Giant Kelp Forests: Stepping Stones to Biodiversity

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Giant kelp is highly dynamic
Giant kelp is a foundation species
Giant kelp is a foundation species

The number of living creatures of all Orders whose existence intimately depends on the kelp is wonderful.
Darwin 1839

Yet if in any country a forest was destroyed, I do not believe nearly so many species of animals would perish as would here from the destruction of the kelp.
Darwin 1839
1. How is giant kelp resilient to repeated disturbance?

2. How does repeated disturbance impact giant kelp community structure?
Landsat satellite imagery enables us to monitor kelp over large space and time scales

- Landsat imagery available from 1984-present w/ 16 day repeat cycle
- Cloud free image available every 2-3 months
**In situ** data enables us to transform imagery into biologically meaningful data.

- Collected kelp canopy biomass data from SCUBA diver surveys.
In situ data enables us to transform imagery into biologically meaningful data.

- Diver measurements enable us to transform kelp fractions to canopy biomass.

Cavanaugh et al. (2010, 2011)
Bell et al. (in review)
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\[ r^2 = 0.62, \quad p < 0.001 \]

*Cavanaugh et al. (2010, 2011)*
*Bell et al. (in review)*
First repeated, regional scale estimates of kelp canopy biomass

- Highly variable from year to year
- No clear long-term trend
- Declines during strong El Niños

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Wave disturbance is an important control of kelp abundance and net primary production (NPP)

\[ r^2 = 0.50 \]
\[ p < 0.001 \]
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Lower, more variable wave disturbance in southern California

Reed et al. (2011)

Higher, more variable NPP in southern California

[Graph showing wave height and NPP comparison between S. California and C. California]
How is giant kelp resilient to repeated disturbance?
Connectivity of giant kelp is key to resilience

- Giant kelp reproduces by releasing a reproductive stage that sinks slowly
- Dispersal distances are on the order of meters to kms

Santa Barbara
We used Landsat satellite imagery and ROMS ocean current simulations to...

1. Delineate “patches” of kelp

2. Estimate connectivity between patches

Cavanaugh et al. (2014)

Mitarai et al. (2009)
Connectivity improves recovery and persistence

Castorani et al. (2015, 2017)
Connectivity improves recovery and persistence:
A tale of two patches
Well connected patches are less likely to go extinct and more likely to recover from extinctions.

Santa Barbara kelp canopy biomass (t)
Isolated patches are more likely to go extinct and less likely to recover.
How does loss and recovery of kelp affect the community?

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*Darwin 1839*

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*Darwin 1839*
Large scale giant kelp disturbance experiment

- 4 sites
- 2,000 m² plots
- 9 years
- Removed all giant kelp in treatment plots each winter
- Measured abundance and diversity of all trophic levels
Frequent loss of giant kelp:

Castorani et al. (in revision)
Frequent loss of giant kelp:

Increases amount of light that reaches seafloor…

…Improving the growth of smaller understory algae

Castorani et al. (in revision)
Frequent loss of giant kelp:

Creates space on the rocky seafloor substrate...

...Facilitating invertebrates that grow attached to rock

Castorani et al. (in revision)
Frequent loss of giant kelp:

Reduces the amount of food from living and detrital giant kelp…

…Reducing the abundance of giant kelp herbivores

<table>
<thead>
<tr>
<th>Biomass (g dry/m²)</th>
<th>Frequency of disturbance to giant kelp</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Understory algae</strong></td>
<td><strong>Epilithic</strong></td>
</tr>
<tr>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>0</td>
<td>200</td>
</tr>
<tr>
<td><strong>Sessile invertebrates</strong></td>
<td><strong>Herbivores</strong></td>
</tr>
<tr>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>0</td>
<td>60</td>
</tr>
</tbody>
</table>

*Castorani et al. (in revision)*
Disturbance to foundation species has ecosystem wide consequences due to impacts of physical habitat and food availability.
Summary

1. Disturbance controls primary production of giant kelp forests in California.

2. Connectivity of giant kelp populations makes them resilient to disturbance.

3. Repeated disturbance to giant kelp impacts community by altering physical habitat and availability of food.
Long-term environmental change or multiple interacting stressors can overwhelm the resilience of giant kelp.
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Acknowledgements

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