Primary Production
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Zackary Johnson
Department of Oceanography
http://www.soest.hawaii.edu/oceanography/zij/education.html

Major Concepts
- Primary production is the first link in converting “environmental” energy to biological energy
- Oceanic primary production is dominated by single celled “plants” called phytoplankton
- Phytoplankton are exceptionally diverse
- Primary production is typically limited by light or nutrients

What is primary production?
Primary = first, initial
Production = formation / creation of something
Primary production = the first conversion of energy from the environment into “biological” energy
What types of organisms are primary producers in the ocean?

What is primary production?
Photosynthesizers (plants): use sunlight energy to convert carbon dioxide into simple sugars
\[ H_2O + CO_2 \rightarrow CH_2O + O_2 \]
Chemosynthesis (some types of bacteria): use chemical energy to create simple sugars
ex. \[ H_2S + 2O_2 + CO_2 \rightarrow CH_2O + SO_4 \]
ex. hydrothermal vent bacteria in worms

Facts about marine primary production
What fraction of primary production is done by photosynthesizers?
(A)1%
(B)50%
(C)99%

Facts about marine primary production
- Photosynthesizers contribute >99% of the total primary production in the ocean

Chemosynthesis is important in certain areas (especially in areas where there is not light – ex. deep sea, deep sea vents, etc.), but is a small fraction of total primary production of the ocean.
Facts about marine primary production

About what fraction of the earth's primary production occurs in the ocean?

(A) 1%
(B) 50%
(C) 99%

Facts about marine primary production

Marine photosynthesis is about equal to terrestrial (land) photosynthesis (~50Gt/yr), even though the ocean is "blue"

The ocean is much larger than land (70% vs 30%)
Marine plants double every 2-3 days, terrestrial plants average years
Thus, even though there is less "plant" material in the ocean, as a whole the ocean is about as productive as land. Sometimes called the "invisible forest."

Facts about marine primary production

What types of organisms are responsible for most marine primary production (photosynthesis)?

(A) Phytoplankton
(B) Seaweed
(C) Benthic (bottom attached) Algae

Phytoplankton Diversity

Phytoplankton are exceptionally diverse major groups of importance to marine ecosystems:

- diatoms
- dinoflagellates
- cyanobacteria
- prymnesiophytes
- prasinophytes
- silicoflagellates

- Only one algal class, the Chlorophyceae, gave rise to land plants
- Include both prokaryotes and eukaryotes
- Many taxa have unique properties
- This diversity has implications for the functioning of the ecosystem and biogeochemical cycles

Phytoplankton Diversity

Diatoms
- Dominant primary producers in high latitude, coastal, and upwelling environments
  - (high nutrient)
  - siliceous ooze - high latitude sediments
  - Centric – radial symmetry (pelagic, benthic)
  - Corethron
  - Coscinodiscus
  - Thalassiosira

Pennate – bilateral symmetry (pelagic,benthic)
- Nitzschia
- Asterionella
- Chaetoceros
- Blackenship, 2002
**Phytoplankton Diversity**

Seminidaleates
- Important producers at high & low latitudes
- Toxic blooms - "red tides", paralytic shell-fish poisoning
- Zooxanthellae - symbiotic in corals & some protozoans
- Bioluminescence

**Cyanobacteria**
- Ubiquitous in temperate & warm-water open ocean
- Particularly important in oligotrophic (nutrient poor) oceans

**CHARACTERISTICS:**
- Prokaryotic - no organelles
- Synechococcus - small, coccoid picoplankters (~1 μm)
- Prochlorococcus - recently discovered, most abundant throughout the water column (10^10 cells/liter)
- Very small (0.6-1.0 μm in diameter)
- Responsible for ~50% chlorophyll / primary production in the oligotrophic waters

**Regulation of Primary Production**

**[Photosynthesis]**

What is required for photosynthesis to occur?

- Light (energy) + Nutrients (substrate)

What can limit primary production in the ocean?

- Light or nutrients!

(phytoplankton get consumed too, but we’ll get to that later...)

**Types of Light Limitation**

- Light Decreases with Depth
- Little Mixing
  - Light OK
  - Euphotic Zone
  - Primary production
- Lots of Mixing
  - Light Limited
  - Aphotic Zone
  - Primary production

Light decreases exponentially with depth, so most of ocean (at depth) is light-limited.

If phytoplankton mix out of light layer (euphotic zone) they become light limited.
Types of Light Limitation → Time (Daily / Seasonal), Latitude

Daily solar cycle (earth’s spinning) and seasonal cycle (earth’s rotation around sun / axis tilt) cause changes in light availability

ex. Half the year the North (and South Pole) receive no sun!

Types of Nutrient Limitation → Nutrients Increase at Depth

Nutrients (ex. PO₄, NO₃) accumulate at depth, so most of ocean (at surface) is nutrient-limited!

Types of Nutrient Limitation → Spatial Patterns (ex. PO₄)

Nutrients (ex. PO₄, NO₃) are abundant in certain regions (high latitudes, equator, coastal areas) because of physical forces (upwelling, mixing)

Pulse of a Planet

Major Concepts redux

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