Algal Ecology

Ecology:
The study of the distribution and abundance of organisms and their interactions with the environment

Patterns, Processes, and Mechanisms

Some factors affecting Algal Ecology

Abiotic	Biotic
Light	Herbivory
Temperature	Epiphytism
Salinity	Competition
Nutrients	
Water Motion	
Sand Burial	

……..not a comprehensive list

LIGHT

= amount of radiant energy impinging on a unit of surface area

Measurement:

Irradiance measured as…

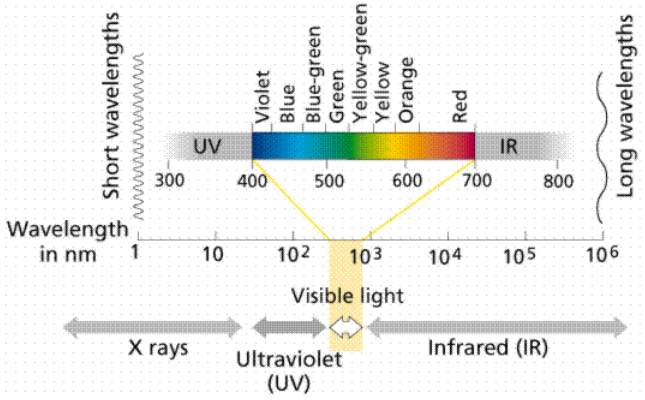
amount of energy falling on a flat surface

many ways to measure:

- microeinsteins per square meter per second
- watts per square meter
- etc….

What light can algae actually use for photosynthesis?

PAR = photosynthetically active radiation = 400-700 nm



Must also deal with UV light (280-320 nm); damage DNA, proteins

- B-carotene absorb UVB ("sunscreen")
- reduced ozone layer = bad news for algae, esp. intertidal, reef

Algal point of view: light is extremely variable in space and time…

-**predictable variation:**

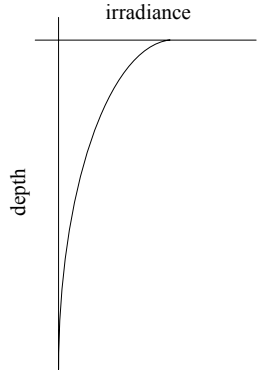
- latitude
- seasonal changes in day length
- solar angle with surface waters

-**less predictable variation:**

- at the surface = waves, white-caps, foam…
- in the water = turbidity from silt, particulate matter, phytoplankton blooms

Attenuation of Light with Increasing Depth

Attenuate: to lessen in severity, intensity, or amount



At ~ 100 m even in clearest water, only 1% of surface radiance makes it through

Different wavelengths transmitted to different depths…

Energy inversely related to wavelength

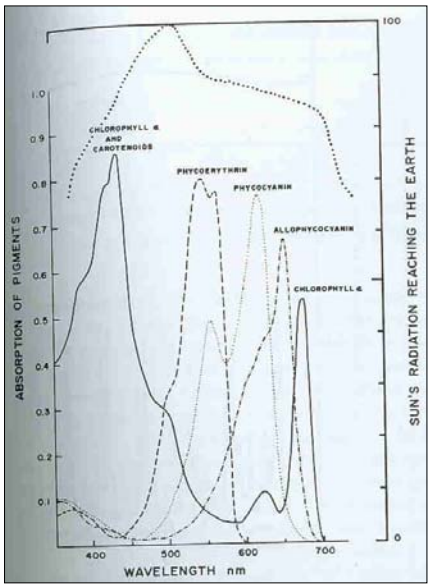
Violet = short wavelength/high energy
(blue or green goes farther)

Red = long wave length/low energy
(red drops out first)

Light attenuation is due to…

- **Scattering** (high energy, short wave lengths scatter due to water molecules and particulates)
- **Absorption** (long wave length, low-energy wavelengths absorbed first, by water itself.)

How do algae cope with attenuation? (1) Pigments



Across species:

✓different Divisions have different pigments, allow different depth distributions (e.g. Reds found deeper, have lots of accessory pigments)

Within a species:

✓Chromatic adaptation (change ratio of pigments)

✓up-regulation of pigments (make more of everything)

How do algae cope with attenuation? (2) Morphology

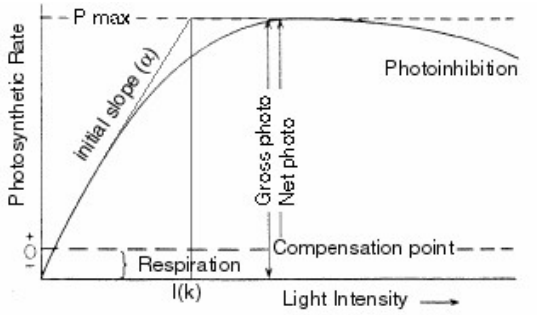
Vs.

Surface area:

- more surface to capture light
- upright forms may shade crustose forms

What happens when algae are exposed to light?

How to interprete a Ps/I curve…



- gross production = total production; net production = gross prod. – respiration
- compensation point = when photosynthesis equals respiration, so net production = 0
- P_{max} = maximum production
- Initial slope a = indicative of photosynthetic efficiency
- I_k= summarizes key characteristics P_{max} and a in one term

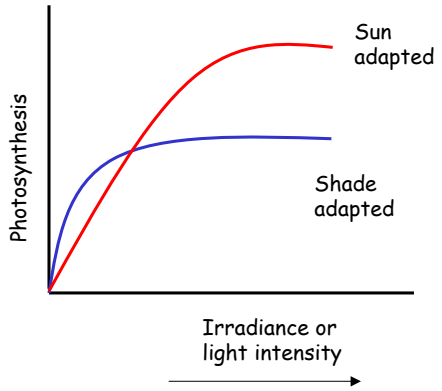
What happens when algae are exposed to light?

How to interprete a Ps/I curve…

Comparison of Ps/I curves across species:

P_{max}?

Slope (alpha)?



Temperature

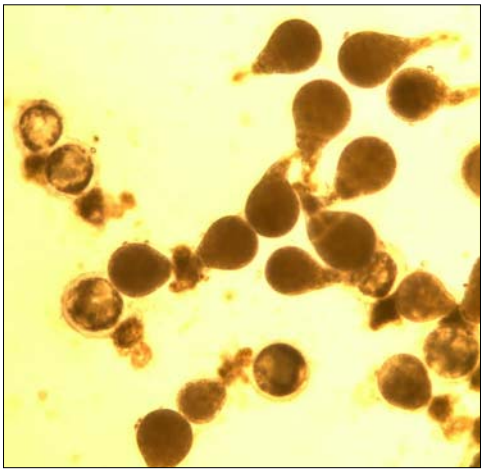
- affects all levels of biological organization – molecules, cells, organisms, communities. In algae – photosynthesis, enzymatic activity

Too high? – denatures proteins, damage enzymes, membranes

Too low? – low enzymatic activity, disrupts lipids, membranes, ice crystal formation

Lethal temp set by tolerance of most susceptible life history stage

All algae are single celled at some stage of life history, even the big kelps; a species' distribution is determined by effect of biotic and abiotic factors across **all stages** of its life history…



Salinity

Definition = grams of salts per kilogram of solution
Measurement = refractometer: measures light refraction

•Unit of Measure – ppt or °/oo, parts per thousand.

(1kg seawater contains 34.7 g of salts ->34.7°/oo)

•Range – oceanic 32-38ppt, estuarine 1-32ppt

•Affect on Seaweeds? – determines osmotic potential of water, affects the water flow in and out of cells, some algae can regulate internal water potential by pumping ions in or out of cells

Nutrients

Macro-nutrients necessary for algal growth =

C, H, O, K, N, S, Ca, F, Mg

- N is often limiting in coastal waters, needed for amino acids, protein synthesis, nucleic acids...

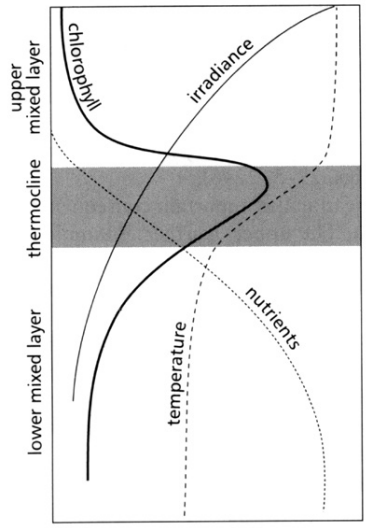
Everything you ever wanted to know about seaweeds and Nitrogen:

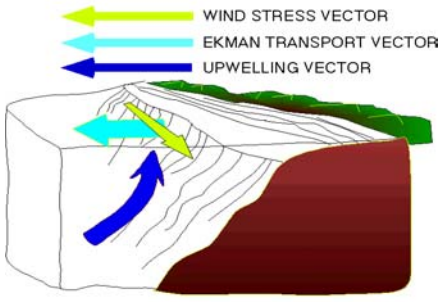
Ammonium (NH_4^+) and nitrate (NO_3^-) are the most common and used nitrogen sources; NH_4^+ is preferred because it can be utilized directly (energy saving)

NO_3^- assimilation by nitrate reductase requires iron (phytoplankton cannot exhaust high NO_3^- pools in Fe-limited Antarctic oceans; famous Fe-addition experiment)

Cyanobacteria can fix atmospheric nitrogen = convert N_2 to NH_4^+; 25-60% of this fixed nitrogen is released into the water

Variation in nutrient availability in space and time:
Issues of depth stratification, role of upwelling





COASTAL UPWELLING

Water Flow

-Algae depend on water motion to deliver gasses, nutrients, and remove O_2 from their surfaces

- in still water or laminar flow: thick boundary layer of water around the alga, slow diffusion of nutrients, gasses across.

- e.g, *Macrocystis*, nitrate uptake increases by 500%, and Ps by 300% if flow goes from zero to 4 cm/second

Interaction of Water Flow and Morphology

In relatively still water (e.g protected coves), surface area becomes really important (more surface area = more diffusion)

Algae in these environments tend to have high SA:V = maximize uptake of nutrients

Costs of high SA:V? In high flow environment = leafy, foliose shapes are a drag ☺

-variation in species composition on wave exposed vs. wave protected shores = particular morphotypes consistently found in particular flow environments

-variation *within* species = phenotypic plasticity in traits that affect water flow around the algal thallus

e.g. *Nereocystis* "ruffles" and wide blades in protected areas

Complicated effects of water flow

Positive effects:

Reduce shading by re-arranging thalli

Mixing of nutrients

Reduce boundary layer

Dispersal of spores, gametes, zygotes

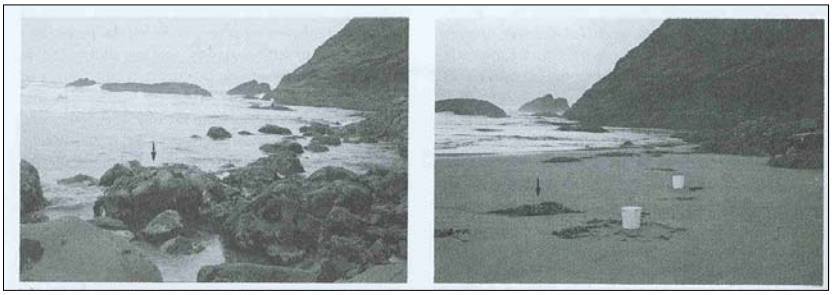
Negative effects:

Damage, destruction

Loss of settling zygotes/germlings

Energetic expense of structure

Sand Burial



How do algae deal with this?

Two basic strategies: **resist** or **recover**…

Opportunistic spp:
Chaetomorpha, Ectocarpus, Ulva



Stress "tolerators":
Gymnogongrus, Laminaria sinclairii, Neorhodomela



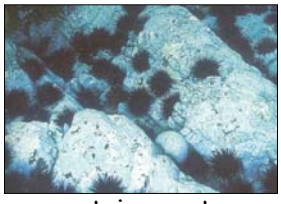
HERBIVORY

(i.e. "predation" on algae)

HERBIVORY

- damage caused by herbivores varies a lot

Macrocystis and sea urchins



…versus certain crustose corallines and limpets

How do algae deal with herbivory?

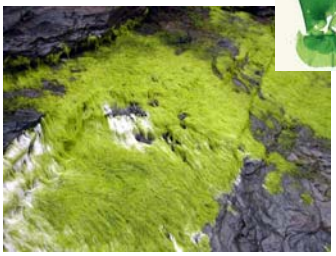
recover, **avoid**, or **resist**…

"Recover"

Limpet example = minimal cost of grazing of algal fitness

rapid growth

Opportunistic recruitment



How do algae deal with herbivory?

recover, **avoid**, or **resist**…

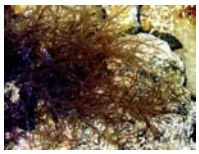
"Avoid"

spatial escape

- ✓ Low herbivory habitats
- ✓ Associational defenses

temporal escape

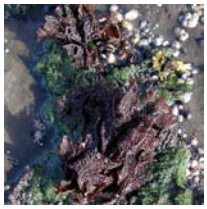
- ✓life history
- ✓size



Hypnea

Sargassum

"Petrocelis" stage



Mastocarpus

How do algae deal with herbivory?

recover, avoid, or **resist**…

"Resist"

structural defenses

tough, spiny

calcified

chemical warfare…

Secondary metabolites (e.g. polyphenolics in browns, terpenes in tropical spp.)

-geographic variation in levels of algal chemical defense

-within-INDIVIDUAL variation in defense

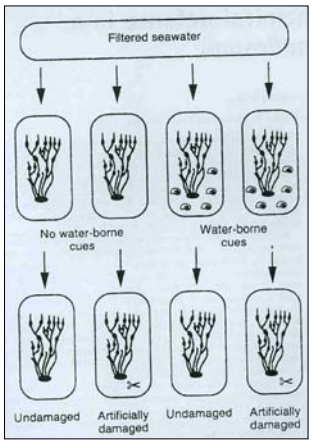
So… why aren't all algae defended?

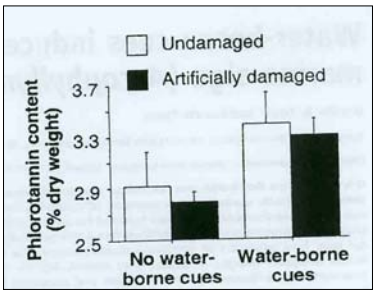
Life history variation is all about **trade-offs**
(limited energy, how do you spend it?)

$$$

Inducible defenses versus Constitutive defenses

-Inducible defense: Can turn on and off
- Constitutive: Always on





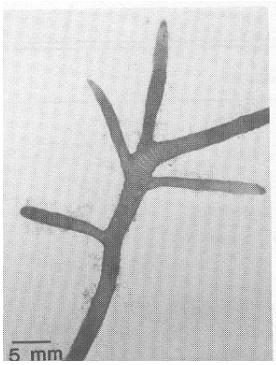
Cues?
Predictability?
Cost of Herbivory?

When do you want one versus the other?

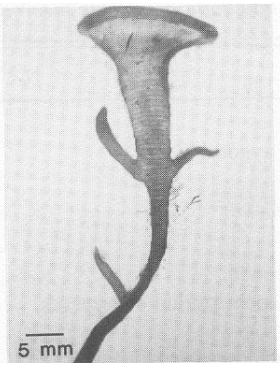
Interaction of grazing and morphology

Padina example…

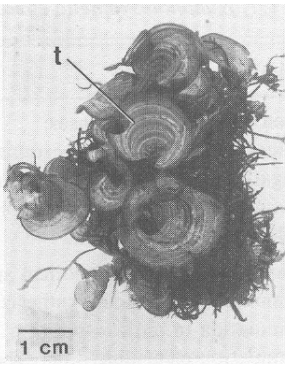
Increased Grazing



Prostrate, Branching thallus



Typical Fan-Shaped thallus



Foliose Fan-Shaped thallus

EPIPHYTISM

Benefits to epiphyte?
- access to resources (nutrients, sunlight, etc…)
- place to live

Costs to basiphyte?
- extra drag
- depleted resources

How do algae deal with epiphytes?

- outrun them (rapid growth, blade turnover)

Membranipora on *Macrocystis*

- ditch them by sloughing off outer layer of cells
  (e.g. *Ascophyllum*, *Silvetia*, other fucoids)

Laminaria blade but not stipe

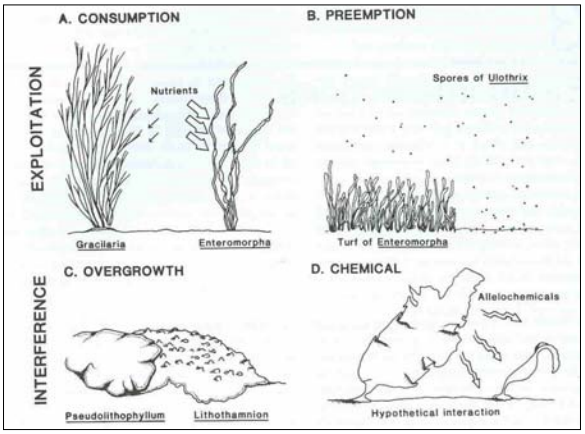
-Resist with chemical defenses

Allelochemicals. E.g. phenolics and polyphenolic compounds originate in plastids,produced by browns, active as antifouling agents and herbivore deterrents

pH. rapid growing spp often have increased pH at thallus surface. e.g. *Ulva, Enteromorpha*

Chondrus crispus inhibits diatoms

COMPETITION



Exploitative: scramble for a limiting resource (no direct antagonism)
Interference: interactions between organisms (limiting resource not necessary)