7.014 Handout

PRODUCTIVITY: THE "METABOLISM" OF ECOSYSTEMS

Ecologists use the term **"productivity"** to refer to the process through which an assemblage of organisms (e.g. a trophic level or ecosystem assimilates carbon. **Primary producers** (autotrophs) do this through photosynthesis; **Secondary producers** (heterotrophs) do it through the assimilation of the organic carbon in their food. Remember that all organic carbon in the food web is ultimately derived from primary production.

DEFINITIONS

Primary Produc*tivity*: Rate of conversion of CO_2 to organic carbon (photosynthesis) per unit surface area of the earth, expressed either in terns of weight of carbon, or the equivalent calories

e.g., g C m^{-2} $year^{-1}$
Kcal m^{-2} $year^{-1}$

Primary Produc*tion*: Same as primary productivity, but usually expressed for a whole ecosystem

e.g., tons $year^{-1}$ for a lake, cornfield, forest, etc.

NET vs. GROSS:

For plants: Some of the organic carbon generated in plants through photosynthesis (using solar energy) is oxidized back to CO_2 (releasing energy) through the respiration of the plants – R_A.

Gross Primary Production: (GPP) = Total amount of CO_2 reduced to organic carbon by the plants per unit time

Autotrophic Respiration: (R_A) = Total amount of organic carbon that is respired (oxidized to CO_2) by plants per unit time

Net Primary Production (NPP) = GPP – R_A
The amount of organic carbon produced by plants that is not consumed by their own respiration. It is the increase in the plant biomass in the absence of herbivores.

For an entire ecosystem: Some of the NPP of the plants is consumed (and respired) by herbivores and decomposers and oxidized back to CO_2 (R_H). The amount of carbon that is left is called:

Net Community Production (NCP) = Organic carbon produced through photosynthesis that is not lost through R_A or R_H.

Thus:

$$\mathbf{NPP = GPP - R_A}$$
$$\mathbf{NCP = GPP - R_A - R_H = NPP - R_H}$$

Properties that can be calculated for ecosystems in steady state:
(Note that "biomass" refers to the amount of living matter)

$$\underline{\text{Mean Residence Time}}\ (\text{MRT}) = \frac{\text{mass}}{\text{flux}} = \frac{(\text{Biomass/area})}{(\text{Gross Primary Productivity})} = \frac{\text{g m}^{-2}}{\text{g m}^{-2}\ \text{yr}^{-1}} = \text{years}$$

$$\underline{\text{Fractional turnover}}\ (\text{k}) = \frac{1}{\text{MRT}} = \text{years}^{-1}\ \ (\text{x100} = \%\ \text{per year})$$

ENERGY FLOW, FOOD WEBS, AND EFFICIENCIES

P_n = Productivity at trophic level n (net)

P_{n-1} = Productivity at trophic level n-1 (net)

R_n = Respiration at trophic level n

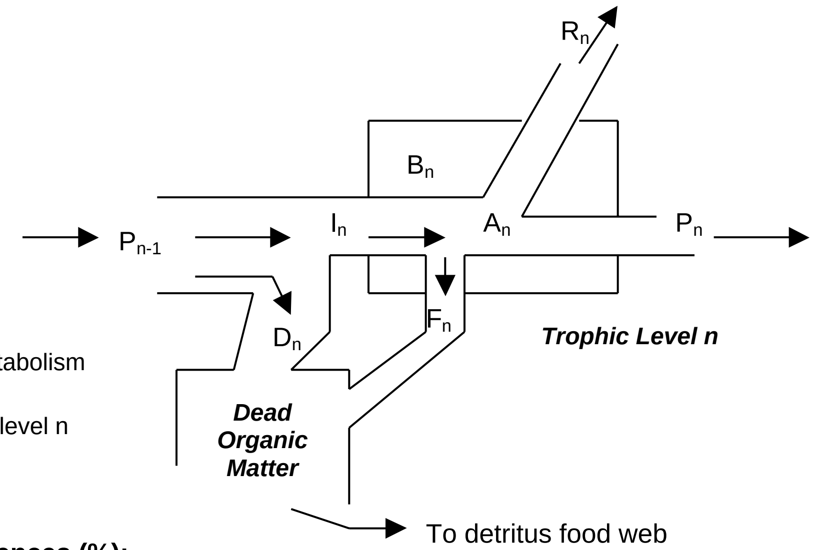
F_n = Fecal matter produced at trophic level n

I_n = Amount Ingestedat trophic level n

A_n = Amount assimilated and available for metabolism

D_n = Fraction of P_{n-1} not consumed by trophic level n

B_n = Biomass at trophic level n



We can now define the following efficiences (%):

Explotation Efficiency (EE), sometimes called consumption efficiency

$$EE = \frac{I_n}{P_{n-1}} \times 100$$

n-1	n	I_n/P_{n-1}
Trees	Insects	1-10%
Grass	Animals	20%
Phytoplankton	Zooplankton	20-40%

Assimilation Efficiency (AE)

$$AE = \frac{A_n}{I_n} \times 100$$

Herbivores ~ 20 - 50%
Carnivores ~ 80%

Production Efficiency (PE)

$$PE = \frac{P_n}{A_n} \times 100 = \frac{P_n}{P_n + R_n} \times 100$$

warm-blooded organisms ~ 2%
cold-blooded organisms ~ 40%

Ecological Efficiency $= \frac{I_n}{P_{n-1}} \times \frac{A_n}{I_n} \times \frac{P_n}{A_n} \times 100 = \frac{P_n}{P_{n-1}} \times 100$

- Tells us how much energy is lost in one trophic transfer in the grazing food chain
- Some of this goes to the detritus food web, some goes to respiration