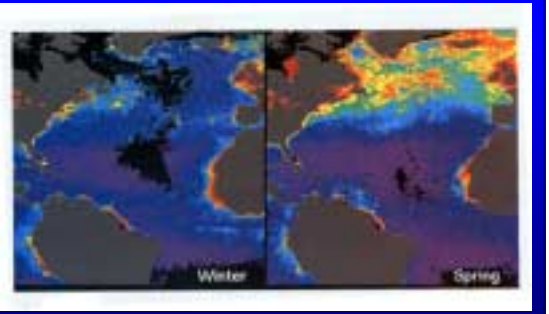


Lecture 38 -- The Oceans

PRIMARY PRODUCTIVITY (PP) IN THE OCEANS

- **Photosynthesis and Chemosynthesis**
- **Gross and Net Primary Production**
- **Cycling of organic matter**
- **Controlling factors**
- **Seasonal variations at different latitudes**
- **Global distribution**

PRIMARY PRODUCTIVITY (PP) IN THE OCEANS

PP = Synthesis of organic matter by autotrophs

1. Photosynthesis by phytoplankton is most important

$$CO_2 + H_2O \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} \text{“}CH_2O\text{”} + O_2$$

PRIMARY PRODUCTIVITY (PP) IN THE OCEANS

2. Chemosynthesis, e.g., by sulfur bacteria at hydrothermal vents

$$H_2S + O_2 \xrightarrow{\text{Bacteria}} SO_4^{=} + \text{Chemical Energy}$$

$$CO_2 + H_2O \xrightarrow{\text{Chemical Energy}} \text{“}CH_2O\text{”} + O_2$$

PRIMARY PRODUCTIVITY (PP) IN THE OCEANS

3. Biosynthesis: Builds other essential organic molecules

Energy must be expended to do this.

$$CH_2O + \text{nutrients (N, P, S)} \dashrightarrow \text{proteins, fats, oils DNA, RNA, etc.}$$

What is the average chemical composition of phytoplankton material?

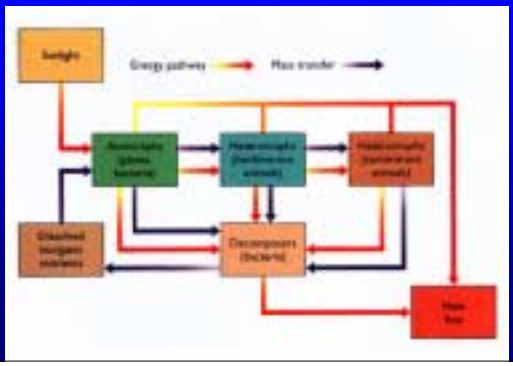
How much N and P are needed per gram of biomass produced?

"Redfield ratio"(average for all PP)

$$[CH_2O]_{106}\,[NH_3]_{16}\,[H_3PO_4]$$

$$C_{106}\,H_{263}\,O_{110}\,N_{16}\,P_1$$

Energy and Biomass are transferred through a food web.



FATE OF ORGANIC MATTER -- HOW PP IS UTILIZED & CYCLED

Gross Primary Production . . (GPP)

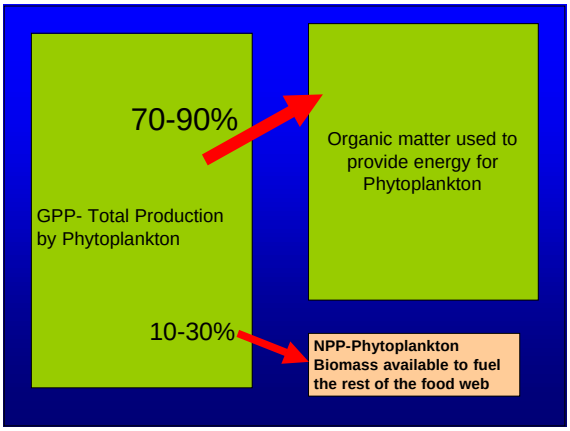
= Total amount of organic matter produced by primary producers (phytoplankton)

Net Primary Production . . (NPP)

= GPP minus energy utilized (organic matter respired) by phytoplankton for life processes

•GPP and NPP are rates, gm C / m² - yr

•Biomass, or "standing crop" is "density," gm C / m²



ORGANIC MATTER "CYCLING" IN THE OCEANS

Global balance: Total production = Total respiration

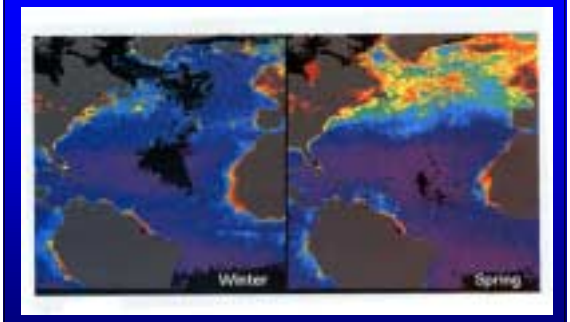
Oceans:

- Prod. > Consump. + Decomp. in the photic zone
- Prod. < Consump. + Decomp. below the photic zone
- Slight excess production (~0.1% of GPP) in oceans

---> deposition and preservation of OM in sediments

Fate of organic matter in sediments

- Returned to ocean-atmosphere system
  - (10^8 year process, roughly)
- Tectonic uplift at convergent boundaries
- Exposure and oxidation of organic matter



FACTORS CONTROLLING PRIMARY PRODUCTIVITY

1. Sunlight- in two different ways

•Photosynthesis

•Seasonal heating -- stratification of surface waters

–Warm surface waters- less dense

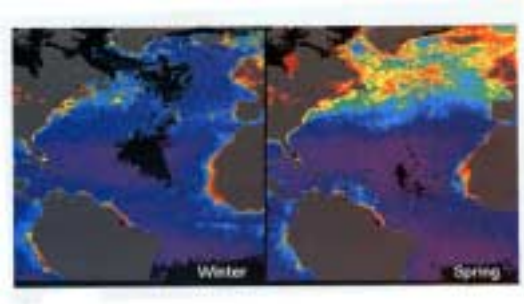
–Sit on top and do not sink

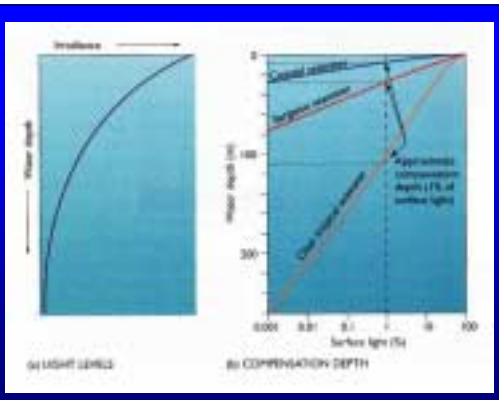
–versus Winter mixing-

•surface cooler, denser

•sinks to perhaps 100m

•convection



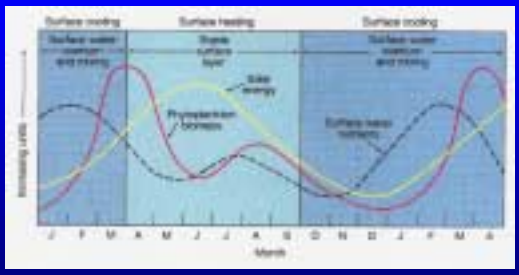


2. Nutrients

Vertical mixing ...
- **seasonal density stratification**

Upwelling of deep waters

Proximity to land-derived nutrients

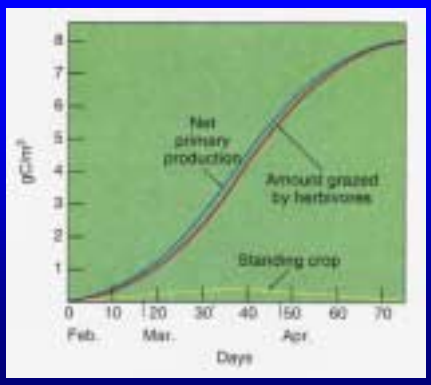


FACTORS CONTROLLING PRIMARY PRODUCTIVITY

3. Grazing by herbivores: Affects...

Phytoplankton biomass ("standing crop")

Rate of photosynthesis (i.e., productivity)



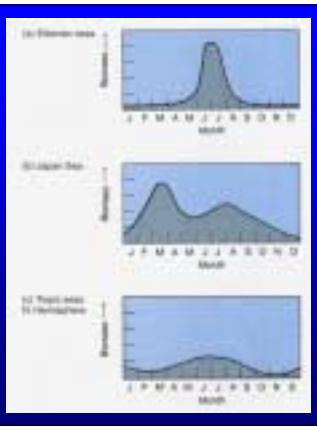
SEASONAL PRODUCTIVITY AND BIOMASS AT DIFFERENT LATITUDES

1. Polar oceans -- intense mid-summer "bloom"

- **Nutrients are abundant -- good vertical mixing**
- **Bloom initiated by summer sunlight (low-intensity, but constant)**

Warming --> density stratification
--> phytoplankton can remain in photic zone

Productivity controlled by sunlight



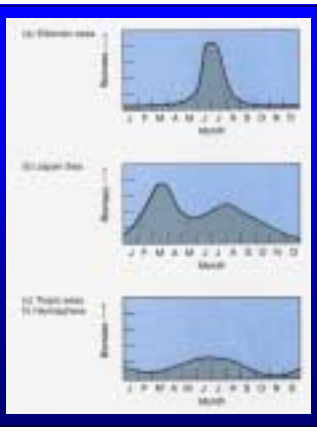
Tropical oceans

Relatively constant but low productivity throughout the year

High-intensity sunlight all year

- **Density-stratified surface waters**
- **Little vertical mixing, thus low nutrient levels**

Productivity controlled by nutrient availability



Mid-latitude oceans

Spring and autumn "blooms"

Winter:

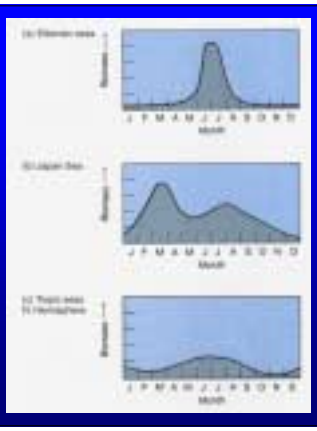
- Surface-water mixing (cooling, storms, waves)
- Nutrients are available, but sunlight is limiting

Spring:

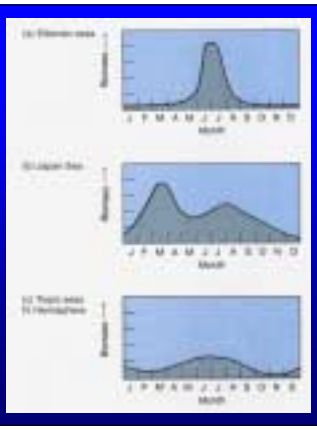
- Increased sunlight and density stratification
- Phytoplankton remain at surface --> intense bloom

Summer:

- Zooplankton grazing reduces phytoplankton biomass
- Nutrients are released --> second, less intense bloom



Productivity controlled by both sunlight and nutrient availability



GLOBAL DISTRIBUTION OF PRIMARY PRODUCTIVITY (PP)

Open oceans

Limited nutrient supply --> low PP rates [gm C / m^2 - yr]

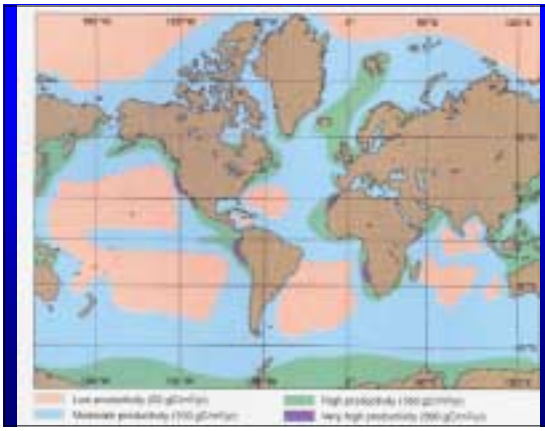
Polar and equatorial upwelling zones in open ocean

Upwelling: Ekman transport, thermohaline circulation.

Good nutrient supply --> moderate to high PP rates

Continental shelves

High nutrient supply (runoff, vertical mixing) --> high PP rates



GLOBAL DISTRIBUTION OF PRIMARY PRODUCTIVITY (PP)

Coastal zones of intense upwelling at low latitudes

High nutrient supply (Ekman transport, winds, surface currents)

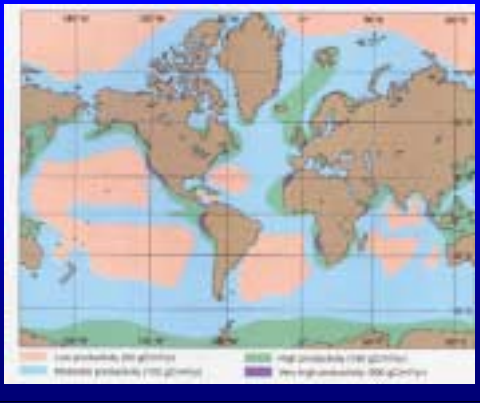
+ low-latitude sunlight --> very high PP rates

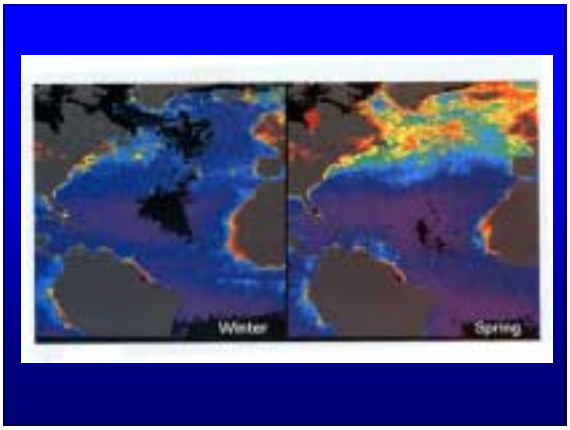
Estuaries and shallow coastal waters

Nutrients abundant: vertical mixing, land runoff

Photic zone extends to bottom: benthic plants and algae

--> very high PP rates




Winter
Spring