Social - Ecological Interactions in Coastal Marine Ecosystems

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Santa Barbara Coastal LTER
LTER Coastal Marine Ecosystems

- California Current Ecosystem
- Palmer Station
- Santa Barbara Coastal
- Virginia Coast Reserve
- Georgia Coastal Ecosystem
- Florida Coastal Everglades
- Plum Island Ecosystem
- Moorea Coral Reef
CONCEPTUAL FRAMEWORK

Human behavior

Human outcomes

Environmental drivers

Long-term "press"

Short-term "pulse"

Biotic structure

Community function

Ecosystem services
Environmental Drivers of Coastal Marine Ecosystems

Climate
- temperature
- wave disturbance
- nutrients
- acidification
- sea level

Land use
- runoff
- pollution
- sedimentation
- eutrophication

Extraction
- recreational fishing
- commercial fishing
- Non-renewable resources

Non-renewable resources
- extraction of non-renewable resources

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Drivers affecting nutrient delivery to coastal marine ecosystems

- a continuum, not a dichotomy
- drivers interact in space and time
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Giant Kelp Forests

Macrocystis pyrifera

Distribution of *Macrocystis*
The number of living creatures of all Orders whose existence intimately depends on the kelp is wonderful. *Darwin 1860*

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 1860*
Giant Kelp Forests Have High Functional Value

** Annual Net Primary Production **

- Mean (g dry mass m$^{-2}$ y$^{-1}$)
- ** Arctic Tundra**
- ** Desert**
- ** Grassland**
- ** Oldfields**
- ** Forest**
- ** Giant Kelp**

** Nutrient Cycling (Annual turnover) **

- NPP / Foliar standing crop (y$^{-1}$)
- ** Desert**
- ** Grassland**
- ** Deciduous forest**
- ** Coniferous forest**
- ** Giant kelp**

* from Knapp and Smith 2001, Science 291:481-484
* from Webb et al. 1983, Ecology 64:134-151
* from SBC LTER
Environmental Drivers Cause Changes in the Abundance of Giant Kelp, which Cause Shifts in Community Structure.

- Predator decline
- Herbivore increase
- Large waves (that remove kelp)
- Warm, nutrient-poor conditions

- Predator increase
- Herbivore decline
- Large waves (that remove grazers)
- Cool, nutrient-rich conditions

Forested
Complex structure

Deforested
Simple structure
Environmental Drivers Cause Changes in Kelp Forest Structure

Occupancy of giant kelp on reefs in southern California

Environmental Drivers Cause Changes in Kelp Forest Structure

Species composition of kelp forest fish assemblage

- **Gopher rockfish** (northern sp.)
- **Garibaldi** (southern sp.)

Graph showing the proportion of assemblage over time, with years 1970 to 1995 and proportion ranging from 0.20 to 0.50. The graph indicates changes in the proportion of northern and southern species over the decades.

 PDO cool  Pacific Decadal Oscillation warm

- **PDO cool** and **Pacific Decadal Oscillation warm**

Environmental Drivers Affect Kelp Forest Function

Interannual variability in net primary production

* from Knapp and Smith 2001, Science 291:481-484
* from SBC LTER
Kelp Forest Community Structure and Function Are Tightly Coupled

Kelp net primary production is dependent on kelp standing crop

Data from SBC LTER
Giant kelp is a major source of dietary carbon for a diverse food web.

Kelp Forest Community Structure and Function Are Tightly Coupled

Data are annual means of samples collected during 2001-2005. SBC LTER

Stable isotope analysis of reef food web

- Suspension feeder
- Benthic feeder

Change due to trophic enrichment

δ^{15}N (‰)

δ^{13}C (‰)
Kelp Forest Community Structure and Function Are Tightly Coupled

Giant kelp subsidizes the foodwebs of adjacent ecosystems

Density of amphipods

Density of black-bellied plovers

Dugan et al. 2003 Estuarine Coastal Shelf Science 58:133-158
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Ecosystem Services Provided by Giant Kelp Forests

Provisioning Services
- Fisheries
- Aquaculture
- Pharmaceuticals
- Bio Fuel

Cultural Services
- Education
- Recreation
- Aesthetics
- Tourism

Regulating Services
- Biodiversity conservation
- Water quality
- Modify sea surface state
Changes in Biotic Structure Affect Ecosystem Services

Red sea urchin roe fishery (data from Pt. Loma)

Red Sea Urchin Landings (tons)

Kelp Canopy Biomass (tons)

Year


El Niño

El Niño
California’s Ocean Economy

Direct Market Value = $21.4 Billion
Competing Ecosystem Services

Southern sea otter “Keystone species”

Cultural Services
• Tourism
• Education
• Aesthetics

Regulating Services
• Water quality
• Conservation

Provisioning Services
• Fisheries
• Oil and gas development
California Sea Otter Population

- Hunted to near extinction for their fur in the 1800’s
- Recovery linked to regulatory changes

<table>
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<th>Year</th>
<th>1900</th>
<th>1920</th>
<th>1940</th>
<th>1960</th>
<th>1980</th>
<th>2000</th>
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<tr>
<td>Population size</td>
<td>0</td>
<td>500</td>
<td>1000</td>
<td>1500</td>
<td>2000</td>
<td>2500</td>
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</tbody>
</table>

- Fur hunting banned
- Gill net fishing restrictions
- Additional fishing restrictions
CONCEPTUAL FRAMEWORK

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- Biotic structure
- Community function

Ecosystem services flow into and out of the human behavior and environmental drivers.
Competing Ecosystem Services Lead to Controversial Legislation

Defines the "coastal zone" and establishes land use control for the zone

Requires the state Department of Fish and Game to design and manage an improved network of marine protected areas

Establishes a new isolated population of sea otters at an offshore island and restricts the expansion of sea otters along the mainland

Implement the Marine Life Protection Act
Changes in Policy Coincide with Changes in Environmental Drivers

Monthly values for the PDO index: 1900 – October 2006

- Warm
- Cool
- Warm

Marine Life Protection Act enacted
Santa Barbara Channel Islands Marine Reserve Established
Changes in Policy Coincide with Changes in Environmental Drivers

Density of black surfperch at Santa Cruz Island

Warm PDO

Cool PDO?

Channel Islands Marine Reserve Established

Data from SBC LTER
Distinguishing Between the Effects of Natural vs. Anthropogenic Drivers

Fished species fluctuate more than unfished species

- 50 year data set used to distinguish between human & natural drivers
- Information on magnitude and sources of variability needed for effective management

Role of LTER in Society and the Environment

• Long-term data are needed to understand patterns and causes of changing ecosystems

• Such knowledge is essential for evaluating the effectiveness of policies enacted to alter human behaviors that influence the structure and function of ecosystems and the services that they provide