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

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BC Coastal Ecosystem Services
A Story of Sea Otters
Sea otter reintroduction

Sea urchins

Kelp forests
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?
Ecosystem service model

Nearshore food webs & productivity

Mapping & modeling kelp forests

Kelp-derived carbon & productivity

Human values

Management indicators
Sea otters

Sea urchins

Kelp forest habitat size and productivity

+  

-  

-  

-
Do sea otters enhance reef fish populations; how?

Sea otters ➔ + ➔ Sea urchins ➔ - ➔ Kelp forest habitat size and productivity ➔ + ➔ Rocky reef and kelp forest fish productivity
Absent/Low (Gwaii Haanas) *RCA*

Present/Low (Checleset) *RCA*

Absent/High (Barkley Sound)

Present (20y) (Cape Flattery)

Present (5y) (Clayoquot Sound)

Present (20y) (Kyuquot)
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.
Urchin abundance and kelp forest habitat size
**A. Urchins /sq.m**

- **Otters-absent**
  - 16 ± 2 / m²

- **Otters-present**
  - Urchins rare

**B. Kelp depth (m)**

- **1.51 ± 0.15 m**

- **5.58 ± 0.35**

**C. Kelp area (ha)**

- **600 ± 100 m²**

- **11,300 ± 1700 m²**

Markel (in prep)
Finfish abundance

photo: Russ Markel
Catch per unit effort (CPUE) higher with otters

Markel (PhD Thesis & in prep)
Trophic Cascade

Subsidy

Secondary Producers

Sea otters

Sea urchins

Kelp forests

Predictions:
1. Higher secondary productivity where otters present
2. Greater spatial extent of kelp-derived carbon

Proposed Link to Ecosystem Health

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\(^{-3}\)) \textsuperscript{Mackas & Sefton '82}

July 28, 2009

December 26, 2009

Singh et al. (in prep)
Phytoplankton in Diets

Kelp contribution increases as phytoplankton decreases

\[ r^2 = 0.64, \ p < 0.001 \]

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

Sea otters absent

Kyuquot

Clayoquot

~6 years

>20 years

Barkley
Kelp C Found Offshore in All Regions

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

Summer

Winter

More persistent kelp = more stable ecosystem?

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

- Sea otters
- Sea urchins
- Kelp forests
- Higher trophic levels
- Phytoplankton
- Bacteria

Trophic Cascade
Subsidy
Ecosystem service model

- Nearshore food webs & productivity
- Mapping & modeling kelp forests
- Kelp-derived carbon & productivity

Management indicators

- Human values
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)
Sea otters contribute <10% to tourism in most seasons; importance increases in winter.
Ecosystem service model

- Nearshore food webs & productivity
- Mapping & modeling kelp forests
- Kelp-derived carbon & productivity
- Human values
- Management indicators
Conclusions

1. Sea otters down urchins, up kelps—dramatically
2. ... up rockfish
3. Up Kelps up mussel growth—but only in winter
4. Up Kelps up nutrients, stability offshore, too
5. Up Kelps up 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)
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
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Distribution of biomass differs

Proportion of biomass by log-log ratio

Perch, Macrocystis, Rockfish, Greenling, Parastichopus, Pycnopodia, Pterygophora, Nereocystis, Abalone, Small crabs, Small grazers, Understory kelp, Astrea, Fish, Large inverts, Small inverts, Kelp, Urchins

Rebecca Martone and Russell Markel in prep
Sea otters

Sea urchins

Kelp forest habitat size and productivity

Commercial and recreational fishing

- Large predatory fishes
  - Medium-sized omnivorous fishes
    - Small predatory fishes
      + Macro-invertebrates

Productivity

Habitat

Markel (PhD Thesis & in prep)
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

A. Black rockfish
   - % Kelp-derived carbon
   - Trophic position
   - Otters-absent
   - Otters-present

B. Copper rockfish
   - % Kelp-derived carbon
   - Trophic position
   - Otters-absent
   - Otters-present

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

Mixed effect model, p=0.007

Mixed effect model, p=0.115

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