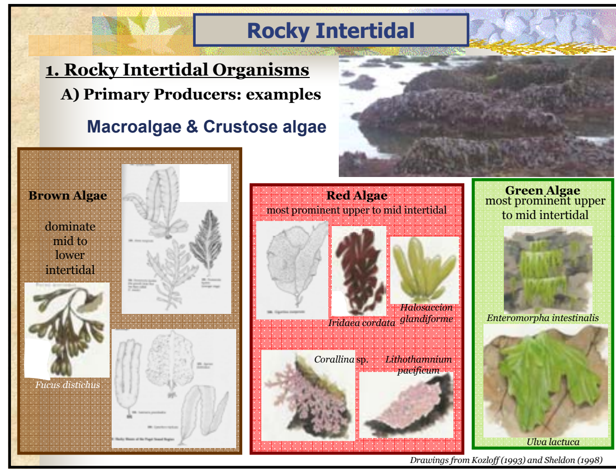
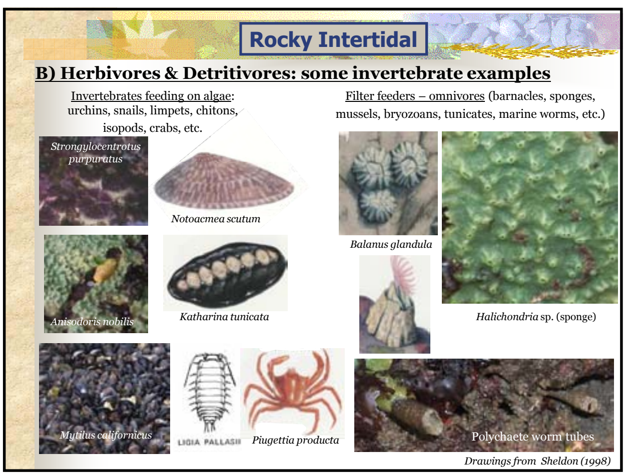
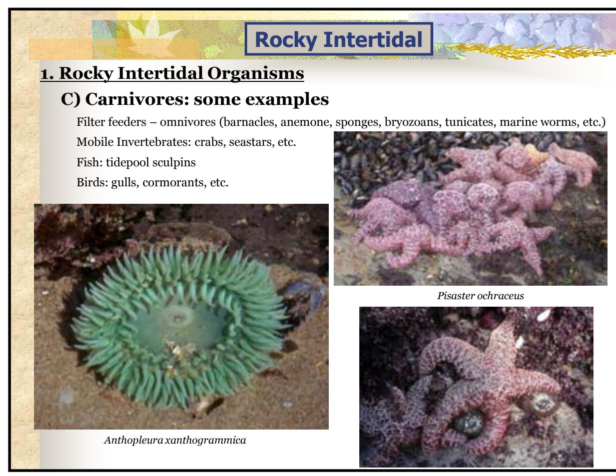
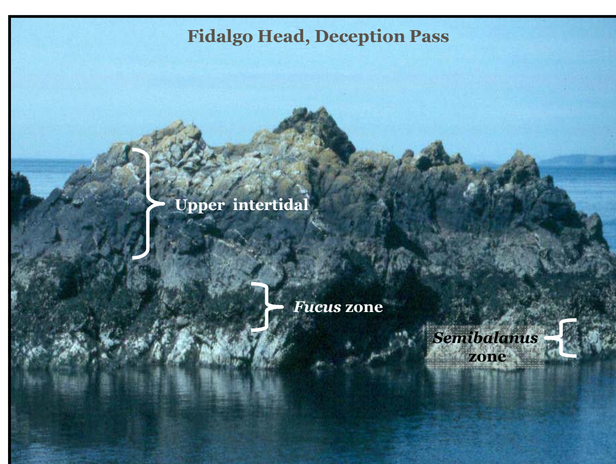

Littoral Ecosystems: Rocky Intertidal

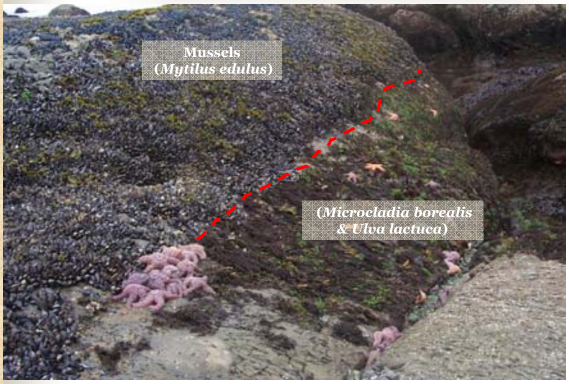

Rocky Intertidal
1. Rocky Intertidal Organisms
A) Primary Producers: examples
Macroalgae & Crustose algae
Brown Algae
dominate mid to lower intertidal
Fucus distichus
Red Algae
most prominent upper to mid intertidal
Iridaea cordata
Halosaccion glandiforme
Corallina sp.
Lithothamnium pacificum
Green Algae
most prominent upper to mid intertidal
Enteromorpha intestinalis
Ulva lactuca
Drawings from Kozloff (1993) and Sheldon (1998)


Rocky Intertidal
B) Herbivores & Detritivores: some invertebrate examples
Invertebrates feeding on algae: urchins, snails, limpets, chitons, isopods, crabs, etc.
Filter feeders – omnivores (barnacles, sponges, mussels, bryozoans, tunicates, marine worms, etc.)
Strongylocentrotus purpuratus
Notoacmea scutum
Balanus glandula
Anisodoris nobilis
Katharina tunicata
Halichondria sp. (sponge)
Mytilus californicus
LIGIA PALLASII
Pugettia producta
Polychaete worm tubes
Drawings from Sheldon (1998)


Rocky Intertidal
1. Rocky Intertidal Organisms
C) Carnivores: some examples
Filter feeders – omnivores (barnacles, anemone, sponges, bryozoans, tunicates, marine worms, etc.)
Mobile Invertebrates: crabs, seastars, etc.
Fish: tidepool sculpins
Birds: gulls, cormorants, etc.
Pisaster ochraceus
Anthopleura xanthogrammica

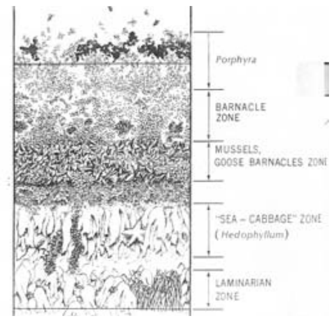

Rocky Intertidal
2. Community organization in the Rocky Intertidal
A) Zonation Patterns
Fidalgo Head, Deception Pass
Upper intertidal
Mid-upper intertidal


Fidalgo Head, Deception Pass
Upper intertidal
Fucus zone
Semibalanus zone



2. Community organization in the Rocky Intertidal

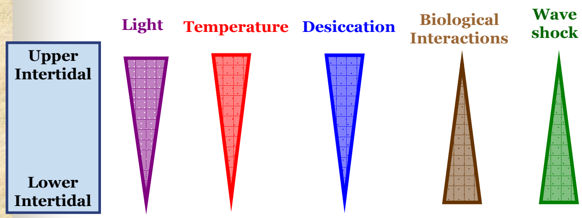
A) Zonation Patterns



West Coast Vancouver Island (Carefoot 1977)

2. Community organization in the Rocky Intertidal

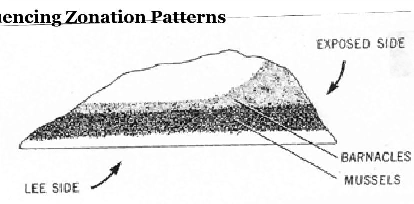
B) Understanding Zonation Patterns



Sharp environmental gradients result from the interaction of :
- steep topography & tides
- position at the interface of terrestrial & aquatic environments

3. Wave action in the Rocky Intertidal

A) Influencing Zonation Patterns



Why do barnacles extend higher on side exposed to waves?

Why don't mussels also extend higher on side exposed to waves?

Vancouver Island (Carefoot 1977)

3. Wave action in the Rocky Intertidal

B) Adaptation to Wave Shock

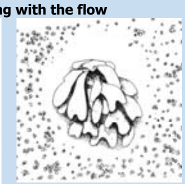
Hanging on

Mussels attach with unique byssal threads

Kelp holdfasts hold firm

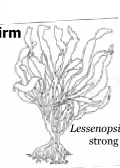
Going with the flow

Postelsia palmaeformis is highly flexible



Fucus distichus clears surrounding area with fronds

Being firm



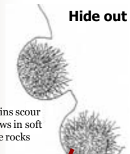
Lessenopsis littoralis has a strong woody base

Drawings from Carefoot (1977)

3. Wave action in the Rocky Intertidal

B) Adaptation to Wave Shock

Hide out



Sea urchins scour out hollows in soft marine rocks

Duck & Cover

Notoacmea scutum has hard shell & flattened body form

Acorn barnacles have armored plates

Safety in numbers

Goose neck barnacles cluster together for protection

Rocky Intertidal

4. Biological Interactions in the Rocky Intertidal

A) Competition

What is competed for in this ecosystem?

~~Nutrients~~ | ~~Water~~ | Light | ~~Pollinators~~ | Space | ~~CO_2 / O_2~~

Competition among algal species is often intense

Rocky Intertidal

4. Biological Interactions in the Rocky Intertidal

A) Competition

Open space on a hard substrate is often a resource in short supply

Rocky Intertidal

4. Biological Interactions in the Rocky Intertidal

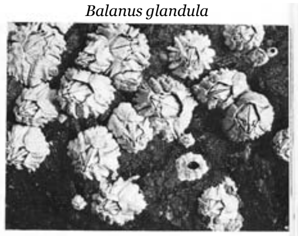
A) Competition

Competition between two barnacle species: a classic story in ecology

Chthamalus dalli

98. *Chthamalus dalli*

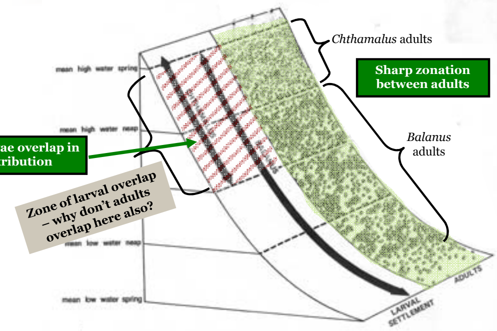
Balanus glandula



99. *Balanus glandula*

Rocky Intertidal

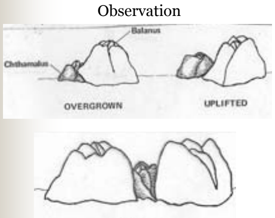
Competition between two barnacle species: a classic story in ecology



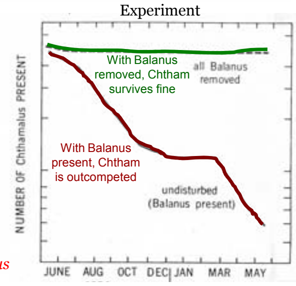
Rocky Intertidal

Competition between two barnacle species: a classic story in ecology

Observation



Experiment



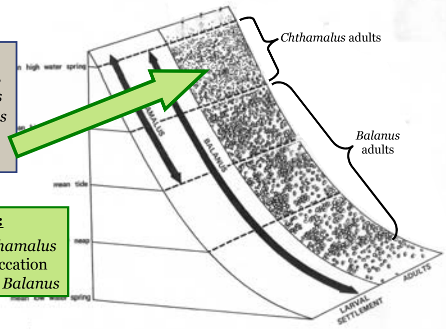
Suggests that *Balanus* excludes *Chthamalus* from lower elevations by competition

Conclusion: *Balanus* outcompetes and excludes *Chthamalus* where they overlap

Rocky Intertidal

Competition between two barnacle species: a classic story in ecology

If *Balanus* is such a superior competitor, why doesn't *Balanus* take over *Chthamalus* beds in the highest intertidal sections?



Answer:

Desiccation! *Chthamalus* withstands desiccation much better than *Balanus*

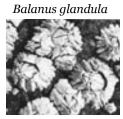
Rocky Intertidal

So what type of factors limit the distribution of these two barnacle species and result in this distinctive zonation?

***Abiotic** factors define the upper limits to organisms' distributions*

Chthamalus dalli

Balanus glandula



Desiccation ↕ **Competition**

Desiccation ↕ **Predation**

***Biotic** factors define the lower limits to organisms' distributions*

What other ecosystems are like this?

Rocky Intertidal

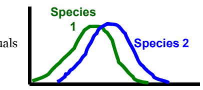
Pisaster Leptasterias

4. Biological Interactions in the Rocky Intertidal

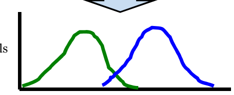
B) Coexistence of Close Competitors

Two sea stars coexist by minimizing prey overlap.

Niche divergence as a mechanism to minimize prey overlap



Time

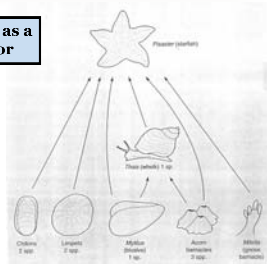


Rocky Intertidal

4. Biological Interactions in the Rocky Intertidal

C) Predation

***Pisaster ochraceus* as a Keystone Predator**



Algae, Plankton, Detritus

Rocky Intertidal

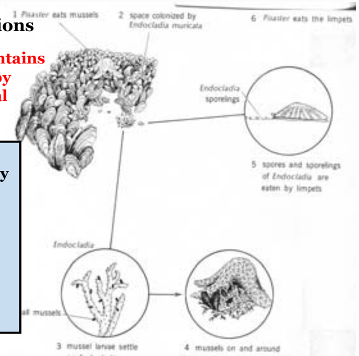
4. Biological Interactions in the Rocky Intertidal

D) Food Web Interactions

A keystone predator maintains its own food source by controlling biological interactions

Pisaster sustains its primary prey (mussels) by

- Opening up space for *Endocladia*, an alga that mussels need for regeneration
- Preying upon limpets that graze *Endocladia*



Rocky Intertidal

4. Biological Interactions in the Rocky Intertidal

E) Mutualism

Green color from 2 photosynthetic microscopic endobionts living inside the anemone's tentacles

Anemone → Shelter, CO_2, Nitrogen → **Endobionts** → Sugars → **Anemone**

Zooxanthellae (dinoflagellates)

Zoochlorellae

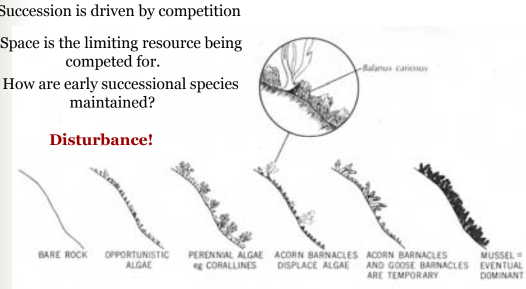
Anthopleura xanthogrammica

Rocky Intertidal

5. Succession in the Rocky Intertidal

1. Succession is driven by competition
2. Space is the limiting resource being competed for.
3. How are early successional species maintained?

Disturbance!



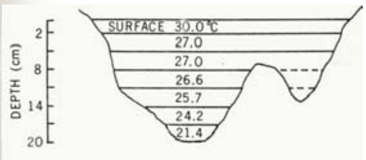
Rocky Intertidal

6. Keys to Biological Diversity in the Rocky Intertidal

1) Biological interactions (predation, competition)
2) Disturbance
3) Environmental Heterogeneity

Topography: tidepools, niches, slope angles & the role of geology

Temperature environment varies with depth in a tidepool

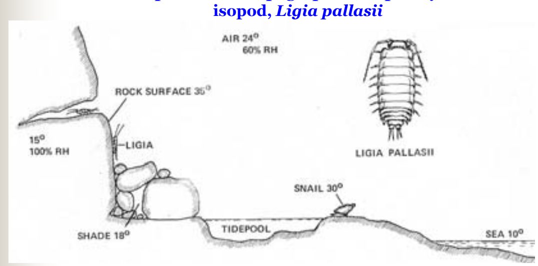


Rocky Intertidal

6. Keys to Biological Diversity in the Rocky Intertidal

1) Biological interactions (predation, competition)
2) Disturbance
3) Environmental Heterogeneity

The importance of topographic complexity for the isopod, *Ligia pallasii*



III. Human Interactions

Marine Ecosystems

I. Habitats
1. Habitat Zones
2. PNW Locations
3. Perspectives in Geological Time

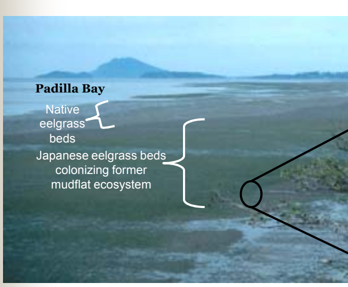
II. Ecosystems
1. Oceanic & Neritic Ecosystems
2. Littoral Ecosystems

III. Human Interactions
1. Introduced Species
2. Harvesting
3. Mariculture
4. Chemical Pollution
5. Land Conversion

Human Interactions

1. Introduced Species ("Smart pollution")
- *Zostera japonica* (Japanese eelgrass)

Japanese eelgrass came along with introduced oysters



Introduced snails (*Batillaria attramentaria*) came along with eelgrass

Former high tideline mudflat ecosystem turned into eelgrass based-system

Human Interactions

1. Introduced Species ("Smart pollution")
- *Zostera japonica* (Japanese eelgrass)
- European green crab

Small shore crab native to North and Baltic seas

Invasion History
- Already invaded into South Africa, Australia, east coast North America
- SF Bay 1989
- Willapa Bay & Grays Harbor 1998
- Probably migrated on ocean currents associated with strong El Nino events of 1997 & 1998

Scary Stuff
- One crab can produce up to 200,000 eggs at one time
- Can survive up to 2 months out of water
- Larvae can survive as plankton up to 80 days
- Very aggressive predator / competitor
- Can outcompete Dungeness crabs (a multi-million $ industry)
- Can outcompete other predators
- Could displace food for native birds & fish

Prognosis
- 1000 trapped in Willapa Bay since 1998
- But aggressive control efforts have so far kept populations low

Human Interactions

1. Introduced Species ("Smart pollution")

seattletimes.com
The Seattle Times

Monday, September 08, 2003, 12:00 a.m. Pacific

Permission to reprint or copy this article/photo ***must*** *be obtained from The Seattle Times. Call 206-464-3113 or e-mail resale@seattletimes.com with your request.*

Regulations not halting aquatic invaders

By Craig Welch
Seattle Times staff reporter

Untold numbers of ship operators are lying, cheating or simply misunderstanding state rules designed to keep them from introducing invasive snails, crabs and other foreign species into Washington waters, according to a recent survey.

State rules adopted to prevent ships from accidentally transporting millions of nonnative species are so toothless that regulators plan to ask state lawmakers in January for the power to board and inspect ships to verify they're being followed.

Spartina anglica

Human Interactions

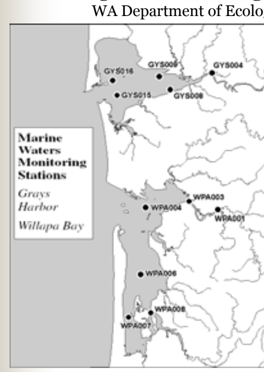
2. Harvesting
Fish, crabs, shellfish,etc.

3. Mariculture
- **A) Invertebrates** (abalone, oysters)
- **B) Algae (Nori farming)**
- **C) Effects of mariculture: exotic species**
  - Japanese oysters → *Zostera japonica* → *Batillaria* snails

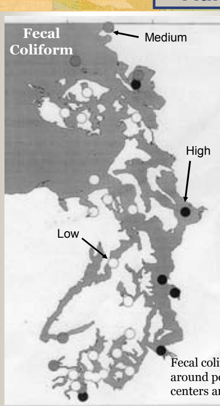
4. Chemical Pollution
- **A) Oil**
- **B) Heavy metals (generally declining since 1960s)**
- **C) Pulp mill effluent**
  - wood fiber (high C/N ratio)
  - toxic processing chemicals
- **D) Sewage, fertilizers, etc.**
- **E) Water Quality / Eutrophication**
  - Sewage & nutrient loading
  - Secondary waste treatment
- **F) Monitoring / Sites at risk**

Marine Water Quality

Long term monitoring sites
WA Department of Ecology



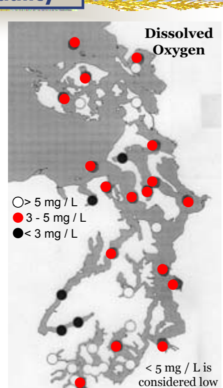
Marine Water Quality



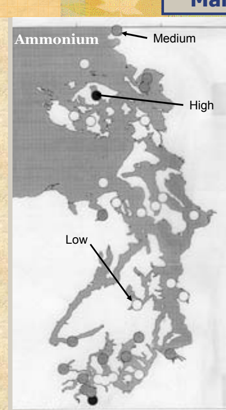
Oxygen & Fecal Coliform

WA Dept of Ecology 2000

Fecal coliform high around population centers and estuaries



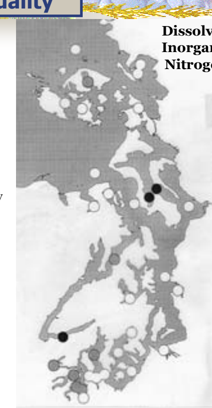
Marine Water Quality



Ammonium & DIN

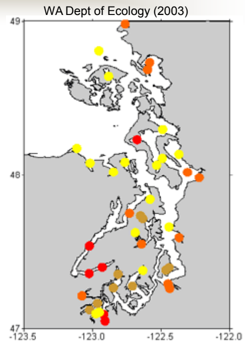
Note effects of tidal flushing and variability in water quality problems at specific sites

WA Dept of Ecology 2000



Marine Water Quality: overall assessment of site risk

	DO	FCB	DIN	NH4	Stratif	Concern
Budd Inlet	Very Low	High	Low	High	P	Very High
S. Hood Canal	Very Low		Low		P	Very High
Penn Cove	Very Low		Low		P	Very High
Commencement Bay	Low	Very High			P	High
Elliott Bay	Low	Very High			P	High
Oakland Bay		Very High	Moderate	Moderate	E	High
Grays Harbor		Very High		Moderate	P-E	High
upper Willapa Bay		Very High	Low	Moderate	E-W	High
Possession Sound	Low	High	Moderate	High	P	High
Sinclair Inlet	Low	High	Low	Moderate	P	High
Bellingham Bay	Low	Moderate	Low	Moderate	P	High
Drayton Harbor		Moderate	Low		S	High
N. Hood Canal	Low		Low		P	High
Port Orchard		High		Moderate	S	Moderate
Case Inlet	Low	Moderate	Moderate	Moderate	S	Moderate
Carr Inlet	Low		Moderate	Moderate	S	Moderate
Quartermaster Hbr	Low			Moderate	S	Moderate
Totten Inlet			Moderate	Moderate	E	Moderate
Saratoga Passage	Low		Moderate		P	Low
Holmes Harbor	Low				P	Low
Skagit	Low				P	Low
Port Susan	Low				P	Low
West Point		Moderate			E	Low
Dungeness	Low				S	Low
Port Gamble	Low				S	Low
Sequim Bay	Low				S	Low
Discovery Bay			Low		S	Low
Willapa Bay			Low			Low
Dyes Inlet			Moderate		S	Low
Eld Inlet			Moderate		S	Low
East Sound				High	S	Low
Burley-Minter				Moderate	E	Low
Port Townsend	Low				W	Low
Strait of Georgia	Low				S	Low



Strong effects of population, land use, & tidal flow on water quality problems

Human Interactions

5. Land Conversion

Puget Sound Tidal Estuaries

Pre European Settlement: 40 mi²

2000: < 3 mi²

↓ 93 %

Restoring Tidal Ecosystems

What things are critical to pay attention to?

1. Topographic complexity (plateaus, blind tidal channels, distribution channels, etc.)
2. Sediment dynamics / water flow / topography / salinity
3. Invasive, non-native species
4. Social context
5. Estuary-wide effects:

   interconnectedness of estuarine ecosystems in sediment, trophic exchange, etc.

Marine Ecosystems

I. Habitats

1. Habitat Zones
2. PNW Locations
3. Perspectives in Geological Time

II. Ecosystems

1. Oceanic & Neritic Ecosystems
2. Littoral Ecosystems

III. Human Interactions

1. Introduced Species
2. Harvesting
3. Mariculture
4. Chemical Pollution
5. Land Conversion