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

1. Photosynthesis by phytoplankton is most important

\[ \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{CH}_2\text{O} + \text{O}_2 \]

Sunlight
Chlorophyll

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

\[ \text{H}_2\text{S} + \text{O}_2 \rightarrow \text{SO}_4^{2-} + \text{Chemical Energy} \]

Chemical Energy

3. Biosynthesis: Builds other essential organic molecules

Energy must be expended to do this.

\[ \text{CH}_2\text{O} + \text{nutrients (N, P, S)} \rightarrow \text{proteins, fats, oils DNA, RNA, etc.} \]

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)

\[ \frac{\text{[CH}_2\text{O]}_{106}}{\text{[NH}_3]}_{16} = \frac{[\text{H}_3\text{PO}_4]}_{16} \]

C\text{106} H\text{263} O\text{110} N\text{16} P_1
Energy and Biomass are transferred through a food web.

**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

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

- **GPP - Total Production by Phytoplankton**
  - 70-90%

- **NPP - Phytoplankton Biomass available to fuel the rest of the food web**
  - 10-30%

**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
  - (10⁸ 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)
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 $\rightarrow$ low PP rates [gm C / m² - yr]

Polar and equatorial upwelling zones in open ocean
Upwelling: Ekman transport, thermohaline circulation.
Good nutrient supply $\rightarrow$ moderate to high PP rates

Continental shelves
High nutrient supply (runoff, vertical mixing) $\rightarrow$ high PP rates

Coastal zones of intense upwelling at low latitudes
High nutrient supply (Ekman transport, winds, surface currents)
$+$ low-latitude sunlight $\rightarrow$ very high PP rates

Estuaries and shallow coastal waters
Nutrients abundant: vertical mixing, land runoff
Photic zone extends to bottom: benthic plants and algae
$\rightarrow$ very high PP rates