Using long-term rocky intertidal monitoring data to assess change and inform policy

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pacificrockyintertidal.org











Outline

- General MARINe overview
- Olympic Coast trends
- Sea star trends and SSWD
- New findings from coast-wide analyses

Multi-Agency Rocky Intertidal Network

General goal: To develop a long-term, spatially extensive program providing baseline data in areas typically having none in order to assess the structure and dynamics of rocky intertidal communities

Key assets include:

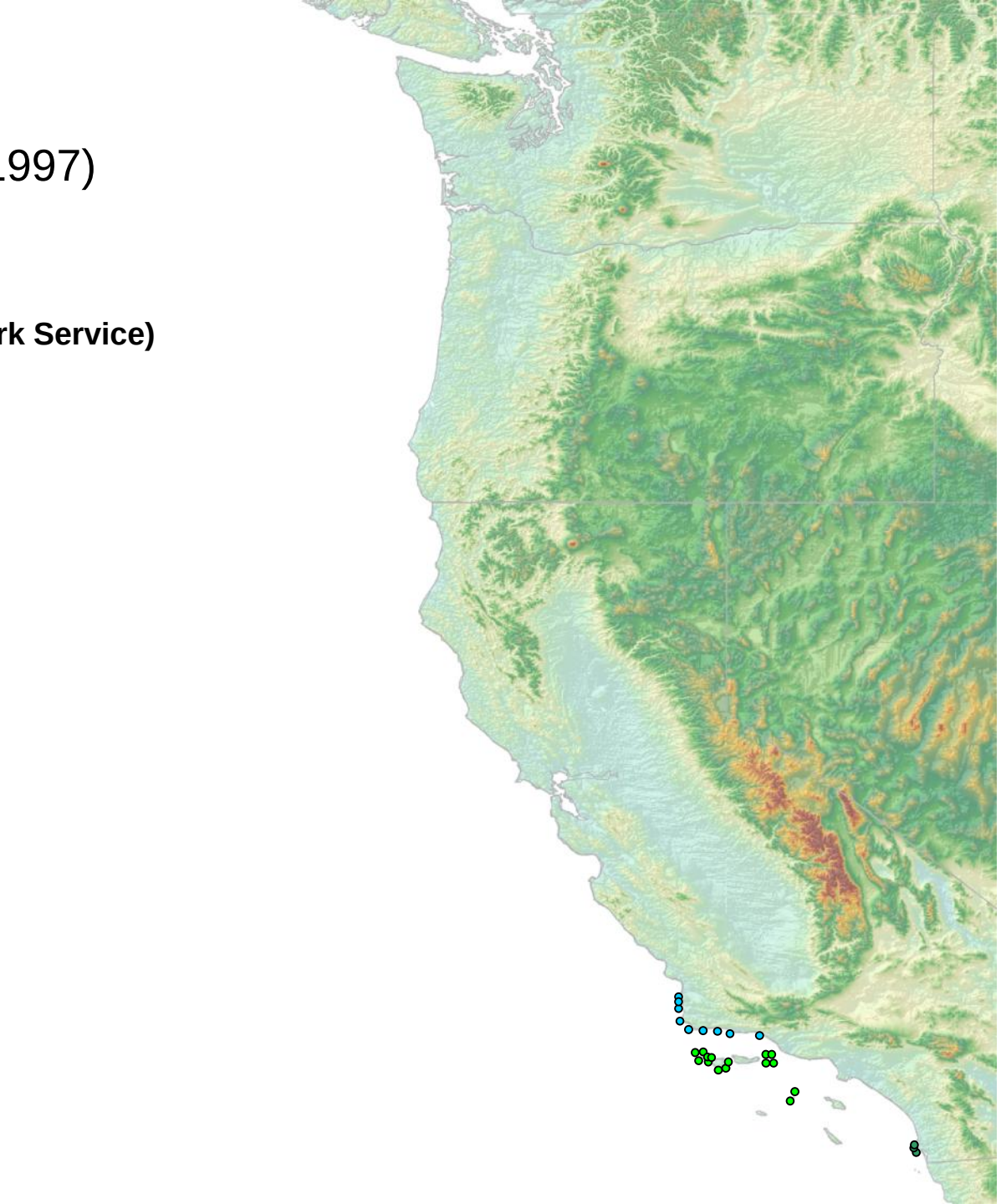
- **Standardized, vetted protocols**
- **A network of monitoring sites that provide**:
  - A baseline from which to assess change in ecological communities
  - Specific approaches for evaluation of questions of special interest (e.g., oil spills, endangered species, disease, climate change, fisheries management, coastal resilience)
- **Centralized database**
- **A set of web-based visualization tools for the public, managers, policy makers and other scientists**
- **A diverse and buffered funding model**

1992

(MARINe officially established 1997)

MARINe partners

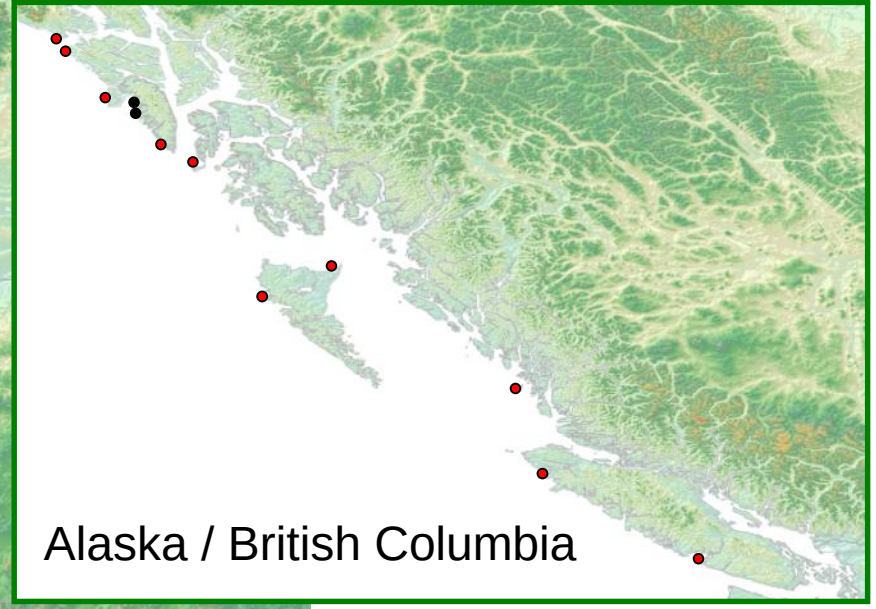
- Channel Islands National Park (**National Park Service)**
- Cabrillo National Monument
- MMS (**BOEM**)

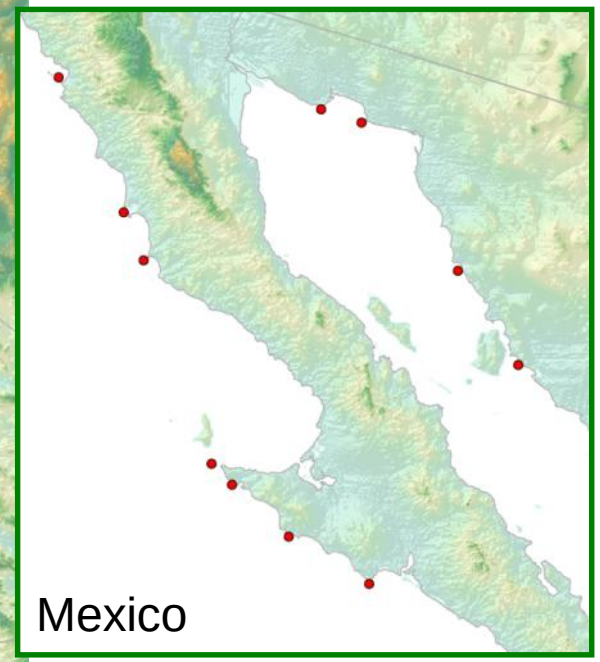


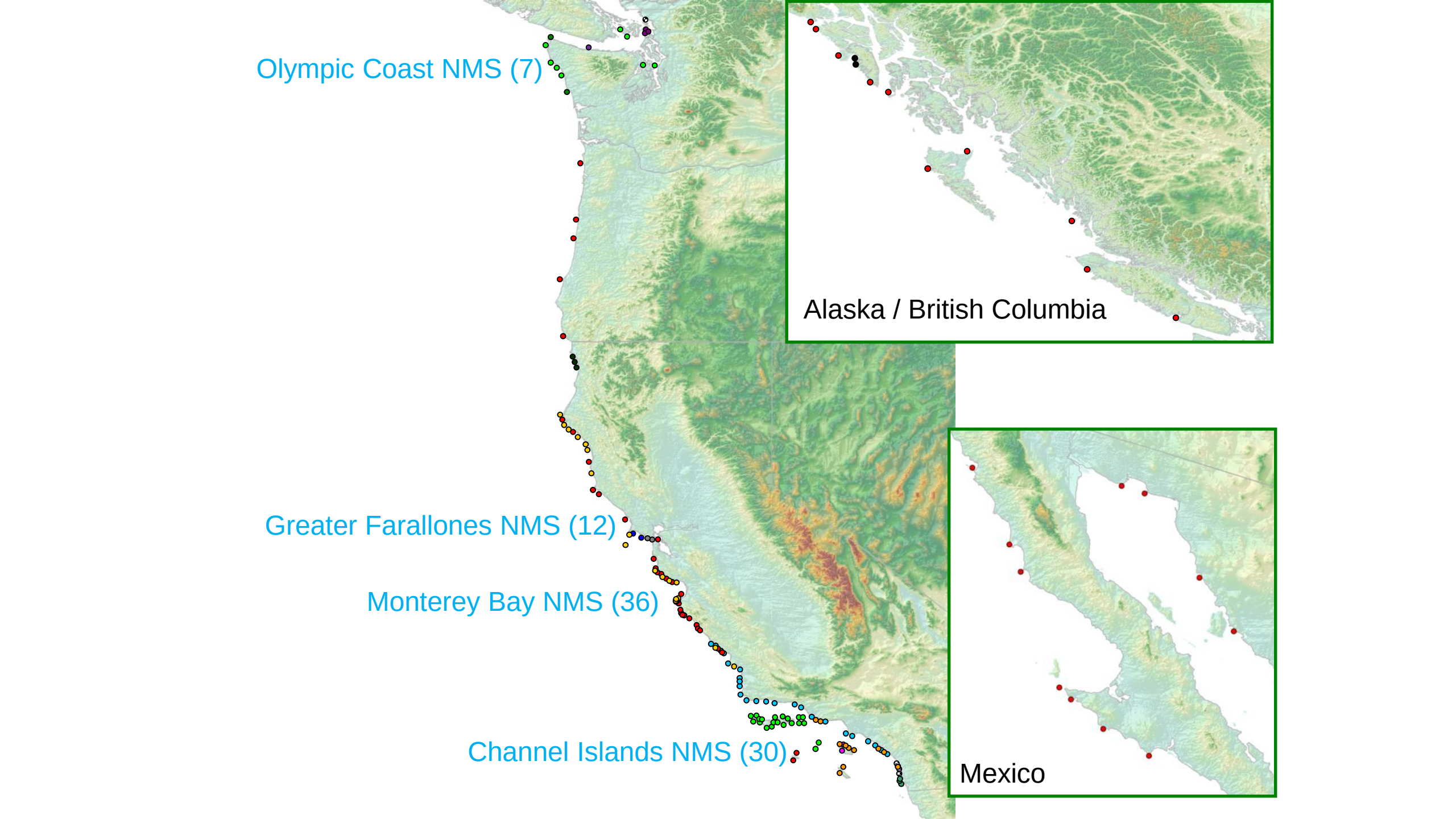
2019

MARINe partners

- Channel Islands National Park (**National Park Service)**
- Cabrillo National Monument
- **BOEM**
- CA Coastal Commission
- US Navy
- Tatman Foundation
- **PISCO**
- Redwood Nat'l & State Parks
- Monterey Bay Nat'l Marine Sanctuary
- Point Reyes Nat'l Seashore
- Golden Gate National Recreation Area
- Olympic National Park
- Olympic Nat'l Marine Sanctuary
- Padilla Bay National Estuarine Research Reserve
- CA State Water Board
- Sitka Sound Science Center
- Feiro Marine Life Center
- **Ocean Protection Council (CA MPAs)**
- WA Dept. of Natural Resources
- University of Washington
- U.S. Airforce



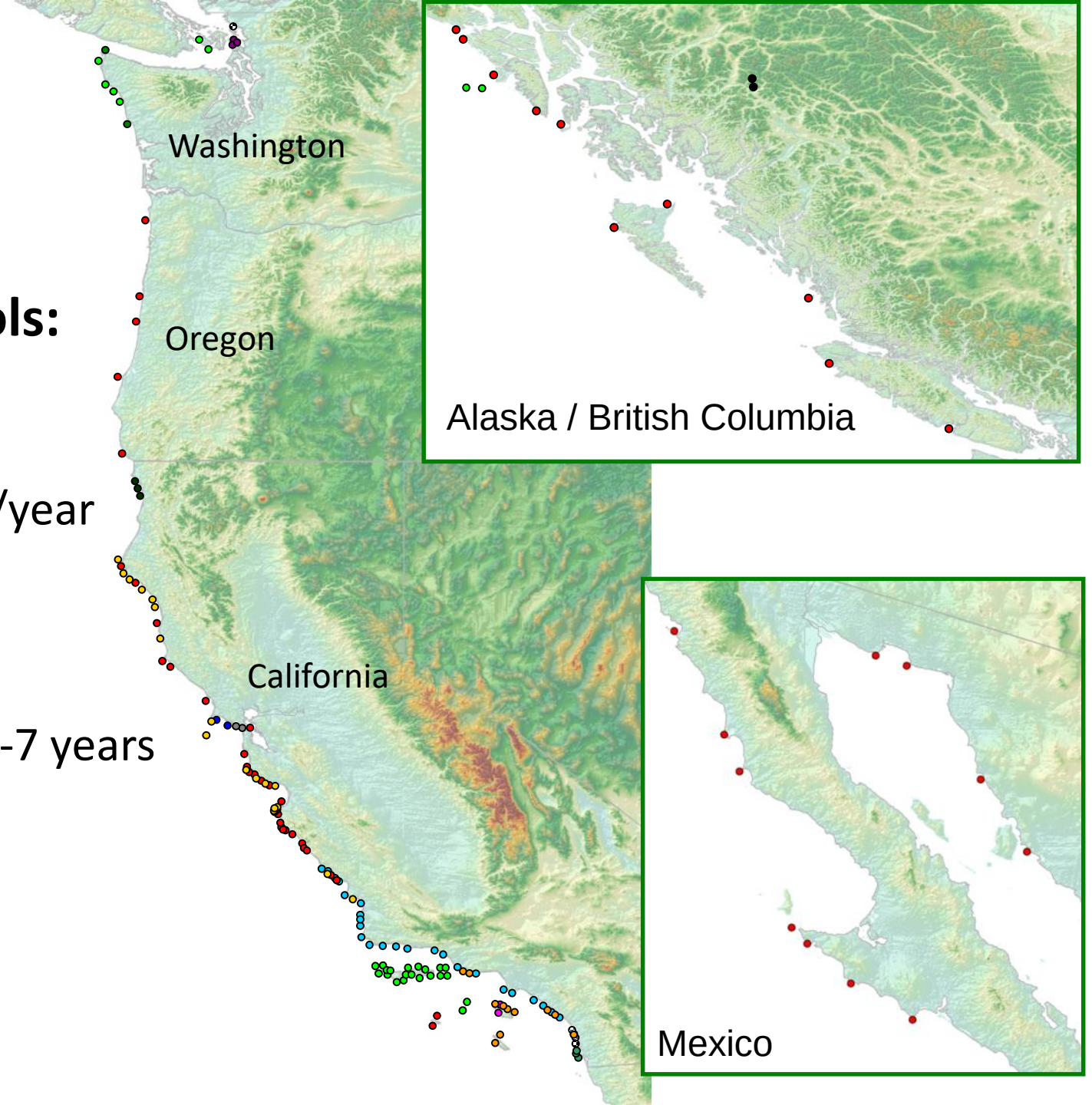



Olympic Coast NMS (7)
Alaska / British Columbia
Greater Farallones NMS (12)
Monterey Bay NMS (36)
Channel Islands NMS (30)
Mexico

Two sets of protocols:

1) “Long-Term”
   - Sampled 1 or 2x/year
   - ~130 sites

2) “Biodiversity”
   - Sampled every 5-7 years
   - ~180 sites



Long-Term Surveys: ~130 sites in CA, OR, WA, AK sampled annually or semi-annually

- Targeted assemblages/species (most are foundation or keystone species)

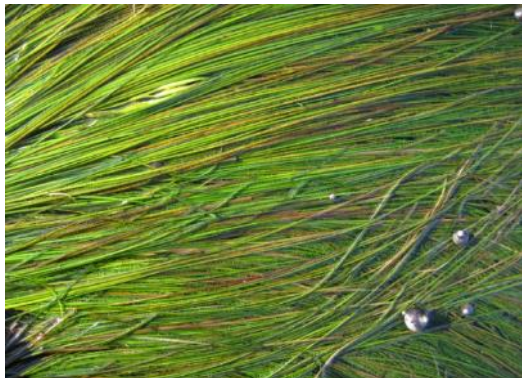








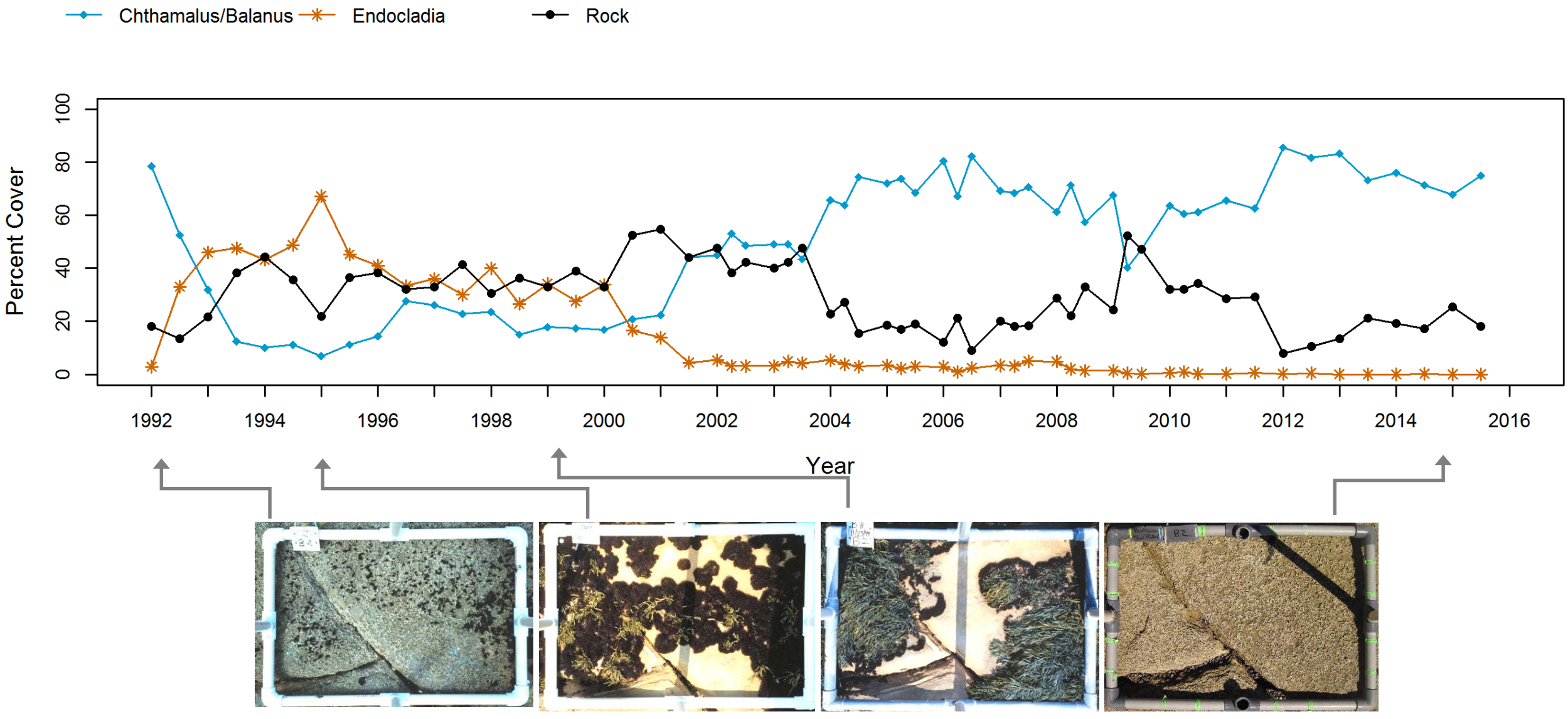




“Long-Term” Protocols:
1) Percent cover in Permanent Plots & Transects

100, evenly spaced points sampled along 10m transect or within 50 x 75cm quadrat.

Trends in Species Abundance Over Time

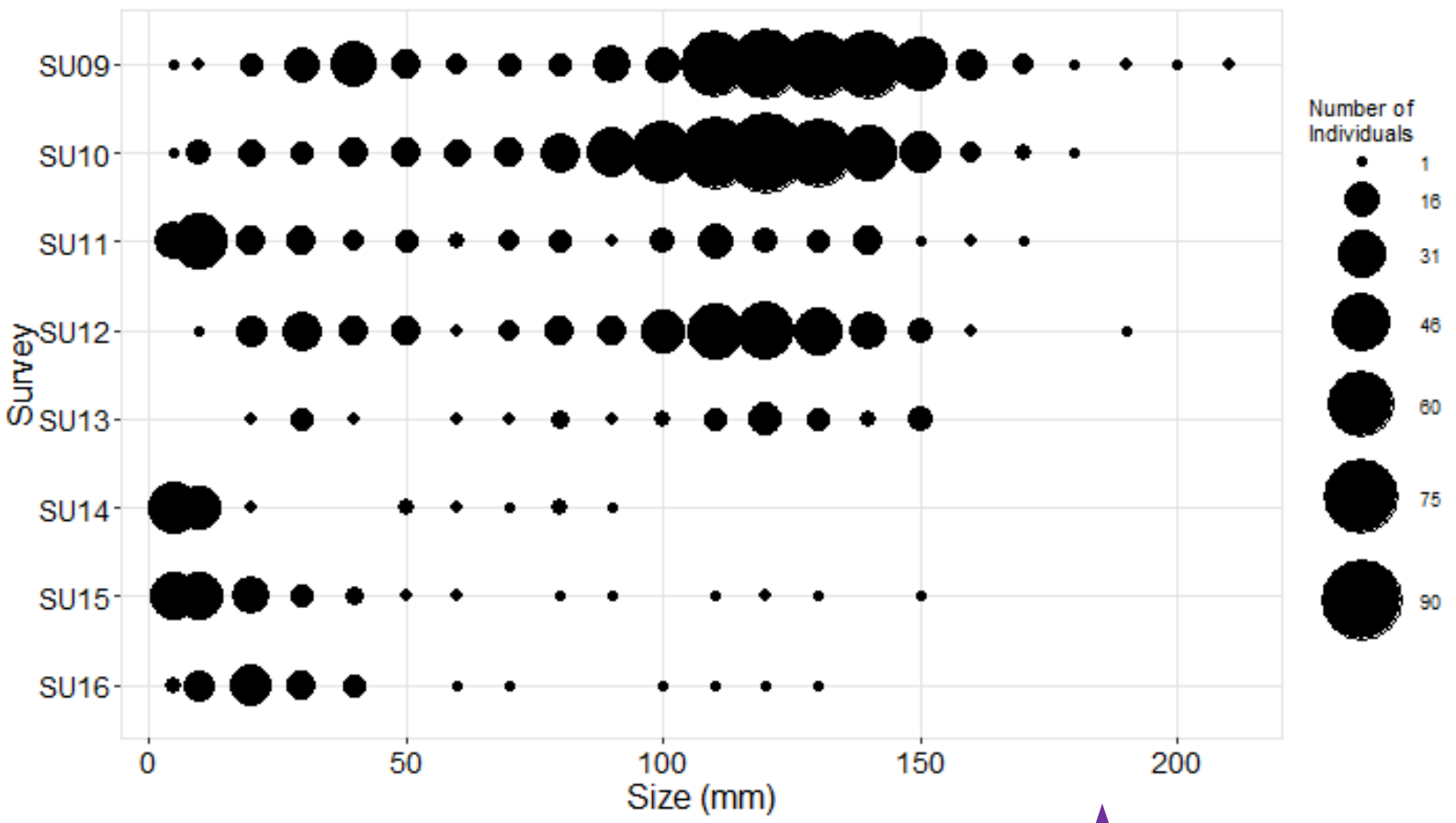


“Long-Term” Protocols:
2) Counts and Sizes in Permanent Plots

Katharina tunicata (black katy chiton)

Pisaster ochraceus ochre star

Pisaster ochraceus sizes over time

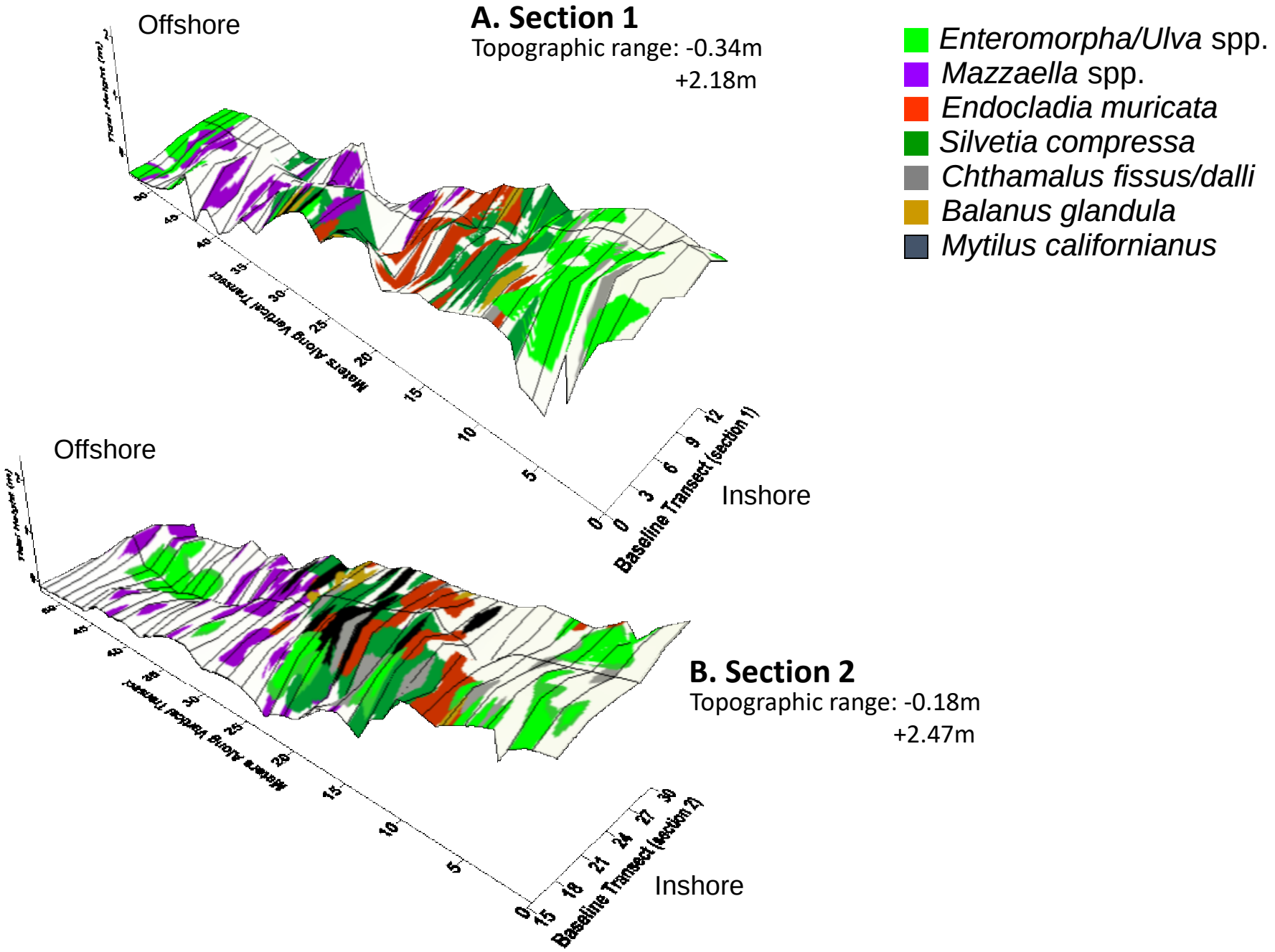


Long-term Surveys:
Fixed plots = high power to detect changes in species abundance over time, BUT cannot extrapolate trends to whole site

Biodiversity Surveys:

~180 from Mexico to Alaska sampled approx. every 5-7 years

- Monitor overall biodiversity
- Determine species' abundances and distributions
- Explicitly associate habitat features with species distributions


Offshore
A. Section 1
Topographic range: -0.34m
+2.18m
Meters Along Vertical Transect
Baseline Transect (section 1)
Inshore
Offshore
Meters Along Vertical Transect
Baseline Transect (section 2)
Inshore
B. Section 2
Topographic range: -0.18m
+2.47m
Enteromorpha/Ulva spp.
Mazzaella spp.
Endocladia muricata
Silvetia compressa
Chthamalus fissus/dalli
Balanus glandula
Mytilus californianus

Kydikabbit

Pt. of Arches

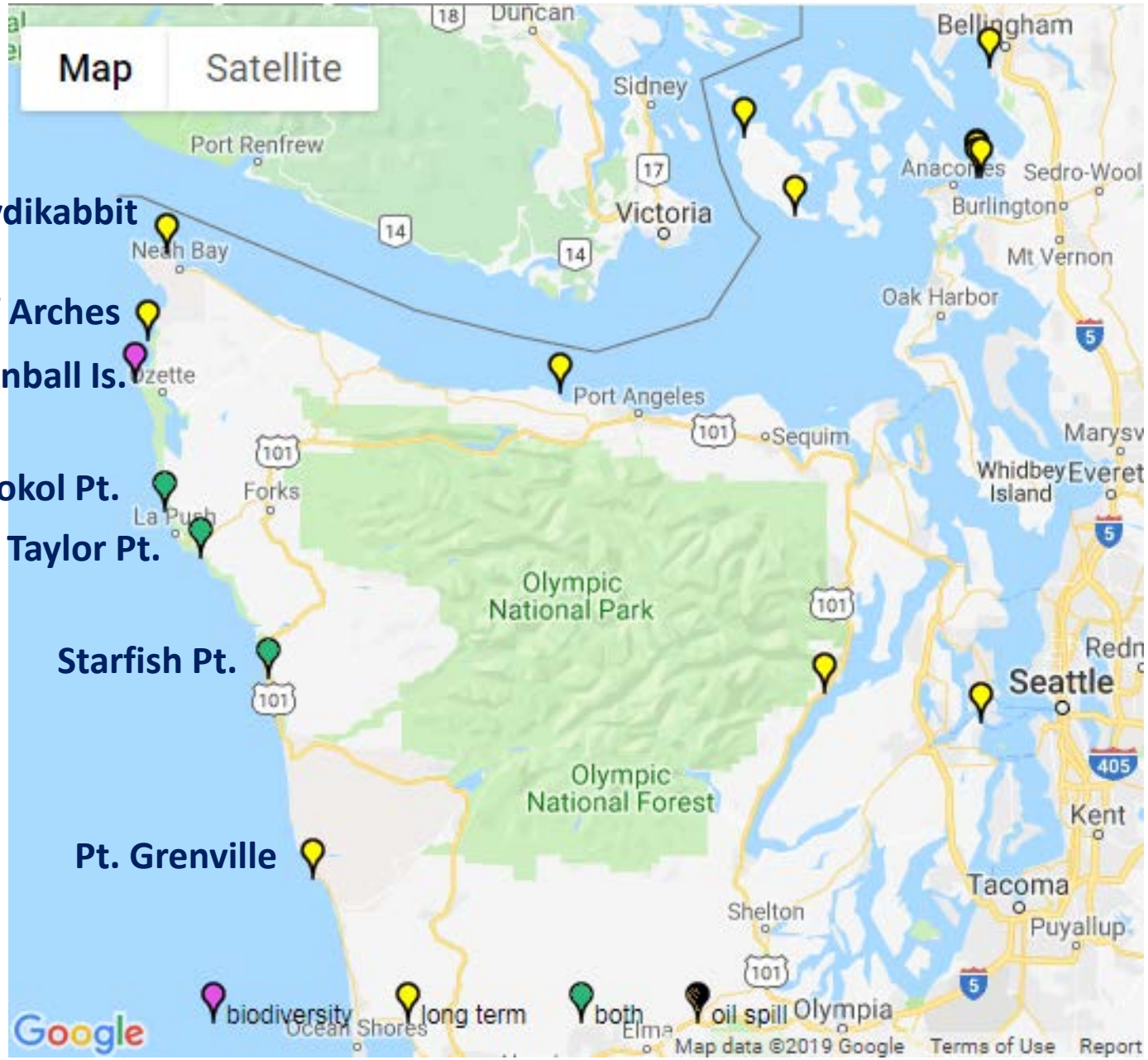
Cannonball Is.

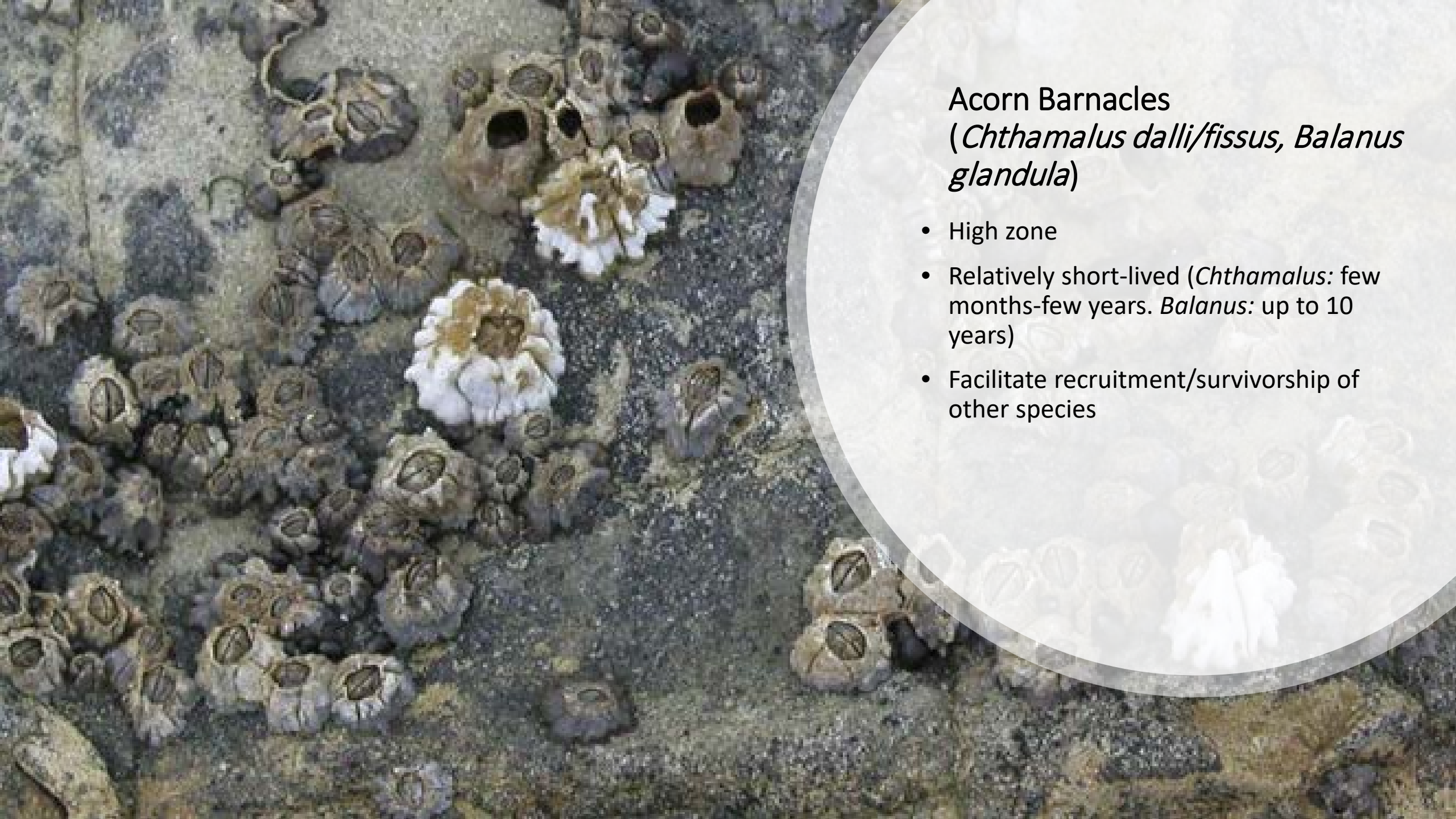
Sokol Pt.

Taylor Pt.

Starfish Pt.

Pt. Grenville





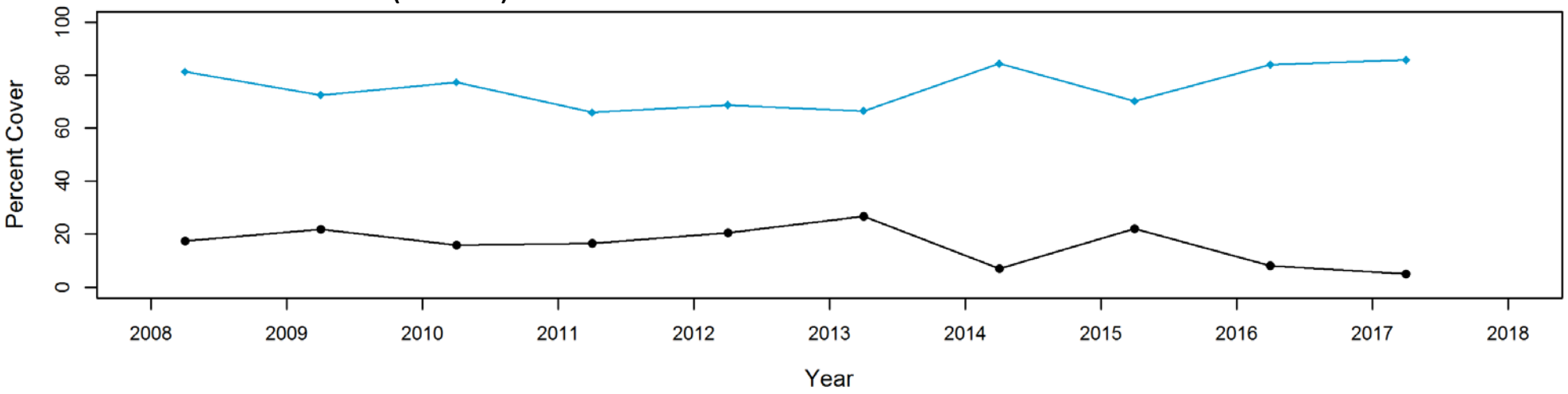
Acorn Barnacles (*Chthamalus dalli/fissus, Balanus glandula*)

- High zone
- Relatively short-lived (*Chthamalus:* few months-few years. *Balanus:* up to 10 years)
- Facilitate recruitment/survivorship of other species

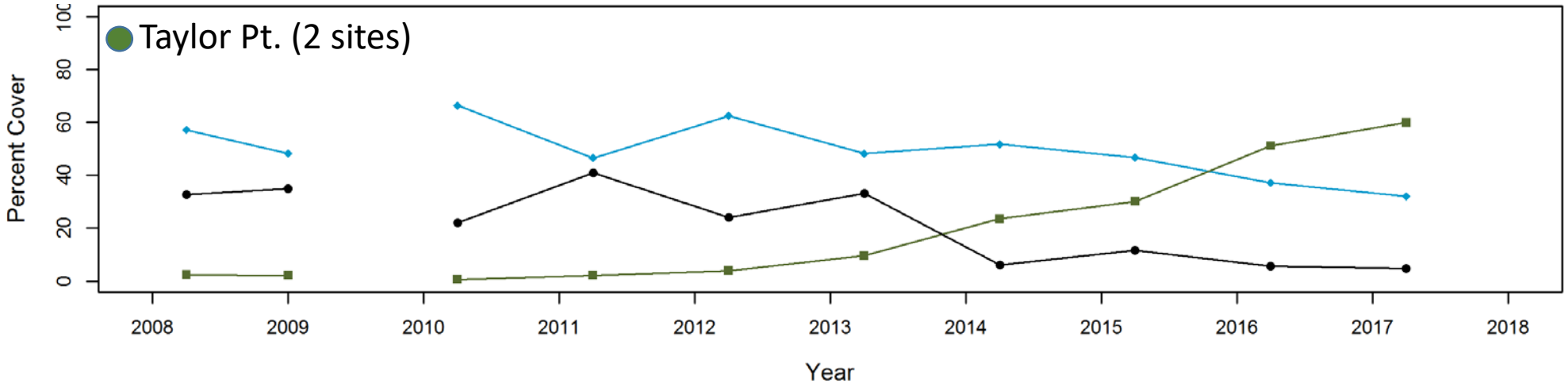
Acorn Barnacles
(*Chthamalus dalli/fissus, Balanus glandula*)

Chthamalus/Balanus — Fucus — Rock

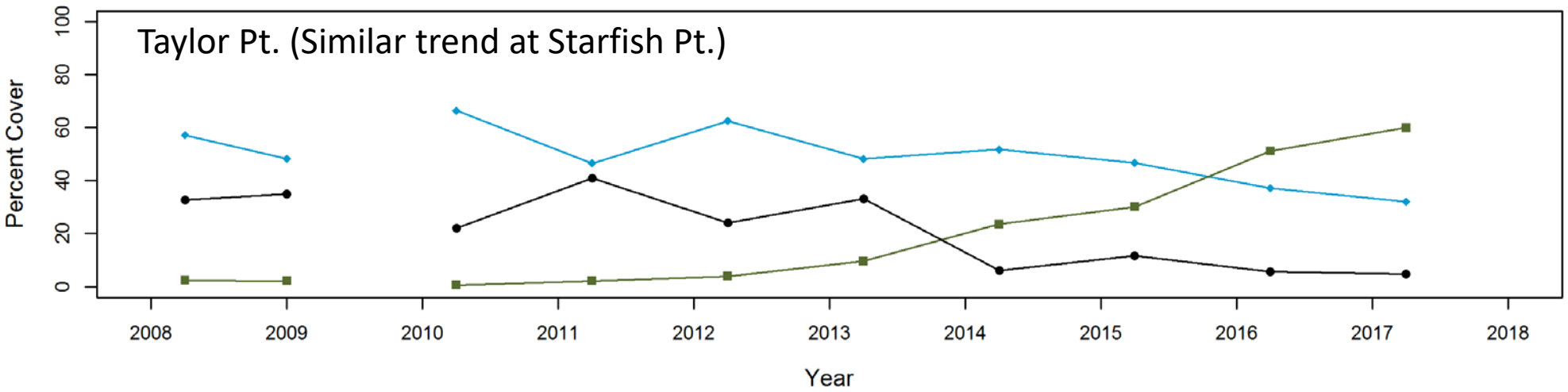
Point of Arches (3 sites)

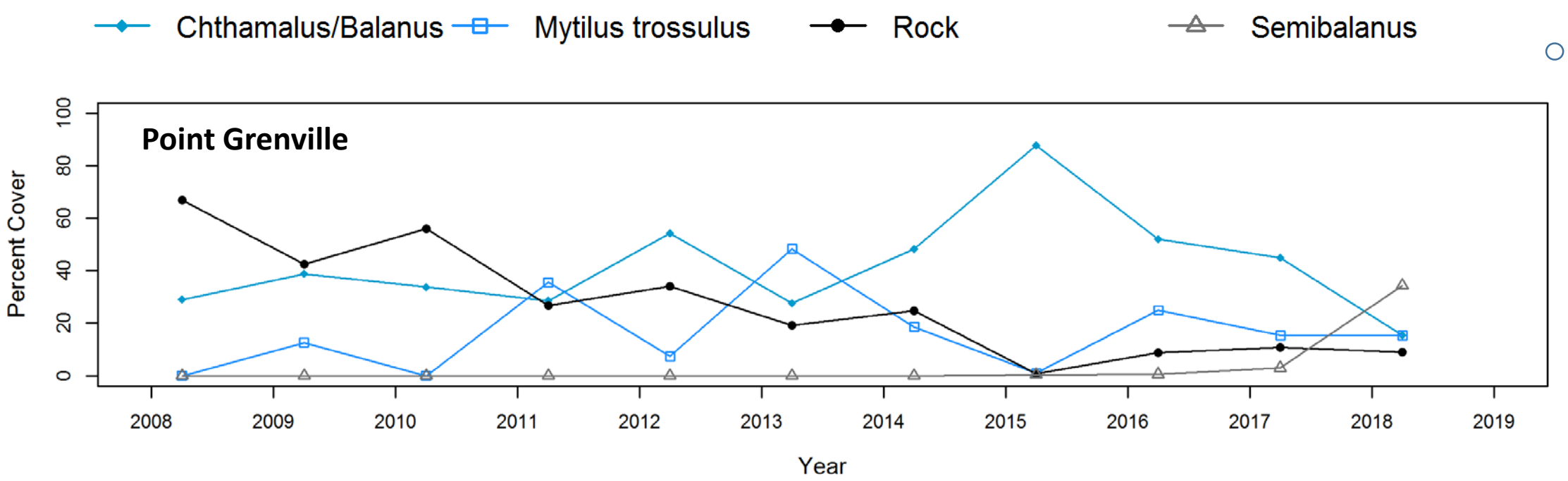


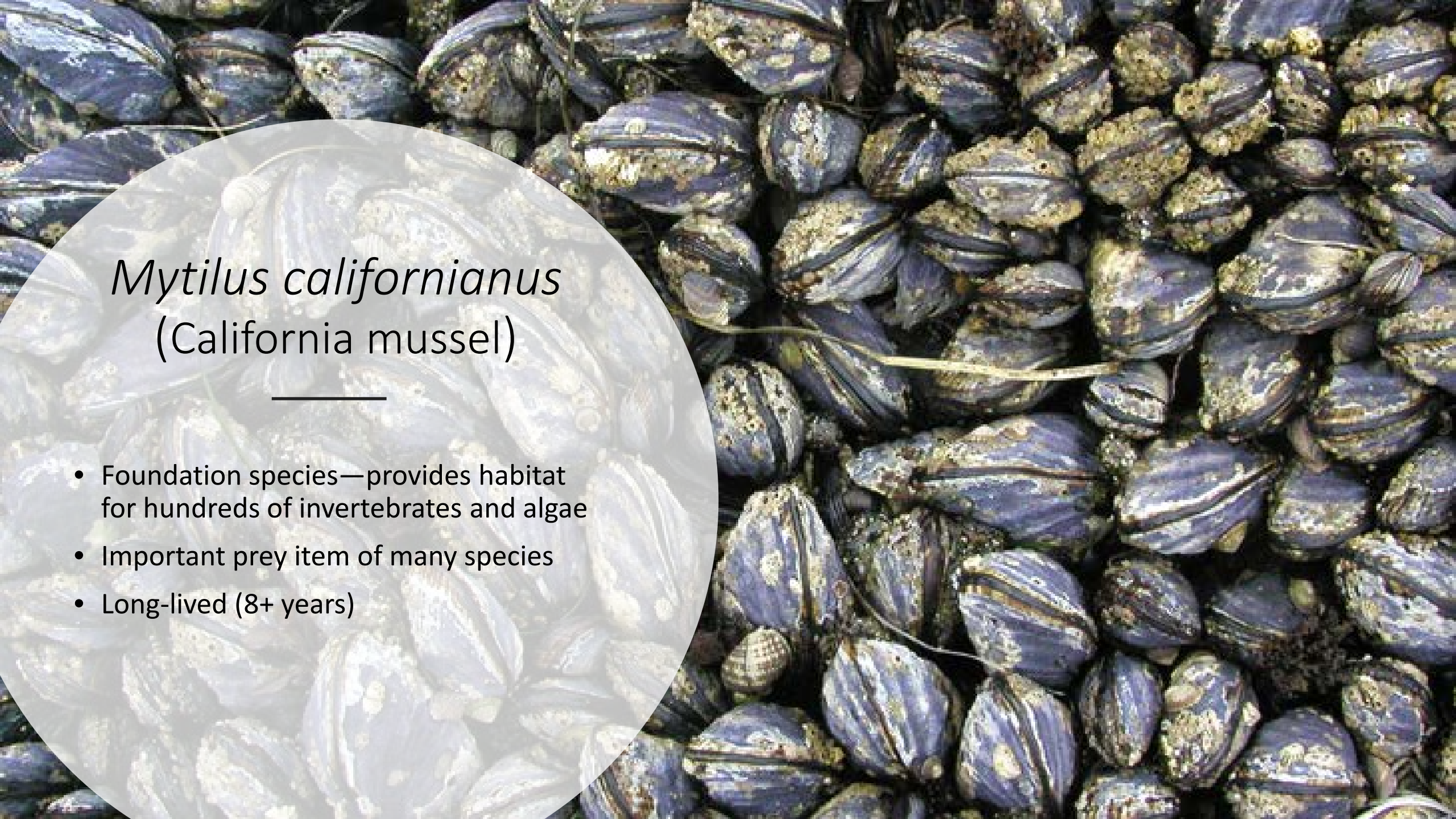
Taylor Pt. (2 sites)



Acorn Barnacles
(*Chthamalus dalli/fissus, Balanus glandula*)



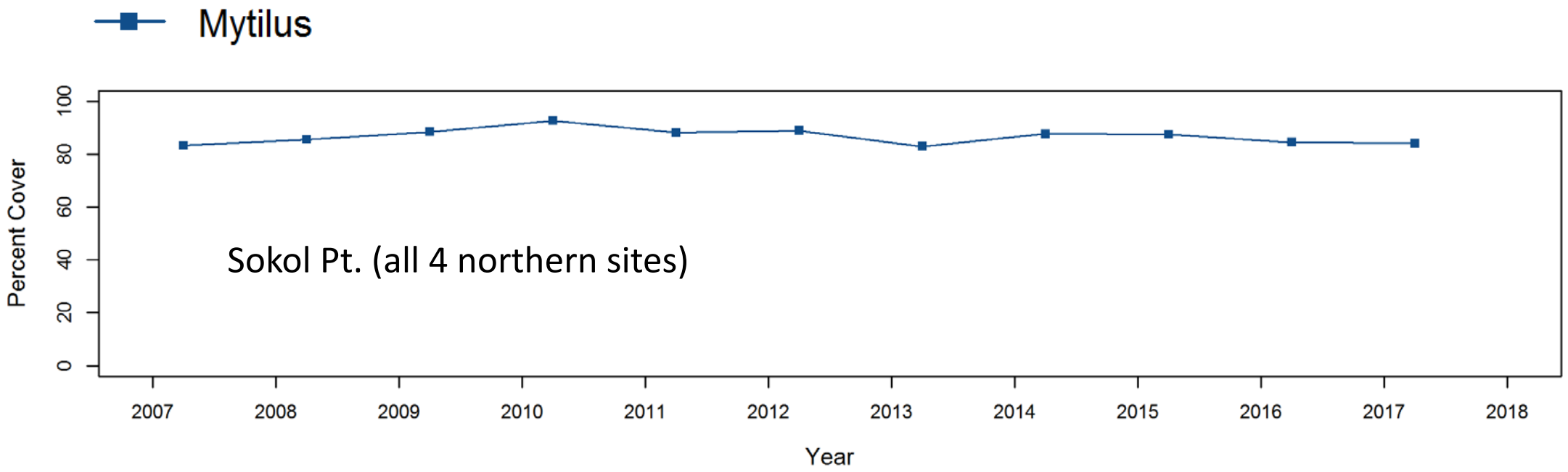

Chthamalus/Balanus
Mytilus trossulus
Rock
Semibalanus
Point Grenville
Percent Cover
0
20
40
60
80
100
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year

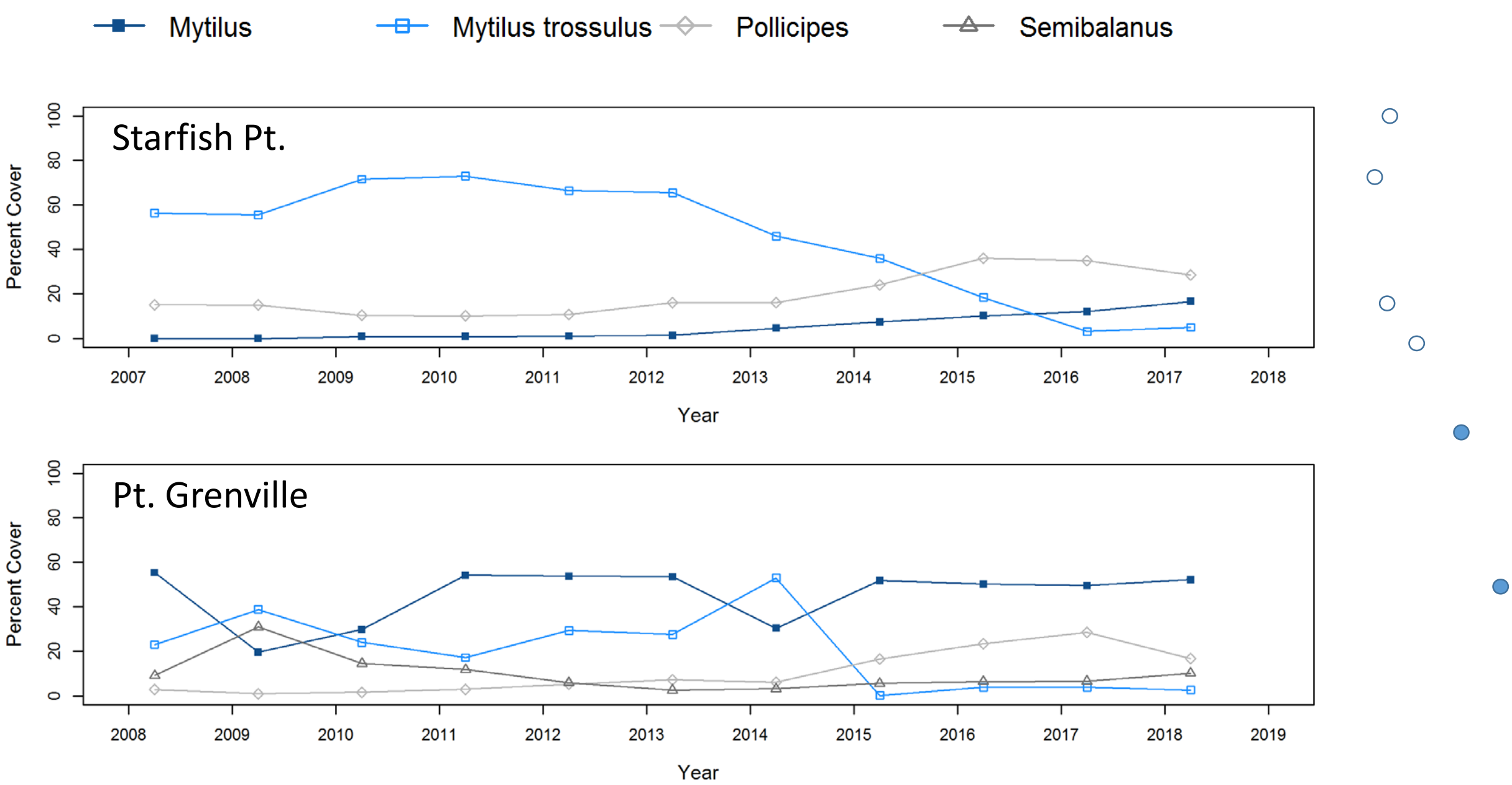


Mytilus californianus (California mussel)

- Foundation species—provides habitat for hundreds of invertebrates and algae
- Important prey item of many species
- Long-lived (8+ years)

California mussel (*Mytilus californianus*)




Mytilus
Mytilus trossulus
Pollicipes
Semibalanus
Starfish Pt.
Percent Cover
0
20
40
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80
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2007
2008
2009
2010
2011
2012
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2015
2016
2017
2018
Year
Pt. Grenville
Percent Cover
0
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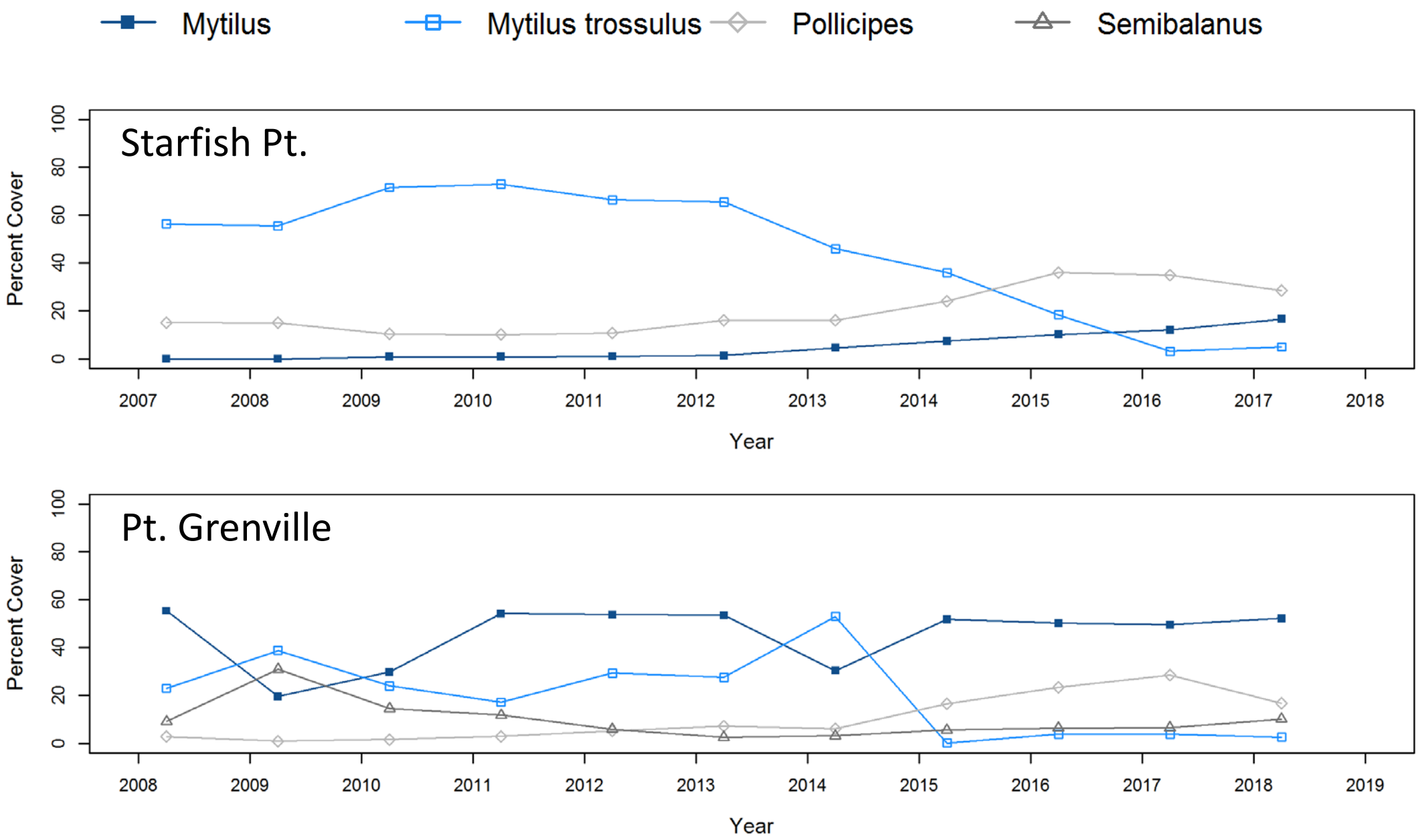
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Year
Pt. Grenville
Percent Cover
0
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40
60
80
100
2008
2009
2010
2011
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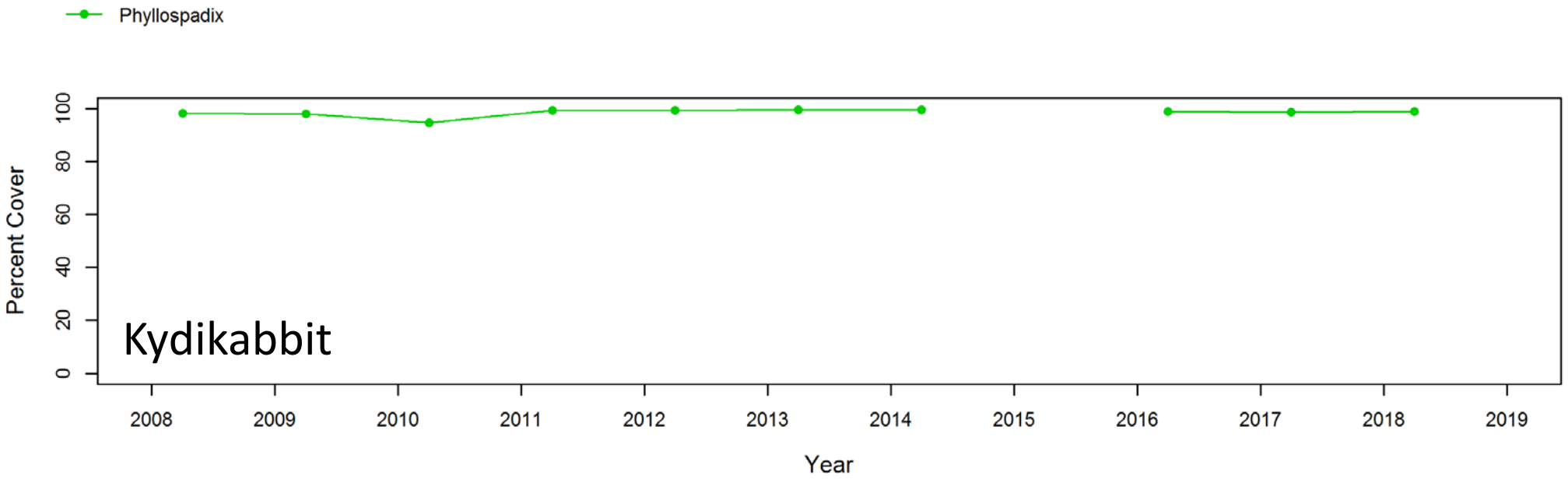
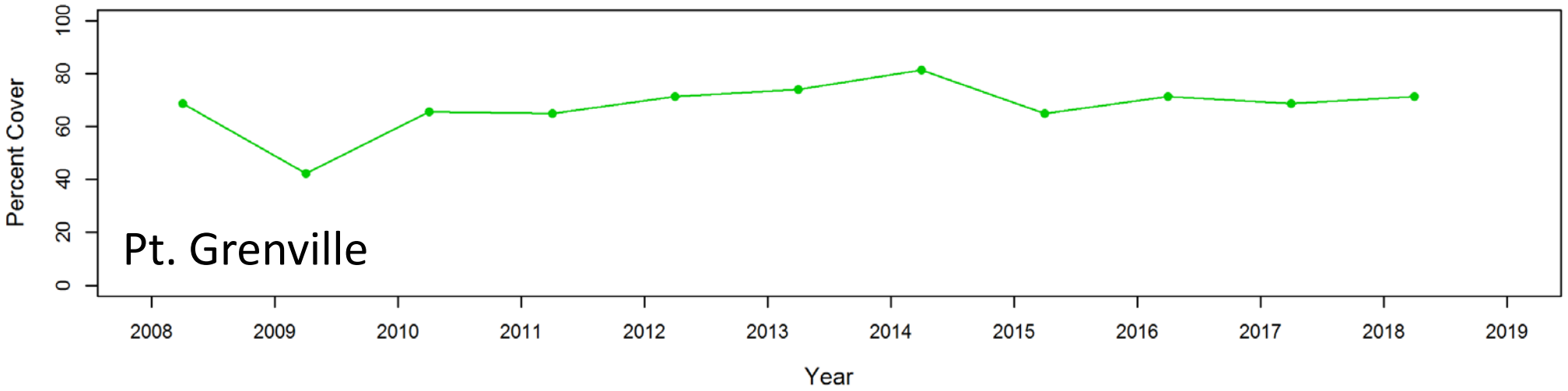
2015
2016
2017
2018
2019
Year

Surfgrass (*Phyllospadix* spp.)

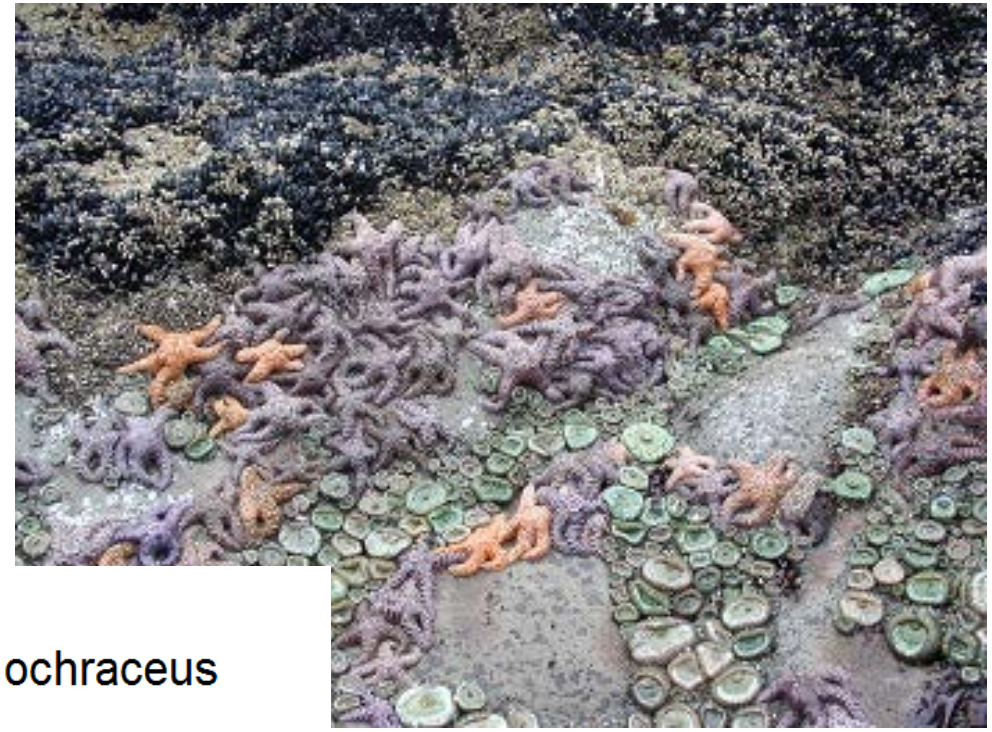
- Important nursery habitat for many fishes and inverts
- Modifies current velocity, surf
- Traps/stabilizes sediment—increases water clarity
- Strongly impacted by oiling and sewage
- Long recovery time if rhizomes lost
- Climate change mitigation?

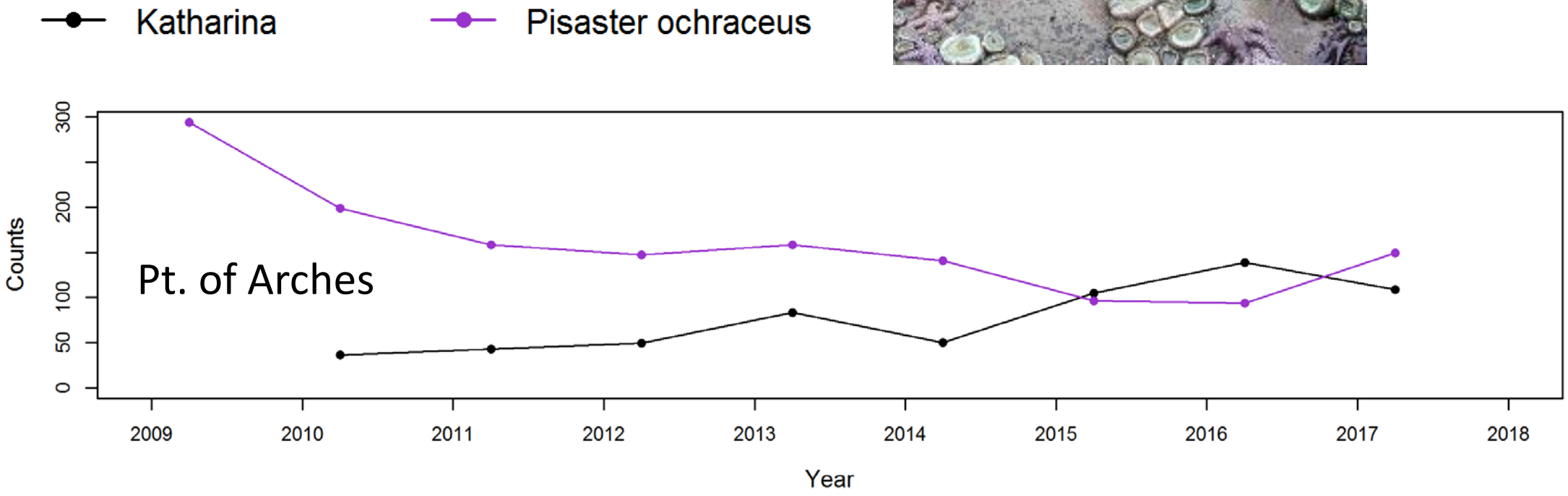
Surfgrass (*Phyllospadix* spp.)





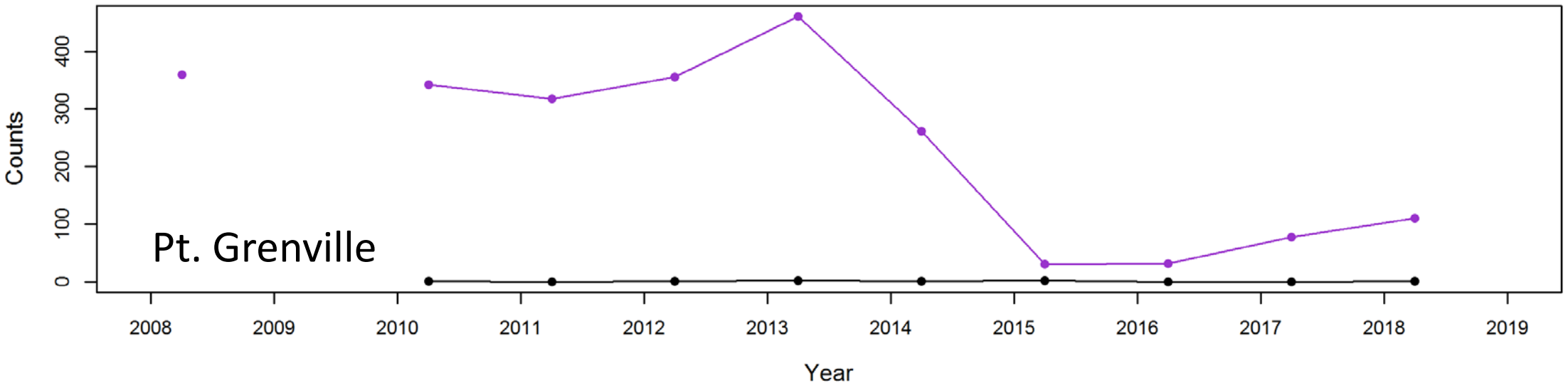
Ochre stars and Katy chitons
(*Pisaster ochraceus* & *Katharina tunicata*



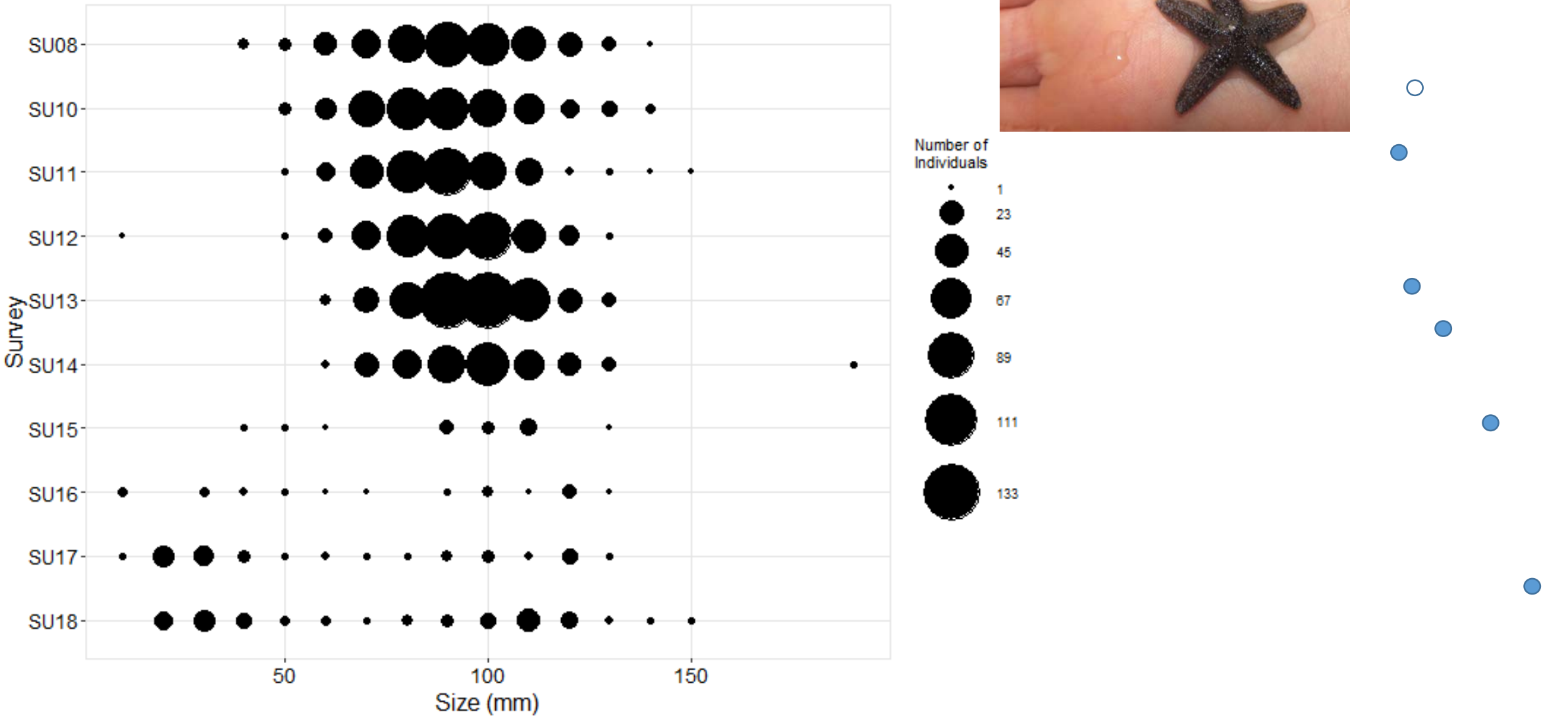


Katharina

Pisaster ochraceus



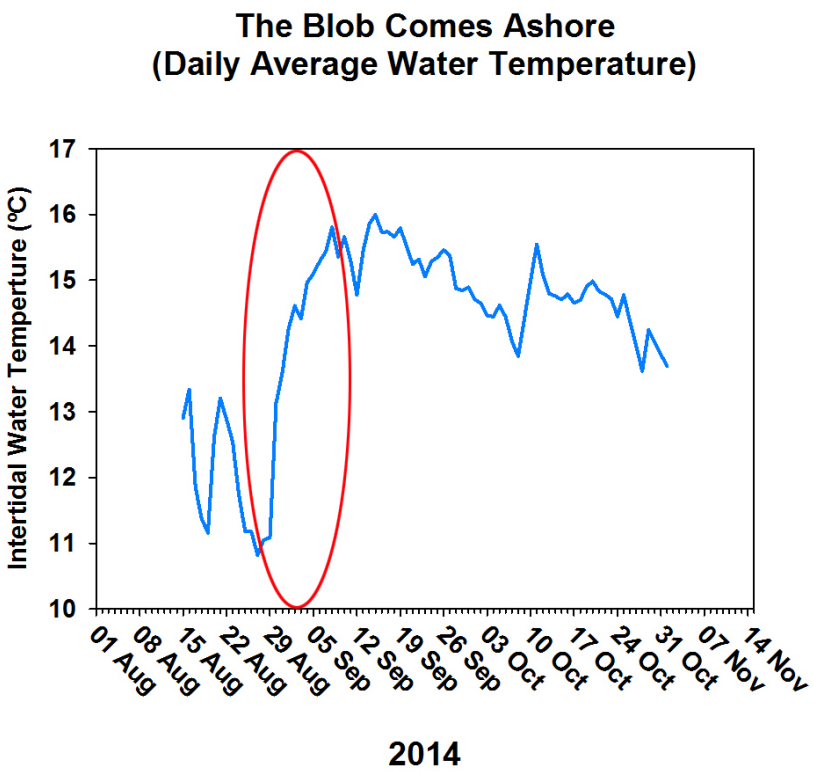
Pt. Grenville

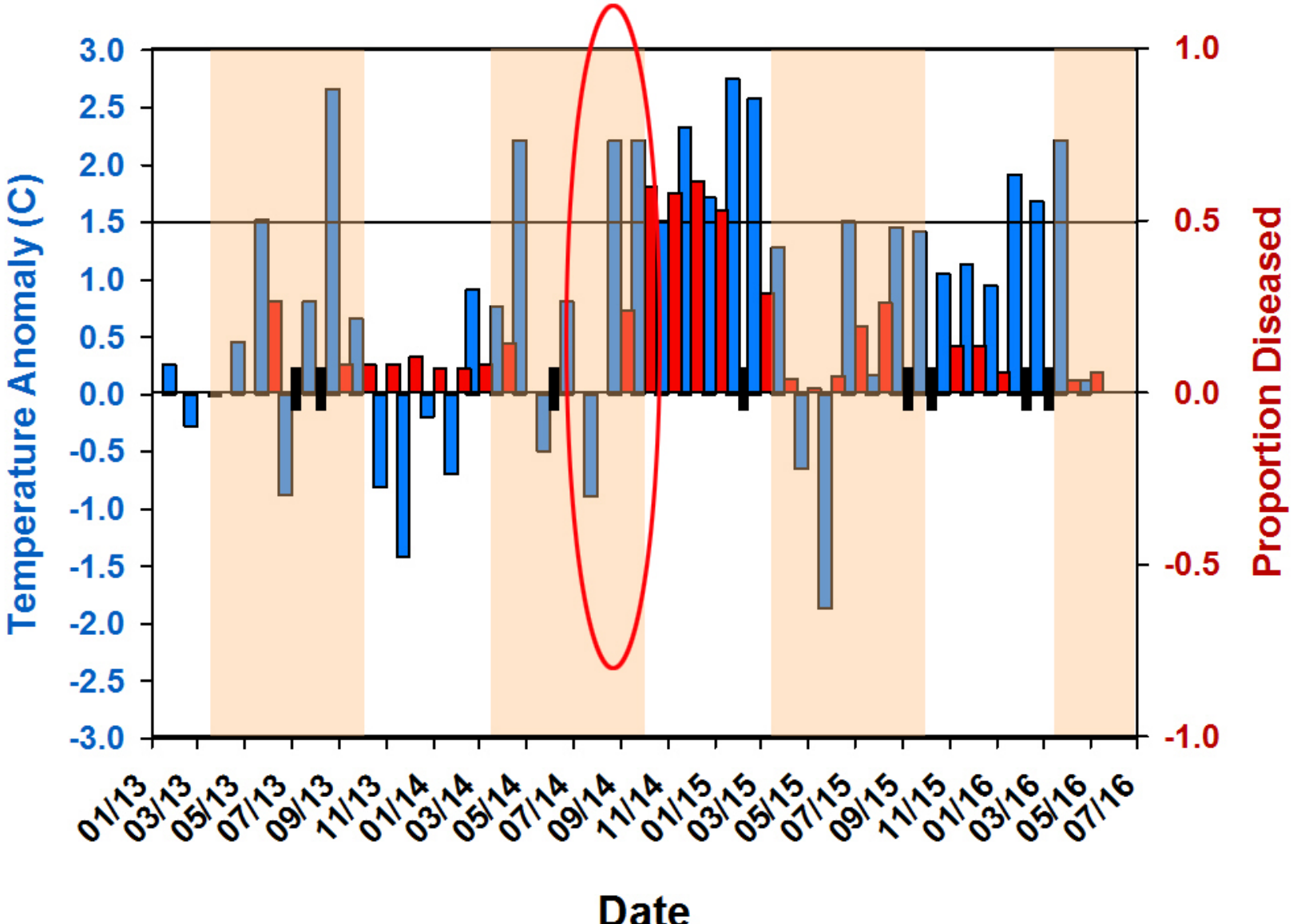


Sea Star Wasting Disease: What is it?

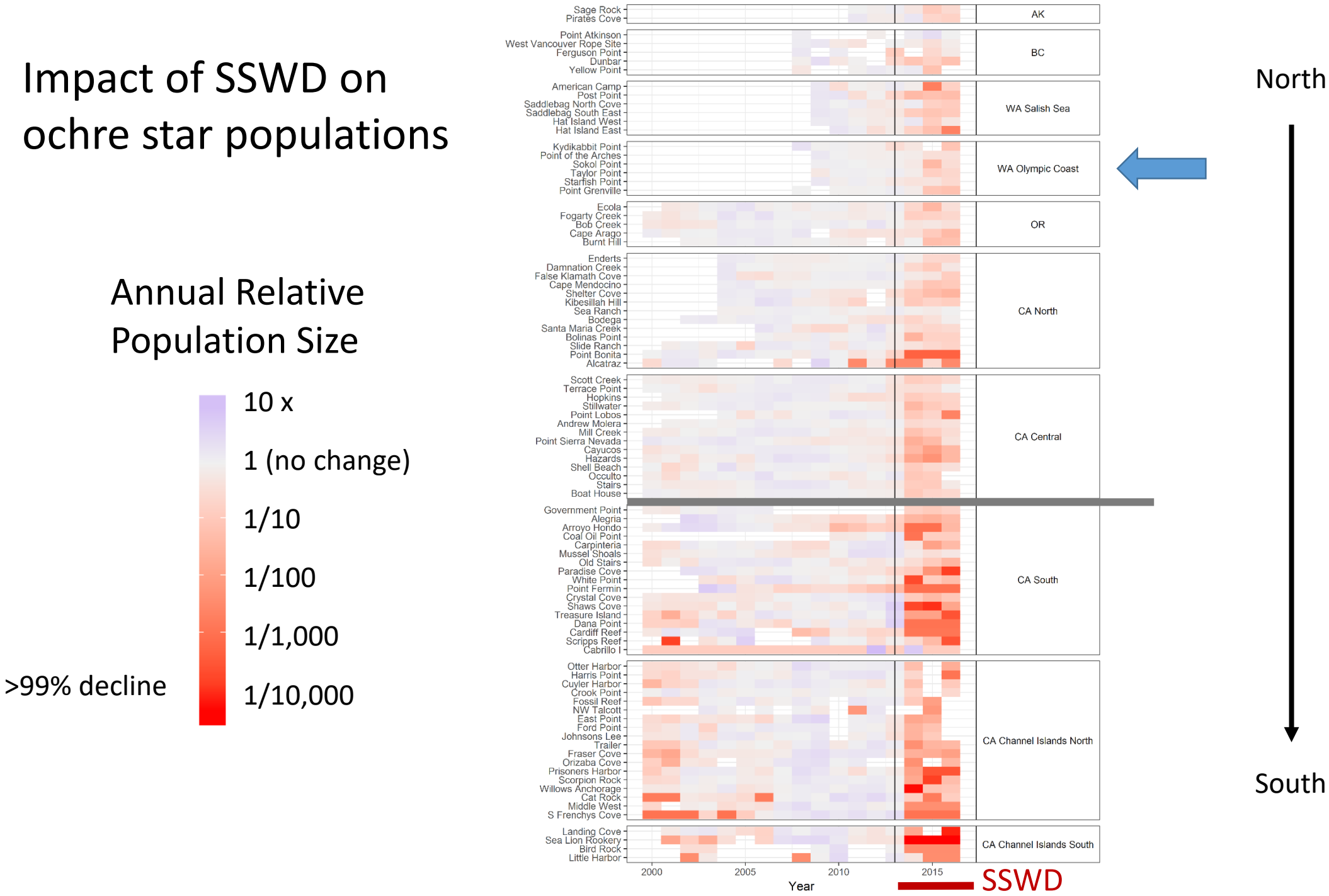
- General description for a set of symptoms that have been seen in many species of sea stars (and historically other echinoderms)
- Previous events were much smaller in scale, cyclical (tied to warm water), and pathogen never identified
- Continued study of the microbiome (viruses and bacteria) associated with sick stars (Hewson, Cornell and others) and how other factors (e.g., temp, pH) might contribute
- > 20 species affected
- Has persisted in system since 2013 (6 years)
- No temperature link at broad scale, but localized correlation found

SSWD-temperature link on the Olympic Coast





Impact of SSWD on ochre star populations

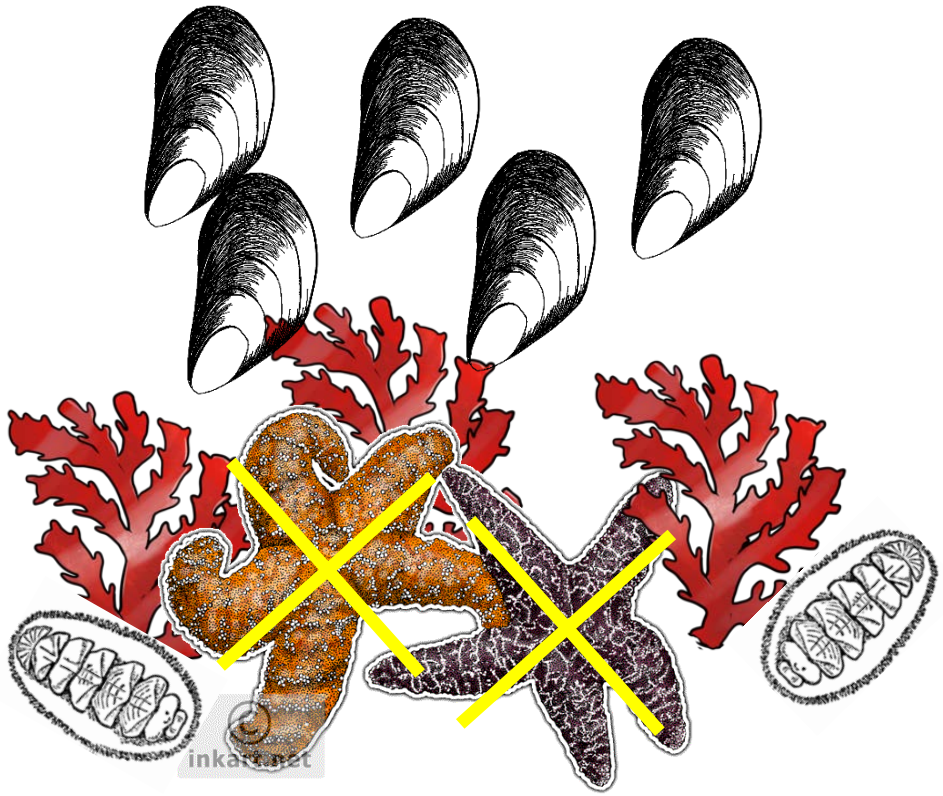


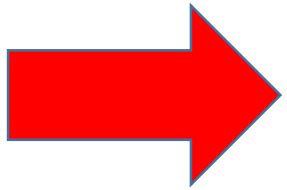
Recruitment Patterns

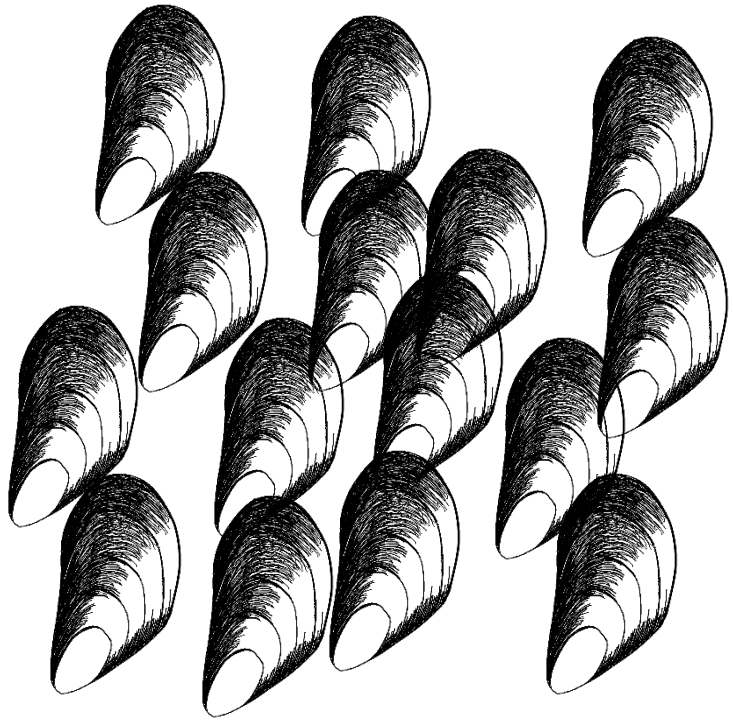
Impacts of sea star wasting syndrome

- Population-level (long-term surveys)
- Whole-community change (biodiversity surveys)
  - Shifts in community structure that could result from loss of keystone predator

Pisaster ochraceus = keystone predator

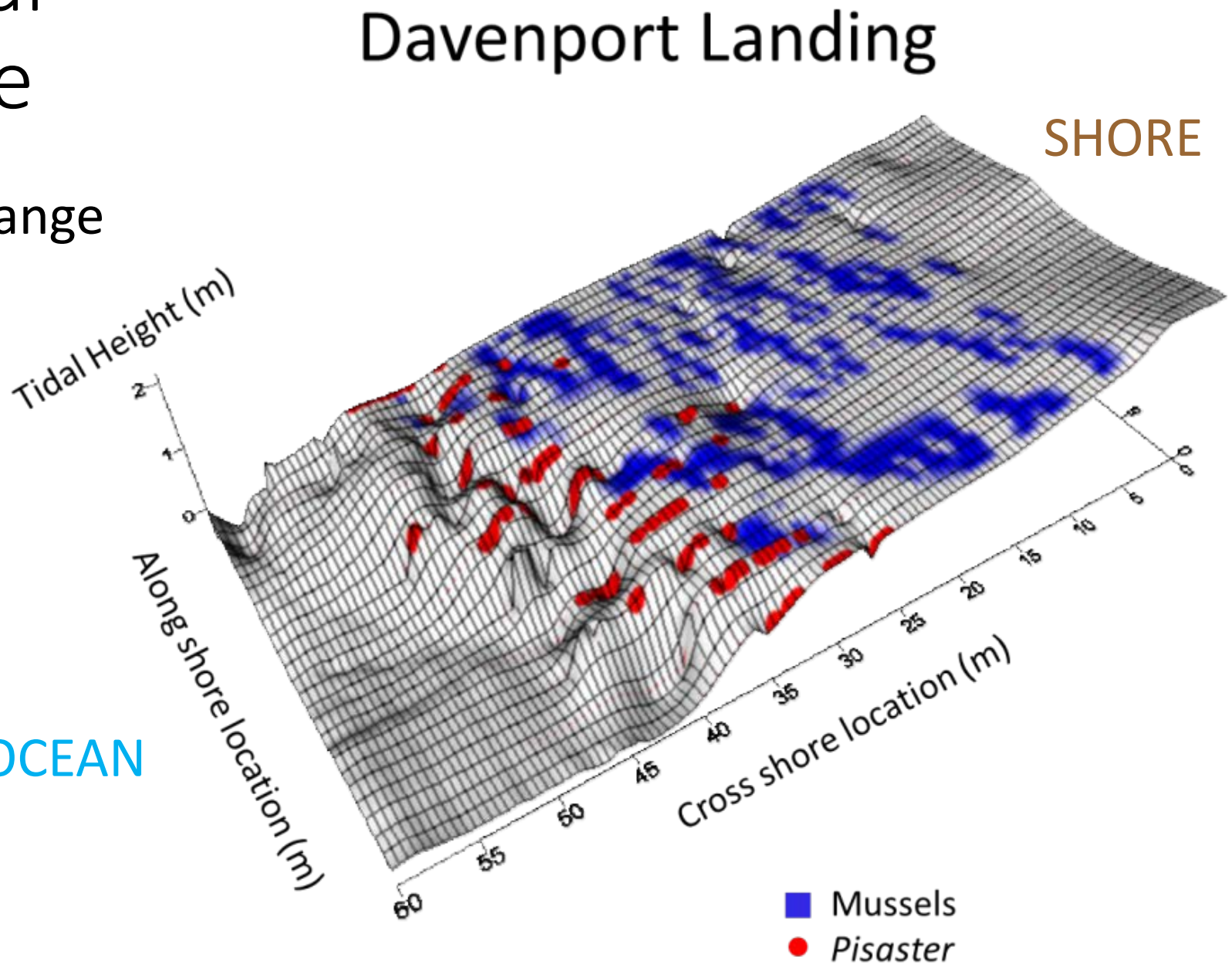






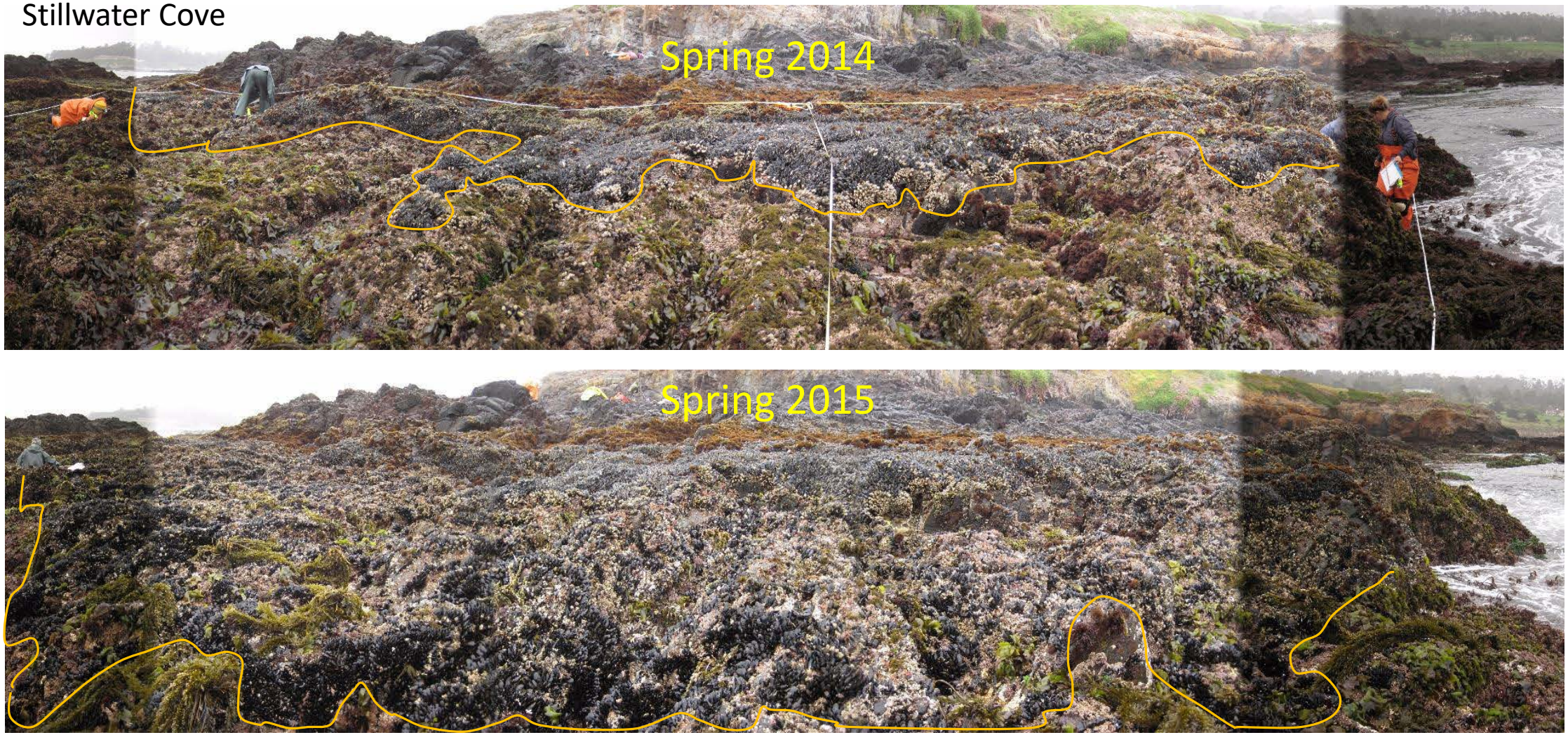
Impacts of sea star wasting syndrome

- Whole-community change (biodiversity surveys)



Expansion of mussel zone in Monterey, CA

Stillwater Cove



Summary

- SSWD has had MAJOR impact on ochre star populations throughout entire range along the Pacific coast of N. America, but SoCal was hit hardest (only moderate impacts to Olympic Coast)
- Community change (expansion of mussel bed) has already occurred at some sites where ochre stars have declined—need to repeat biodiversity surveys in WA!
- Post-SSWD recruitment of ochre stars has been high at some sites, but has been restricted to northern portion of range, and is patchy even in north
- Juveniles are growing/surviving, but SSWD is still present so still lots of uncertainty in long-term recovery estimates.
- Sunflower stars are showing up again in a few locations—tentatively hopeful for recovery

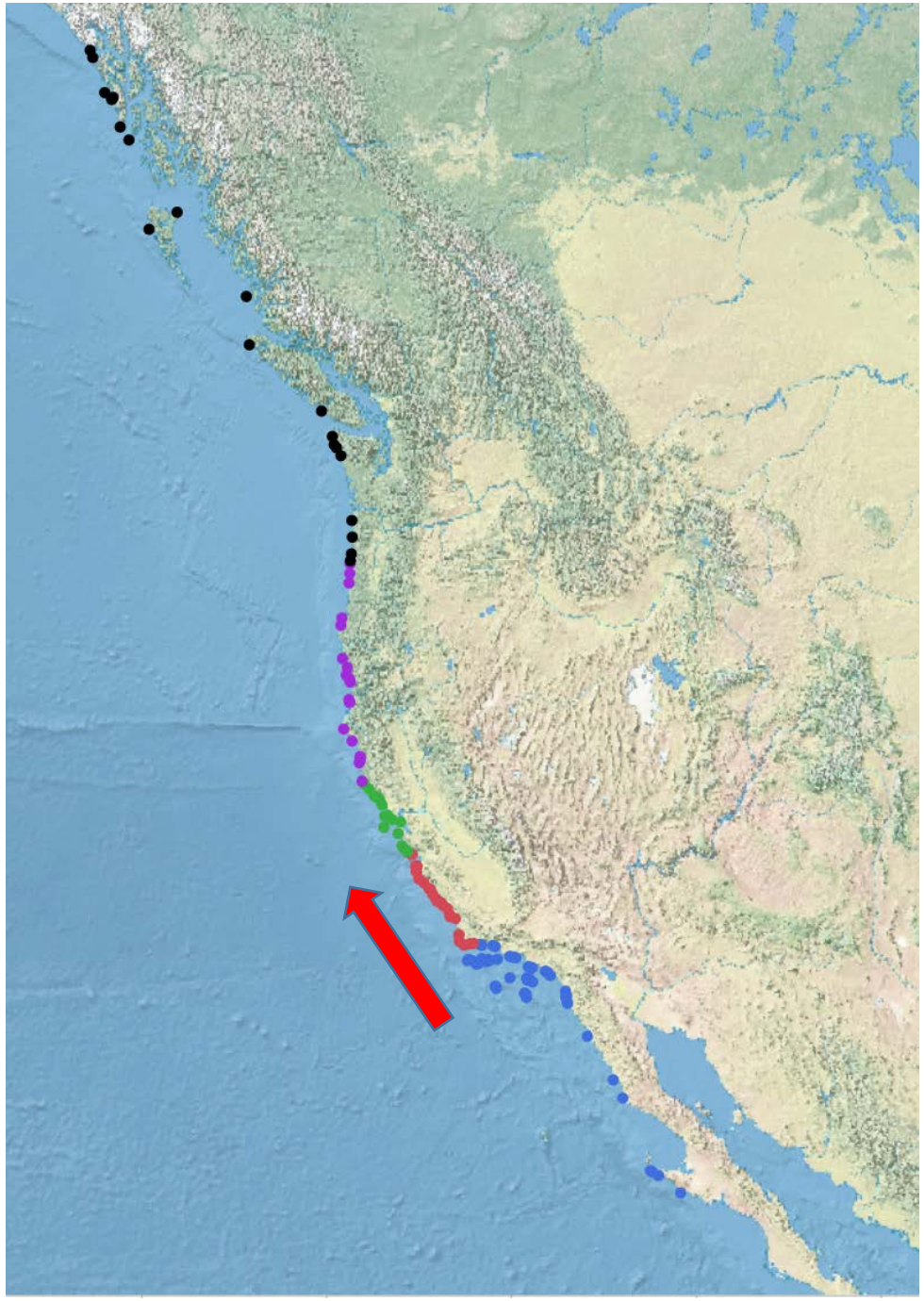
Broadscale Analyses – Climate Change

- Community shifts – geographic (among sites)
- Spatial patterns of resilience (site and regional scale)

Climate change

- Prediction: Communities will shift poleward ("tropicalization" of communities)

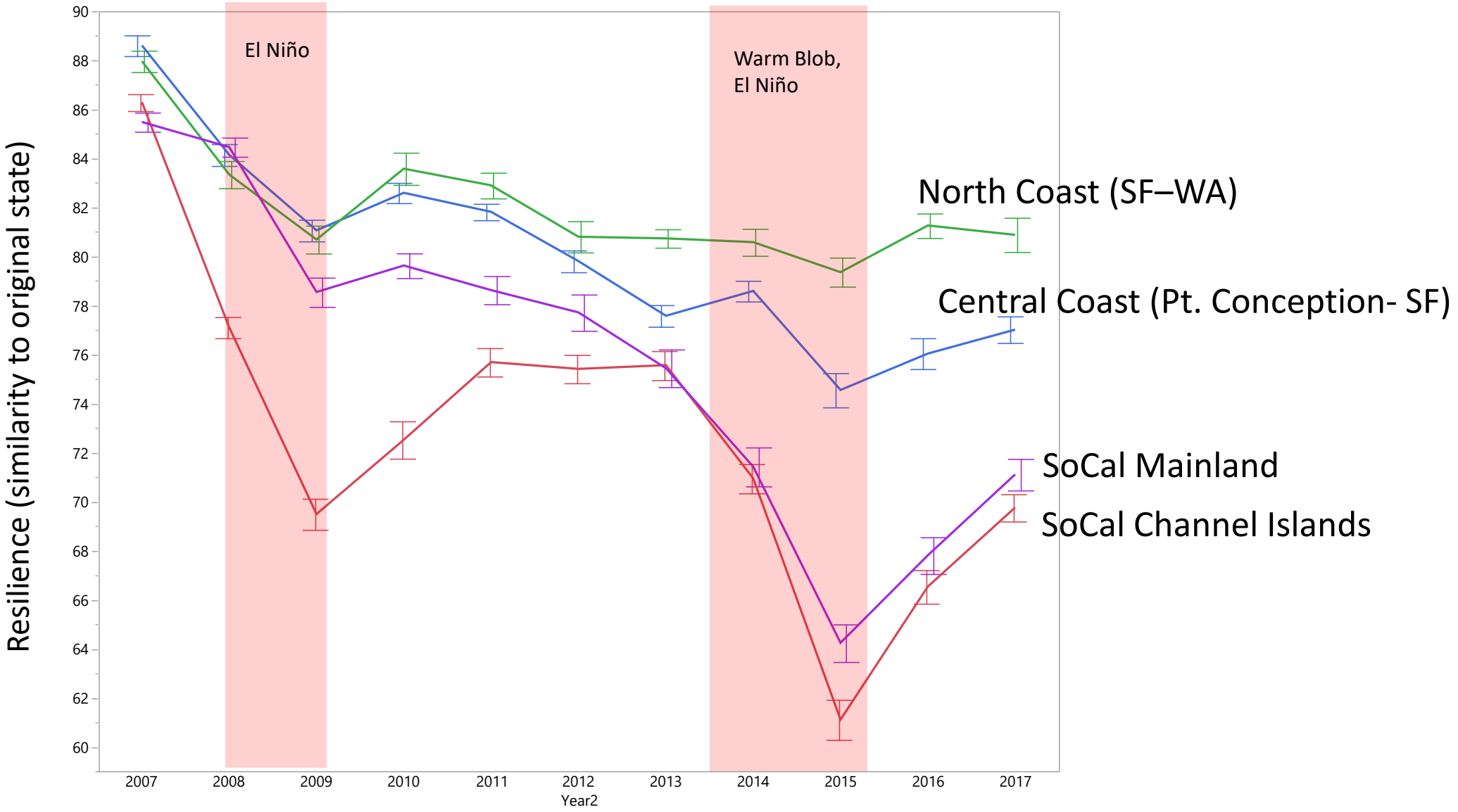
  Currently we are seeing a shift of about 3-5 KM per year on average



Broadscale Analyses – Climate Change

- Community shifts – geographic (among sites)
- Spatial patterns of resilience (site and regional scale)

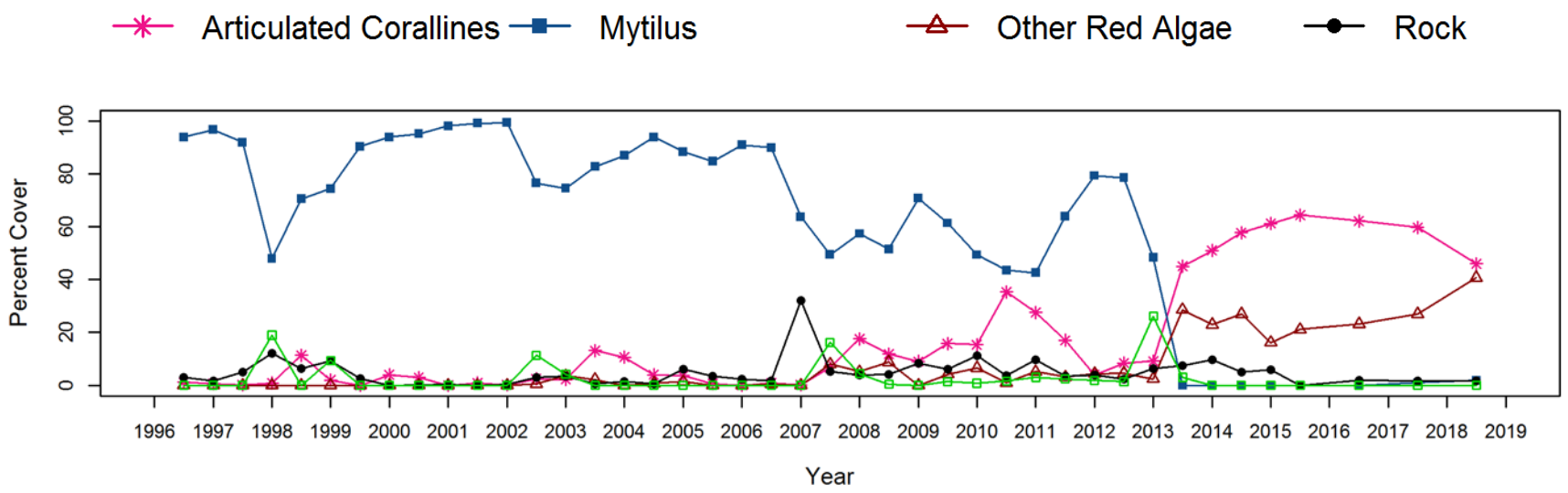
Resilience relative to community in 2006



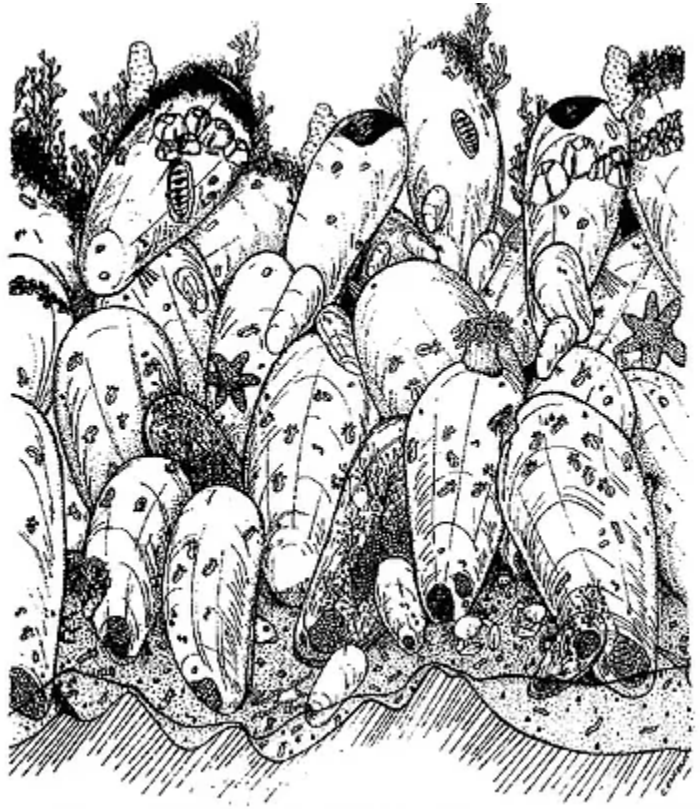
Factors important to Resilience

- High Species Richness (# of species)
  - Consistent with resilience literature
- Low Species Evenness (how evenly species are distributed)
  - ???

Factors important to Resilience: foundation species, *Mytilus californianus*



- Mussel decline MARINe sites in SoCal
- Pfister et al. 2016 “Our results show that shells of *M. californianus* in Washington State are significantly thinner today compared with conspecific individuals in middens dating from 1000 to 2500 years BP”



Online Resources

- Site info
- Trend graphs (static and interactive)
- Download data
- SSWD—ID guides, tracking map
- GIS data display tool
- MBON interactive infographics

MULTI-AGENCY ROCKY INTERTIDAL NETWORK (MARINe)

Overview | MARINe

Rocky intertidal shores occur at the interface between the terrestrial and marine environments. This unique location results in a physical complexity that leads to high biological diversity, including many species that are found only in this narrow band of coastal habitat. Rocky shores are also the most accessible marine habitat, which fosters a strong public appreciation of these communities, but also makes them vulnerable to degradation resulting from human activities. Natural temporal variation in rocky intertidal systems can be quite high, and can occur on the scale of months (seasonal), years, and even decades, so long-term monitoring is essential for separating natural change from human-induced.

Because rocky intertidal communities are highly diverse and subject to constant change, monitoring of these areas must be done in a well-designed, systematic manner, over long periods of time. Our monitoring program began with the goal of developing an approach that would enable researchers to collect statistically sound data using methods that were simple enough to maintain over the long-term, using minimal resources, and has grown into a consortium of groups that now monitor sites along the entire Pacific Coast of North America, from Alaska to Mexico, and several East Coast sites in Maine and New Hampshire.

Approach

Rocky intertidal areas tend to be dominated by several "key" species, which often form distinct vertical bands/zones along the shoreline. These species shape the community by creating habitat for other species, or

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Sea Star Wasting Syndrome

SEA STAR WASTING MAP (**AS OF MAR 13, 2014**) SUMMARY UPDATES (**AS OF JAN 21, 2014**)

If you have photos to send along with your observations, please send them here.

Sea Star Disease Observation Log

Please continue to send in tracking logs after spending time diving or tidepooling. We are constantly updating our website with the latest reports, and will update the map on a regular basis. Please remember to fill out a log even if you search and only find healthy sea stars, or no sea stars! This information is just as valuable as observations of diseased individuals.

* Required

Site/Location *

Name of site or place along the coast where survey was done.

Have you submitted observations from this site before? *

If no, the Latitude/Longitude need to be entered below in order to include the observation(s) on our tracking map. If yes, you do not need to re-enter the Latitude/Longitude for the referenced site.

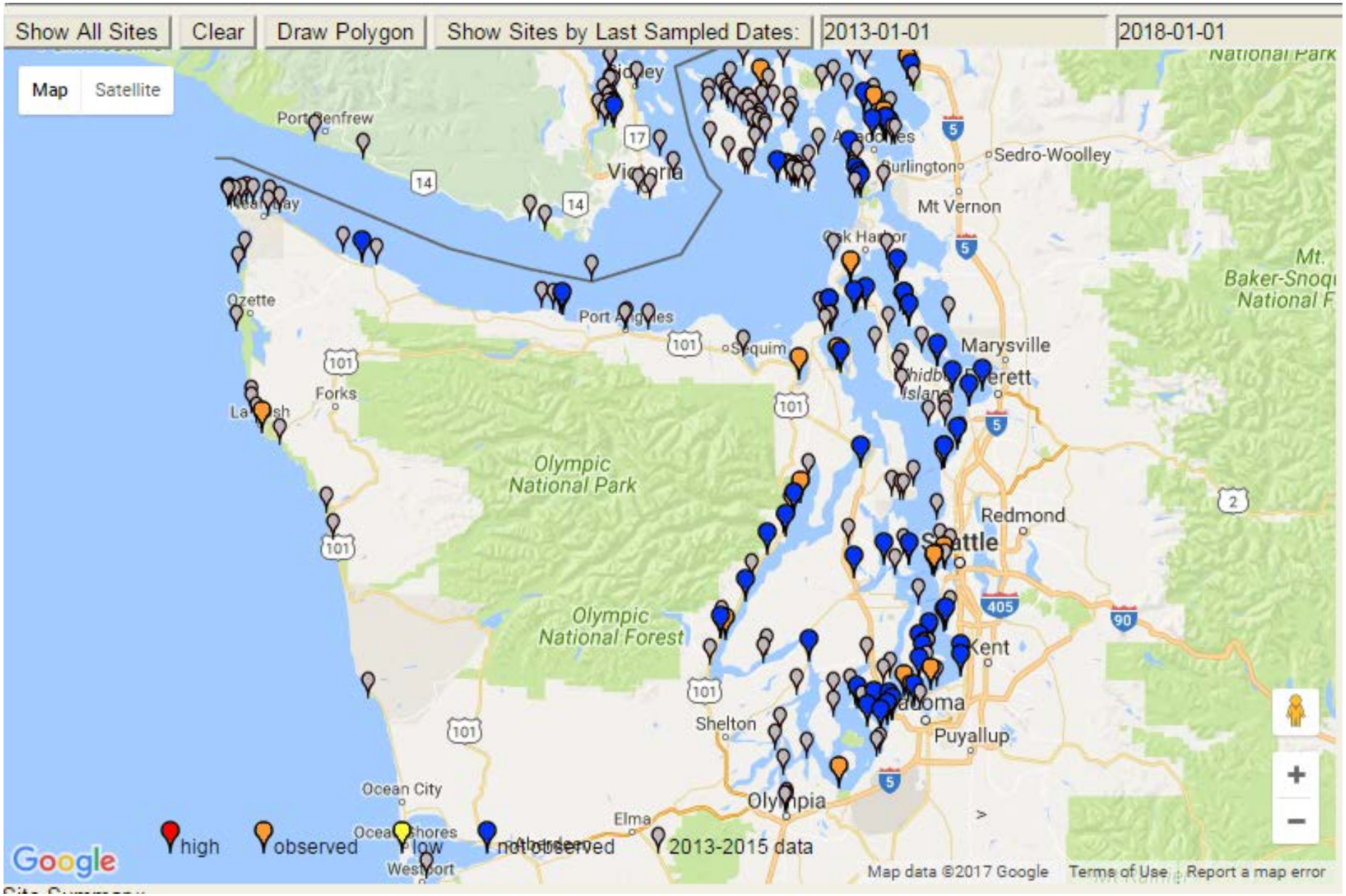
- Yes
- No

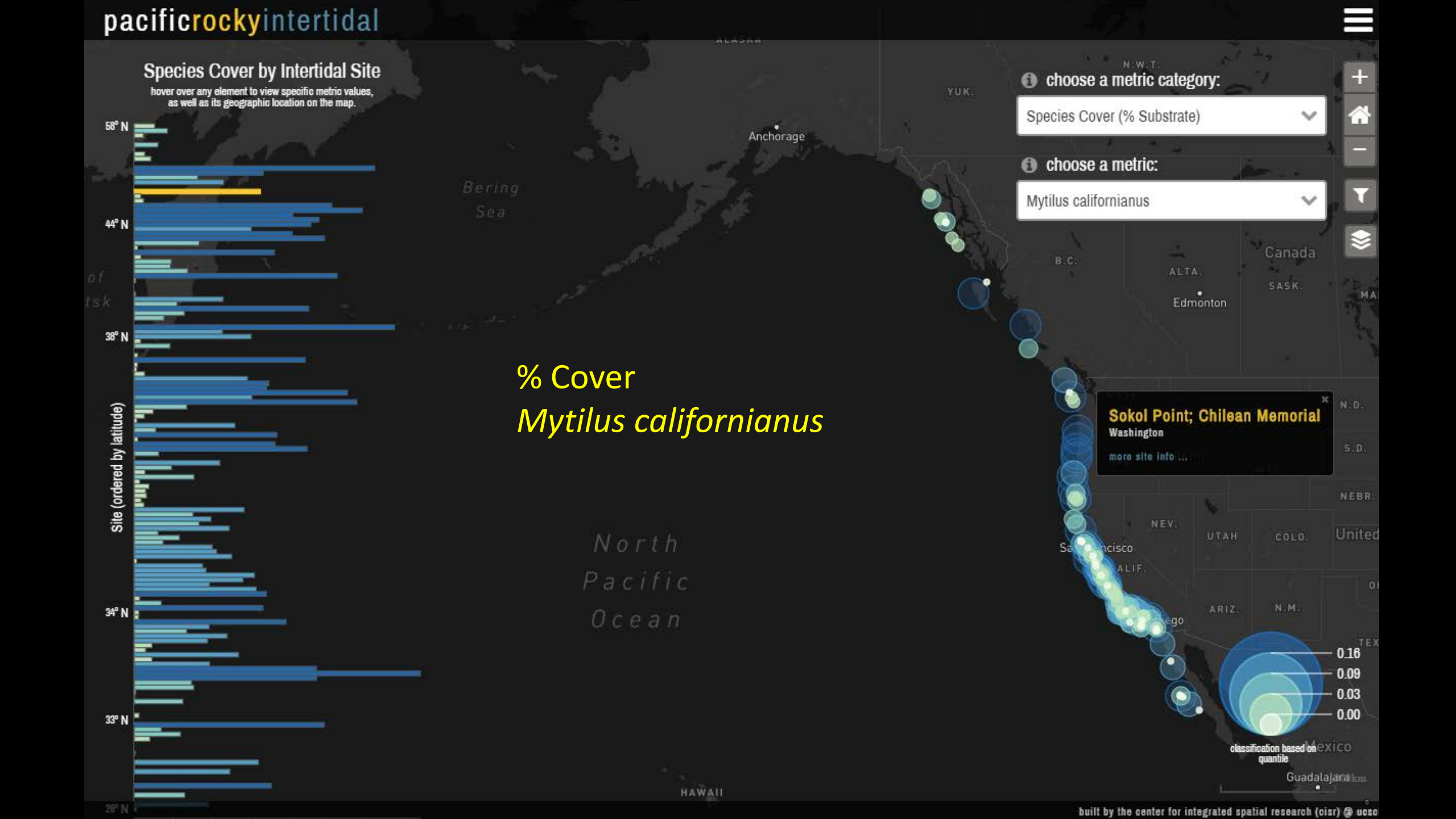
Latitude in decimal degrees (eg. 36.94851473)

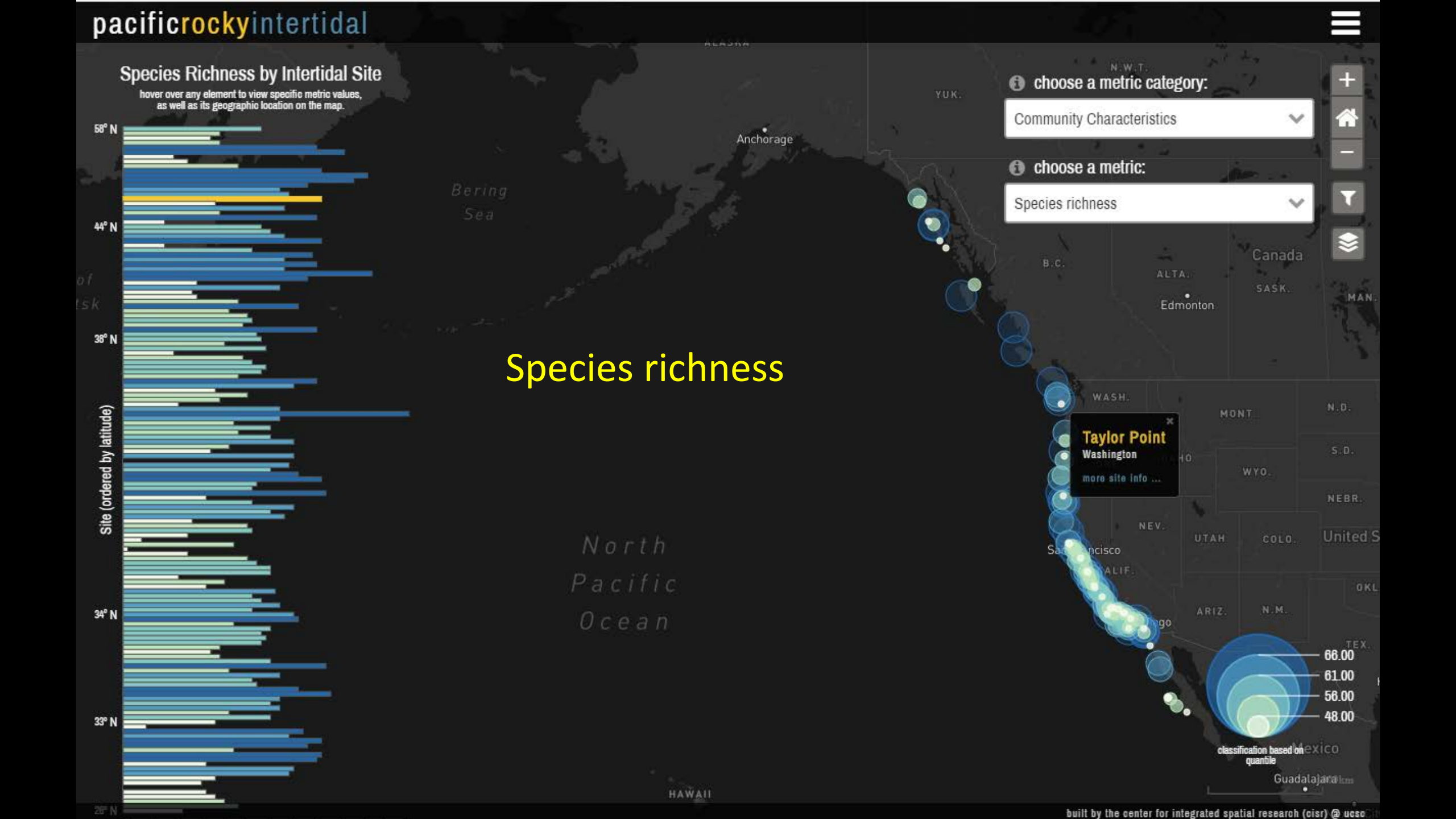
To convert your coordinates to decimal degrees, please visit the following page: http://www.csgnetwork.com/gpscoordconv.html

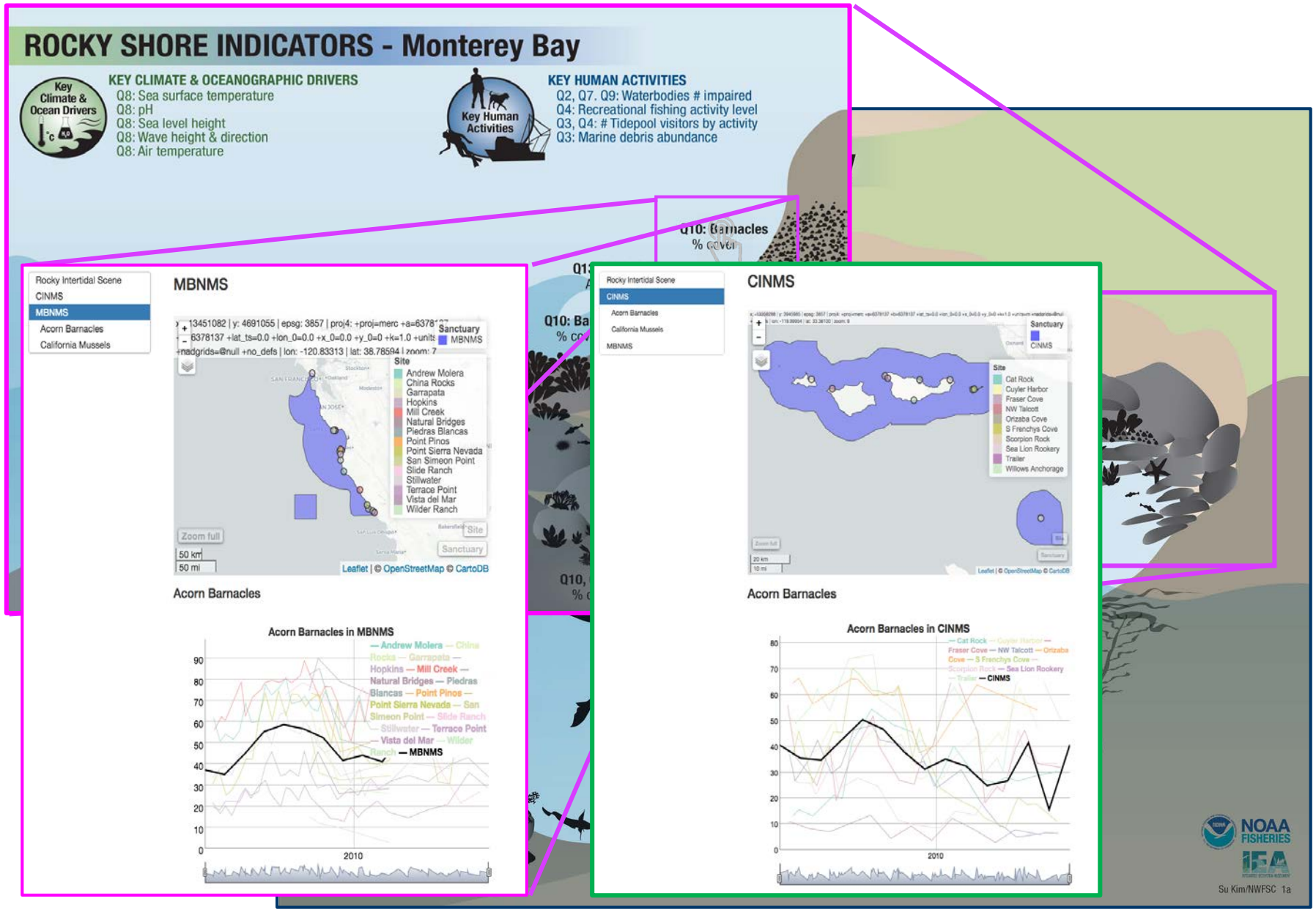
Projects and Data Products home

SSWD Tracking Map




pacificrockyintertidal
Species Cover by Intertidal Site
hover over any element to view specific metric values, as well as its geographic location on the map.
58° N
44° N
38° N
34° N
33° N
Site (ordered by latitude)
choose a metric category:
Species Cover (% Substrate)
choose a metric:
Mytilus californianus
% Cover
Mytilus californianus
Sokol Point; Chilean Memorial
Washington
more site info ...
Anchorage
Bering Sea
North Pacific Ocean
HAWAII
Canada
Edmonton
0.16
0.09
0.03
0.00
classification based on quantile
built by the center for integrated spatial research (cisr) @ ucsc


pacificrockyintertidal
Species Richness by Intertidal Site
hover over any element to view specific metric values, as well as its geographic location on the map.
58° N
44° N
38° N
34° N
33° N
Site (ordered by latitude)
choose a metric category:
Community Characteristics
choose a metric:
Species richness
Species richness
Taylor Point
Washington
more site info ...
Anchorage
Edmonton
Canada
Bering Sea
North Pacific Ocean
HAWAII
66.00
61.00
56.00
48.00
classification based on quantile
built by the center for integrated spatial research (cisr) @ ucsc



NASA NOAA IOOS BOEM

MBON

Marine Biodiversity Observation Network

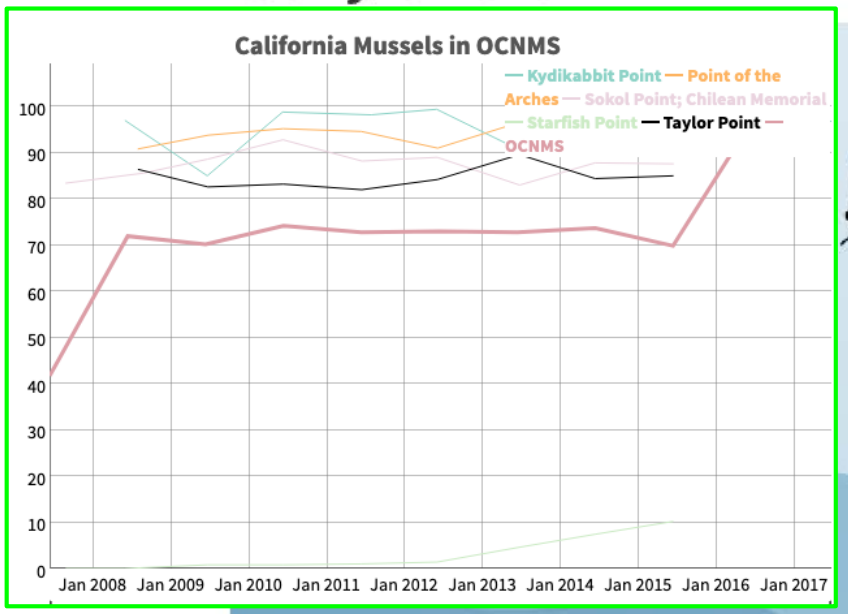
Goal: to make ongoing monitoring information available via dynamic Sanctuary status and trends reports (effort led by Jennifer Brown and Ben Best)

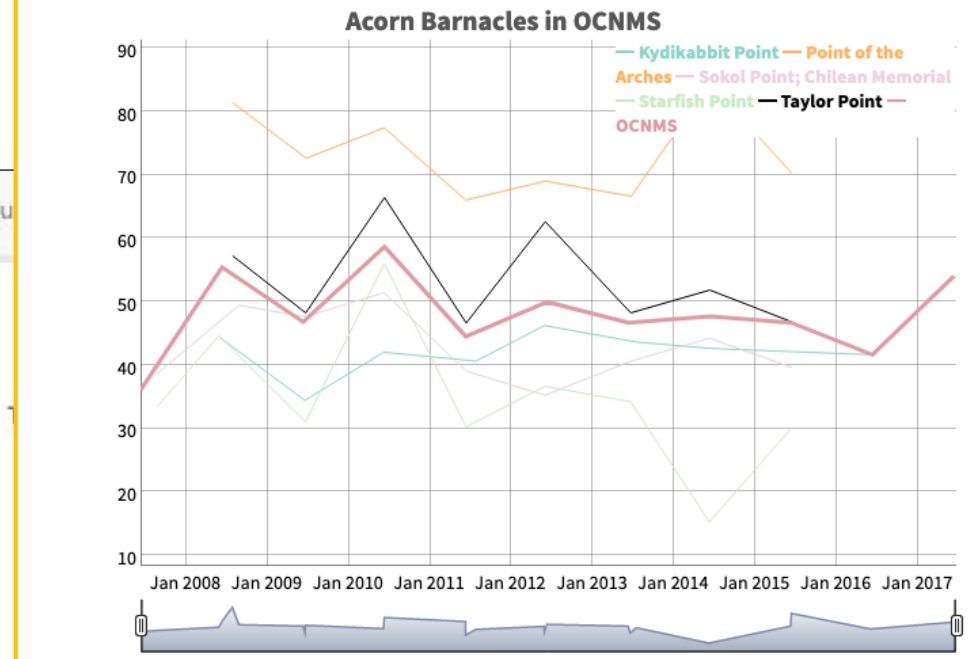
Interactive infographics for MARINe data now available for:

- MBNMS
- CINMS

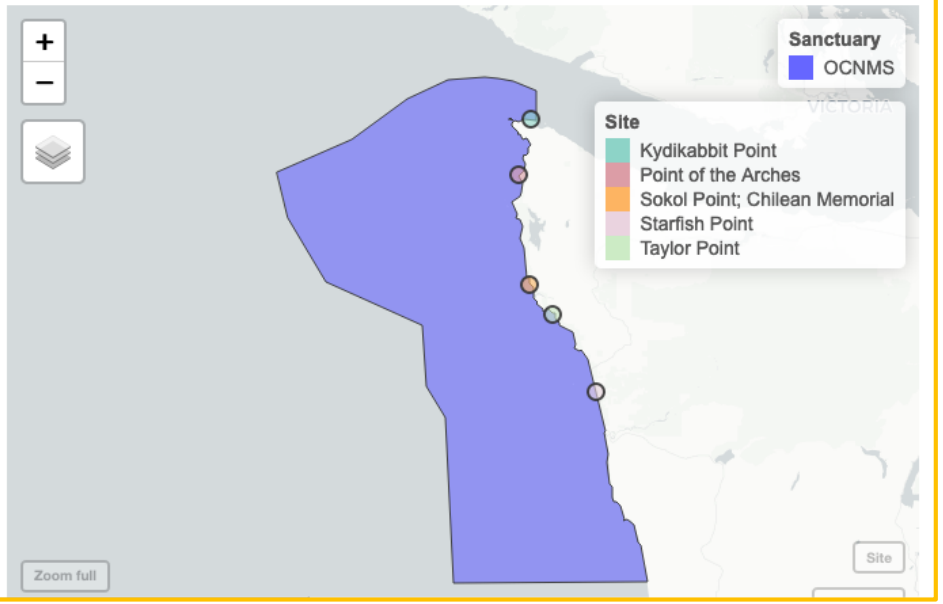
OCNMS | Deep Seafloor | Estuary | Kelp Forest | Pelagic | Rocky Shore | Sandy Beach | Sandy Seafloor | Seamou

Rocky Shore





Map of Sites



Acknowledgements:

Thanks to the many, many scientists and volunteers who have contributed to this project over the past 34 years!

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The Bureau of Ocean Energy Management

Partnership for Interdisciplinary Studies of Coastal Oceans

The National Park Service

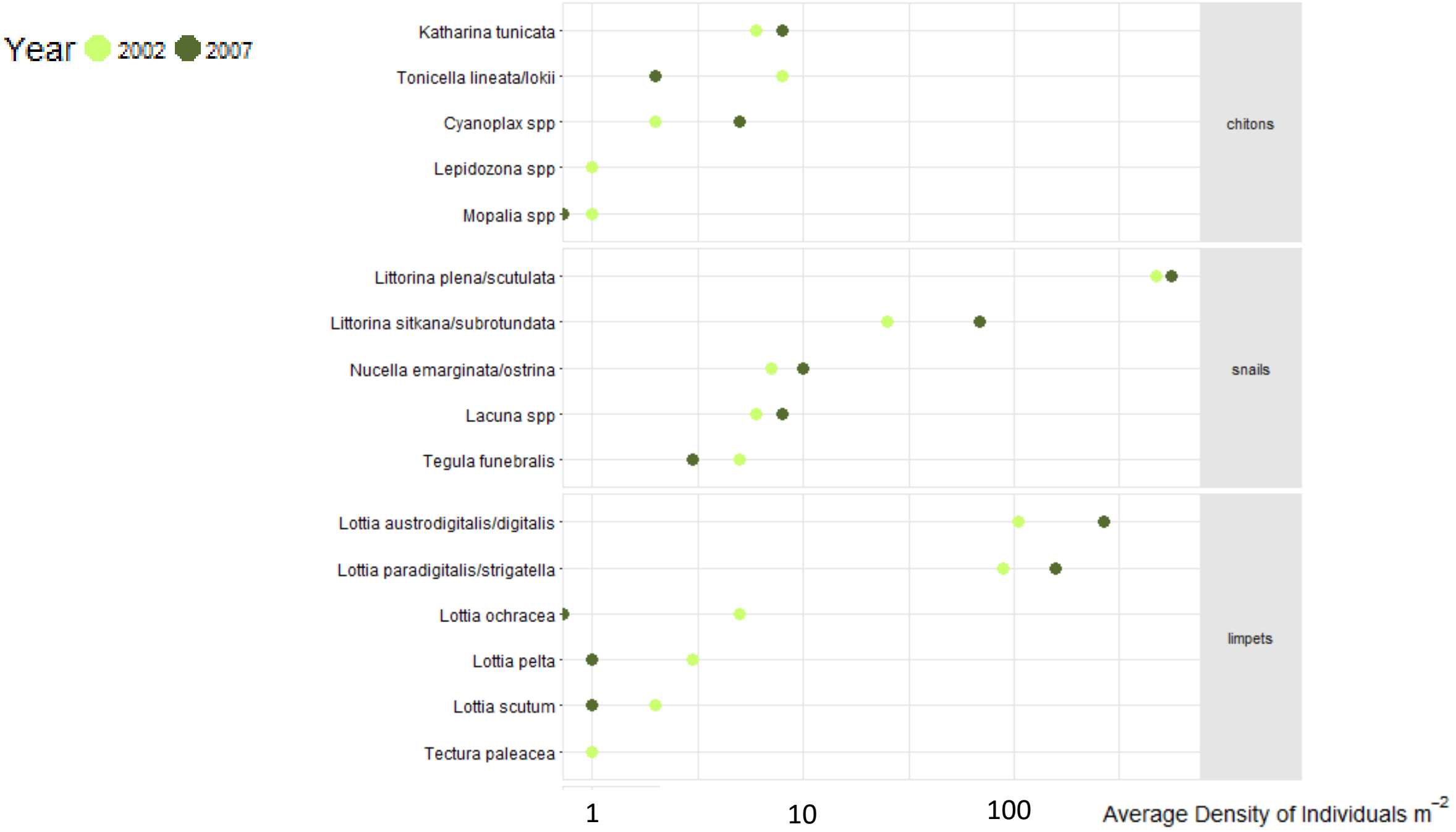
California Sea Grant

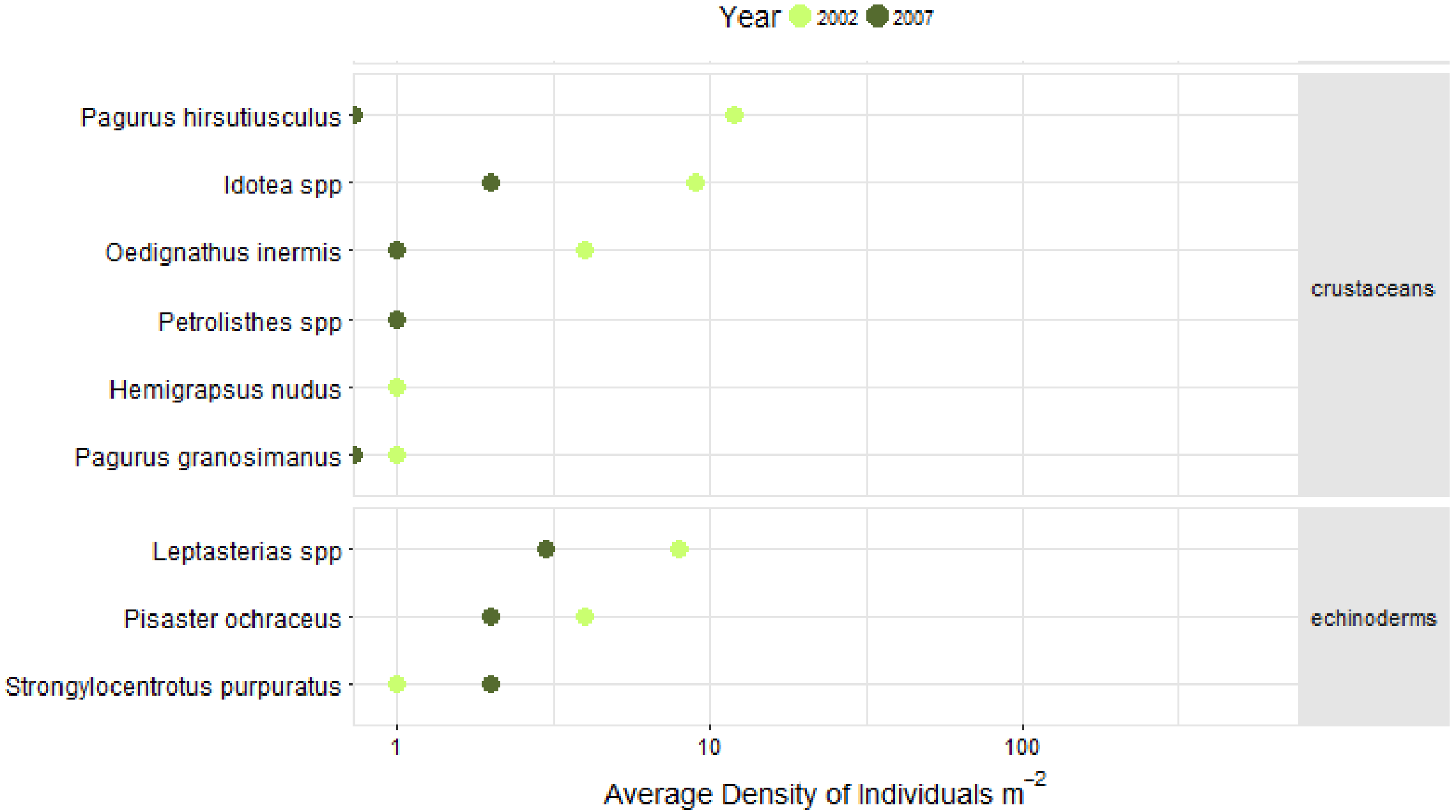
pacificrockyintertidal.org

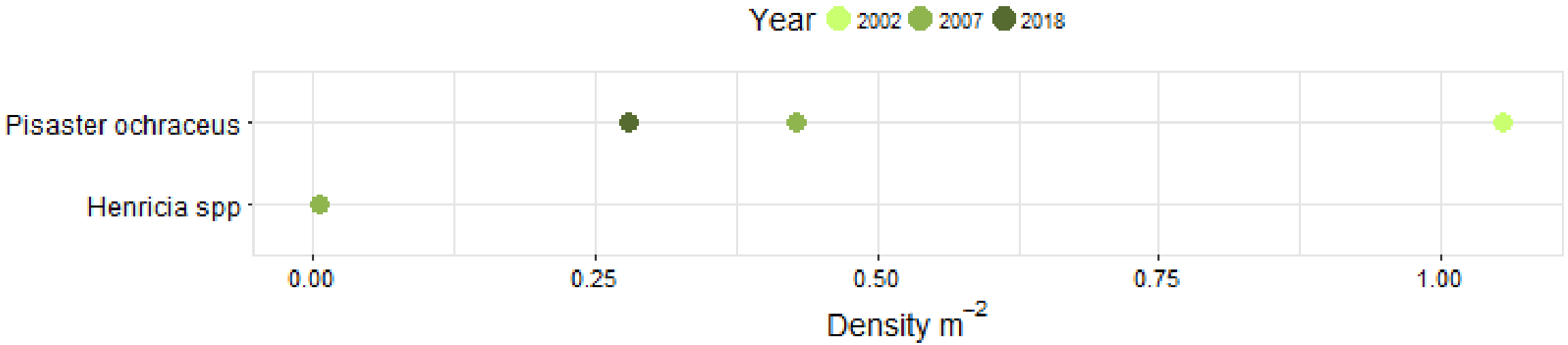
How MARINe data have been used:

- Oil spill impact assessment
- Water quality and discharge related impact
- Potential impacts of Wave Energy Conversion Devices
- Non-native species introduction and spread
- Placement and Effectiveness of MPAs
- Disease spread and impact
- Impacts related to climate change

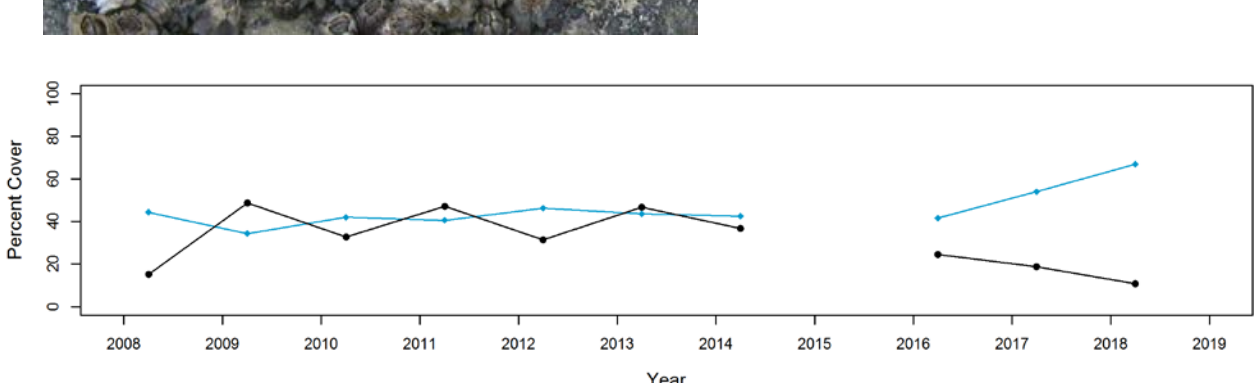

www.history.com

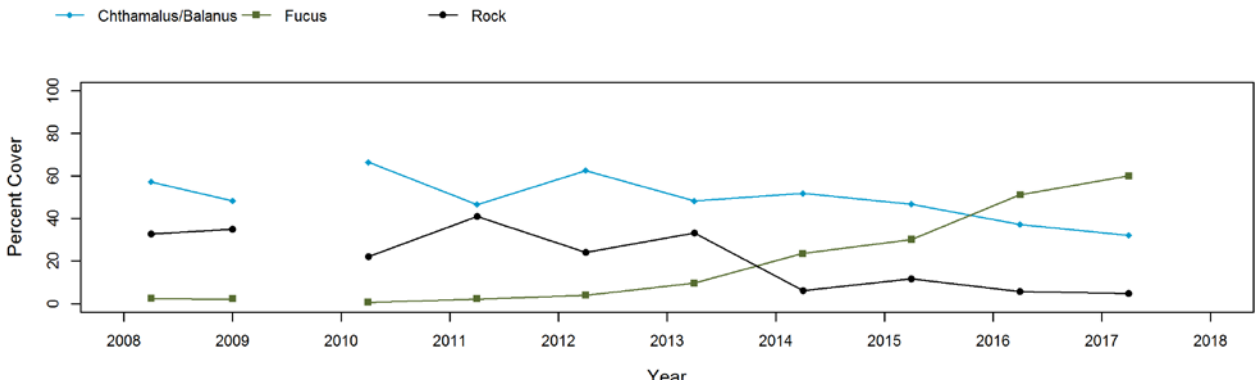

Year
2002
2007
Katharina tunicata
Tonicella lineata/lokii
Cyanoplax spp
Lepidozona spp
Mopalia spp
chitons
Littorina plena/scutulata
Littorina sitkana/subrotundata
Nucella emarginata/ostrina
Lacuna spp
Tegula funebralis
snails
Lottia austrodigitalis/digitalis
Lottia paradigitalis/strigatella
Lottia ochracea
Lottia pelta
Lottia scutum
Tectura paleacea
limpets
1
10
100
Average Density of Individuals m-2

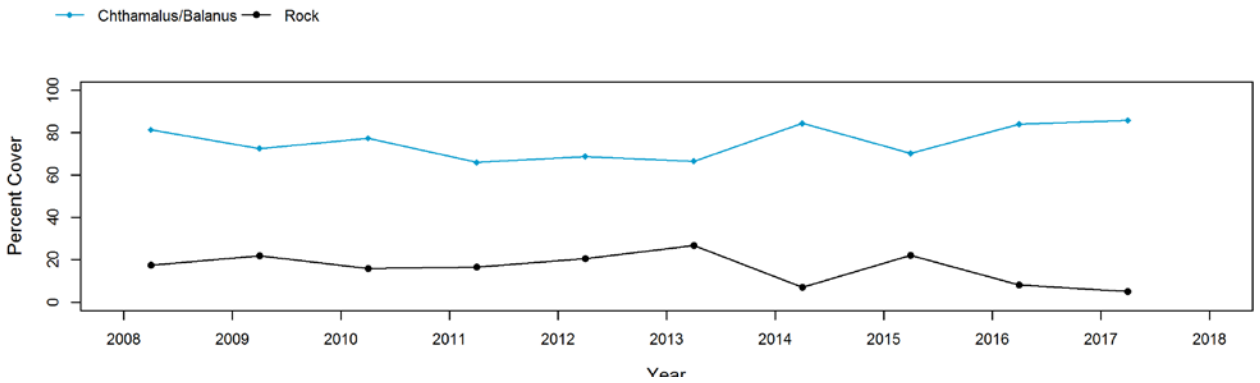

Year
2002
2007
Pagurus hirsutiusculus
Idotea spp
Oedignathus inermis
Petrolisthes spp
Hemigrapsus nudus
Pagurus granosimanus
crustaceans
Leptasterias spp
Pisaster ochraceus
Strongylocentrotus purpuratus
echinoderms
1
10
100
Average Density of Individuals m^{-2}

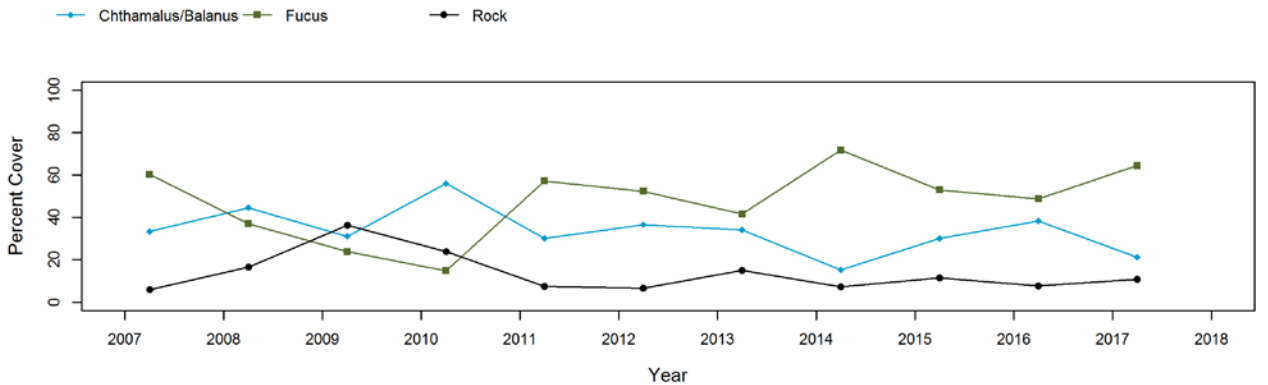

Year
2002
2007
2018
Pisaster ochraceus
Henricia spp
0.00
0.25
0.50
0.75
1.00
Density m^{-2}

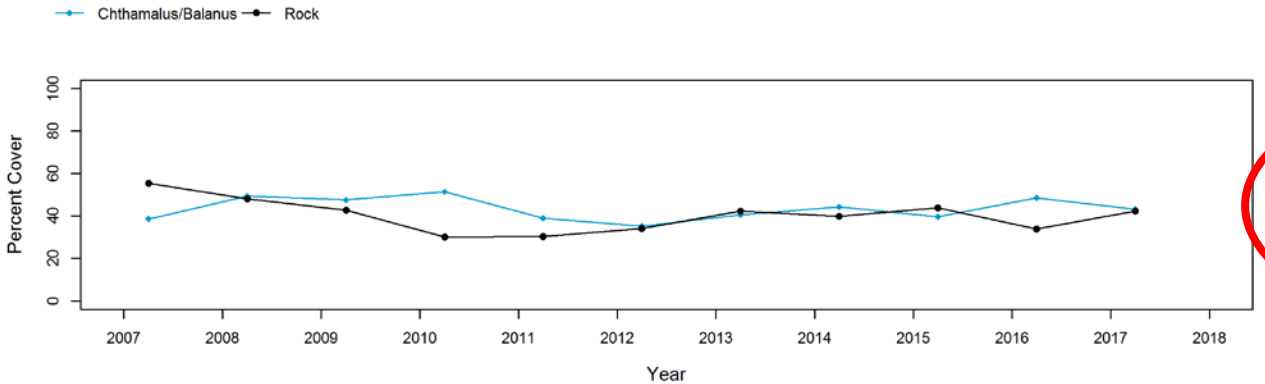
Acorn Barnacles
(*Chthamalus dalli/fissus, Balanus glandula*)

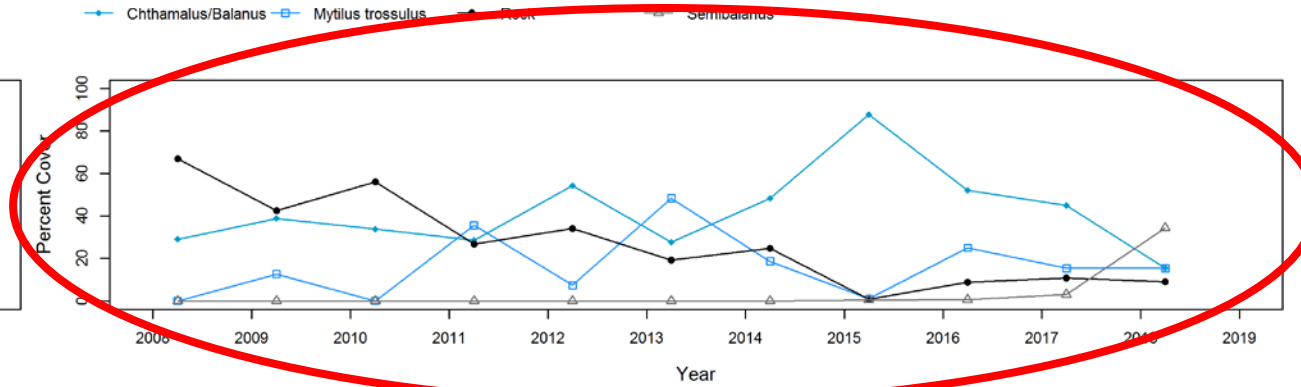


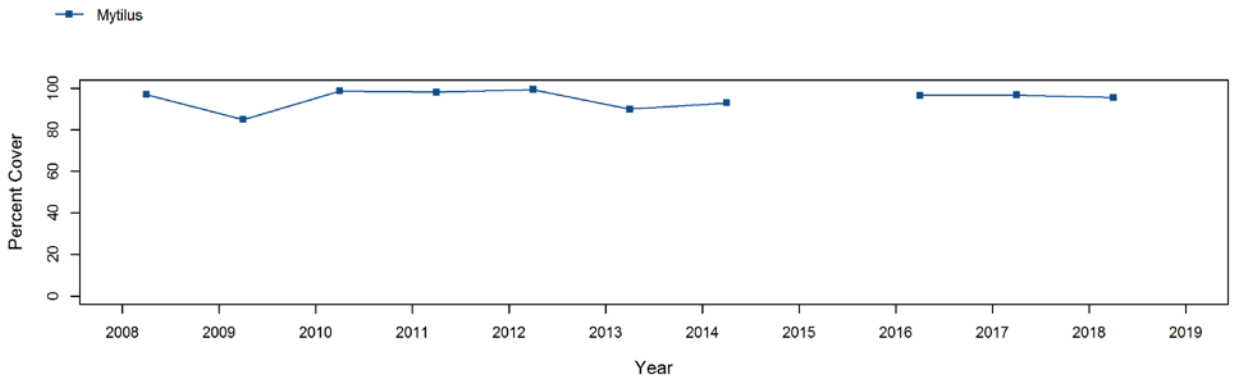


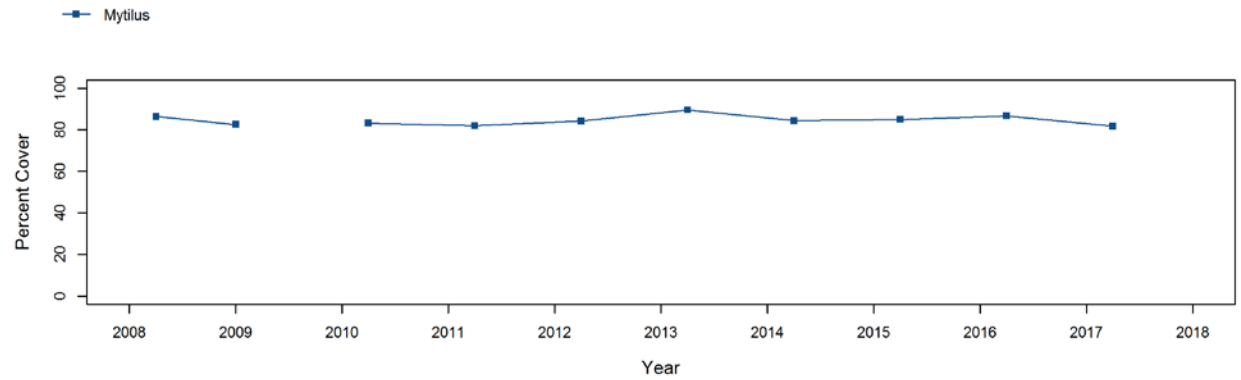


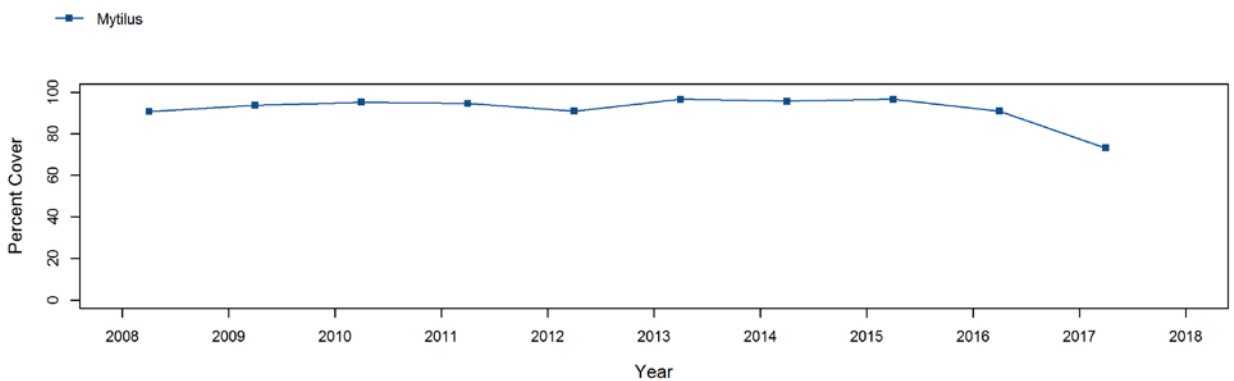


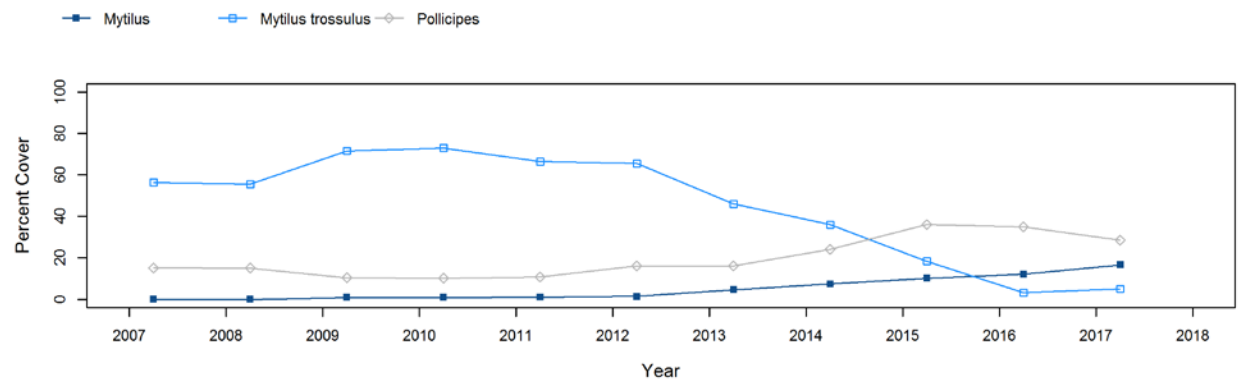


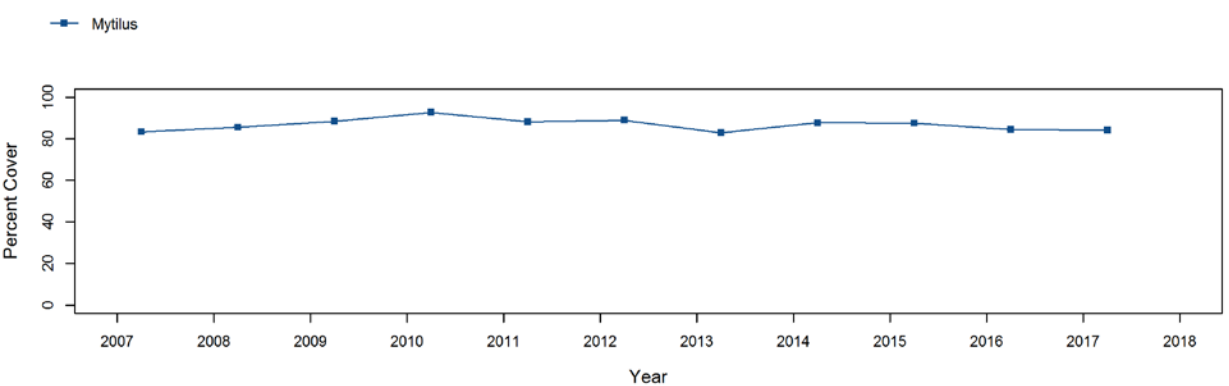


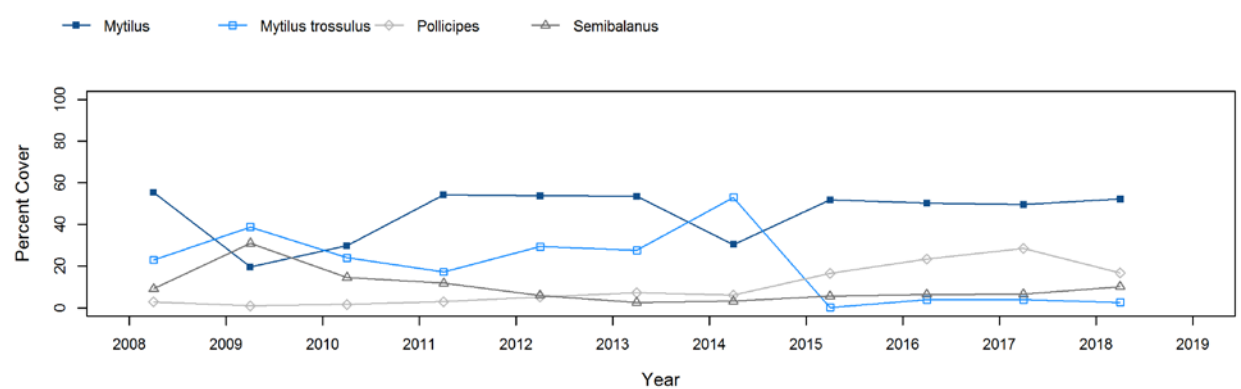

Mytilus
Percent Cover
0
20
40
60
80
100
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year


Mytilus
Percent Cover
0
20
40
60
80
100
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Year

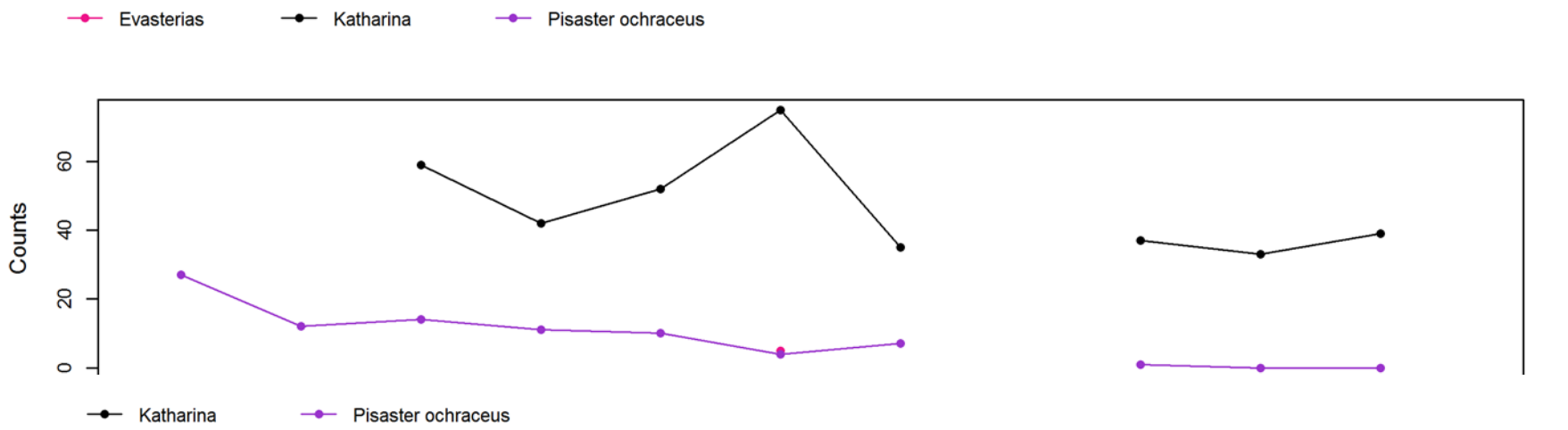

Mytilus
Percent Cover
0
20
40
60
80
100
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Year

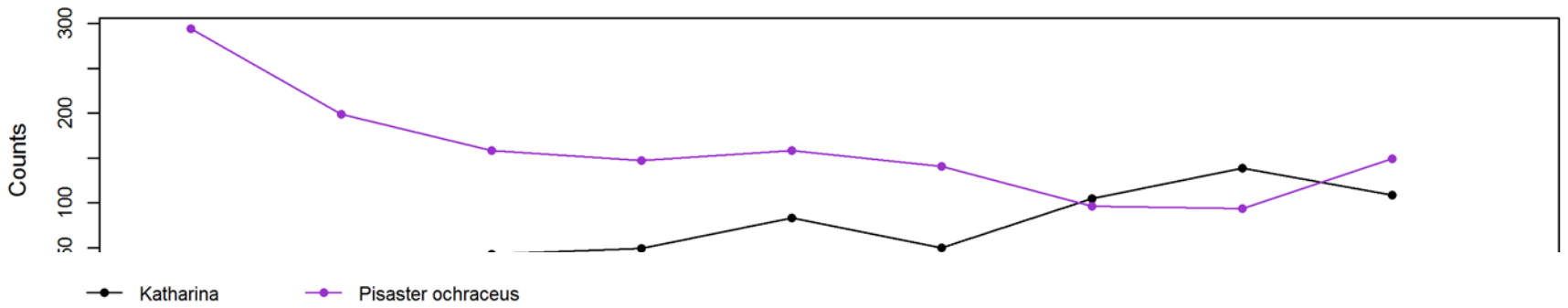

Mytilus
Mytilus trossulus
Pollicipes
Percent Cover
0
20
40
60
80
100
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Year

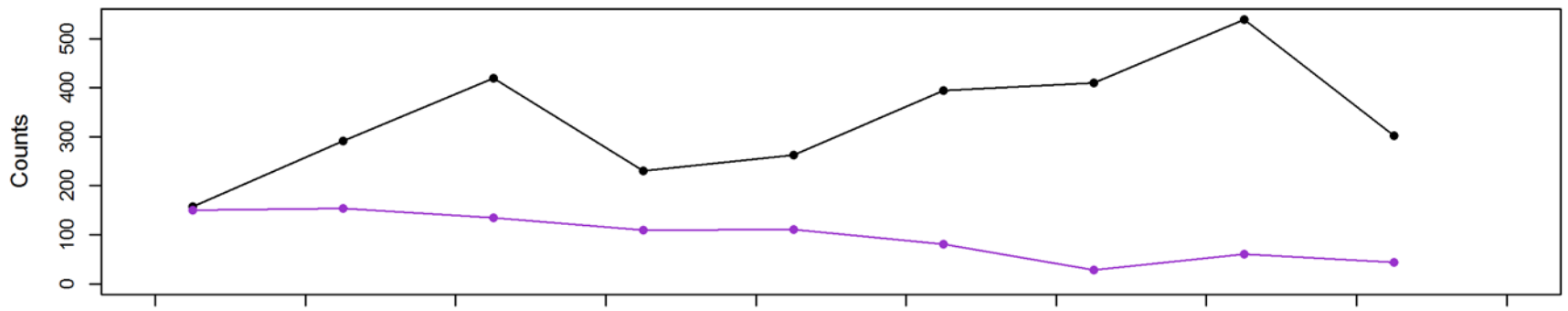

Mytilus
Percent Cover
0
20
40
60
80
100
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Year

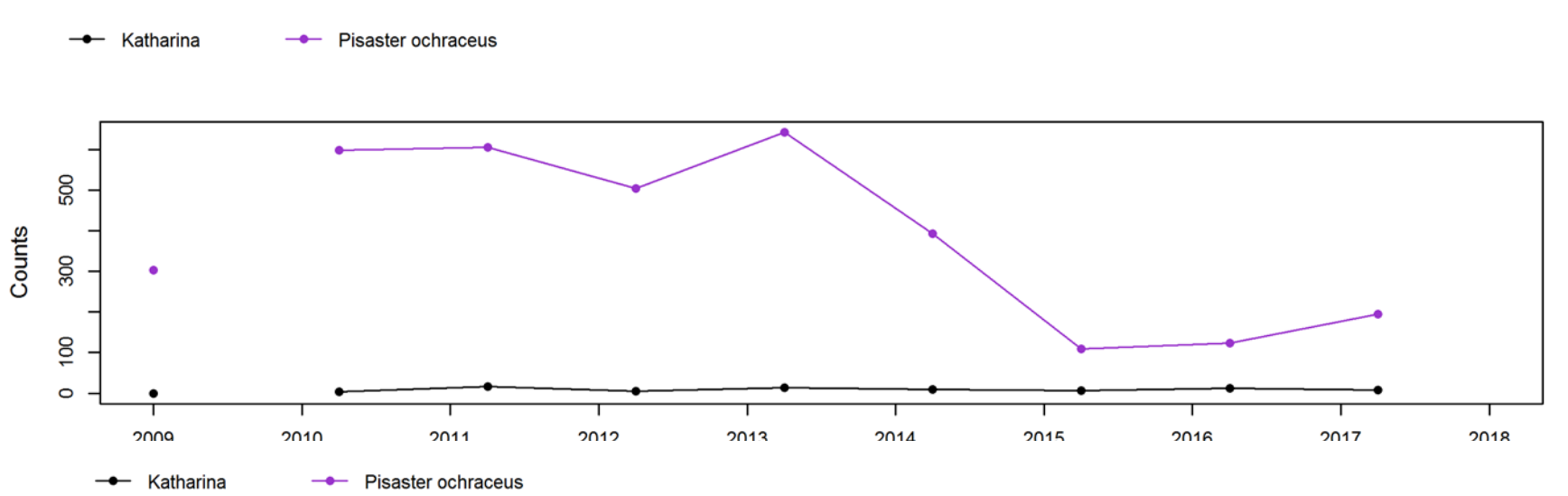

Mytilus
Mytilus trossulus
Pollicipes
Semibalanus
Percent Cover
0
20
40
60
80
100
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year

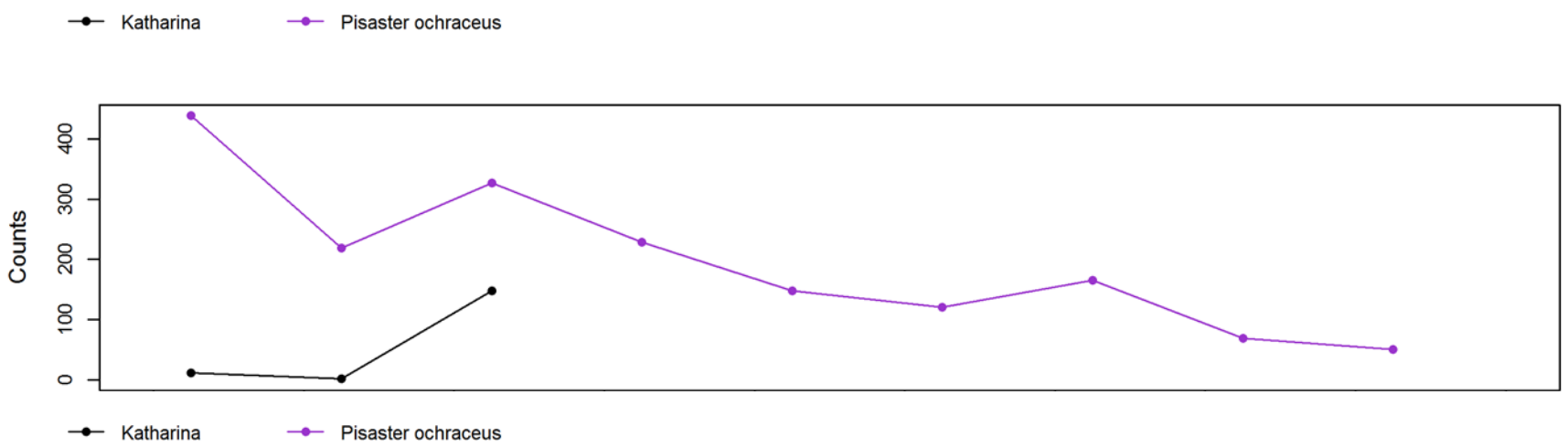
Sea star counts/trends

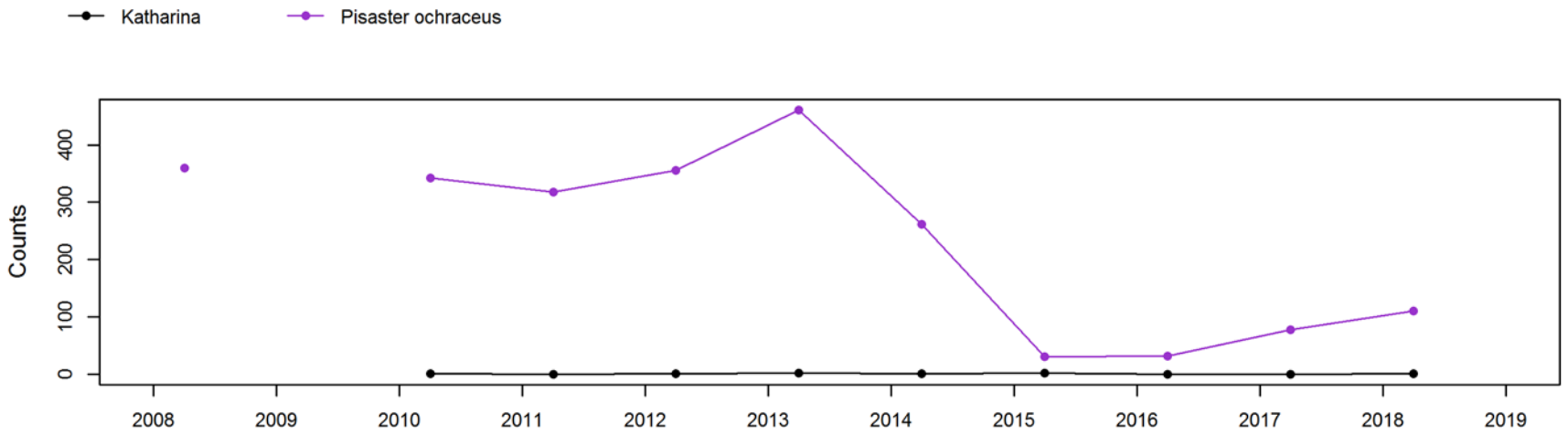






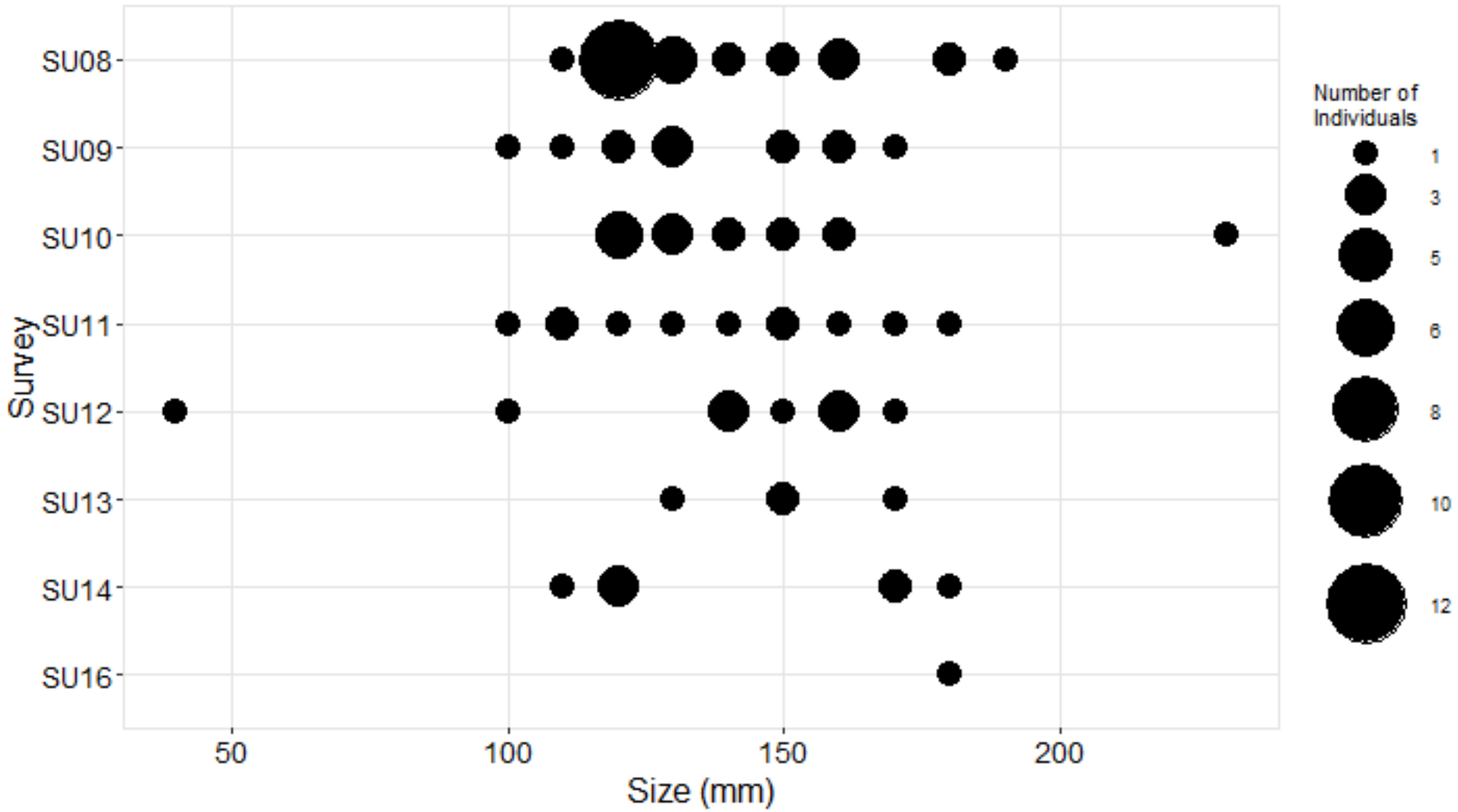

Katharina
Pisaster ochraceus
Counts
0
100
300
500
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018


Katharina
Pisaster ochraceus
Counts
0
100
200
300
400

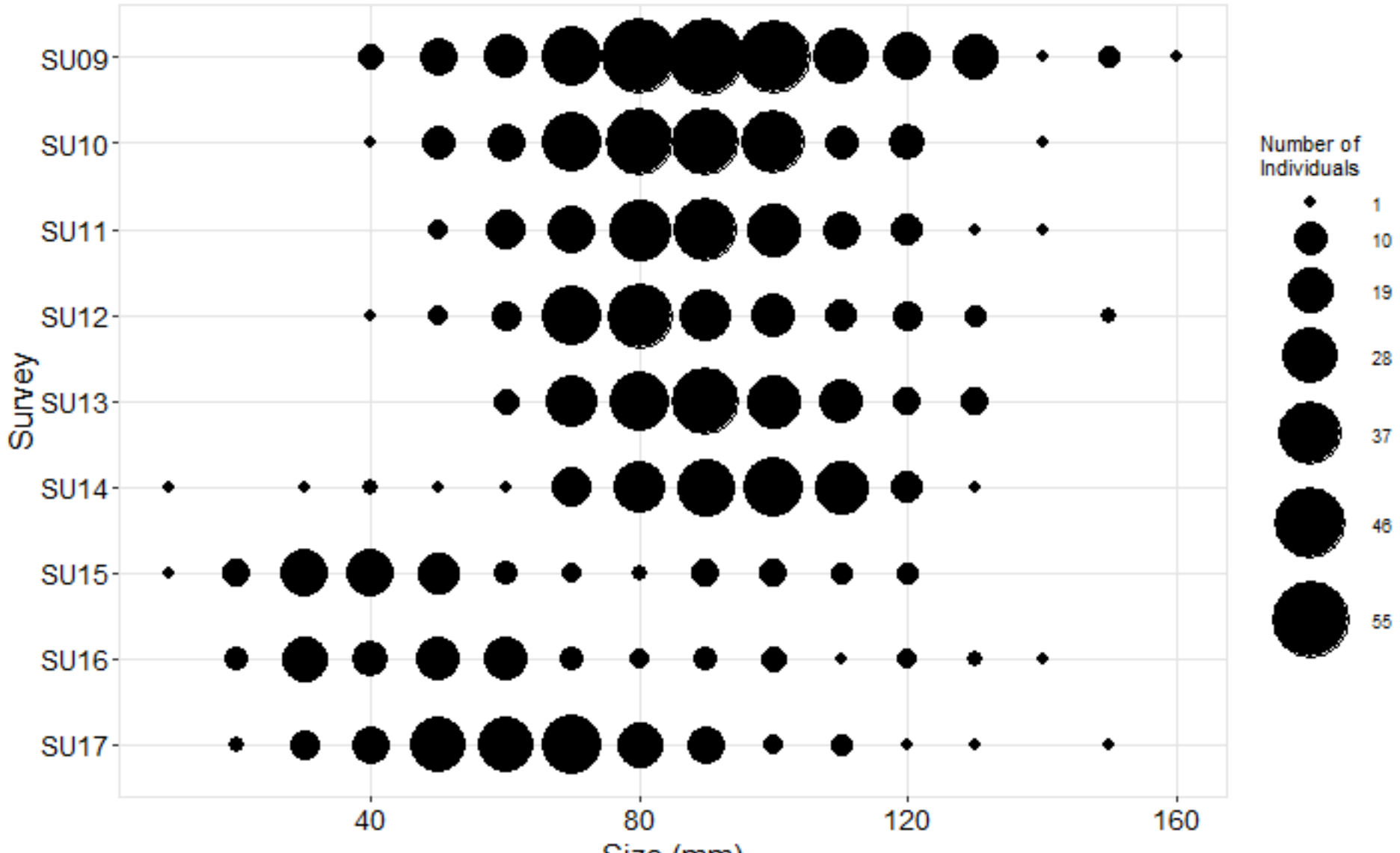

Katharina
Pisaster ochraceus
Counts
0
100
200
300
400
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019

KYDI

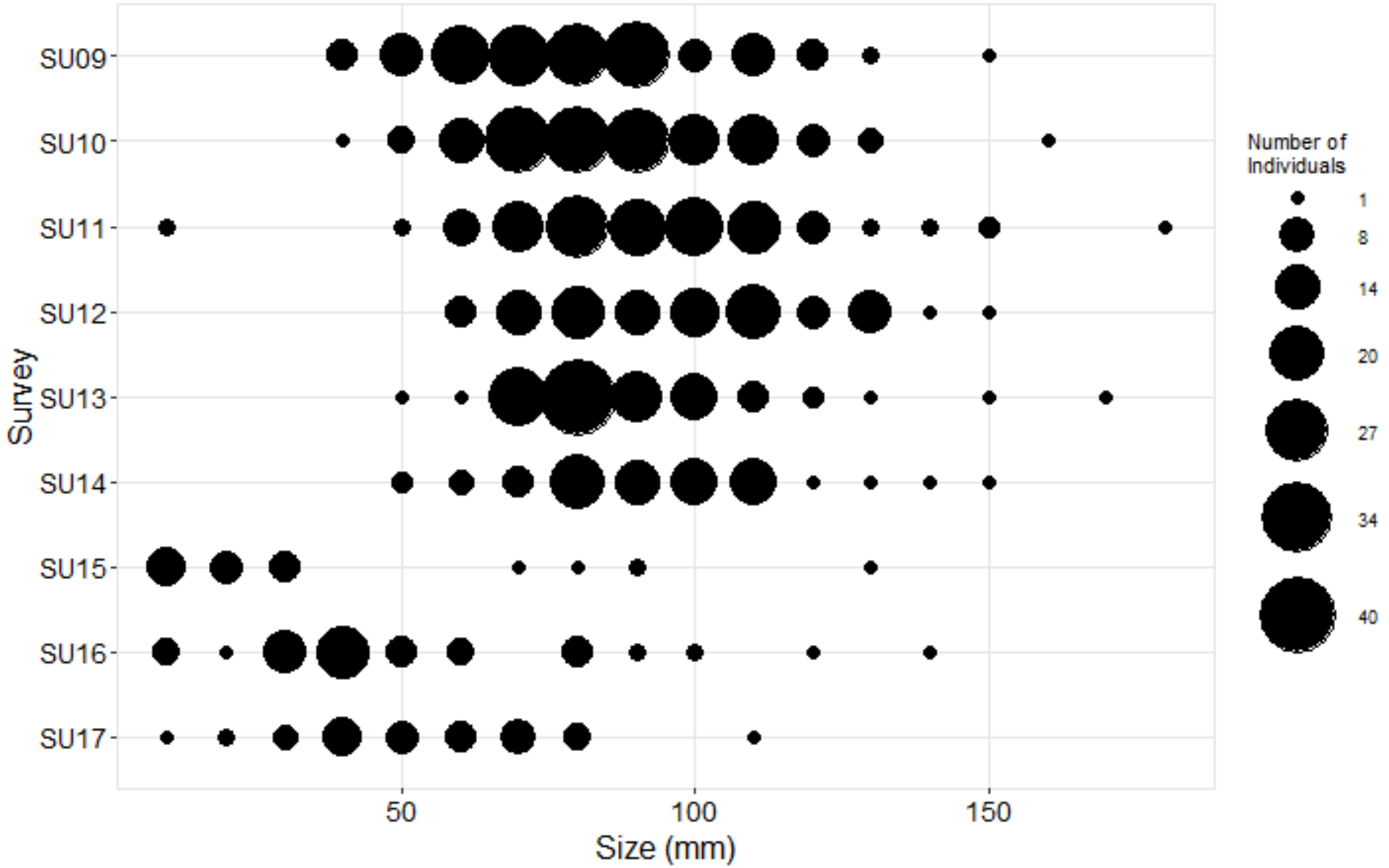
Sea star sizes/recruitment/recovery—maybe lump sites w/hi or low recruitment together?



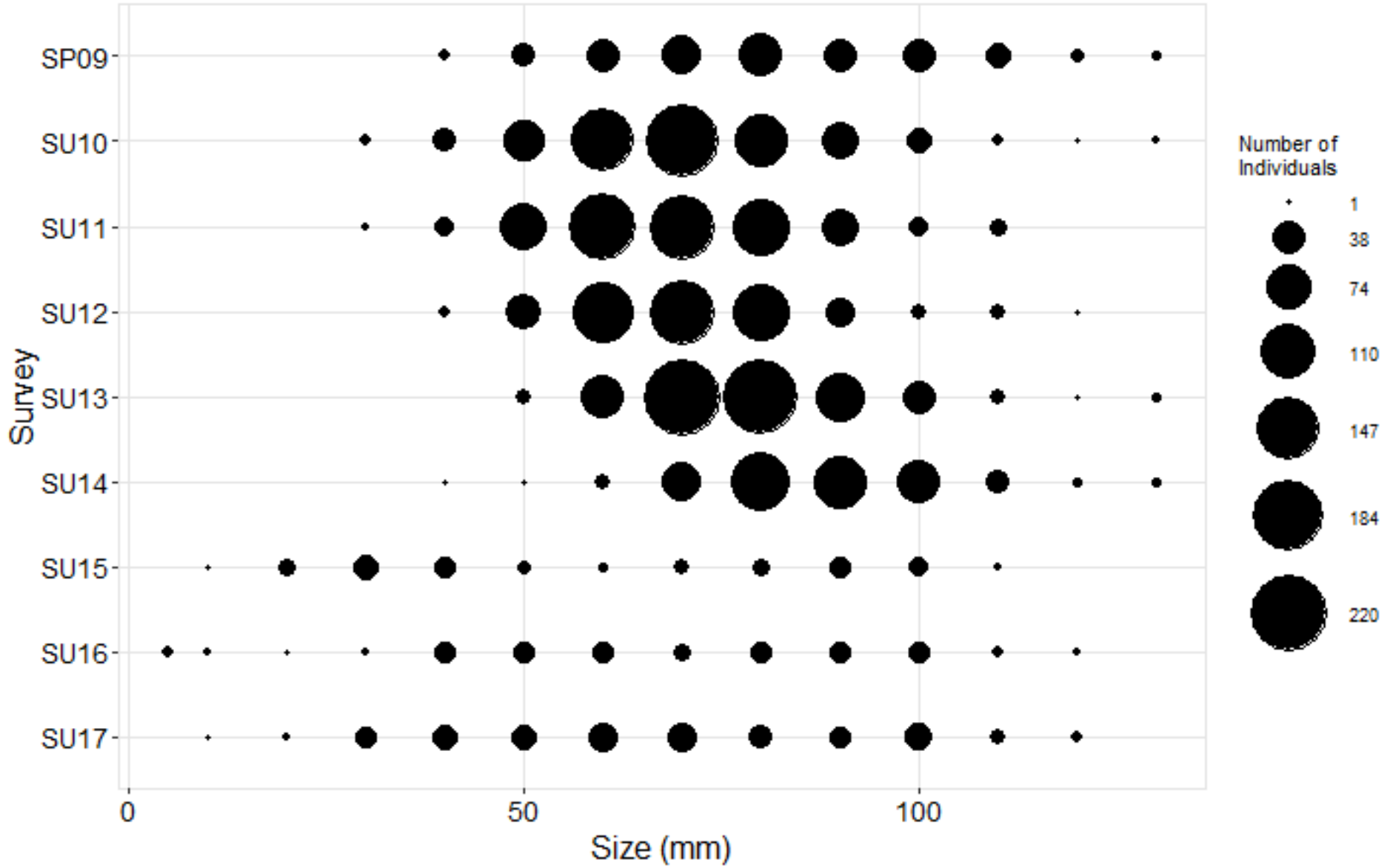
POA

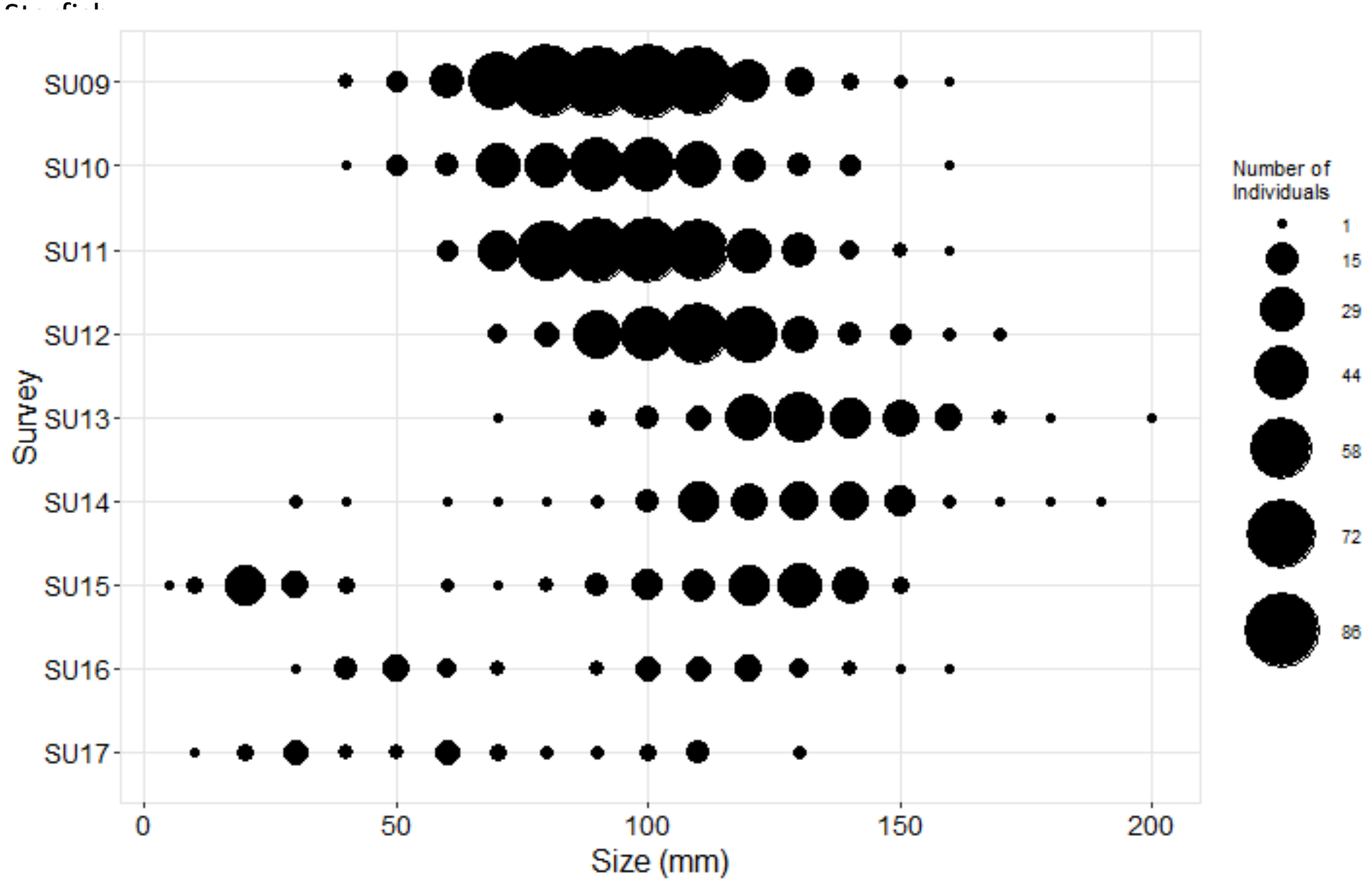

SU09
SU10
SU11
SU12
SU13
SU14
SU15
SU16
SU17
Survey
40
80
120
160
Size (mm)
Number of Individuals
1
10
19
28
37
46
55

Sokal

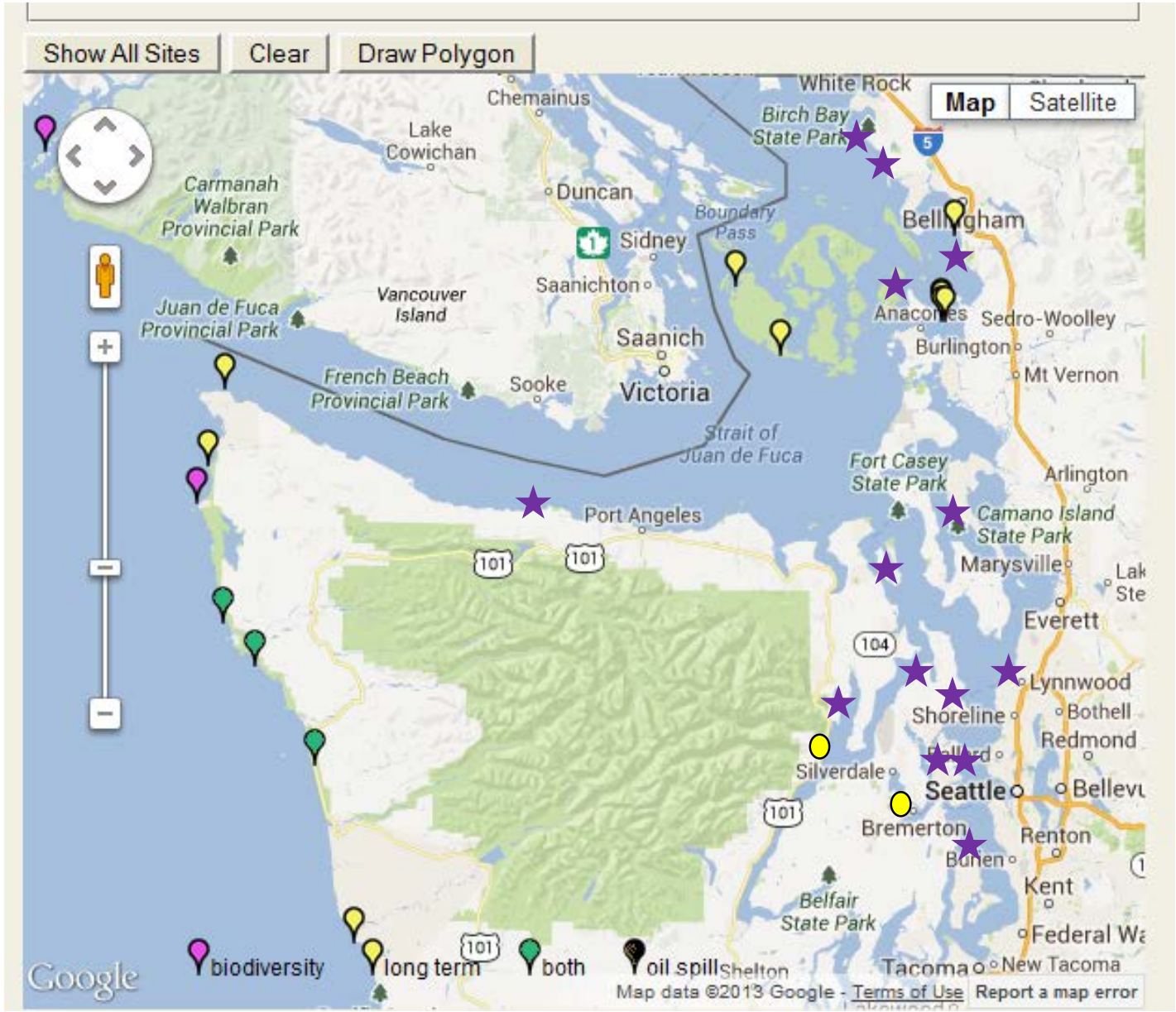

SU09
SU10
SU11
SU12
SU13
SU14
SU15
SU16
SU17
Survey
50
100
150
Size (mm)
Number of Individuals
1
8
14
20
27
34
40

Taylor


SP09
SU10
SU11
SU12
SU13
SU14
SU15
SU16
SU17
Survey
0
50
100
Size (mm)
Number of Individuals
1
38
74
110
147
184
220


SU09
SU10
SU11
SU12
SU13
SU14
SU15
SU16
SU17
Survey
0
50
100
150
200
Size (mm)
Number of Individuals
1
15
29
44
58
72
86

Citizen Science: filling in data gaps



WA Long-term Monitoring Sites
+
Citizen Science Sites

★ Citizen Science Site
>20 in Salish Sea

Related Work

- Continued study of the microbiome (viruses and bacteria) associated with sick stars (Hewson, Cornell and others) and how other factors (e.g., temp, pH) might contribute
- Broad-scale (OR to CenCA) experiments combined with documentation of community response to ochre star loss to:
  - better understand (variable) keystone predator role of *Pisaster ochraceus*
  - Identify factors that make communities resistant to change (e.g. “replacement” predators, mussel recruitment/growth, sea star recovery)
- Explore the genetic consequences of the SSWD outbreak in adult and juvenile *P. ochaceus* using RNA-seq methods (Schiebelhut, UC Merced and others)

Did mass mortality event cause selection that re-shaped genetic diversity of *P. ochraceus*? Results can be used to:

- Determine potential for *P. ochraceus* to respond to future perturbation
  - Might be better suited to survive another SSWD event BUT
  - Worse suited for other types of perturbations due to decrease in genetic diversity
- Track recruitment/survivorship/recovery patterns if sufficient genetic distinction among sub-populations

Poleward shift of communities