Kelp Bed / Forest Ecology

I. What are kelp beds and forests?
Stands of large brown algae in the order Laminariales (i.e., kelps) that provide food and shelter for a diverse array of marine plants and animals.

II. Distribution
- worldwide in temperate seas (cold & nutrient rich)
  - larger forests in water <20° C
- generally shallower than 15-40 m

III. Morphology

IV. Kelp life cycle

V. Biological characteristics of kelp forests

VI. Abiotic Influences

VII. Effects of kelp on biotic conditions

VIII. Biotic interactions

IX. Kelp harvesting

Kelp Forest vs. Kelp Bed
- terms often used interchangeably, but technically:
  - kelp forest = large brown algae that form floating surface canopies
  - kelp bed = large brown algae that do not form a surface canopy

II. Distribution
North and South American west coasts:
- kelp forests are dominated by two genera of canopy-forming kelps:
  - Nereocystis (bull kelp) in north
  - Macrocystis (giant kelp) in north & south
II. Distribution

- on the North American east coast, Asian east coast, and in Europe, kelp beds are dominated by *Laminaria*

- in South Africa, Australia, and New Zealand, kelp beds are dominated by *Ecklonia*

III. Kelp Morphology

- **holdfast** - rootlike attachment to substrate
- **stipe** – long stem
- **blades** - “leaves”
- **pneumatocysts** - gas-filled floats

IV. Kelp Life Cycle

**Alternation of generations, haploid and diploid:**

- diploid sporophytes produce haploid spores
- haploid gametophytes (male & female) produce haploid gametes that fuse to form a diploid sporophyte

V. Biological Characteristics of Kelp Forests

- **High productivity**
  - *Macrocystis* can grow up to 50 cm per day & reaches 60 m long

- **High diversity**

**Productivity**

<table>
<thead>
<tr>
<th>FOREST TYPE</th>
<th>NET PRODUCTION (dry kg / m² / yr)</th>
<th>PRODUCER MASS (dry kg / m²)</th>
<th>LITTER MASS (dry kg / m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical rain forest</td>
<td>2.2</td>
<td>45</td>
<td>0.2</td>
</tr>
<tr>
<td>Tropical deciduous forest</td>
<td>1.6</td>
<td>35</td>
<td>0.5</td>
</tr>
<tr>
<td>Temperate evergreen forest</td>
<td>1.3</td>
<td>35</td>
<td>3.0</td>
</tr>
<tr>
<td>Temperate deciduous forest</td>
<td>1.2</td>
<td>30</td>
<td>2.0</td>
</tr>
<tr>
<td>Boreal forest</td>
<td>0.8</td>
<td>20</td>
<td>4.0</td>
</tr>
<tr>
<td><strong>Giant kelp forest</strong></td>
<td>2.2</td>
<td><strong>0.35</strong></td>
<td><strong>0.015</strong></td>
</tr>
</tbody>
</table>
V. Biological Characteristics of Kelp Forests:

Kelp as food:
- kelps are ~3-10x more productive than shallow-water phytoplankton & about 50x more productive than oceanic phytoplankton
- but few animals directly eat the living fronds of kelps
- as kelp disintegrates, chunks, particles, and organic molecules feed suspension feeders and deposit feeders

Percentage of Kelp-Derived Carbon in Kelp Forest Consumers
(from Duggins et al. 1989, Alaskan kelp forests, Alaria & Laminaria)

<table>
<thead>
<tr>
<th>Percentage of Kelp-Derived Carbon in Kelp Forest Consumers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspension Feeders</td>
</tr>
<tr>
<td>mussel (Mytilus edulis)</td>
</tr>
<tr>
<td>soft coral (Alcyonaria sp.)</td>
</tr>
<tr>
<td>barnacle (Balanus rubens)</td>
</tr>
<tr>
<td>sea anemone (Metridium senile)</td>
</tr>
<tr>
<td>rock jingle (Pododesmus cepio)</td>
</tr>
<tr>
<td>mysid (Pronoeomysis sp.)</td>
</tr>
<tr>
<td>% kelp carbon</td>
</tr>
<tr>
<td>25 - 40</td>
</tr>
<tr>
<td>40 - 70</td>
</tr>
<tr>
<td>75 - 85</td>
</tr>
<tr>
<td>15 - 40</td>
</tr>
<tr>
<td>40 - 55</td>
</tr>
<tr>
<td>45 - 60</td>
</tr>
</tbody>
</table>

Detritivores:  
- amphipod (Anonyx sp.)  
- crab (Dermaturus mandtii)  
- % kelp carbon  
- 70 - 95  
- 20 - 35  

Predators:  
- rock greenling (Hexagrammos lagocephalus)  
- sea star (Leptasterias spp.)  
- cormorant (Phalacorocax pelagicus)  
- % kelp carbon  
- 40 - 65  
- 30 - 55  
- 35 - 70  

Note: more recent research indicates these estimates are too high because of problems with the original methods (Miller and Page 2012)

V. Biological Characteristics of Kelp Forests:  

High Diversity of Consumers

And kelp forests/beds Export their Production to other habitats: e.g., Kelp Wrack

V. Biological Characteristics of Kelp Forests:

Diversity

High Diversity of Primary Producers – not just kelps

Causes of High Diversity

- high structural diversity (3-dimensional structure; like coral reefs and tropical rain forests)  
  - places to hide from predators  
  - unique foraging locations

- high productivity
Microhabitats & associated species in a typical California kelp forest:

A. Canopy assemblage
B. Planktonic assemblage
C. Holdfast assemblage
D. Horizontal substrate assemblage
E. Vertical wall assemblage

Canopy assemblage: isopods, tubeworms, bryozoans, fishes

Membranipora membranacea, filter feeding colonies; eaten by several species of nudibranch and a few fishes

Idotea sp., a common isopod

Canopy assemblage: fishes

giant kelpfish  kelp bass  kelp perch  señorita  blue rockfish

Holdfast assemblage: sea urchins, crustaceans, worms, brittle stars, snails

brittlestars in holdfast

Horizontal substrate assemblage: urchins, sea stars, algae, and bottom fish

blackeye goby  brittlestars

Vertical wall assemblage: coralline algae, anemones, cup corals, sponges, mollusks in crevices

sculpin
VI. Abiotic factors that influence kelp forests

- Light
- Temperature
- Nutrients
- Water Motion
- Hard Substrate

**Light**
availability of light limits depths of kelps:
- need > 1% of surface irradiance
- can grow deeper in clearer water

**Water Motion:**
- big waves rip out kelp forests
- some species better able to deal with high water motion than others:
  - e.g., *Nereocystis* can handle larger waves (water motion) than *Macrocystis*

**Substrate type:**
- kelps generally require a hard substrate to attach to (rocks)
- cannot settle and grow on sand or other soft substrates

**Temperature & Nutrients:**
- correlated: high temperature → low nutrients
- nitrate thought to be key limiting nutrient

**Temperature & Nutrients:**
**Effects of El Niño**

El Niño conditions:
- warm surface waters
- depress thermocline
- keep nutrients away from kelp

Kelp growth declines & then kelps die
Variation in abiotic conditions often drives kelp abundance

- **Seasonal variation** (predictable)
- **Interannual variation** (unpredictable)

### Seasonal variation
- example: *Macrocystis* in Southern California
  - highest abundance & recruitment during winter/spring (cold water, high nutrients)
  - lowest abundance late summer/fall (warm water, low nutrients)

![Graph showing temperature changes over time](Dayton et al. 1992)

### Interannual variation
- example: *Macrocystis* in Southern California (Dayton et al. 1992)
  - highest abundance during cold water periods (La Niña)
  - lowest abundance during warm water periods (El Niño)

![Graph showing variation in kelp abundance over time](Dayton et al. 1992)

### VII. Effects of kelp beds on abiotic conditions
- kelp forests alter the local hydrodynamic regime
  - slow down currents
  - allow sediments to settle out
  - planktivores “filter” edible particles (e.g., plankton)

### VIII. Biological factors that influence kelp forests
- **COMPETITION**
- **GRAZING**
- **PREDATION**
Competition:

- intense competition for light
  - occurs among kelps & understory algae
  - in southern CA, Macrocystis is the dominant competitor because of fast growth

- competition for space
  - competition for attachment spots on hard substrate
  - occurs among algae and also between algae and invertebrates

Trophic Interactions

Alternate Stable States?

**kelp forests and urchin barrens**

Ecosystem changes

Factors that influence sea urchin populations in southern California

- other predators on sea urchins in California
  - lobster
  - California sheephead

- sporadic recruitment of sea urchins in California

- urchin disease
  - known to greatly reduce urchin numbers over relatively wide areas
  - in California these outbreaks of disease are generally associated with periods of warm water
  - expansion of kelp beds have been documented following massive urchin die offs

IX. Kelp Harvesting

- kelp is a main source of algin and other emulsifiers and thickeners
  - foods
  - cosmetics
  - paints
  - pharmaceuticals

- $40 million a year industry in California in the mid 1980's

- started in early 1900's to make potash for gunpowder in World War I
IX. Kelp Harvesting

- boats with cutters about six feet deep take all surface growth and the top 4 feet of the stipes
- kelp beds were leased to private groups
- in California, Kelco (until 2005)
- between 100,000 and 170,000 wet tons were harvested from California waters each year
- no longer harvested in CA

Summary

**Kelp forests** are...
- highly productive
- highly diverse
- highly dynamic
  - due to strong biotic & abiotic influences