Ecological implications of climate change on shallow rocky reefs in southern California

Dan Reed
Marine Science Institute, University of California Santa Barbara
Climate Change

Ecological implications

- Species abundances
- Species distributions
- Community structure
- Ecosystem processes
- Ecosystem services

Sea surface temperature
- Water column stratification
- Nutrients
- Currents

Storms and waves
- Terrestrial runoff
- Sedimentation
- Sea level

Ecological implications

Species abundances
Species distributions
Community structure
Ecosystem processes
Ecosystem services
Recent events provide opportunities to evaluate the ecological implications of climate change in S. California

- Deepened thermocline, warmed mixed layer, decreased nutrients, lowered phytoplankton productivity, altered current patterns observed in the Southern California Bight during previous El Niño events
- Striking effects observed throughout the pelagic food chain
Most pronounced benthic responses were observed in giant kelp forests.

- Grazing
- Wave disturbance
- Heat and nutrient stress
- Disease
- Range extensions & anomalous recruitment

Giant kelp forest structure and function

Dayton & Tegner 1989
Poleward shifts in species distributions associated with increases in ocean temperatures

A replacement of cold-water species of reef fish by warm-water species accompanied the shift from a cool to warm phase of the PDO

Warm water or altered currents?

Holbrook et al. 1997. Ecological Applications
Community-wide changes linked to 3.5 °C increase in ocean temperature at coastal power plant

- No trend toward warmer-water species with southern geographic affinities replacing colder water species with northern affinities.
- Reef communities primarily altered by direct decreases in the abundance of several key taxa (e.g. habitat-forming kelps) due to warming, and indirect effects operating through ecological interactions.

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*
Isolating the effects of different factors is challenging.
Regional comparisons are useful for assessing the relative importance of different factors on giant kelp.

<table>
<thead>
<tr>
<th></th>
<th>Central California</th>
<th>Southern California</th>
<th>Expectations for giant kelp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrients</td>
<td>High</td>
<td>Low</td>
<td>CCalif &gt; SCalif</td>
</tr>
<tr>
<td>Grazing</td>
<td>Low</td>
<td>High</td>
<td>CCalif &gt; SCalif</td>
</tr>
<tr>
<td>Waves</td>
<td>High</td>
<td>Low</td>
<td>CCalif &lt; SCalif</td>
</tr>
</tbody>
</table>

Reed et al. 2011 Ecology
Annual net primary productivity (NPP) by giant kelp was twice as high in S. California compared to C. California and twice as variable.

Results indicate that wave disturbance overwhelmed bottom-up (nutrients) and top-down (grazing) control of giant kelp.

Reed et al. 2011 Ecology
Giant kelp biomass and productivity has direct and indirect effects on community structure.
Wave disturbance that removes giant kelp alters the forest food web

Periodic winter storms increase the diversity and complexity of kelp forest food webs

Byrnes et al. 2011 Global Change Biology
The frequency of severe storms in California has increased over the last half century.

Winter storm intensity

Winter storm frequency

Graham and Diaz 2001

Bormoski et al. 2002
How will southern California kelp forests respond to a future scenario characterized by a higher frequency of intense wave disturbance?

**Hypothesis:** An increase in the frequency of severe kelp-removing storms simplifies kelp forest food webs.
Repeated storm disturbance simplifies kelp forest food webs

Model simulations and experiments show:

1. Species richness goes up following a single storm as increases in the number of species of algae exceed decreases in top consumers. This leads to increases in the average number of feeding links per species.

2. Repeated disturbance leads to less diverse & less complex food webs with fewer trophic levels and fewer feeding links per species.

Byrnes et al. 2011 Global Change Biology
Climate related impacts to giant kelp are likely to affect other ecosystems

Kelp wrack linked to increased abundance and diversity of beach consumers

Kelp accounts for up to 80% of the particulate carbon reaching the deep sea floor and 60% of the diet of sea urchins that live there.
Climate related impacts to kelp forests will have consequences to ecosystem services

Red sea urchin roe fishery at Pt. Loma, CA

Red Sea Urchin Landings (tons)

Kelp Canopy Biomass (tons)

Year

El Niño

El Niño
Summary

The ecological implications of projected climate change on shallow reefs in southern California are likely to be pronounced.

Reef communities will respond to the direct effects of changes in the physical environment and a myriad of indirect effects that arise from ecological interactions.

Accompanying changes in ocean chemistry (e.g. pH and dissolved CO₂) will undoubtedly alter the ecological impacts of climate change on reef communities in unforeseen ways.

Thanks to

Ron McPeak