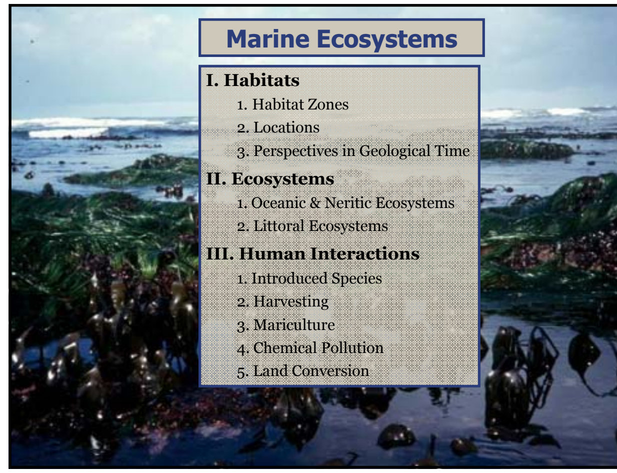
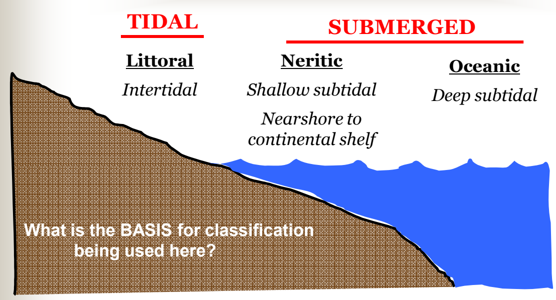


Marine Ecosystems

I. Habitats

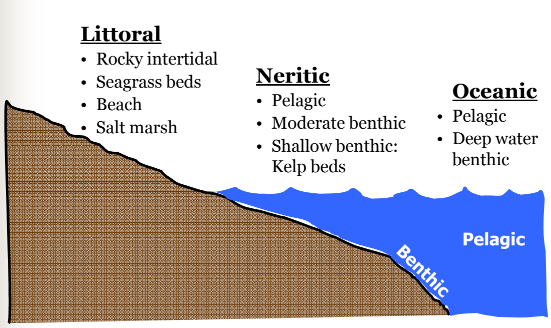
1. Habitat Zones
   - A. Oceanic Zone
   - B. Neritic Zone
   - C. Littoral Zone

Marine Habitat Zones



Marine Habitat Zones

Typical Habitats within Zones



Marine Ecosystems

I. Habitats

1. Habitat Zones
   - A. Oceanic Zone
   - B. Neritic Zone
   - C. Littoral Zone

Oceanic Zone Habitats

Pelagic Habitats

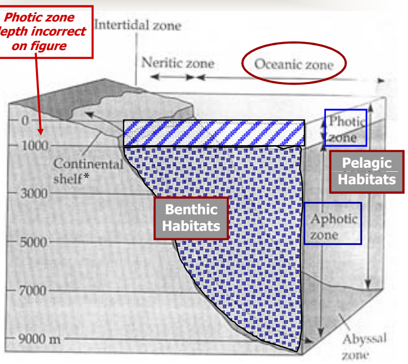
photic zone
(0 – 200 m depth)

aphotic zone
(> 200 m depth)

Benthic Habitats

Benthic Habitats
Habitats on a solid surface within an aqueous medium

Pelagic Habitats
Habitats surrounded by an aqueous medium



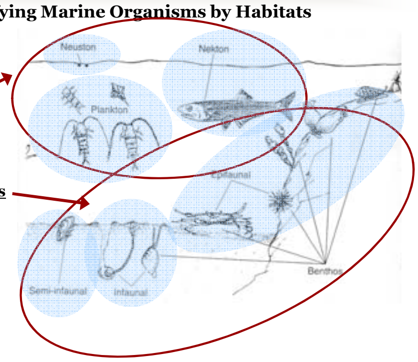
* Continental shelf extends 10-300 km offshore with depths up to 1-200 m

Oceanic Zone Habitats

Classifying Marine Organisms by Habitats

Pelagic Organisms
- Nekton
- Plankton
- Neuston

Benthic Organisms
- Epifaunal
- Semi-infaunal
- Infaunal



Marine Ecosystems

I. Habitats

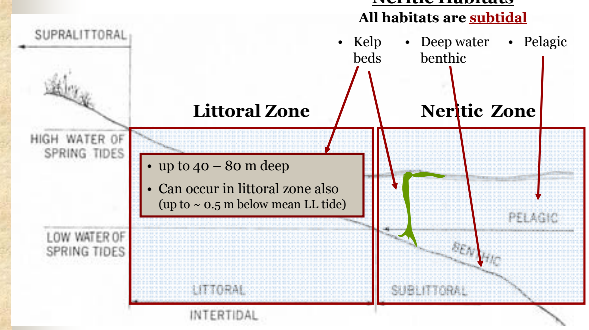
1. Habitat Zones
   - A. Oceanic Zone
   - B. Neritic Zone
   - C. Littoral Zone

Neritic Zone Habitats

Neritic Habitats

All habitats are subtidal

- Kelp beds
- Deep water benthic
- Pelagic



Marine Ecosystems

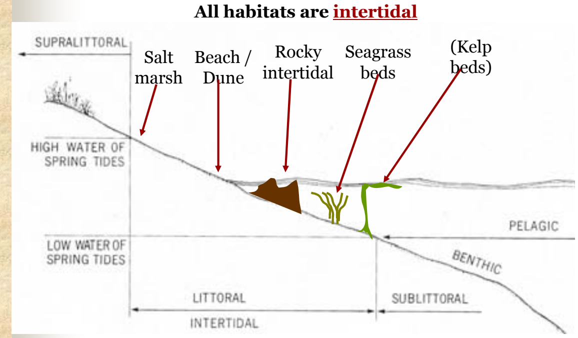
I. Habitats

1. Habitat Zones
   - A. Oceanic Zone
   - B. Neritic Zone
   - C. Littoral Zone

Littoral Zone Habitats

Littoral Habitats

All habitats are intertidal

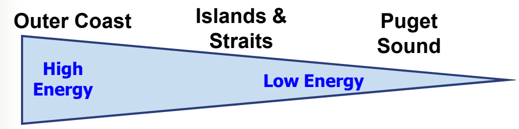


Marine Ecosystems

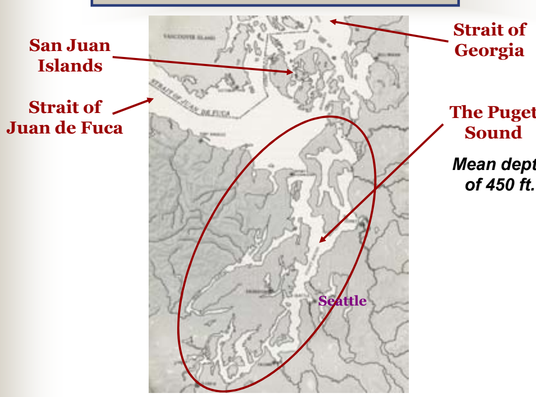
I. Habitats

1. Habitat Zones
   - A. Oceanic Zone
   - B. Neritic Zone
   - C. Littoral Zone
2. PNW Locations
3. Perspectives in Geological Time

Marine Habitats: PNW Locations



Marine Habitats: PNW Locations



Mean depth of 450 ft.

The Puget Sound: Channel Depth & Water Flow

Mean depth of ~ 450 ft.

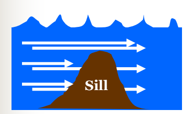
Max depth of ~ 930 ft.

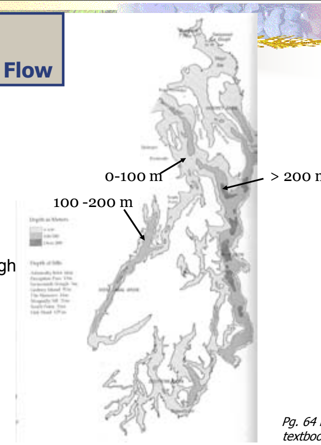
Typical channel depths of ~ 3 - 600 ft.

<u>Sills</u>

Channel sills ~ 150 - 200 ft. high

Minor sills ~ 10 – 70 ft. high





Pg. 64 in textbook

Marine Ecosystems

I. Habitats

1. Habitat Zones
   - A. Oceanic Zone
   - B. Neritic Zone
   - C. Littoral Zone
2. PNW Locations
3. Perspectives in Geological Time

Perspectives in Geological Time

I. Continental Shelf / Outer Coastline

<u>1. Terrane accretion – evolutionary template</u>

Accreting land masses bring new organisms

This alters the biogeographic picture of nearshore organisms

Perspectives in Geological Time

I. Continental Shelf / Outer Coastline

2. Continental glaciation – sea level, coastlines & nutrients

Recent glacial retreat begins 14 – 18,000 YBP

Sea levels rise rapidly (~ 100 m) inundating coastlines.

Nearshore land rich in nutrients is now part of the submerged continental shelf

Continent rises slowly (isostatic rebound) but not to the extent it was submerged. Much of the nutrient-rich former shoreline remains as subtidal benthic habitat.

This rich nutrient base of the subtidal / continental shelf zone is critical in nearshore primary productivity. Its availability is controlled by upwelling (*more on this later*).

Perspectives in Geological Time

II. Puget Sound

Puget Sound waterways formed during retreat of Vashon Stade of the Fraser Glaciation (14 – 18,000 YBP)

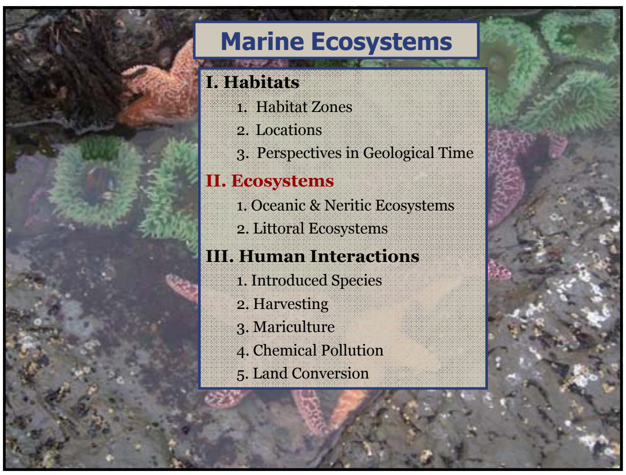
Ecosystems are relatively young: 10 – 15,000 yrs old

Short time for development of ecological community through primary succession

Marine systems have rapid dispersal → *rapid community development*

Short time for evolution & coevolution relationships to be established

Implications for susceptibility to biological invasions?



Marine Ecosystems

I. Habitats
1. Habitat Zones
2. 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

Marine Ecosystems

Patterns in Primary Productivity

Many of these nearshore marine ecosystems we will examine are among the most productive on Earth

Biome	NPP (g C/m²/yr)
Terrestrial systems	
Tropical rain forest	900
Tropical dry forest	675
Temperate evergreen forest	585
Temperate deciduous forest	540
Boreal forest	360
Tropical grasslands	315
Cultivated land (USA)	290
Chaparral	270
Prairie	225
Tundra	65
Desert	32
Extreme desert	1.5
Aquatic systems	
Swamp	1125
Algal beds and coral reef	900
Estuaries	810
Upwelling zones	225
Continental shelf	162
Open ocean	57

(Source: *Ecology: Theory and Application*, by P. Stiling, © 1996. Reprinted by permission of Prentice-Hall, Inc., Upper Saddle River, NJ.)

Marine Ecosystems

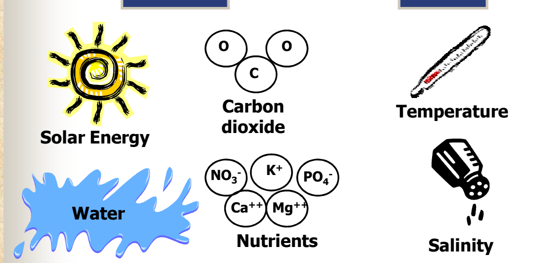
II. Ecosystems
1. Oceanic & Neritic Ecosystems
2. Littoral Ecosystems

Oceanic & Neritic Ecosystems

I. Abiotic Environment & Primary Productivity

What are the principal constraints to primary productivity?

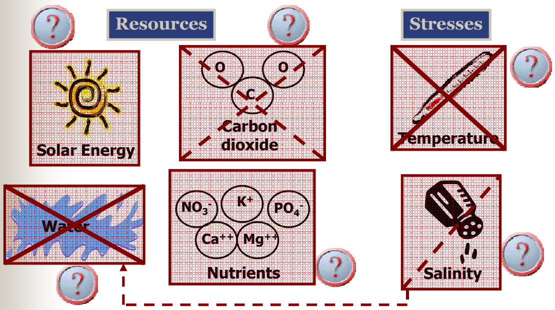
Resources | **Stresses**



Oceanic & Neritic Ecosystems

I. Abiotic Environment & Primary Productivity

Which constraints to primary productivity are most important in these ecosystems?



Oceanic & Neritic Ecosystems

I. Abiotic Environment & Primary Productivity

1. Light

Rapid attenuation with depth even in clear marine waters

Note that the "effective" photic zone is on the order of 10 m or less. Pelagic primary productivity can sometimes be linked to the DEPTH of the photic zone

What factors influence the rate of light attenuation (i.e., depth of the photic zone)?

1) Suspended particulates
   - Living organisms (plankton, neuston)
   - Dead and inorganic materials

2) Wave action (surface losses)

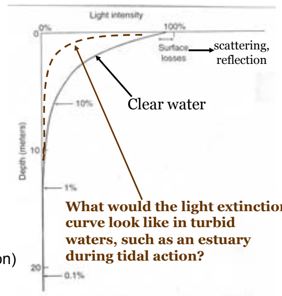


Fig. 2.10 An example of the pattern of exponential decline in light intensity with increasing depth (in meters) in a coastal marine water column.

Oceanic & Neritic Ecosystems

I. Abiotic Environment & Primary Productivity

2. Nutrients

A) Major limiting nutrients:

Nitrogen – **N**
Phosphorus – **P**
Potassium – **K**

B) Nitrogen Sources

Nitrogen fixation ($N_2 \rightarrow NH_4^+$)

Terrestrial (riverine) input

Benthic upwelling →

<u>Offshore</u> or <u>alongshore</u> winds displace surface water. Water from near benthos rises to replace surface waters, bringing nutrient-rich particulates to photic zone where they can be used in photosynthesis

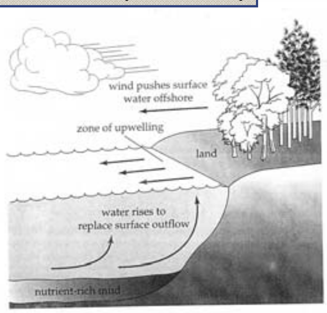


Figure 6.3 A diagrammatic representation of upwelling, which brings nutrients to the surface waters.

Oceanic & Neritic Ecosystems

I. Abiotic Environment & Primary Productivity

2. Nutrients

A) Major limiting nutrients:

Nitrogen – **N**
Phosphorus – **P**
Potassium – **K**

B) Nitrogen Sources

Nitrogen fixation ($N_2 \rightarrow NH_4^+$)

Terrestrial (riverine) input

Benthic upwelling

C) Phosphorus & Potassium Sources

Terrestrial (riverine) input

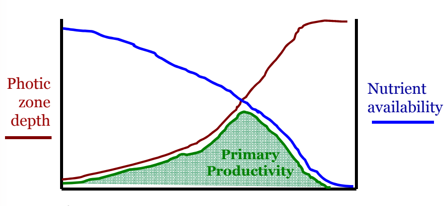
Benthic upwelling

Oceanic & Neritic Ecosystems

I. Abiotic Environment & Primary Productivity

2. Nutrients

D) Patterns of coastal primary productivity: interactions of nutrients and light

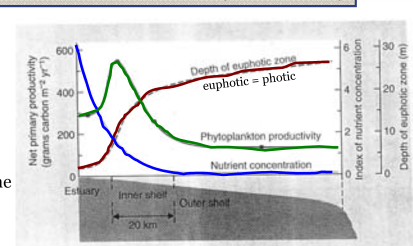


Oceanic & Neritic Ecosystems

I. Abiotic Environment & Primary Productivity

2. Nutrients

D) Patterns of primary productivity: interactions of nutrients and light along the Georgia coastline



Patterns of availability of two principal limiting resources (light and nutrients) result in peak in primary productivity somewhere offshore

Oceanic & Neritic Ecosystems

I. Abiotic Environment & Primary Productivity

3. Carbon Dioxide & Oxygen

Gas diffusion (supply rate) more limited in a liquid medium than in air

Factors influencing soluble gas availability

A. Physical aeration (wind, wave action)

B. Photosynthesis / respiration

C. Water temperature (↑ °C → ↓ gas solubility)

Bottom line

Soluble gases are usually not a major limitation except under conditions of algal blooms (nutrient loading) and stagnant water

Oceanic & Neritic Ecosystems

I. Abiotic Environment & Primary Productivity

4. Water Temperature

A. Vertical Patterns:

Epilimnion – upper photic zone
- Temperature influenced by patterns of solar radiation
- Diurnal & seasonal temperature fluctuations

Thermocline – lower photic to aphotic zone
- Zone of rapid temperature drop
- Thermocline depth can vary seasonally in temperate latitudes

Hypolimnion – aphotic zone
- Cold, constant temperatures

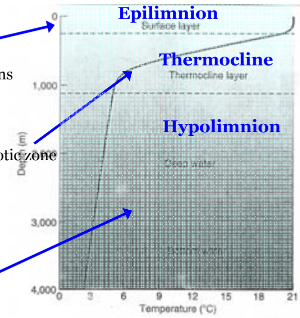


Fig. 2.15 An idealized profile of sea water temperature as a function of depth.

Oceanic & Neritic Ecosystems

I. Abiotic Environment & Primary Productivity

4. Water Temperature

B. Geographical Patterns: Puget Sound vs. Outer Coast

Surface water temperature (°F)

	Jan	Mar	May	Jul	Sep	Nov
Neah Bay	45	47	51	53	53	49
Seattle	47	46	51	56	56	51

Puget Sound surface waters **warmer** than outer coast, except following cool down into late winter

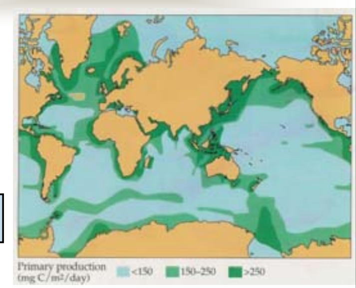
Does this temperature difference influence productivity?

I. Abiotic Environment & Primary Productivity

4. Water Temperature

C. Water Temperature & Primary Productivity: Global Patterns

Do global patterns of primary productivity appear to follow expected water temperature patterns?



Productivity is more tightly tied to nutrients

High productivity only near coastlines

Low latitude coastlines: nutrient input from terrestrial landscape

High latitude coastlines: nutrient input from benthic upwelling

Oceanic & Neritic Ecosystems

I. Abiotic Environment & Primary Productivity

4. Water Temperature

B. Geographical Patterns: Puget Sound vs. Outer Coast

Surface water temperature (°F)

	Jan	Mar	May	Jul	Sep	Nov
Neah Bay	45	47	51	53	53	49
Seattle	47	46	51	56	56	51

Puget Sound surface waters warmer than outer coast, except following cool down into late winter

So, do these temperature differences likely result in primary productivity differences?

Oceanic & Neritic Ecosystems

I. Abiotic Environment & Primary Productivity

5. Salinity

A. Principal Influences

Organism water balance

Species diversity

Habitats with variable salinity (space & time) are difficult to adapt to; results in few species

Oceanic & Neritic Ecosystems

I. Abiotic Environment & Primary Productivity

6. Puget Sound & the Outer Coast: Comparing Productivity Constraints

	Puget Sound	Outer Coast
Relative Nutrient Availability	***Higher ?***	
Terrestrial nutrient input	**High**	**Low**
Upwelling nutrient input	**Low**	**High**
Photic Zone Depth		***Higher***
Water clarity	**Low**	**High**
Input of suspended particulates	**High**	**Low**
Dissolved gases		***Higher***
Turbulence	**Low**	**High**
Water temperature	**High**	**Low**

Oceanic & Neritic Ecosystems

II. Pelagic Biota

Primary Producers: phytoplankton

Consumers:

Herbivores: almost nothing strictly herbivorous

Omnivores:

Zooplankton

Filter feeders (fish & whales)

Schooling fish: Pacific herring, Northern anchovy, Pacific sardine (streamlined bodies)

Baleen Whales: grey, blue, right, humpback

Detritivores:

Flat fish (bottom fish): sole, halibut, flounder

Various invertebrates (e.g., marine worms, sand dollars, clams)

Pelagic stages of these benthic organisms

Oceanic & Neritic Ecosystems

II. Pelagic Biota

Carnivores:

some zooplankton

Predatory fish : e.g., tuna, mackrel, salmonids

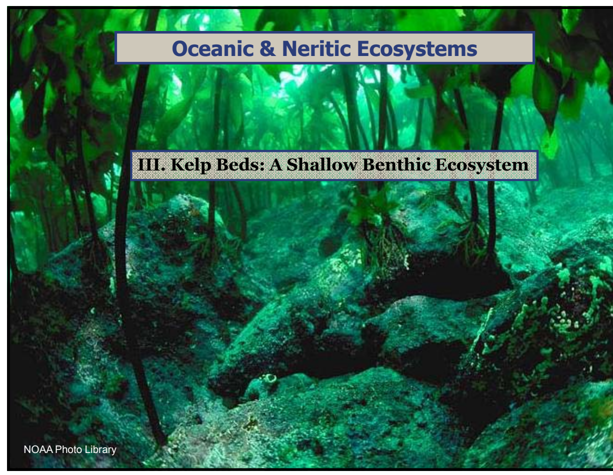
Sharks

Toothed whales (orcas) & dolphins / porpoises

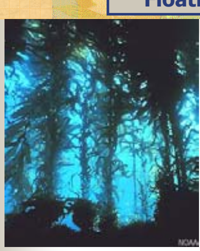
Octopus & squid (e.g., giant pacific octopus & opalescent squid)

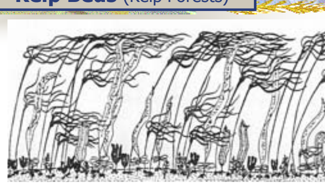
Pinnipeds: seals, otters, sea lions

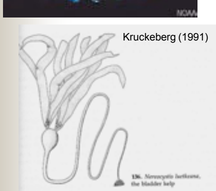
[Pelagic feeding birds (e.g., gulls, cormorants, shearwaters, albatrosses)]



"Floating" Kelp Beds (Kelp Forests)







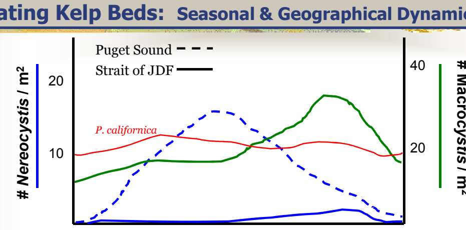
Dominated by 3 large brown algal species (kelp):

Nereocystis luetkeana (bull kelp)
- Up to 20 m tall
- Annual
- Puget Sound, straits, protected outer coast

Macrocystis integrifolia (giant kelp)
- Up to 10 m tall; perennial
- Outer coast nearshore & western straits

Macrocystis pyrifera
- Up to 40 m tall; perennial
- Outer coast further away from shore
- In water up to 80 m deep

Floating Kelp Beds: Seasonal & Geographical Dynamics



Nereocystis beds in Puget Sound : strong seasonal dynamics.

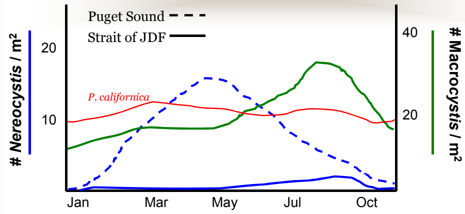
Nereocystis beds in the Strait: less seasonal dynamics & different seasonal peak.

However, *Nereocystis* beds in the strait are dominated by another brown alga, *Pterygophora californica*. This is a perennial, providing these *Nereocystis* beds with year round cover, unlike those in Puget Sound.

Macrocystis beds in the strait show moderate seasonal dynamics, with an autumn peak and considerable presence year round.

data from Shaffer, J. (1998)

Floating Kelp Beds: Seasonal & Geographical Dynamics



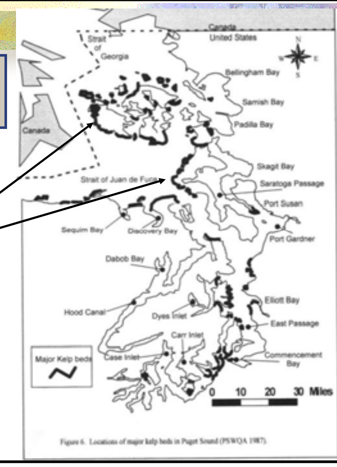
Bottom Line: Not all kelp beds are created equal! This has large implications for understanding kelp bed ecology and for conservation & mitigation of human impacts!

Can a restoration of a Puget Sound *Nereocystis* bed replace destruction of a *Nereocystis* bed in the strait?

data from Shaffer, J. (1998)

Kelp Bed Distribution in Puget Sound & San Juan Islands

Note the greater abundance on more exposed shorelines



Marine Ecosystems

Patterns in Primary Productivity

Kelp beds are as productive as tropical rainforests

Biome	NPP (g C/m²/yr)
Terrestrial systems	
Tropical rain forest	900
Tropical dry forest	675
Temperate evergreen forest	585
Temperate deciduous forest	540
Boreal forest	360
Tropical grasslands	315
Cultivated land (USA)	290
Chaparral	270
Prairie	225
Tundra	65
Desert	32
Extreme desert	1.5
Aquatic systems	
Swamp	1125
Algal beds and coral reef	900
Estuaries	810
Upwelling zones	225
Continental shelf	162
Open ocean	57

(Source: Ecology: Theory and Application, by P. Stiling, © 1996. Reprinted by permission of Prentice-Hall, Inc., Upper Saddle River, NJ.)

This slide NOT on handout – simply a repeat of slide from page 3

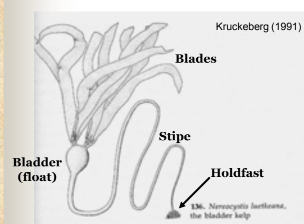
Kelp Bed Primary Productivity

Why do kelp beds have such high primary productivity ?

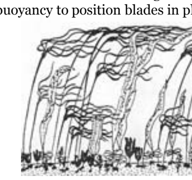
1. Typical limiting resources are less limiting

Nearshore position results in good nutrient input / availability

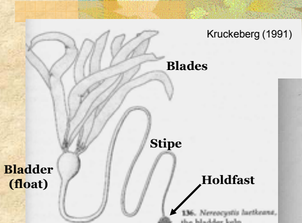
Nearshore position & buoyancy of photosynthetic structures provides good access to light

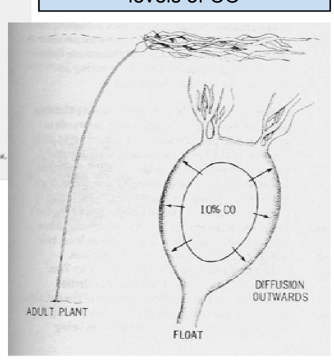


Bladder takes advantage of water's buoyancy to position blades in photic zone



Fun fact: kelp float works by containing extraordinarily high levels of CO



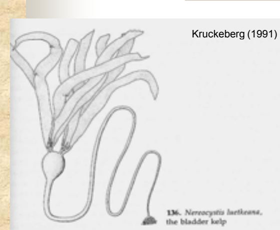


Kelp Bed Primary Productivity

Why do kelp beds have such high primary productivity ?

2. Buoyancy of habitat medium allows resource investment to maximize productivity

Buoyancy → **↓ structural needs** → **↑ energy available to invest in photosynthetic structures**



Which organism requires more investment to access light?

Kelp Bed Energy Flow

Primary Producers

Dominated by large brown algae – kelp (surprise ☺)

Nereocystis leutkeana (bull kelp) is characteristic but there is a high diversity of others

Understory species in kelp beds vary greatly with:

- dominant overstory species
- region (PS, straits, outer coast)
- energetics of water at the site
- season

Kelp act as **ecological engineers** in influencing habitat for other organisms, even other primary producers

Crustose epiphytic algae are important primary producers

Kelp Bed Energy Flow

Consumers

Invertebrates feeding on kelp: *urchins, snails, etc.*

Filter feeders using kelp as structural resource *(sponges, bryozoans, tunicates, marine worms, etc.)*

Invertebrates: *crabs, shrimp, etc.*

Pinnipeds: *sea otters*

Fish: *bass, lingcod, perch, sculpins, etc.*

There is a rich variety of consumers that vary through time & space – we cannot do them justice here

Kelp Bed Energy Flow

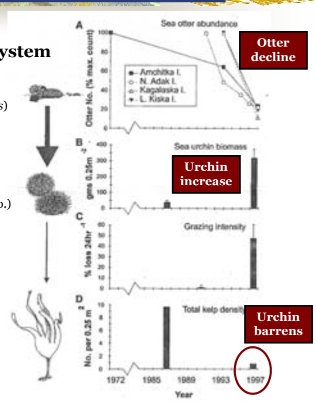
Trophic Relationships

Top-down control of trophic system

Carnivore — Sea otters (*Enhydra lutris*)

Herbivore — Sea urchins (*Strongylocentrotus* sp.)

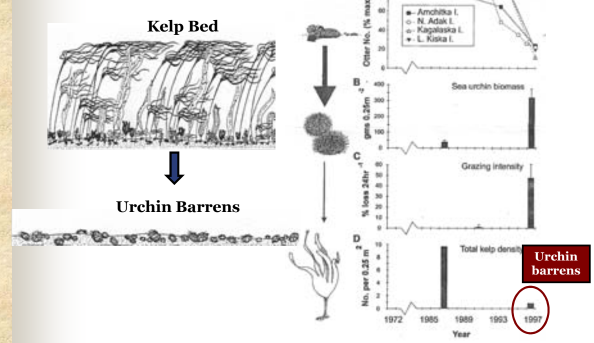
Primary Producer — Bull Kelp (*N. leutkeana*)



Kelp Bed Energy Flow

Trophic Relationships

Top-down control of trophic system



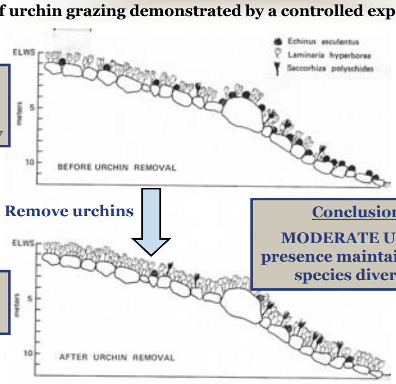
Kelp Bed Energy Flow

Effects of urchin grazing demonstrated by a controlled experiment

High algal diversity at moderate urchin density

Remove urchins

Low algal diversity with no urchins



Conclusion:

MODERATE Urchin presence maintains algal species diversity

Kelp Bed Succession

Succession following disturbance in a kelp bed ecosystem

Urchin barrens

Urchin population declines

Year 2 — Mixed kelp bed

Perennial kelp *Lamanaria* outcompete *Nereocystis* for space

Year 1 — *Nereocystis* bed

Perennial kelp *Lamanaria* excludes competitors

BOTTOM LINE

Disturbance necessary to maintain diversity

Year 3 — *Lamanaria* bed

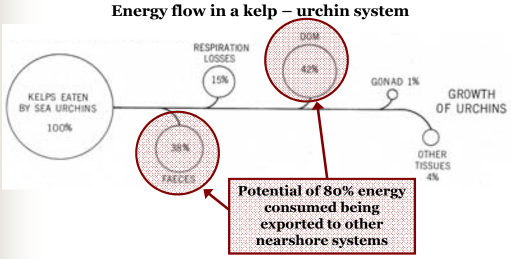
Perennial kelp *Lamanaria* dominates until disturbance and/or recovery of urchin population

Kelp Bed Energy Flow

Are Kelp Beds "Leaky" Ecosystems?

<u>Nutrient / Energy Retention</u>

Energy flow in a kelp – urchin system



Lamanaria kelp ecosystem in Nova Scotia (Carefoot 1977)