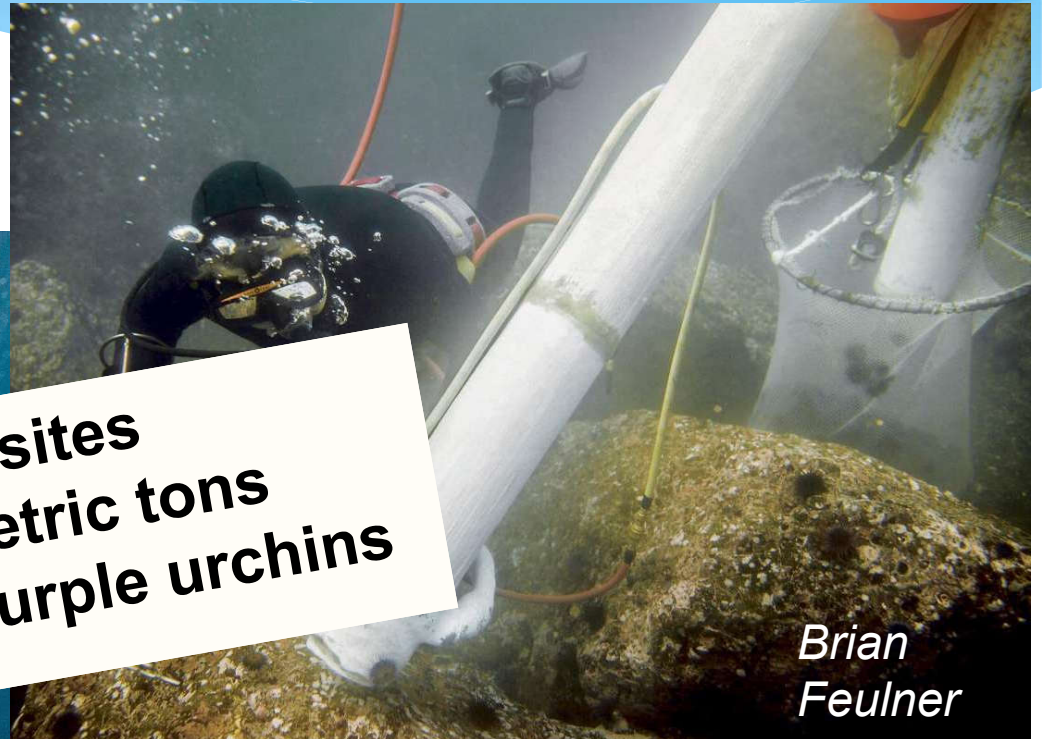
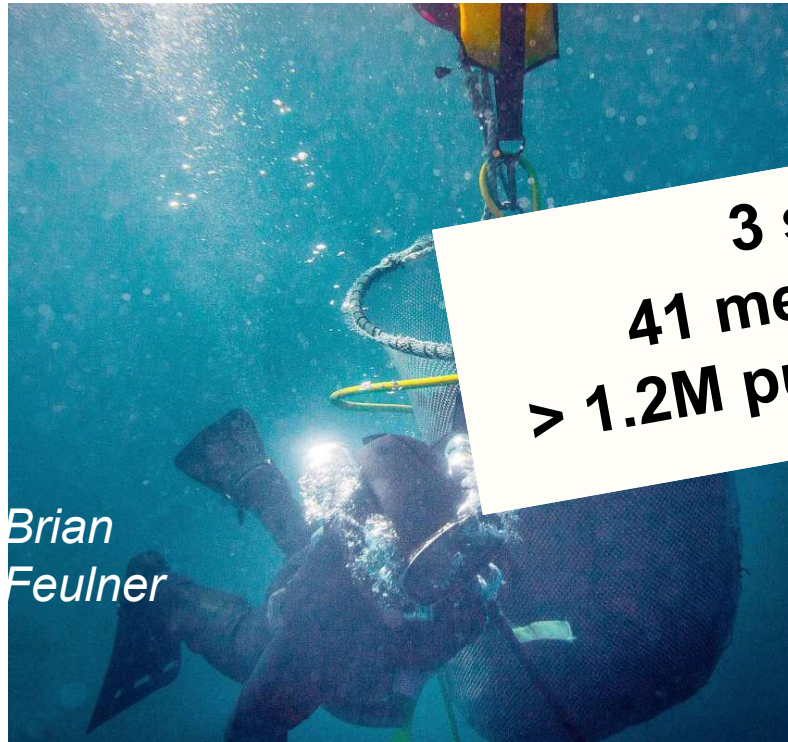


Edible Marin and wine country



Sea Urchin Ranching. Photo Murasaki

Coordinated Commercial Harvest in 2018



3 sites
41 metric tons
> 1.2M purple urchins

CDFW estimates harvest and records sizes

Divers plan recreational harvest of purple sea urchins

- * Change in Regs
- * Old limit 35 day
- * New limits
- * 40 gallons day
- * Hum, Men, Son
- * No possession limit
- * DFW Code Section 29.06 as of 2019



Coordinated Recreational Harvests in 2018 (Russo)



**4 sites
40-100 divers / weekend
> 2,000 gal / weekend
> 200,000 purple urchins harvested**



Josh Russo Waterman's Alliance



URCHINOMICS

Purple Urchin Ranching

- Trials at SDSU and BML
- Trials currently in progress!





URCHINOMICS

Purple Urchin Feeding Experiments BML July 2019



Barrens Urchins July 2019 Rogers-Bennett & Kuwata

Important Current Work

Continue Tracking:

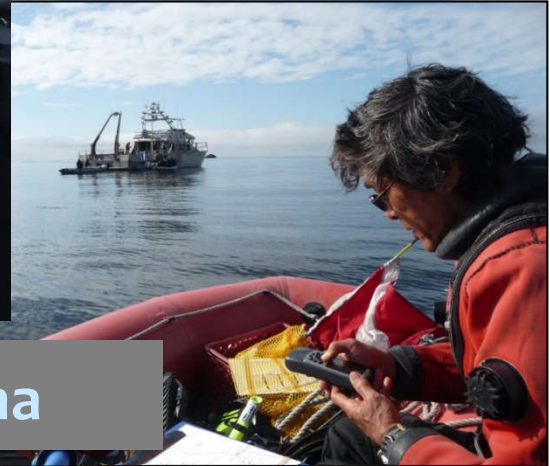
- Ocean conditions
- Ecosystem community structure
- Sea star and urchin populations
- Abalone Health and Reproduction
- Bull kelp distribution and abundance

Conduct bull kelp restoration experiments:

Help develop purple urchin markets:

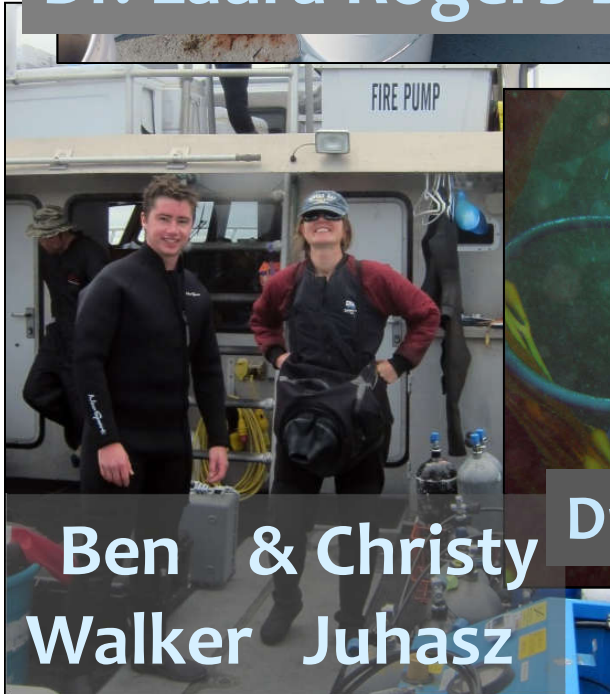
- Experimental urchin harvesting
- Warm water impacts on spore / gametophytes
- Microclimate and resilience

Questions Welcome



Dr. Laura Rogers-Bennett Shelby Kawana

**Jerry Kashiwada
Katie Sowul**



**Ben & Christy
Walker Juhasz**



Dr. Cynthia Catton



Tallulah Winquist

