

Lectures 5 and 6 - Primary Productivity

READINGS

- ❑ Smith and Smith – p42-50; Ch 6, pp. 91-92; Chapter 24, esp. pp 478- 490; p. 632-640; Ch 25, pp512-514; Ch 31, esp. pp 666-667
 - ❑ Morton, O. 2007. Introduction. “Eating the Sun: How Plants Power the Planet”
 - ❑ Chisholm, 1992 “What Limits Phytoplankton Growth?” Oceanus Magazine. 35:36-46
 - ❑ Falkowski: 2002. The Ocean’s Invisible Forest. Scientific American August 2002. p.38-45
- Further Reading (optional, but may be helpful in study questions). You can look these papers up at the library.
- ❑ Nemani, RR et al. 2003. Climate-driven increases in global terrestrial net primary productivity from 1982 to 1999. Science. 300:1560-1563.
 - ❑ Field, C.B., M.J. Behrenfeld, J. T. Randerson, and P. Falkowski. 1998. Primary Production of the Biosphere: Integrating Terrestrial and Oceanic Components. Science. 281:237-240
 - ❑ Rojstaczer, S. Sterling, S.M. and N.J. Moore. 2001 Human Appropriation of Photosynthesis Products. Science 294: 2549-2553

Outline:

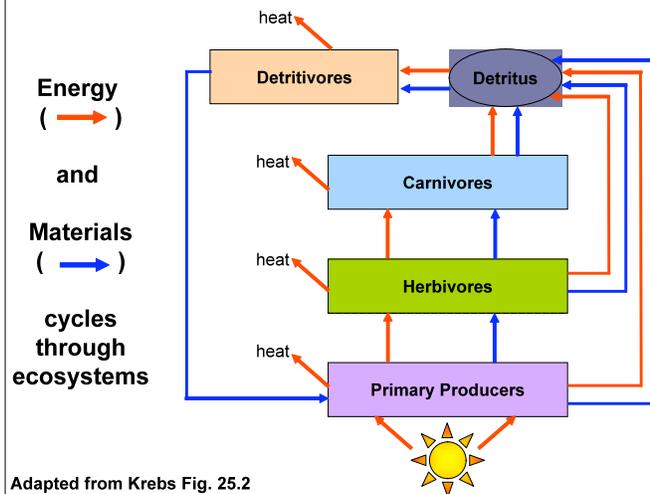
- Earth’s Metabolism emerges from cellular metabolism
- Definitions
- Residence times and turnover rate
- Distribution of Productivity on Earth

Terrestrial Productivity

- Distribution
- Measuring Terrestrial Productivity
- What limits it?

Aquatic Productivity

- Who does it?
- How do we measure it?
- Dynamics of Lakes and oceans



I. Definitions

biomass: total mass (or energy) of all living material (units: g C/m^2 or kJ/m^2)

gross primary productivity (GPP) = rate of conversion of CO_2 to organic carbon per unit surface area

Units: $\text{g C m}^{-2} \text{ year}^{-1}$, or $\text{kJ m}^{-2} \text{ year}^{-1}$

gross primary production has units of g C year^{-1} for a lake, forest, field, ecosystem, biome, etc.

respiration by autotrophs (R_A) = how much energy or carbon is used for plant metabolism

net primary production (NPP) = $\text{GPP} - R_A$ = how much energy or carbon is stored as biomass

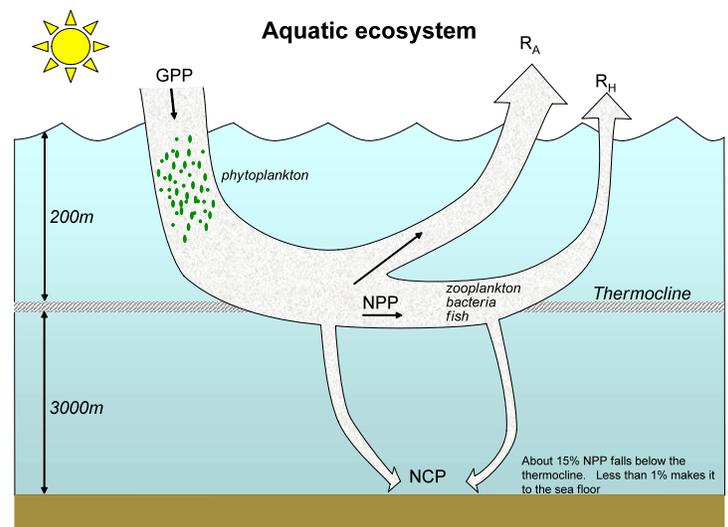
respiration by heterotrophs (R_H) = how much energy or carbon is used for heterotroph metabolism

net community production (NCP) = how much of GPP produced is not lost to respiration

$$= \text{GPP} - R_A - R_H = \text{NPP} - R_H$$

photosynthetic efficiency (PE) = $100 \times (\text{incident radiation converted to NPP}) / (\text{total incident radiation})$

n.b. We're using energy and (reduced) carbon interchangeably. **Conversion: 39 kJ per g C**



II. Residence times and Turnover times

f = flux (mass/area/time).

M = mass (biomass/area)

Mean residence time (MRT) = M/f

$$= (\text{g/m}^2) / (\text{g/m}^2/\text{year}) = \text{years}$$

Fractional turnover (k) = $1 / \text{MRT} \times 100$

= % turning over each year (or some appropriate time interval)

Turnover Time = $1/k$

P:B ratio is the amount of biomass that gets replaced per unit time.

(Units of yr^{-1})

Some helpful unit conversions

Tg (teragram) = 10^{12} g

Pg (petagram) = 10^{15} g = 10^9 metric tons (mt)

Metric ton = 10^6 g

Gt (gigaton) = 10^{15} g = 10^9 ton

Study Questions:

Productivity

1. What is the difference between net and gross primary productivity? What is the difference between net community productivity and net primary productivity? How might you measure these differences in an aquatic or terrestrial ecosystem?
2. What factors can limit primary productivity in terrestrial ecosystems? How are these factors reflected in the global distribution of primary production?
3. What is the turnover time of a forest? How is it measured?
4. What is functionally similar about phytoplankton and trees? What is different?
5. What are the similarities and differences between the flow of energy and carbon in the open ocean and in a mature rain forest?
6. Why are phytoplankton so much more productive (on the basis of biomass) than land-based plants?
7. How might increases in atmospheric CO₂ affect global productivity?
8. The following data are available for two forests. Fill in the missing values. Which forest is older?

	Gemstone	Cerna
Total biomass (kcal/m ²)	200,000	1,500,000
Total photosynthesis (kcal/m ² /yr)	12,200	45,100
Plant respiration (kcal/m ² /yr)	(i) _____	(ii) _____
New plant tissue created (kcal/m ² /yr)	7,500	13,200
Heterotrophic respiration (kcal/m ² /yr)	4,600	13,180
Net community production (kcal/m ² /yr)	(iii) _____	(iv) _____
C residence time	(v) _____	(vi) _____
Fractional turnover	(vii) _____	(viii) _____

9. What are the challenges associated with using uptake of ¹⁴CO₂ to measure primary productivity?
10. Approximately what is the contribution of marine ecosystems to global NPP?
11. Explain why light tends to be more limiting in freshwater or coastal systems than in the open ocean.

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