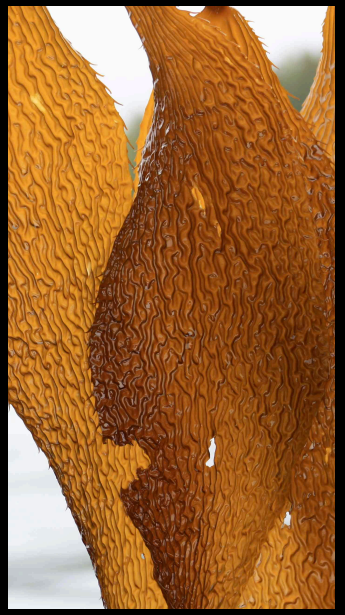
Sea Otters, Kelp Forests, and Coastal Communities: Ecosystem Services among Trophic Cascades


Kai Chan, Russell Markel, Rebecca Martone, Edward Gregr, Jessie Clasen,
Brock Ramshaw, Gerald Singh, Maria Espinosa
Institute for Resources, Environment and Sustainability

LEOPOLD LEADERSHIP PROGRAM
Stanford Woods Institute for the Environment

PICES, Oct 15 2013 @KaiChanUBC

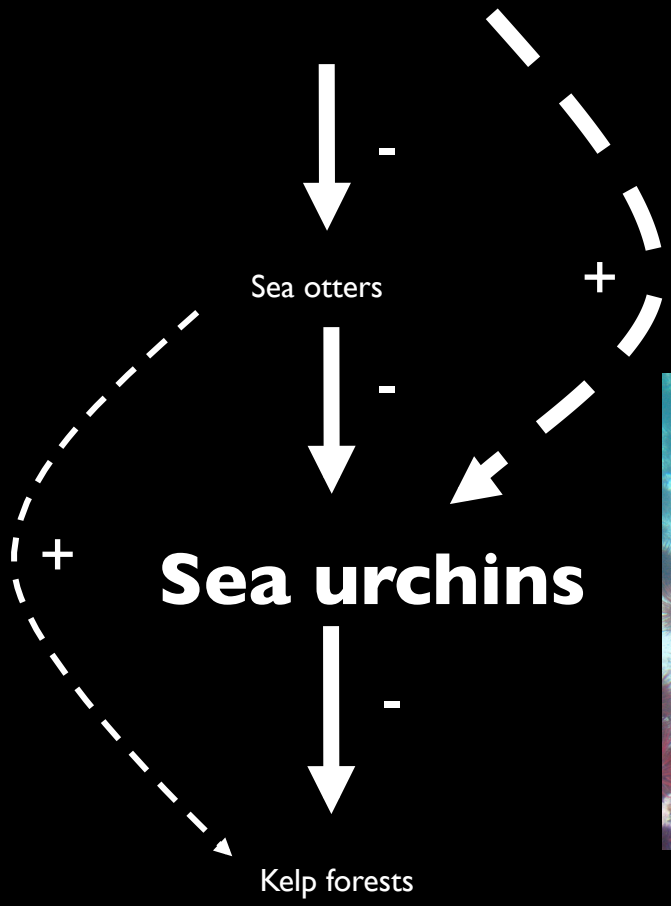
photos: KC

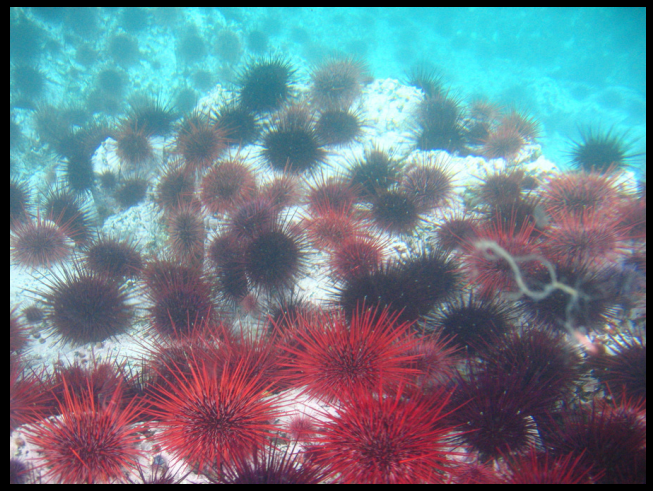
BC Coastal Ecosystem Services

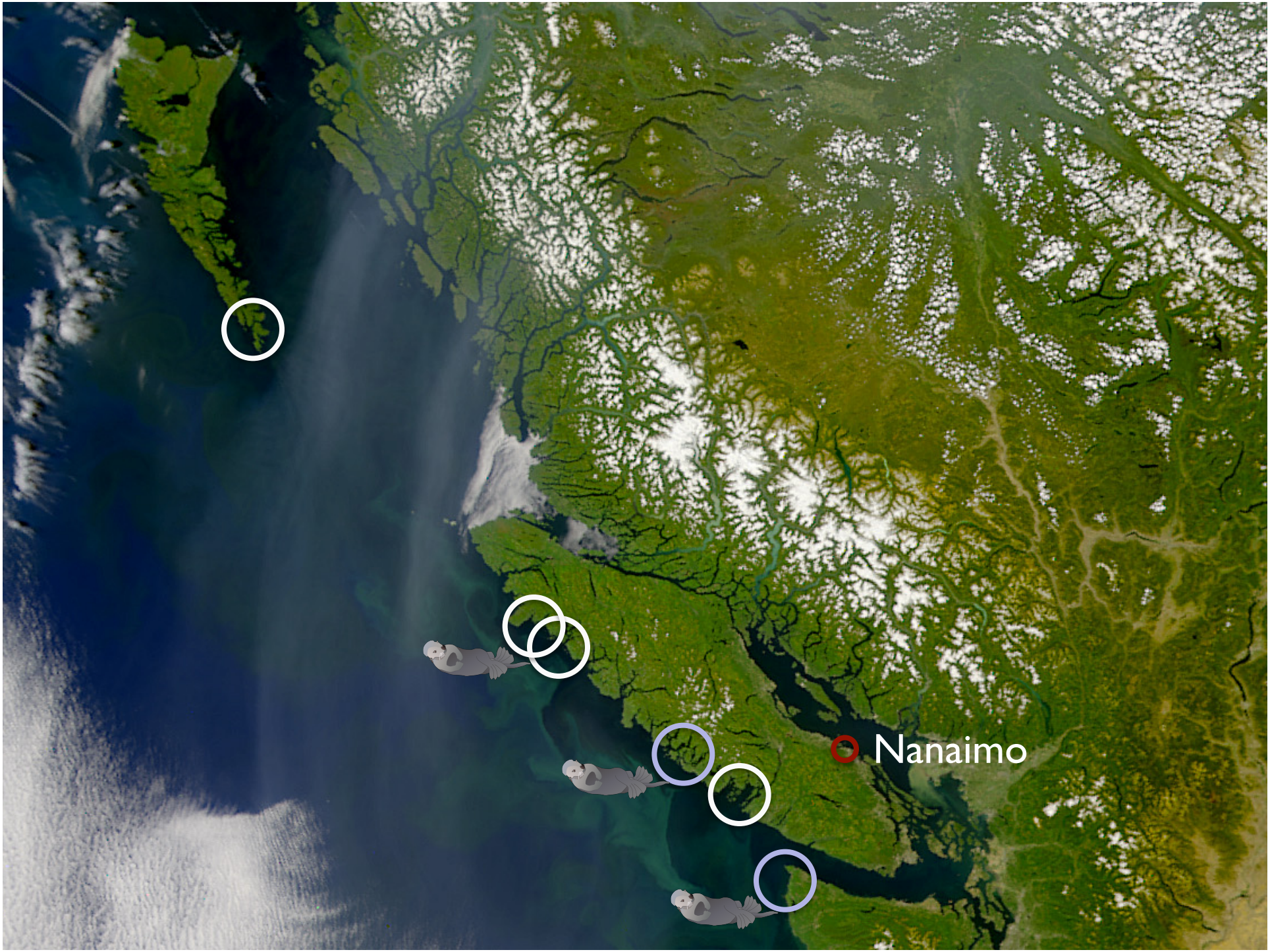
+ Evgeny Pakhomov, Brock Ramshaw, Terre Satterfield, Villy Christensen, Rashid Sumaila, Sven Kaehler, Theraesa Coyle

A Story of Sea Otters

Maritime Fur Trade (ca 1778-1911)






Nanaimo

Sea otter reintroduction

\-

Sea urchins

\+

\-

Kelp forests


KC

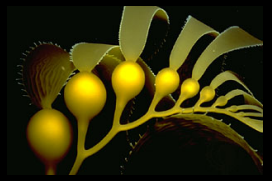
Conflict: Conservation *vs.* Fisheries

- Existence value
- "Natural" ecosystems
- Tourism value

- Rapid shellfish population declines
- Economic loss
- Cultural/traditional loss

But … perhaps this is a narrow view of the benefits and costs


What are the consequences of sea otter and kelp recovery for coastal communities?
KC



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Ecosystem service model

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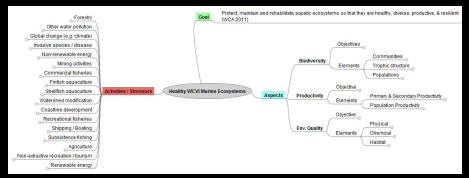
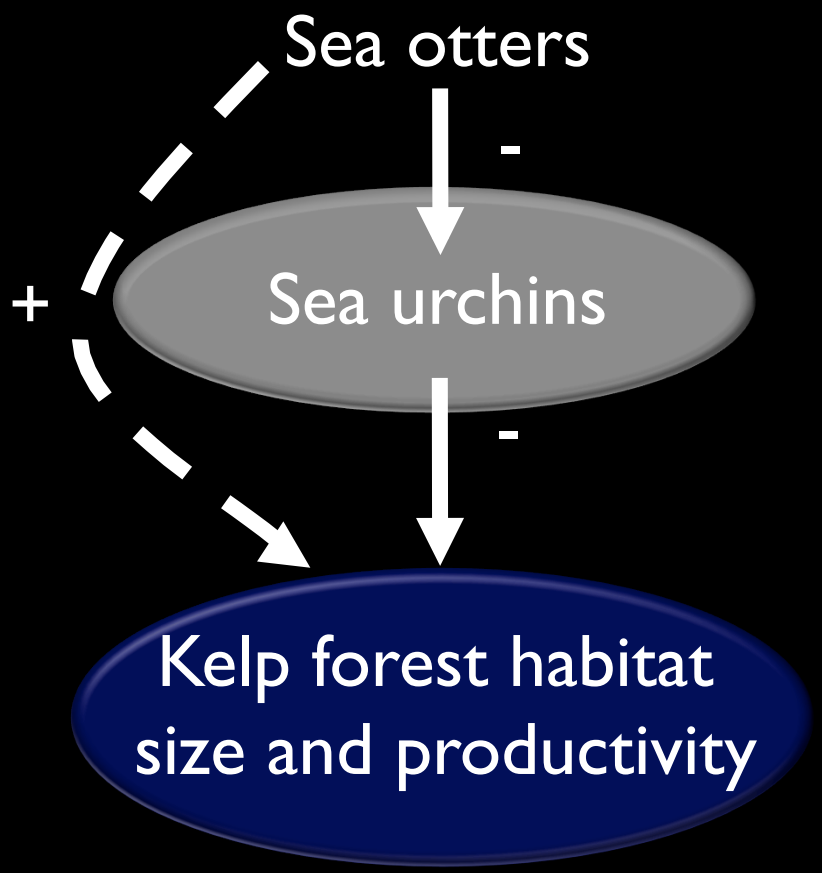
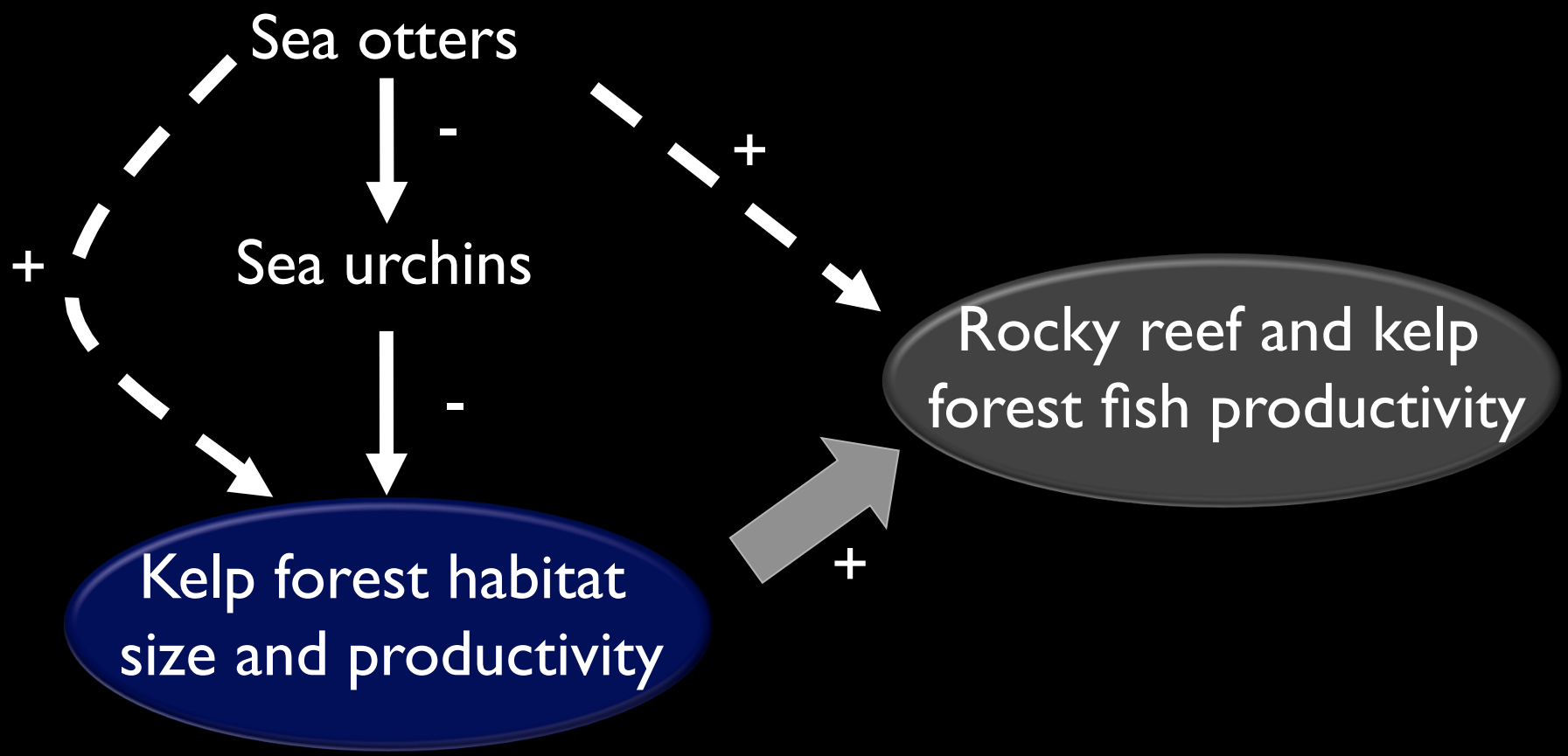
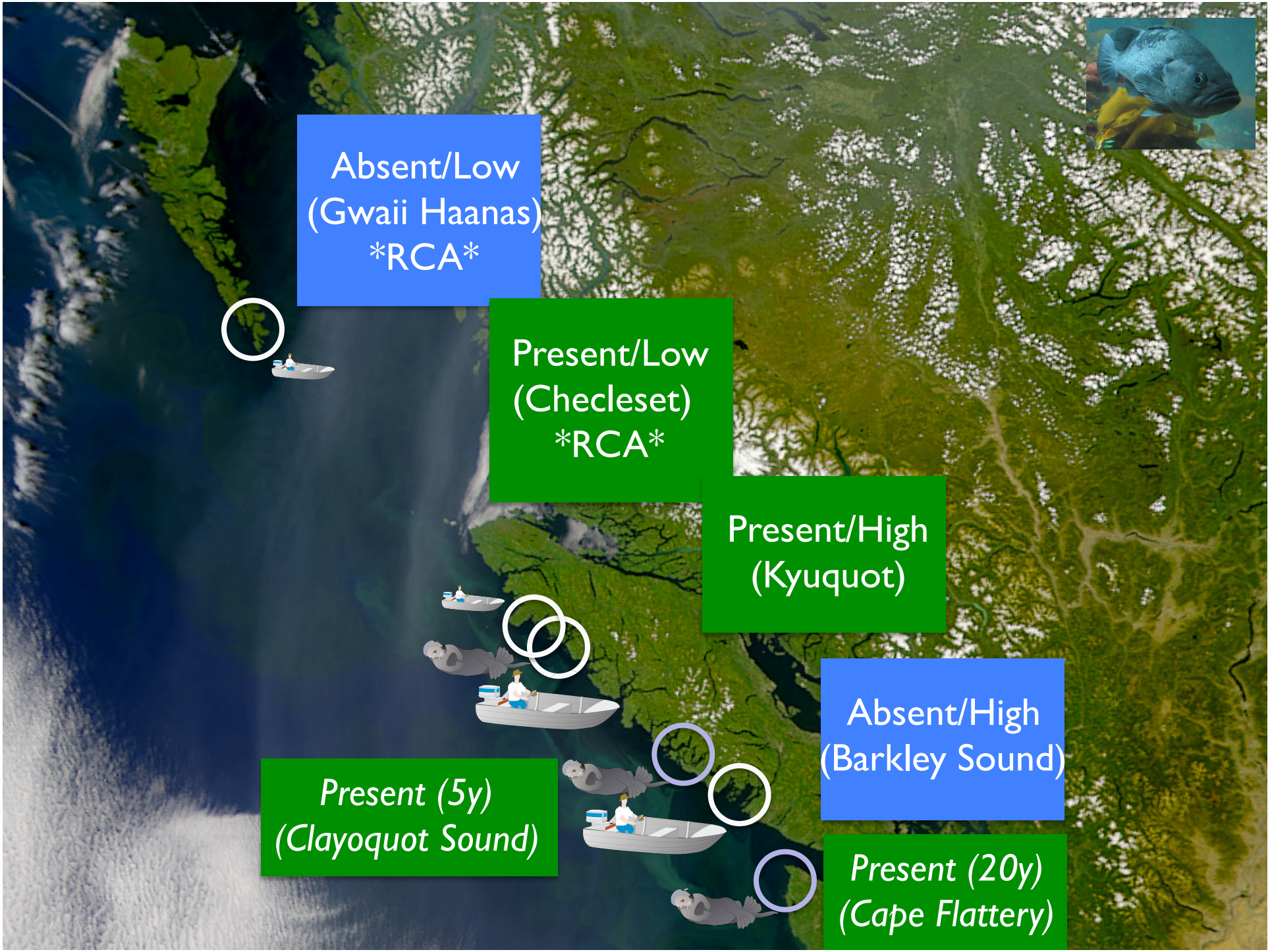
Management indicators




Sea otters
-
+
Sea urchins
-
Kelp forest habitat
size and productivity

Do sea otters enhance reef fish populations; how?

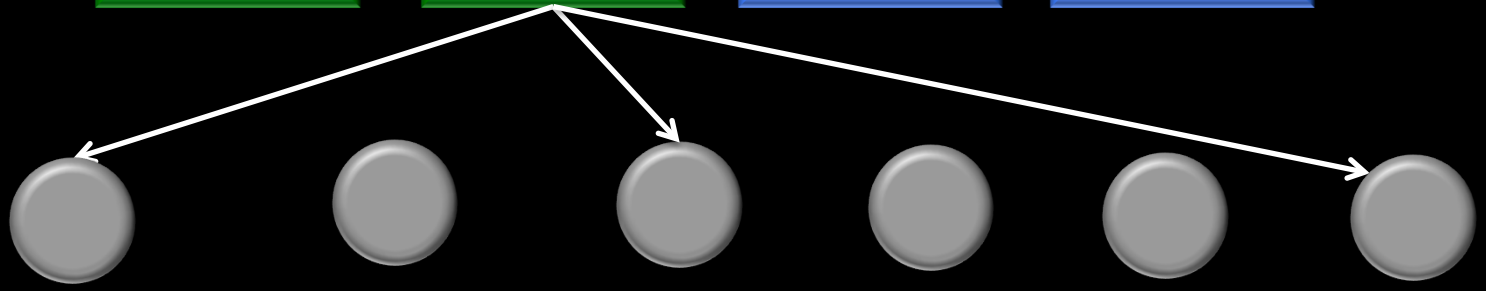



Absent/Low
(Gwaii Haanas)
RCA
Present/Low
(Checleset)
RCA
Present/High
(Kyuquot)
Absent/High
(Barkley Sound)
Present (5y)
(Clayoquot Sound)
Present (20y)
(Cape Flattery)

Regions:

- Absent/High Barkley Sound
- Absent/Low Gwaii Haanas
- Present/High Kyuquot
- Present/Low Checleset

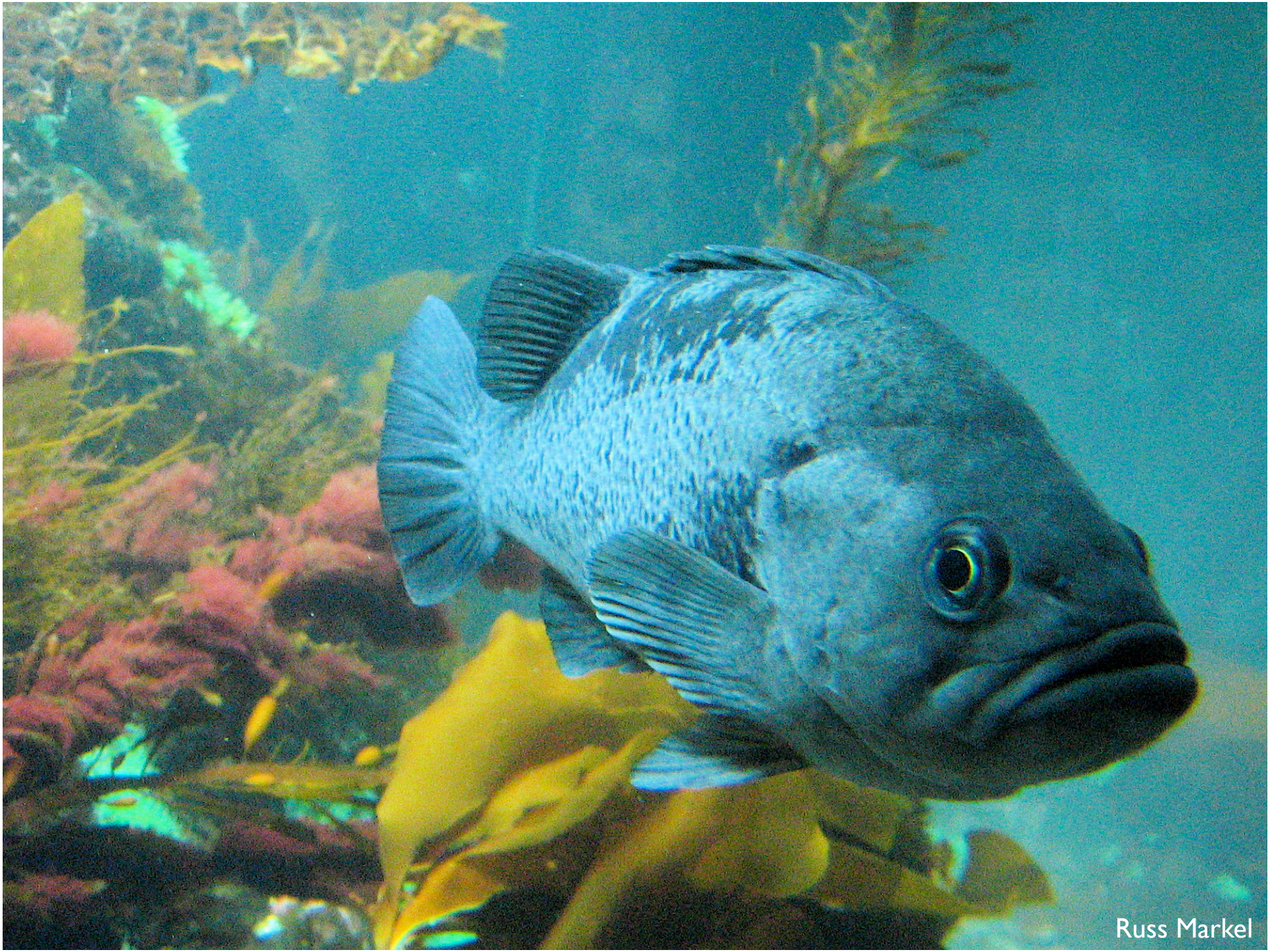
Sites:



Site-level measures:

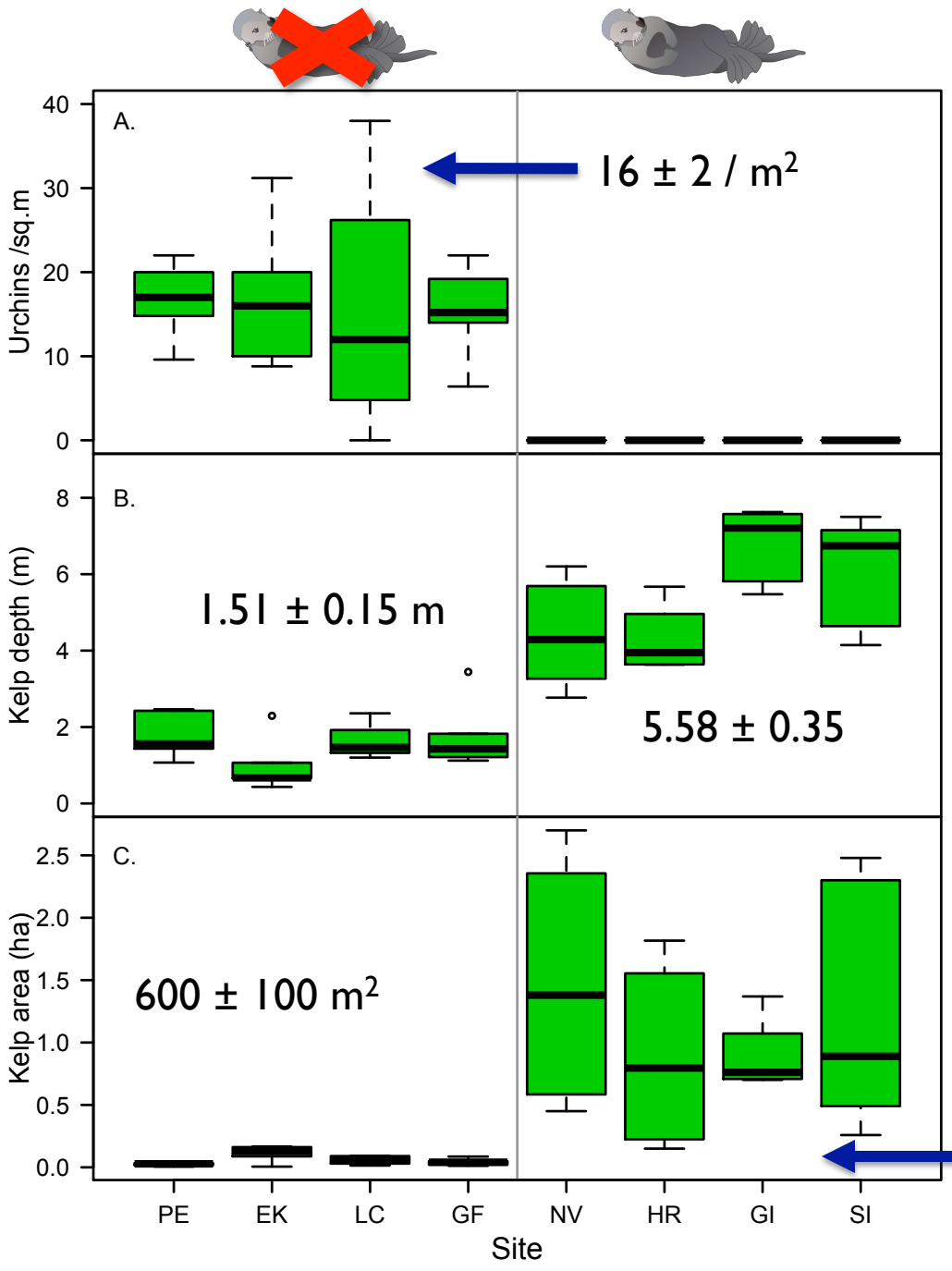
1. Kelp forest depth and size
2. Fish size/abundance (CPUE and dive surveys)
3. Kelp forest food web structure (dive surveys)
4. Fish diet (stomach content analysis)
5. Fish trophic position and carbon supply (stable isotopes)
6. Fish growth rates (otolith microstructure analysis)

Russ Markel, Rebecca Martone *et al.*


Russ Markel

Urchin abundance and kelp forest habitat size

Russ Markel



Urchins rare

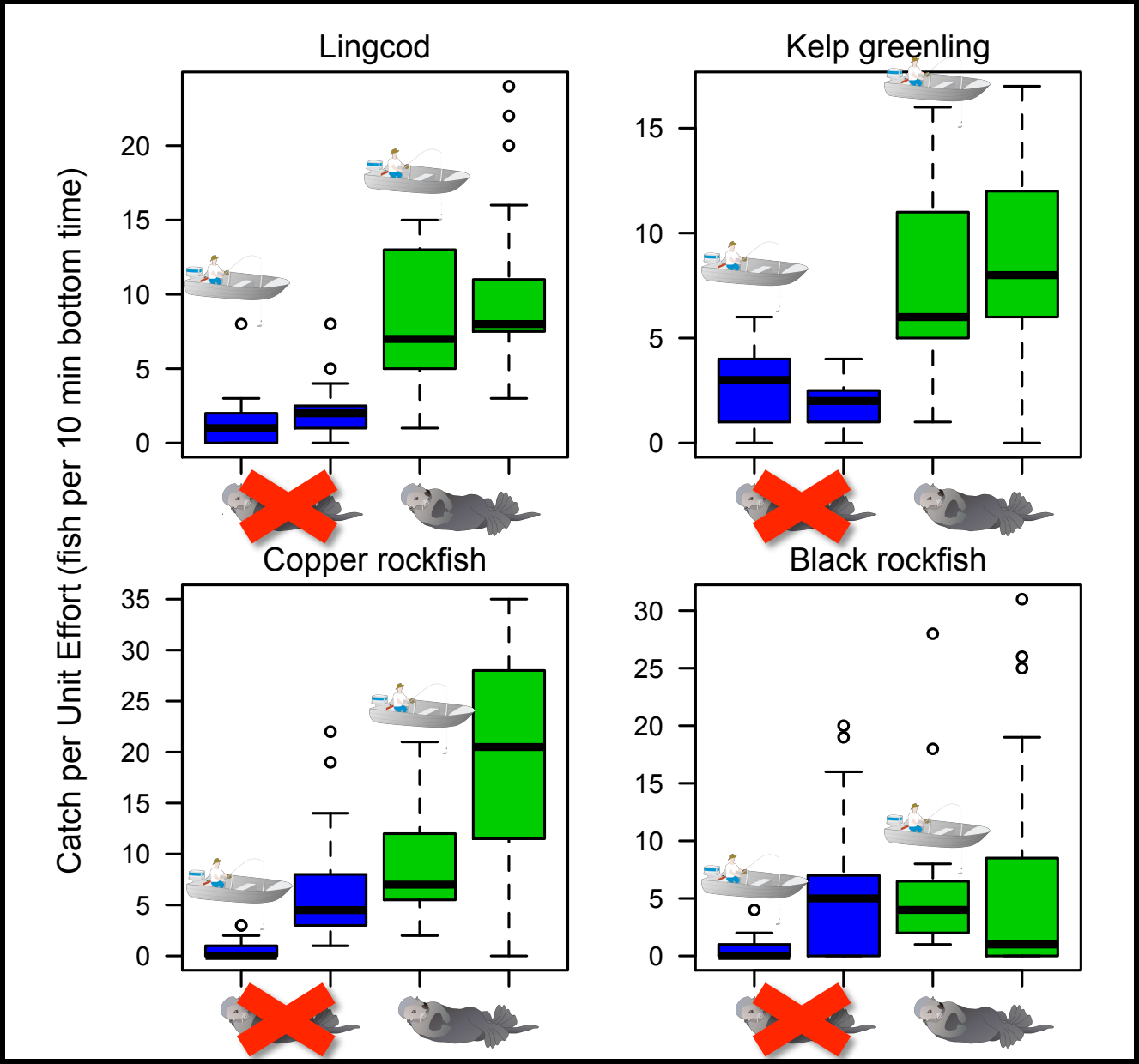
Kelp 3.7x deeper

Kelp 18.8x larger

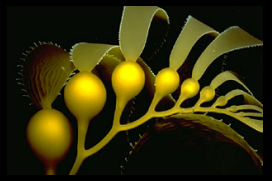
Markel (in prep)

Finfish abundance

Catch per unit effort (CPUE) higher with otters



Markel (PhD Thesis & in prep)



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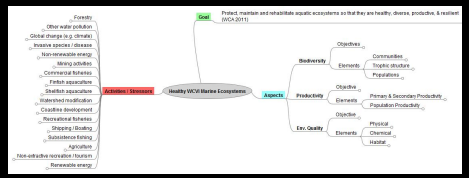
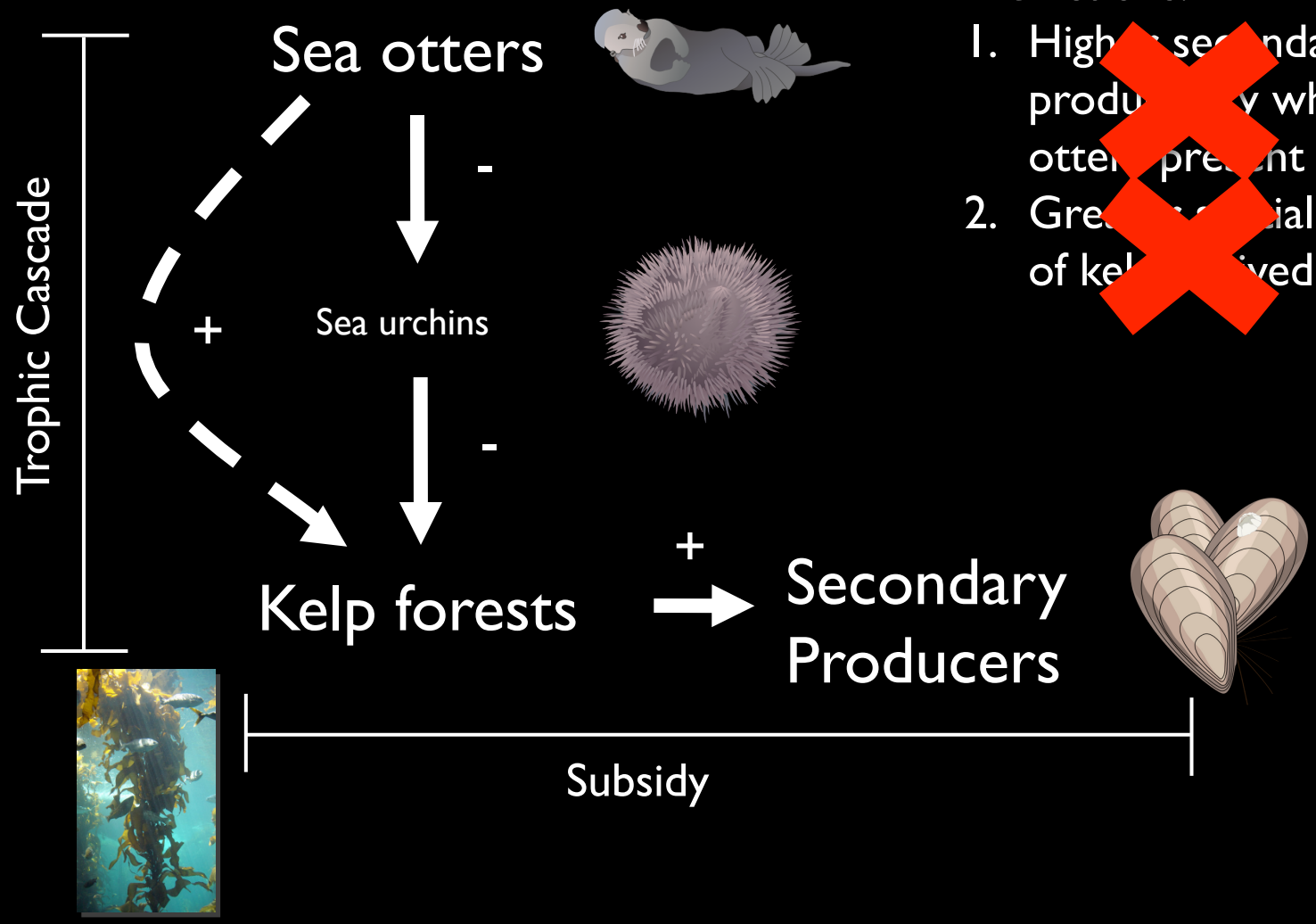


Proposed Link to Ecosystem Health



Predictions:

1. High[illegible] secondary produ[illegible]y where otte[illegible] pre[illegible]nt
2. Gre[illegible]ial extent of ke[illegible]ived carbon

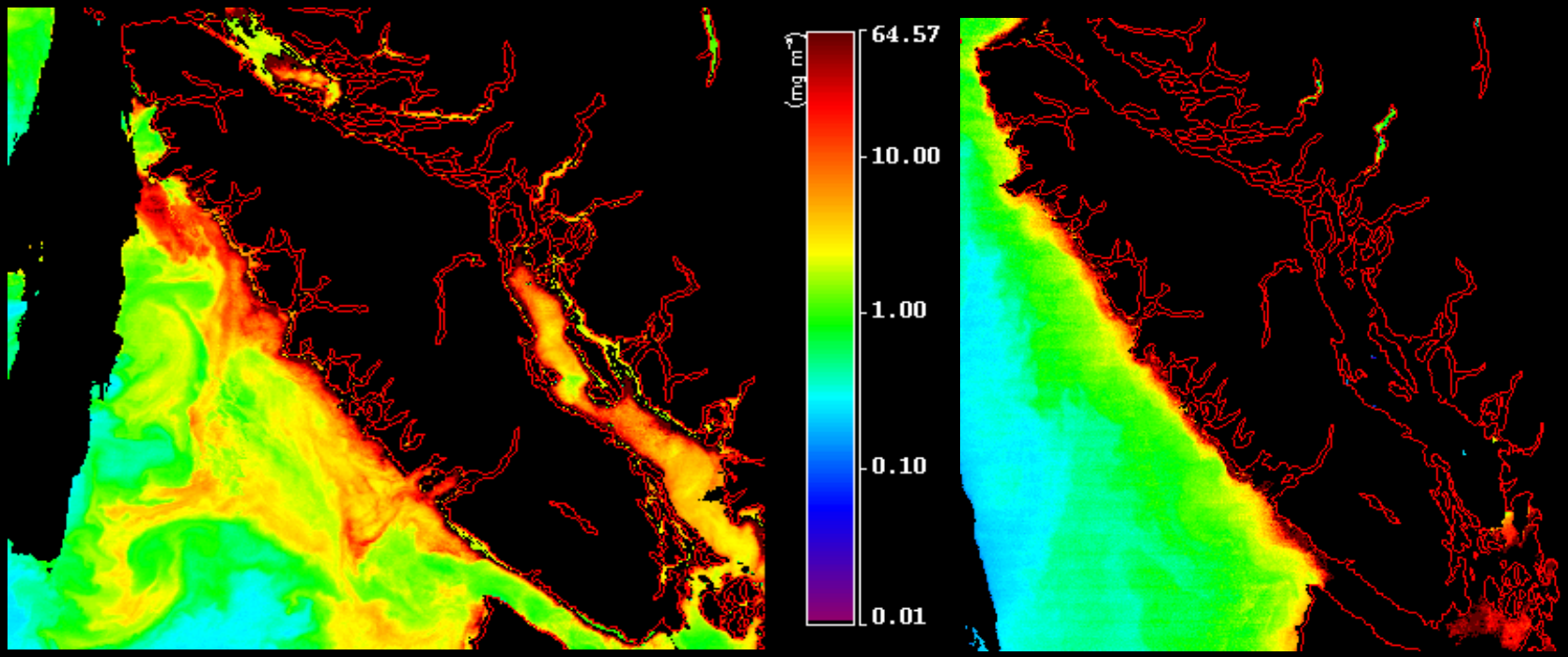
Gerald Singh, Chris Harley, Anne Salomon, RM, RM, KC (in prep)

Phytoplankton

- Food source for secondary producers
- WCVI is highly productive (>50 mg chl m^{-3}) Mackas & Sefton '82

July 28, 2009

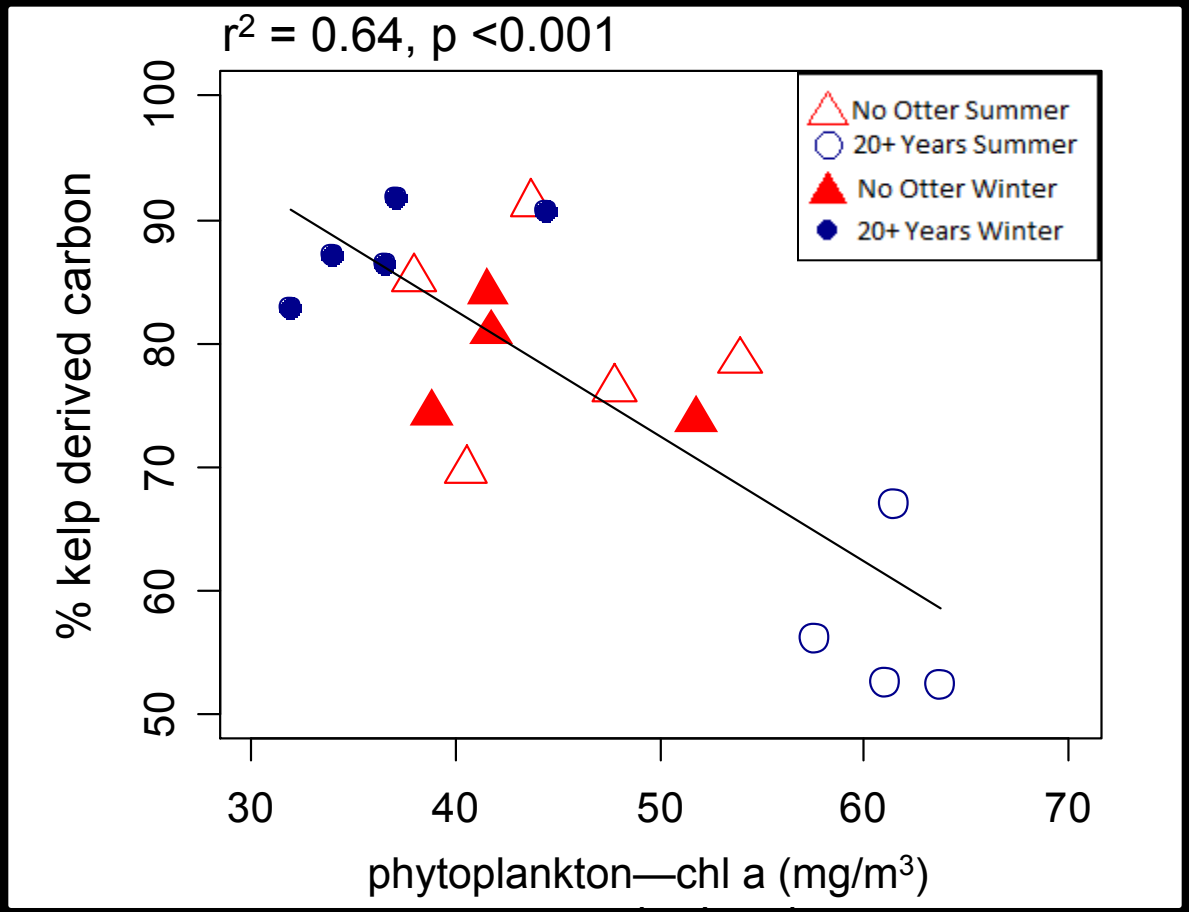
December 26, 2009



Singh *et al.* (in prep)

Phytoplankton in Diets

Kelp contribution increases as phytoplankton decreases

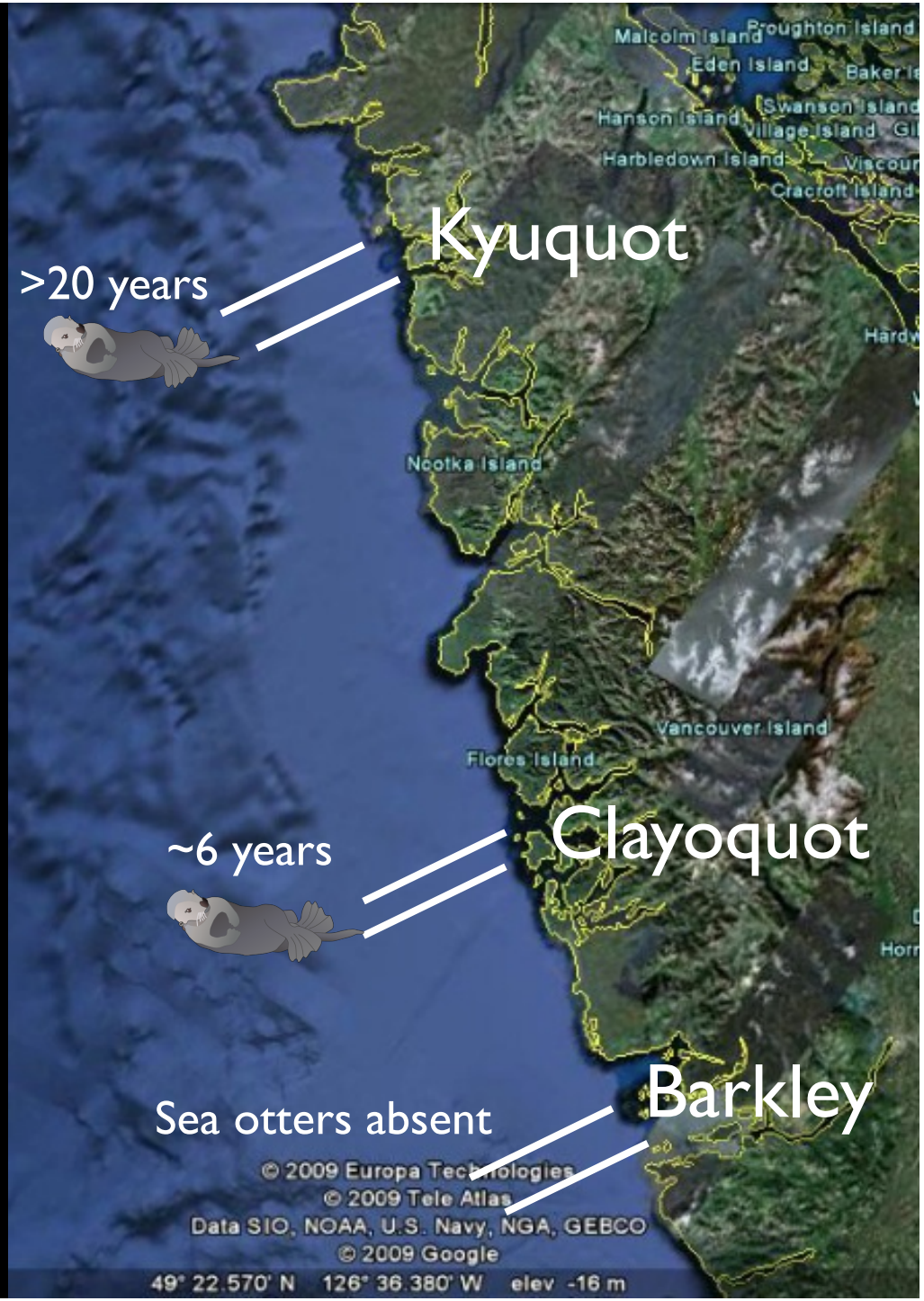


Kelp—alternate food source to phytoplankton

Singh *et al.* (in prep)

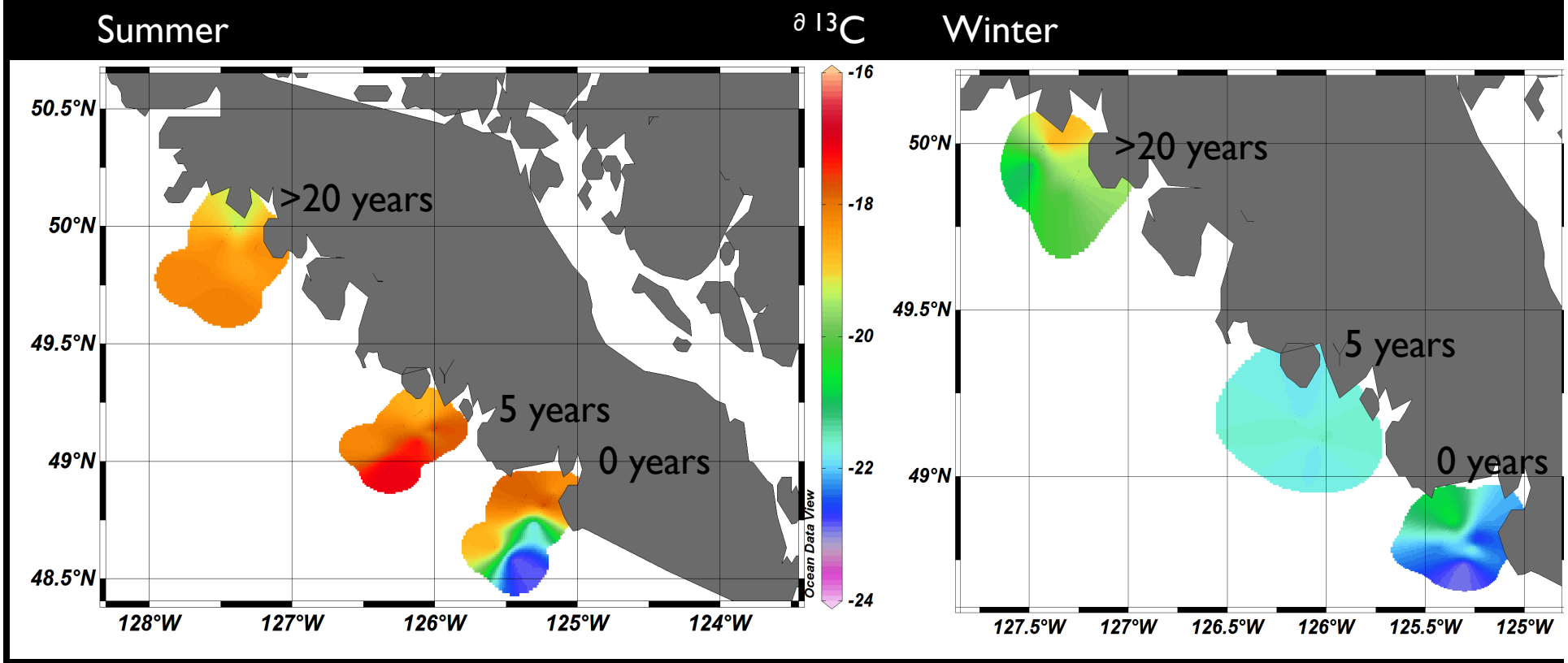
D-P-OM Sampling

- 2 transects/Sound
- Samples at 0, 0.5, 1, 2, 4, 10, 30 km offshore
- In summer 2009, 2010; winter 2010



Kelp C Found Offshore in All Regions

- Kelp carbon offshore in all regions
- More constant where otters abundant/longer

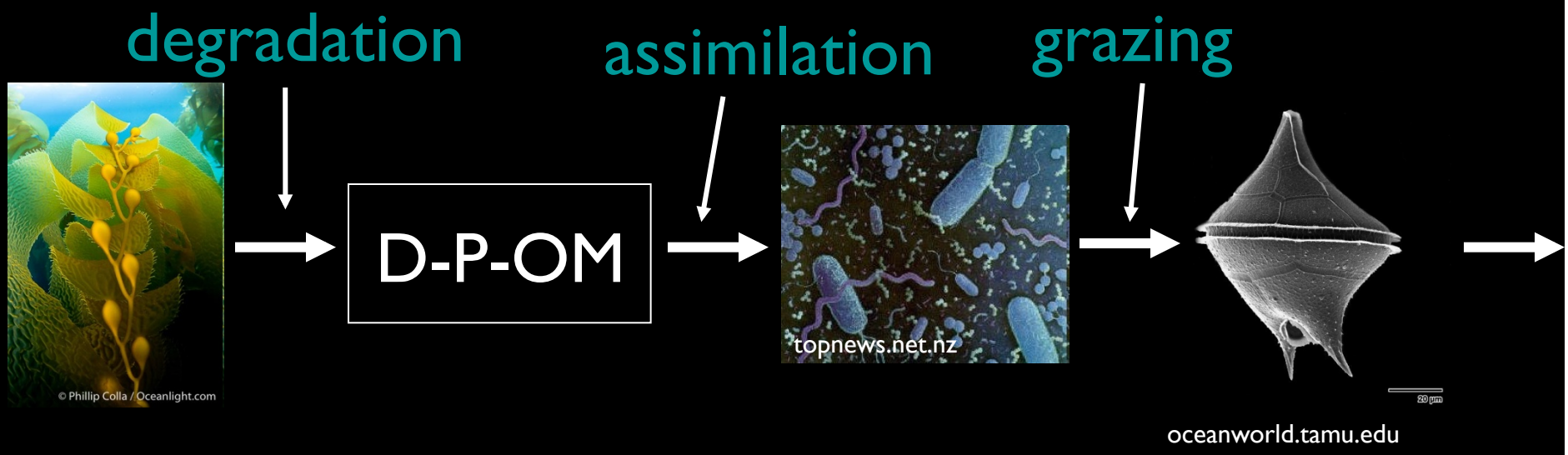


More persistent kelp = more stable ecosystem?

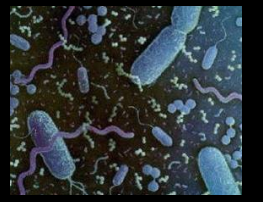
Brock Ramshaw, Evgeny Pakhomov, Russ Markel *et al.* (in prep)

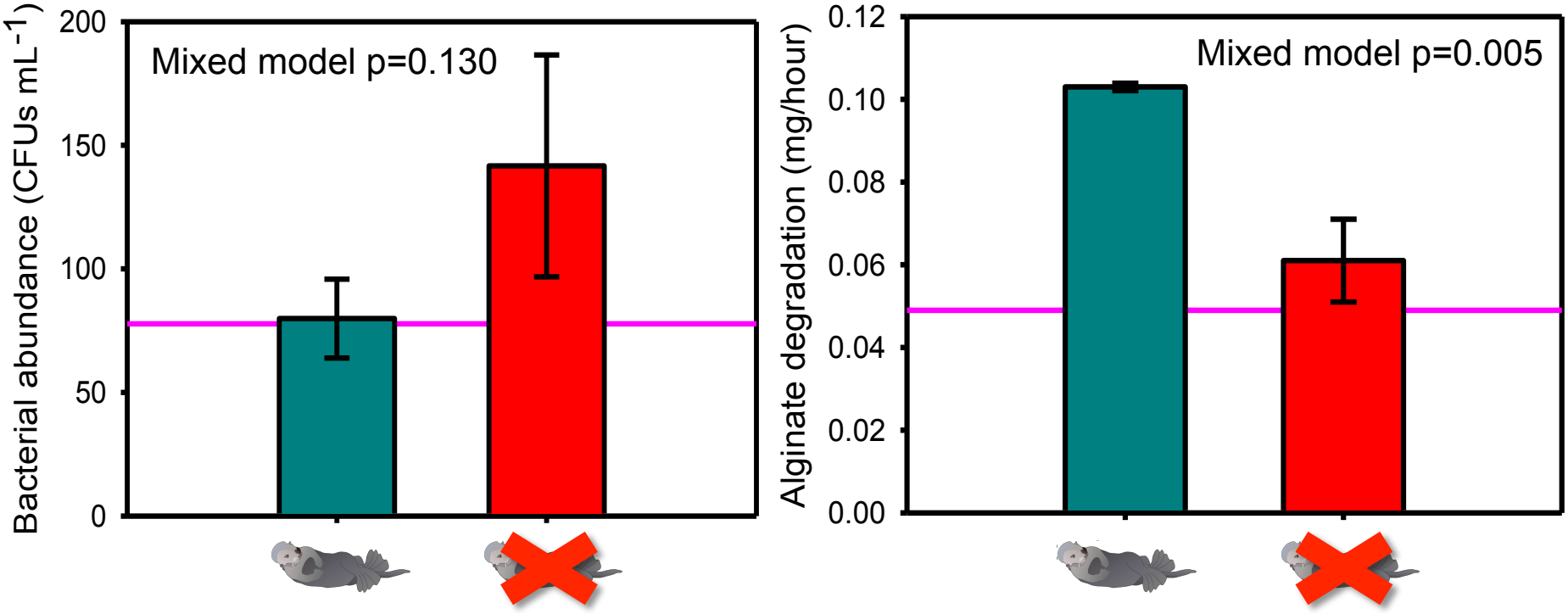
Kelp & Bacteria

- 70-80% of kelp C passes through microbial food webs before entering higher trophic levels (Holloham *et al.* 1986)



Fewer, More Active Kelp-Digesters

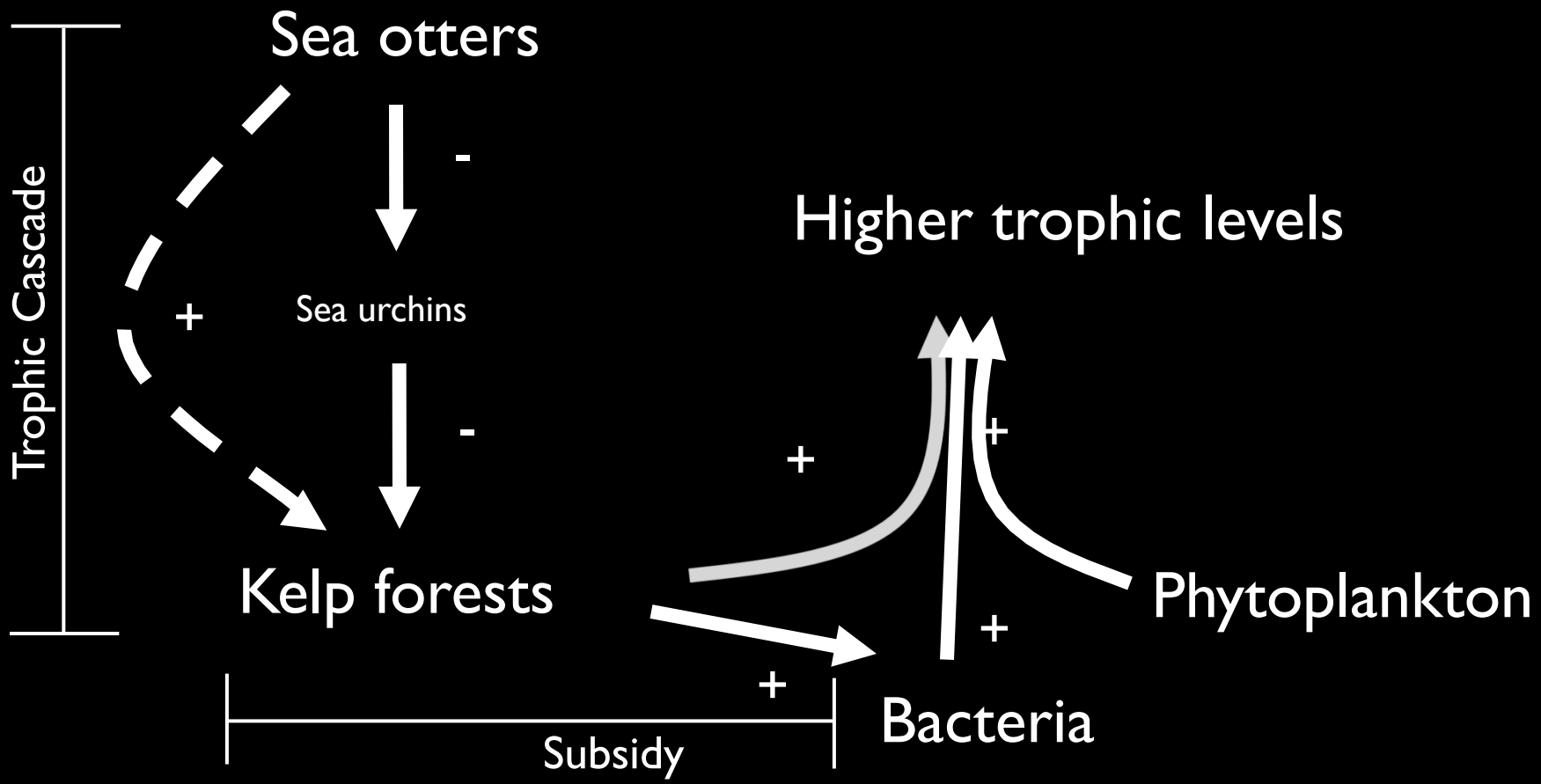


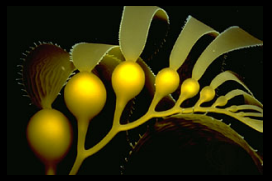


Subcommunity supports broader bacterial community

Jessie Clasen, Jon Shurin *et al.* (in prep)

New Model with New Insights





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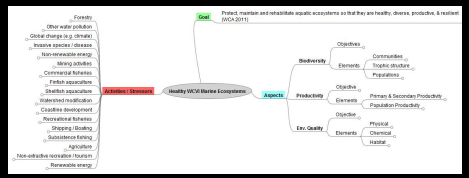
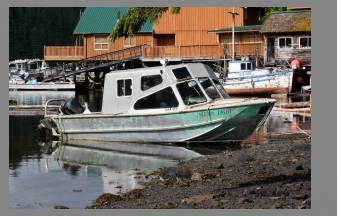
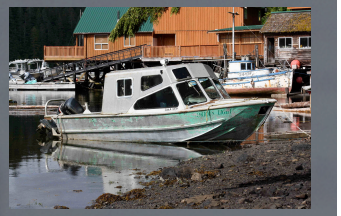


Human Consequences, [Methods]



e.g., Potential +, - social impacts of sea otter reintroduction?
[operator interviews & surveys; tourist choice experiments]

Tourism Value of Otters



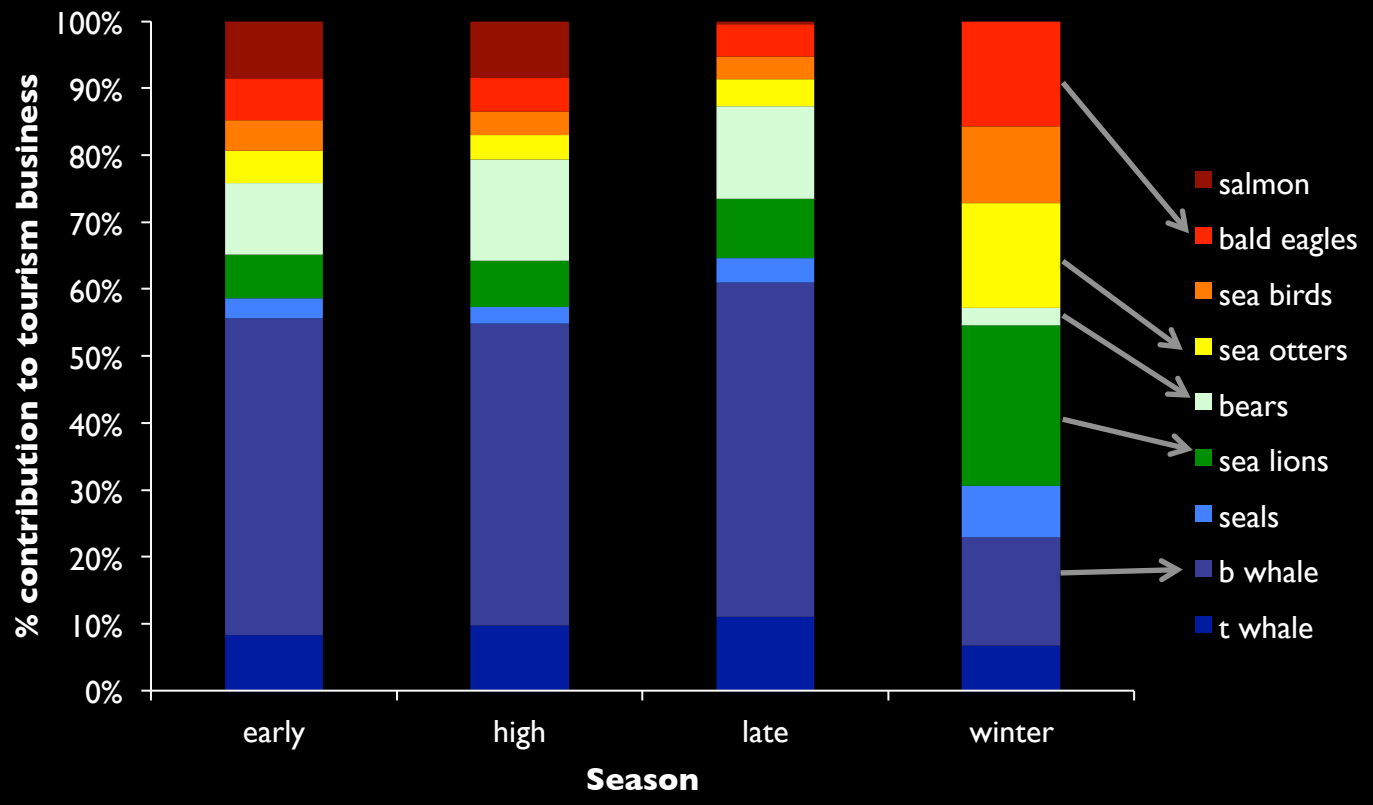
Have sea otters had an impact on your business? (N = 15)
53.3% Yes
40.0% No

If "Yes" (N=8)
75.0% Increase
12.5% Decrease

Stelzer *et al.* (in prep)

Tourism Value of Sea Otters

Sea otters contribute <10% to tourism in most seasons; importance increases in winter



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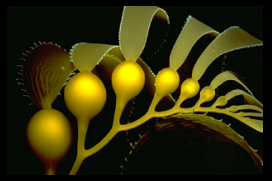

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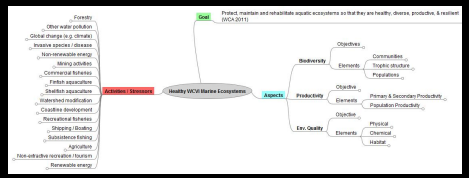

Conclusions

1. Sea otters ↓ urchins, ↑ kelps—dramatically
2. … ↑ rockfish
3. ↑ Kelps may ↑ mussel growth—but only in winter
4. ↑ Kelps ↑ nutrients, stability offshore, too
5. ↑ Kelps ↑ bacteria growth, grazing
6. Historical upheavals, but recent triggers loom large
7. Otters draw tourists, modestly—but memorably
8. Now integrating this complexity by keeping our eyes on the ball (management objectives)

Acknowledgements

Partners and supporting communities:
West Coast Aquatic
Parks Canada Agency
Fisheries and Ocean Canada

Kyuquot-Checleset First Nation
Huu-ay-aht First Nation
Ahousaht First Nation
Tla'oquiaht First Nation
Makah Tribe

Gwaii Haanas NPR & Haida HS

Co-PIs and collaborators:
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Evgeny Pakhomov
Jon Shurin, and
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Villy Christensen
Sven Kaehler
Murdoch McAllister
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Rashid Sumalia

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Jocelyn Nelson
Dana Haggarty
Spencer Wood
Kate Hatchwell
Britt Keeling
Matt Siegle
Maria Espinosa
Theraesa Coyle
Dara Gibson
Megan Mach
Jenn Jorve
Alison Haupt
Andres Cisneros
Travis Ingram
Ohn Lee
Kevin Head
Susie Bostrom
Exploder

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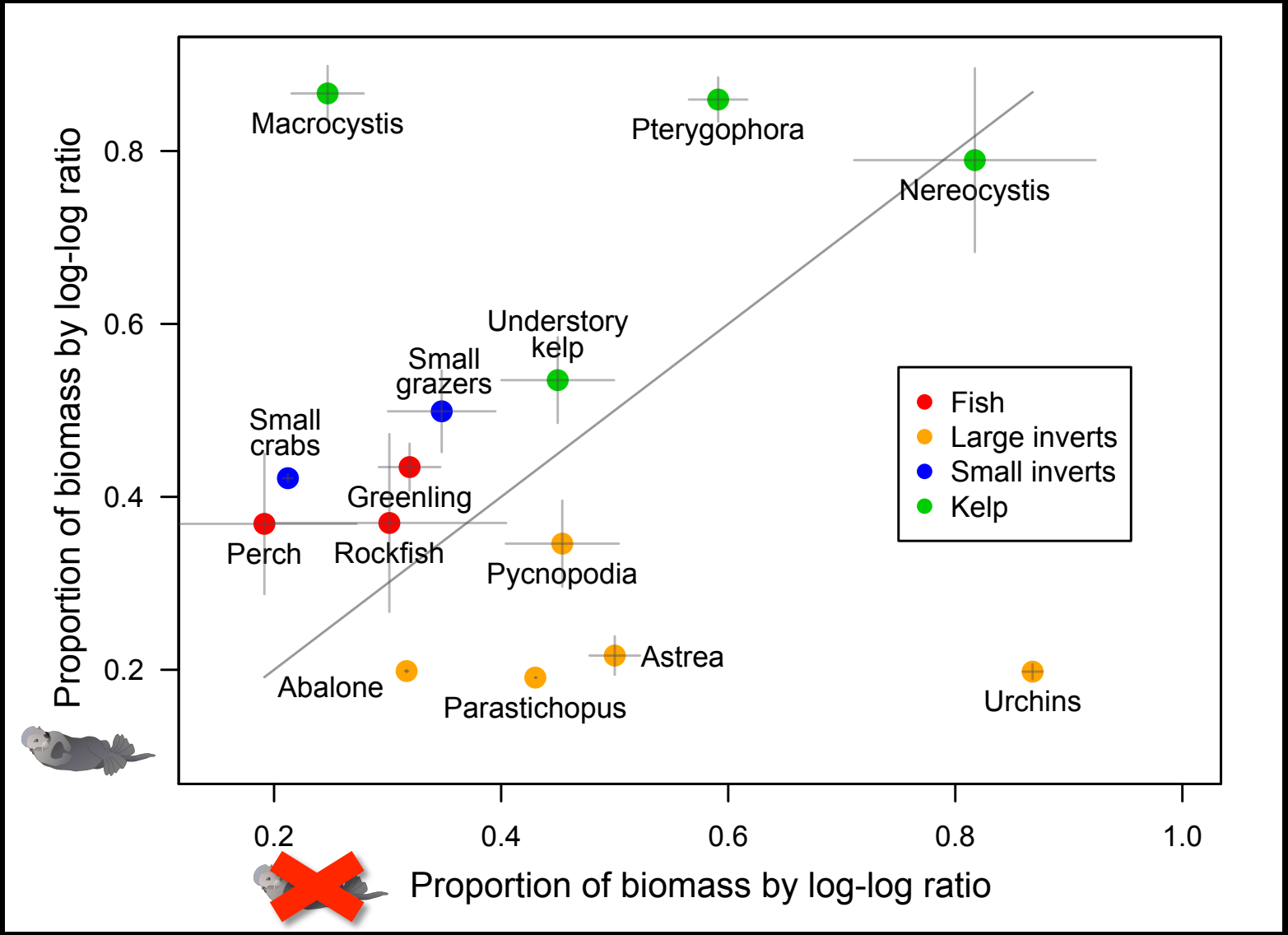
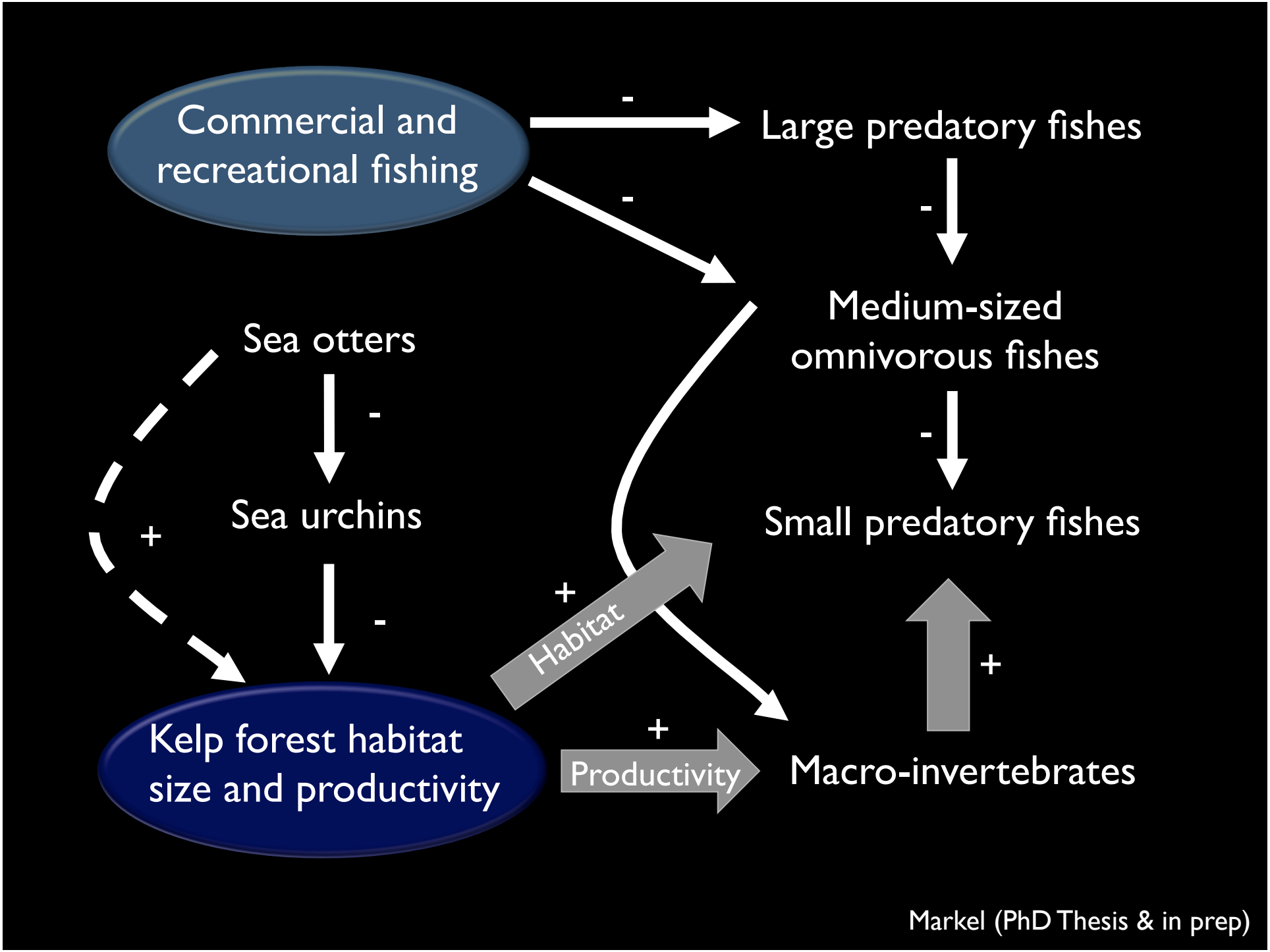
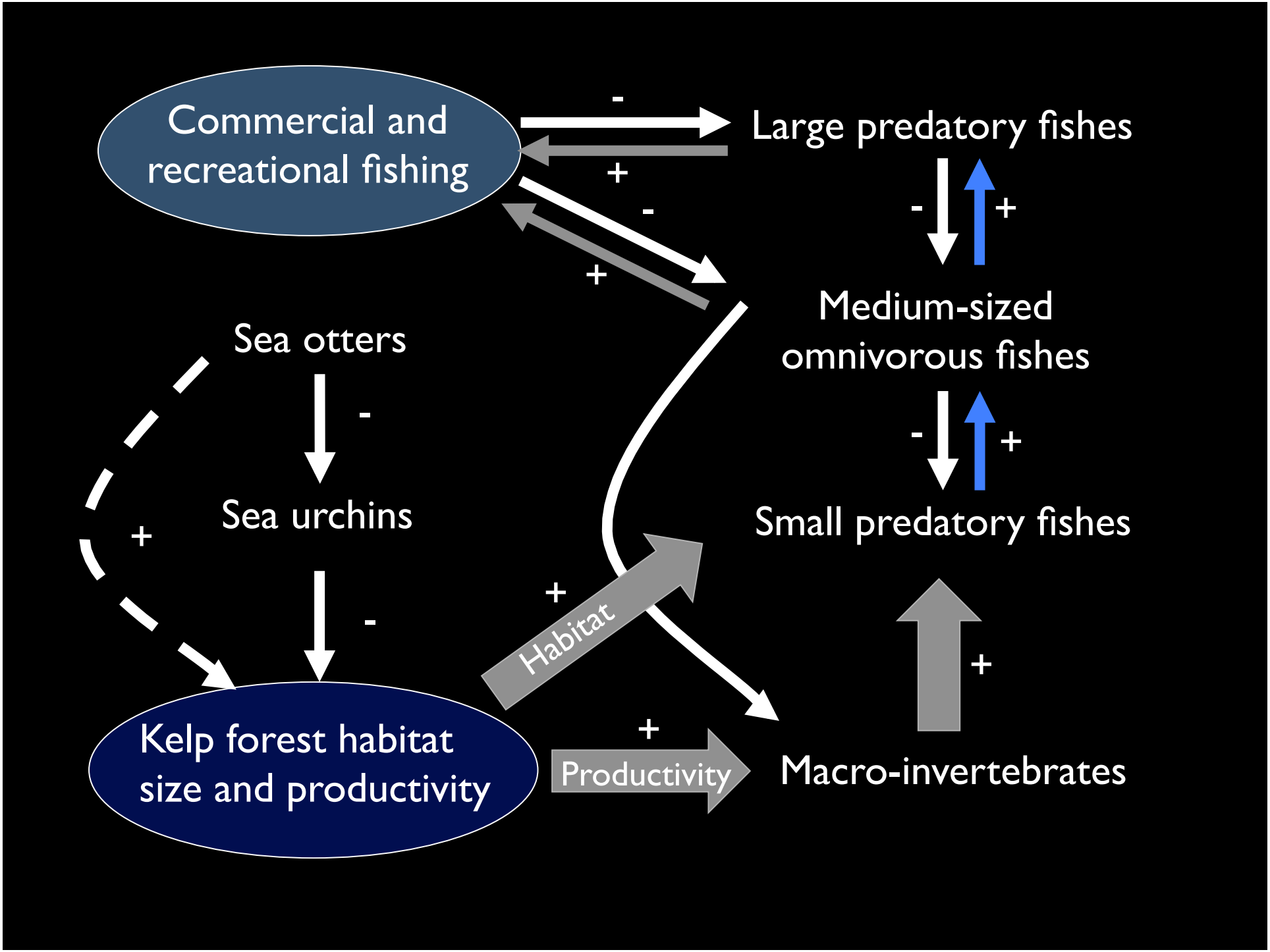
Distribution of biomass differs



Rebecca Martone and Russell Markel *in prep*


Commercial and recreational fishing
-
Large predatory fishes
-
-
Medium-sized omnivorous fishes
Sea otters
-
-
Small predatory fishes
Sea urchins
+
-
+
Habitat
+
Kelp forest habitat size and productivity
+
Productivity
Macro-invertebrates
Markel (PhD Thesis & in prep)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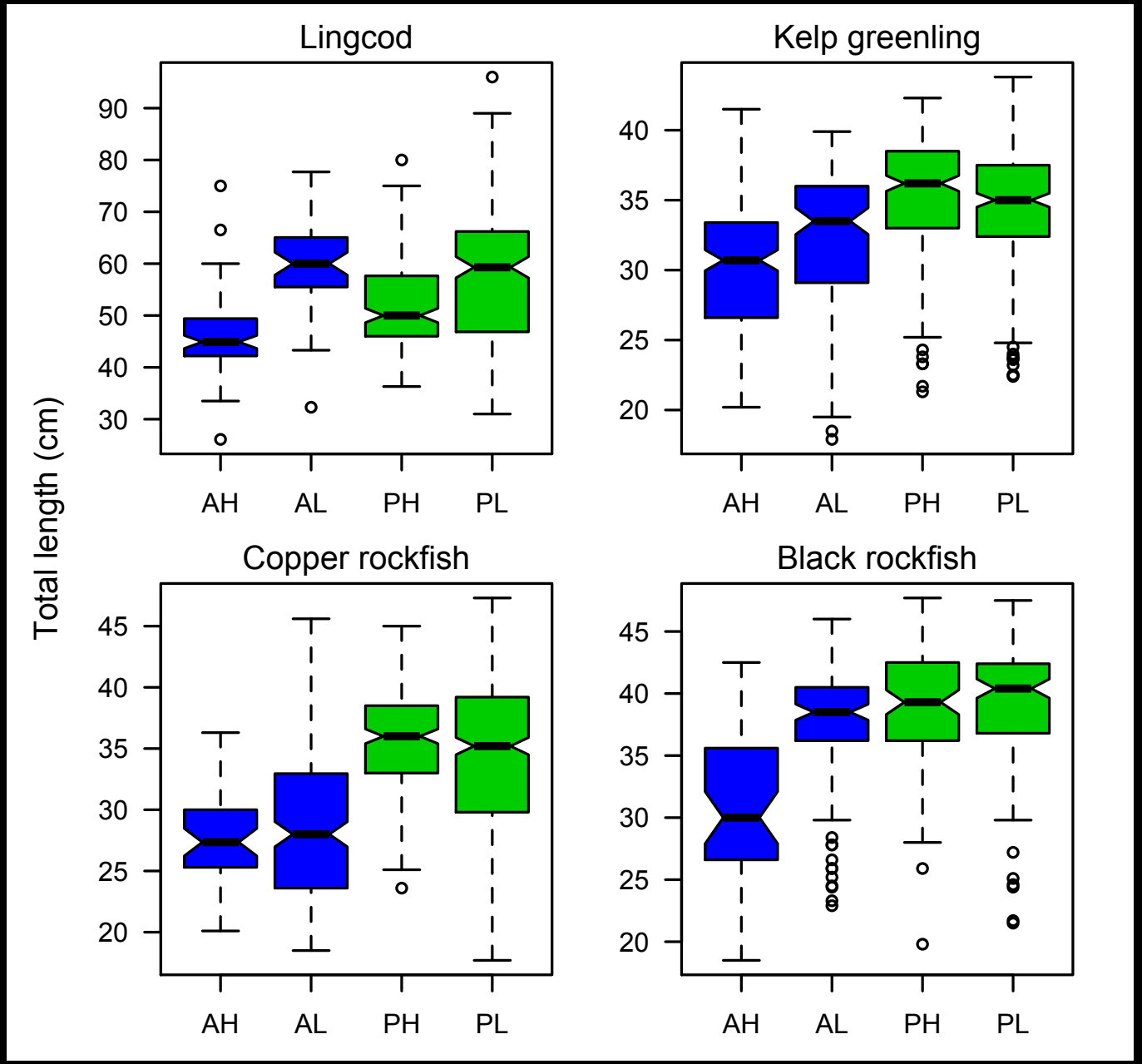
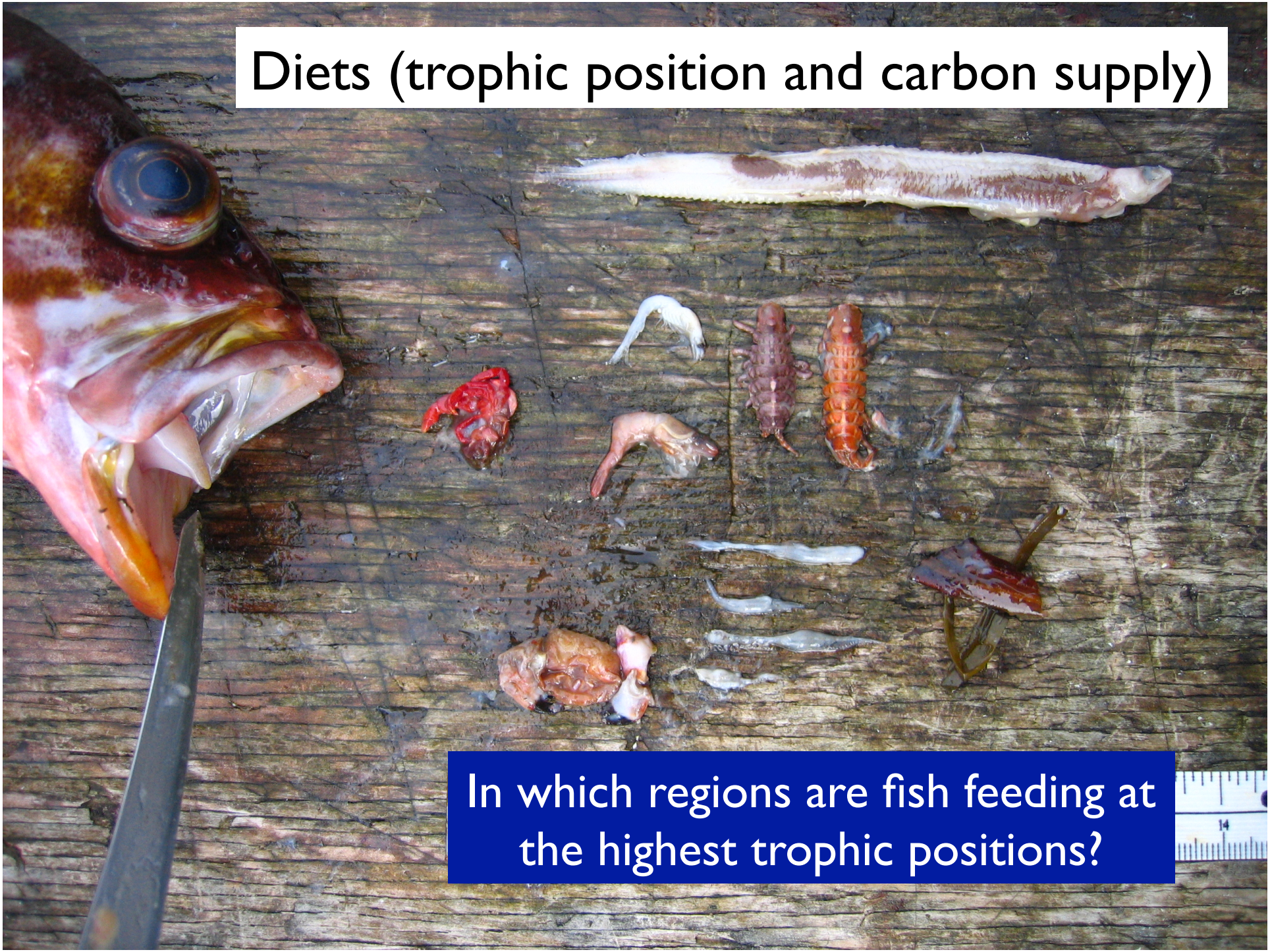
Habitat
Productivity
-
+
-
+
-
+
-
+
-
+
+
-
+
+

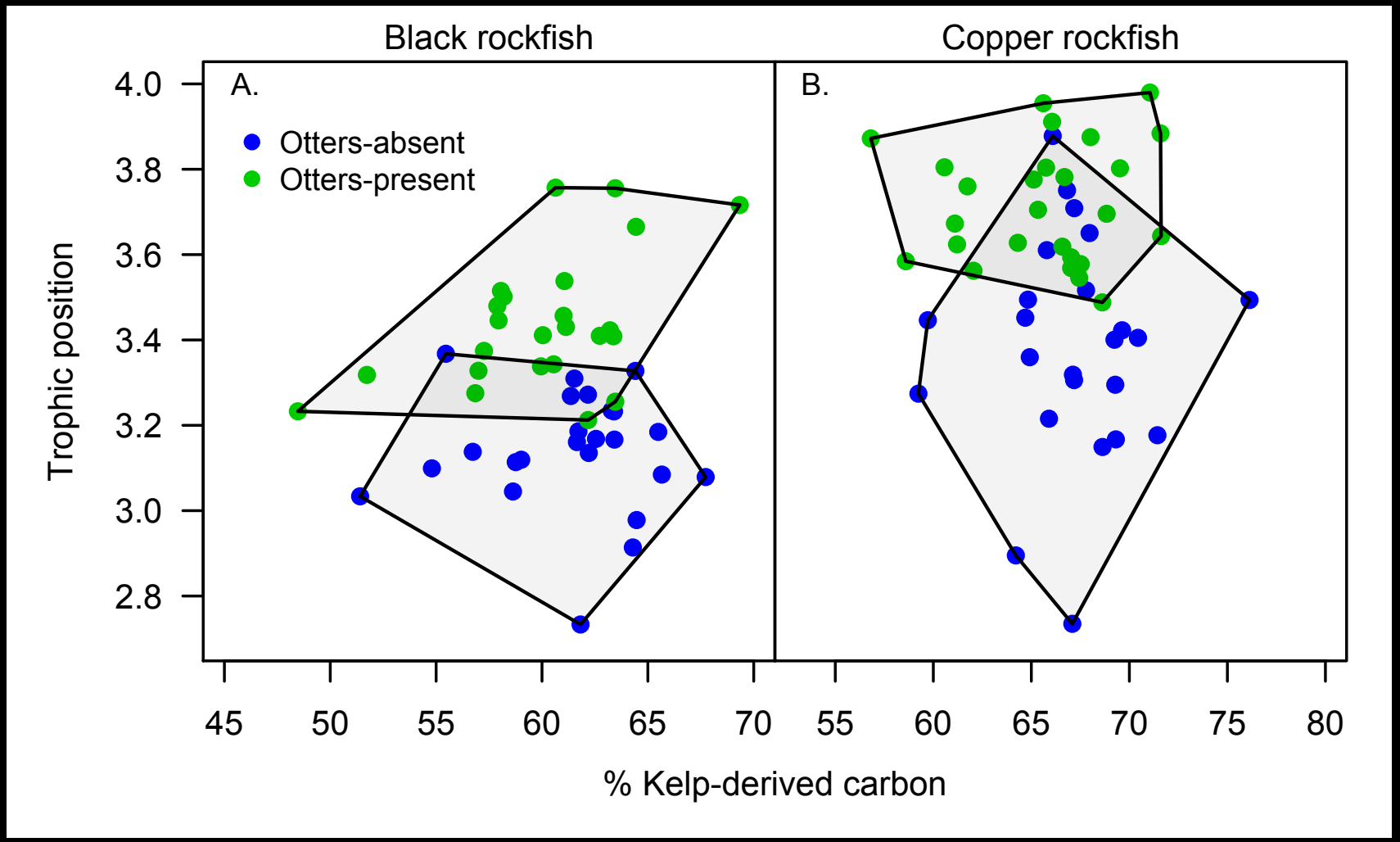

Fish size distributions
Where are reef fish largest?

Fish are larger with otters or low fishing



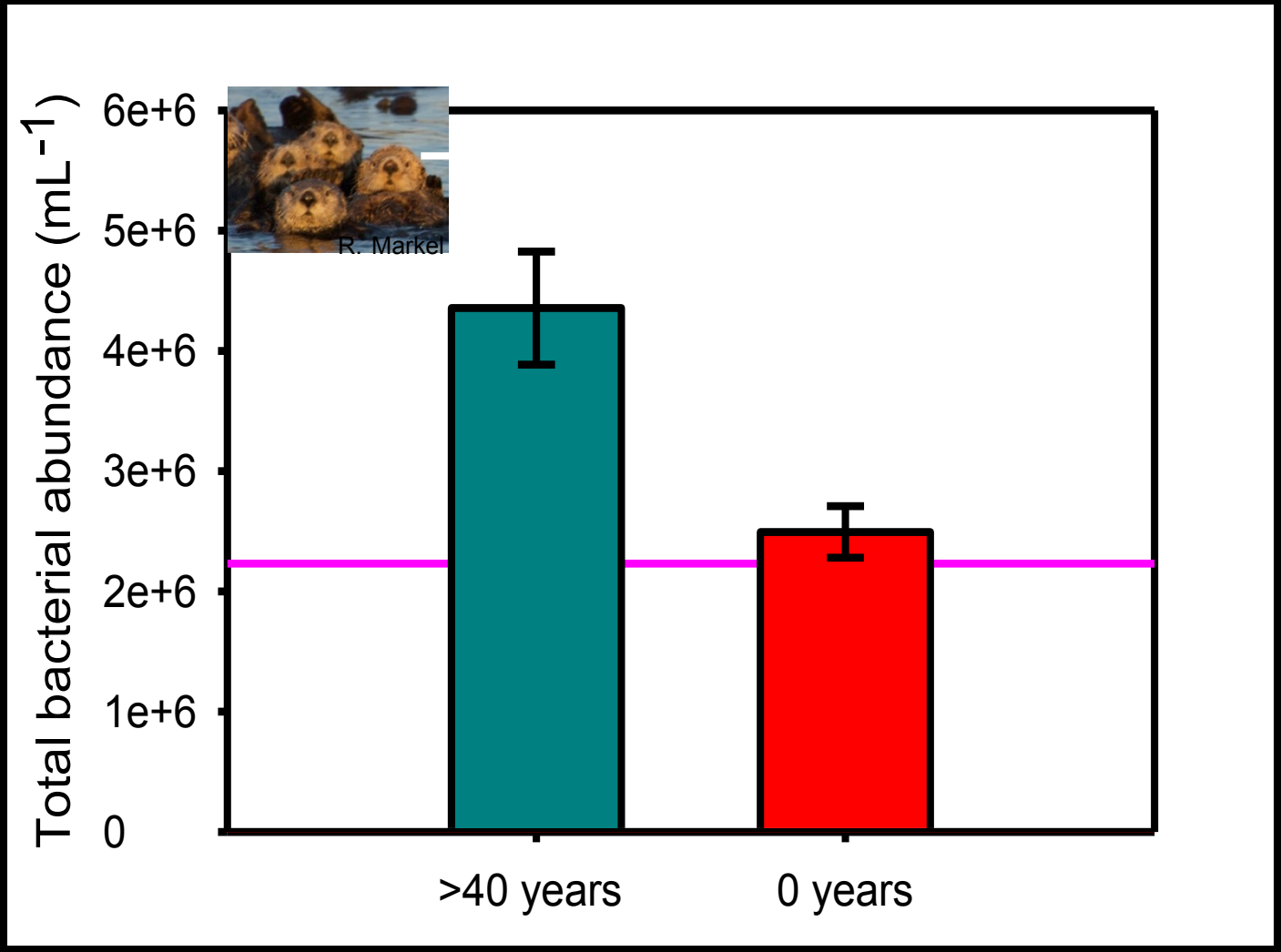

Diets (trophic position and carbon supply)
In which regions are fish feeding at the highest trophic positions?

Higher trophic positions with otters and large kelp forests



Markel (in prep)

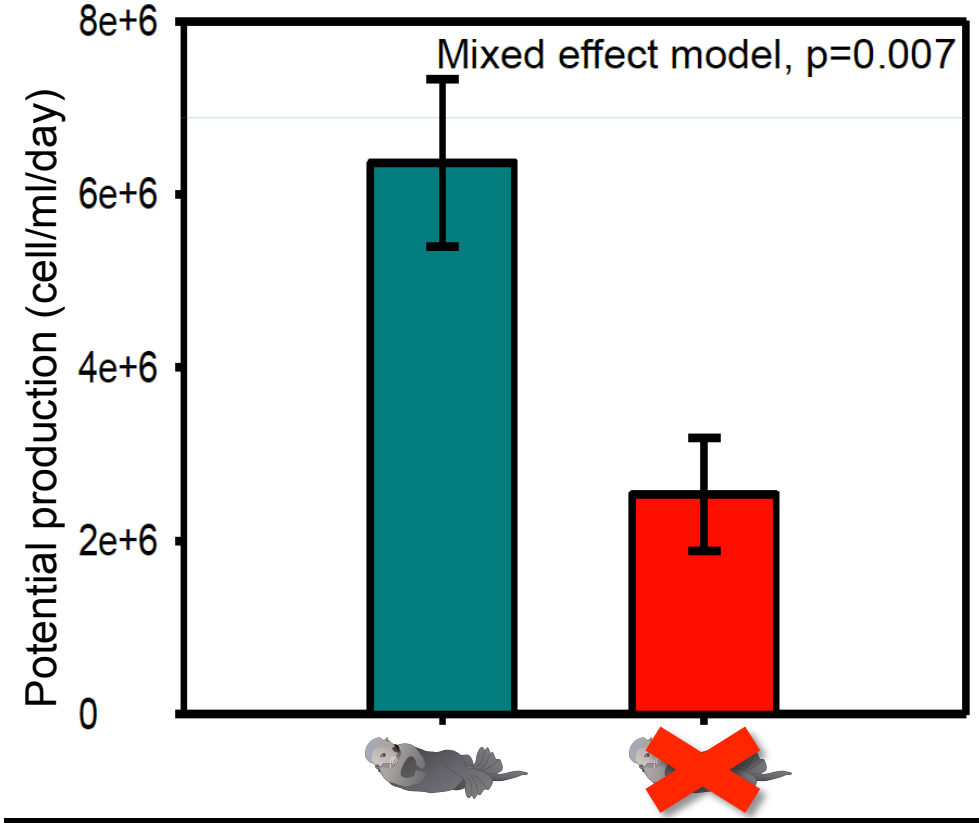
Total bacterial abundance *is* different between regions

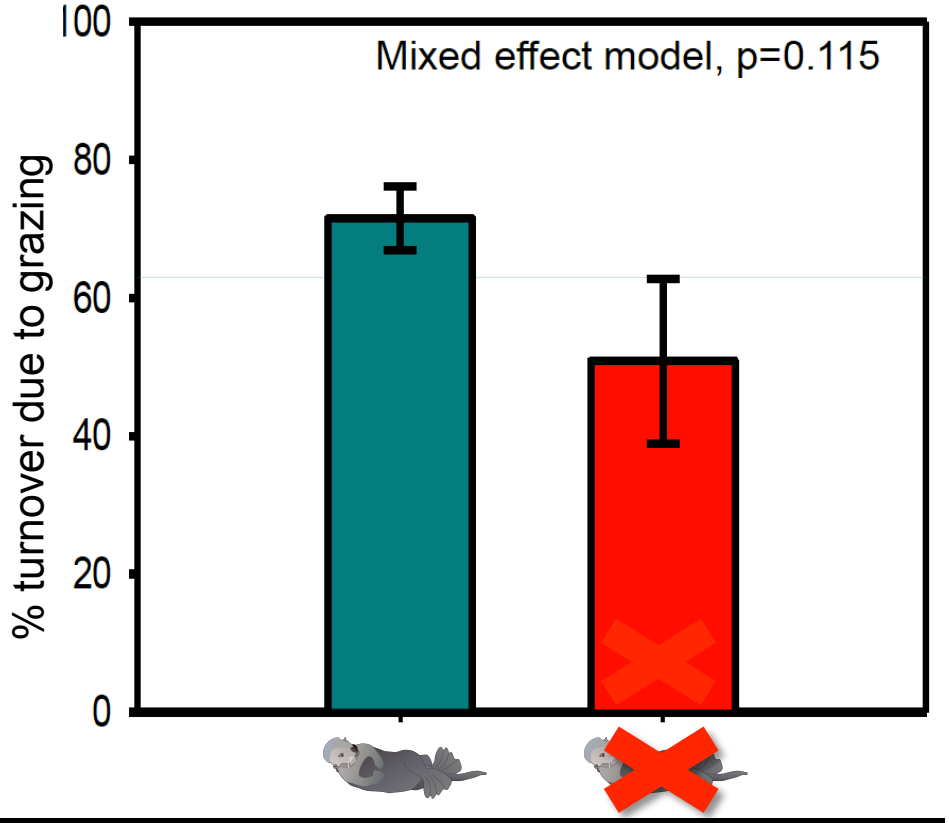


Total bacterial abundance is highest in region with sea otters

Jessie Clasen, Jon Shurin *et al.* (in prep)

Bacterial Growth & Grazing Rates: Higher with More Kelp





Supporting higher trophic levels

Jessie Clasen, Jon Shurin *et al.* (in prep)