

Primary Production

Primary Producers

- Largely photosynthetic
 - Conversion of light energy into chemical energy
 - Need light, CO₂ and photosynthetic pigment
 - Produces O₂ and glucose
 - Pigments include chlorophylls, xanthophylls (particularly fucoxanthin), carotenes and phycobilins
- $$\text{CO}_2 + \text{H}_2\text{O} + \text{light} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + \text{O}_2$$

More Primary Producers

- Several important roles
 - Capturing energy and making it available for living organisms
 - Manufacturing O₂ for respiration
 - Recycling of carbon (CO₂) following respiration

Trophic Level Energy Transfer (graphic)

- 5-20% (average of 10%) of energy passed to next level
- Creates pyramid

Photosynthesis & Respiration (graphic)

Carbon Recycling (graphic)

Taxa of Primary Producers

- Includes all three Domains
 - Bacteria – Some bacteria photosynthetic (other autotrophic bacteria are chemosynthetic), Cyanobacteria
 - Archaea – Primarily chemosynthetic
 - Eukaryota –
 - Kingdom Protista – singled celled organisms
 - Plant-like - Bacillariophyta, Dinoflagellata, Chrysophyta
 - Animal-like – Foraminifera, Polycystina, Ciliophora
 - Kingdom Plantae: Phyla Chlorophyta, Phaeophyta, Rhodophyta, Magnoliophyta

Taxa of Primary Producers (graphic)

Measuring Primary Productivity (graphic)

- Amount of organic material produced per m² of surface area

Measuring Primary Production

- Gross PP - total amount of organic material produced
 - gC/m²/unit time (day or yr) - based on sea surface
- Net PP - Gross minus the amount needed for cellular respiration of the primary producers
- Light - Dark bottle technique
 - Use of O₂ measurements - problem due to zooplankton utilizing oxygen too
 - Use of C¹⁴ (bicarbonate labeled with C¹⁴)

Measuring Primary Productivity (graphic)

Measuring Primary Productivity (graphic)

Global Primary Production (graphic)**Global Primary Productivity (graphic)****Other Measures**

- Standing stock (crop) - a measure of the existing amount of living photosynthetic material
 - Typically used for terrestrial measurements
 - Seaweeds more reasonable to measure than phytoplankton
 - However, phytoplankton play greater role in primary production
 - Thus not a good measure
 - More recent technique of using amount of chlorophyll a as indicator of standing stock

More Other Measures

- Use of satellites - coastal zone color scanner (CZCS) monitoring chlorophyll concentration, both distribution and abundance

Other Measures (graphic)**Variation in Primary Production**

- Dependent on physical, chemical, and biological characteristics of environment
- Theoretically populations can grow unchecked (exponential growth)
- However, biological systems always have some “limiting factor”
 - For phytoplankton - light, nutrients and/or grazing

Effects of Limiting Factors (graphic)**Light**

- Light - depth of photic zone dependent on sun's position, atmospheric and water characteristics (absorption and transparency)
 - May be a few meters (coastal) to 200 m
 - Critical depth - rate of photosynthesis balanced by cellular respiration (no net photosyn.) - less than the photic zone

Effect of Light Intensity on Rate of Photosynthesis (graphic)**Photosynthetic Response of Two Phytoplankton Species (graphic)****Photosynthesis**

- Light reaction requires the pigment to absorb light energy and convert it to a chemical form (ATP or NADPH₂)
- Dark reaction utilizes chemical form of energy to manufacture carbohydrate compounds
- Chlorophyll a absorbs light in reds (700nm) and blues (400nm)
- Problem for marine photosyn. since red is absorbed by water quickly

More Photosynthesis

- Need for accessory pigments which absorb energy and pass it chlorophyll
 - Fucoxanthin (xanthophyll) - in Phaeophyta, Chrysophyta and Dinoflagellata (550nm)

- Phycoerythrin (pycobillins) in Rhodophyta and Cyanobacteria - blues (400nm)
- Marine green algae and grasses (dependent on chlorophyll) have large amounts of pigment and supplement with chlorophyll *b*

Nutrients

- Need components for photosynthesis and for structural components
 - Include C, H, O, N, P and trace elements
- C, H, O readily available as carbonate (CO_3^{-2}), bicarbonate (HCO_3^-) and water (H_2O)
- N available as nitrate (NO_3^{-2}), nitrite (NO_2^-), ammonium (NH_4^+) and N_2
 - N_2 requires nitrogen fixation
- P available as phosphate (PO_4^{-3})

More Nutrients

- General loss of nutrients from photic zone through sinking
 - Requires vertical mixing - wind, wave and tidal mixing vs. upwelling
 - Upwelling caused by offshore winds, coastal currents, and equatorial Coriolis effect of water moving N & S from equator
 - Langmuir cells (parallel with wind direction) may hold nutrients near surface

Even More Nutrients

- El Niño - normal weather based on weather pattern that brings warm surface current from N along Peruvian coast in their summer - causes rainy, humid, warm weather and blocks typical upwelling in the area
 - If El Niño goes further S or stays longer, there's a dramatic effect on marine productivity in the region (also known as the El Niño Southern Oscillation or ENSO)
 - La Niña is the more normal form of southern oscillation

Global Upwelling Areas (graphic)

Vertical Distribution of Nitrate (graphic)

Grazing

- Grazers are herbivores
- Herbivore population dependent on presence and numbers of phytoplankton/primary productivity
- Populations of both vary in a dependent fashion (can be cyclical activity of overgrazing and starvation)

Global Zooplankton Populations (graphic)

Effects of Grazing (graphic)

More Grazing

- Movements of grazers follow phytoplankton (sometimes a preferred species)
 - Copepods and their “red” and “blue dance”
 - Red - move vertically (when chlorophyll in phytoplankton above absorbs blue light)
 - Blue - move horizontally (when little phytoplankton above)

Seasonal Variations

- Dependent on light, nutrients and grazing
- No activity when there is no/little light - may be in cyst form during absence
- Nutrient supply dependent on mixing - when thermocline or pycnocline is absent (and other special sources)
- Finally affected by population of grazers
- Temperate example

Limiting Factors of Photosynthesis (graphic)

Seasonal Variations in Thermocline (graphic)

Seasonal Population Variations (graphic)

Effects of Seasonal Light Conditions (graphic)

More Seasonal Variations (graphic)