Primary Production and Energy Flow

- Terminology

  - Ecosystem – a biological community and all of the abiotic factors that influence that community – in studying ecosystems one must look at abiotic factors as closely as biotic ones – two areas frequently analyzed when studying ecosystems are energy flow and nutrient cycling

  - Primary Production – the fixation of energy by autotrophs in an ecosystem

  - Gross Primary Production – the total amount of energy fixed

  - Net Primary Production – the amount of energy left after the autotroph has used all the energy it needs

  - Net Community Production

    \[ \text{NCP} = \text{NPP} - \text{heterotrophic respiration} \]

  - Secondary Production – energy that remains after maintenance and respiration (fat, growth, and reproduction)
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- Actual Evapotranspiration and Terrestrial Primary Production
  - Rosenzweig (1968) – looked at the relationship between primary production and annual actual evapotranspiration, **AET**, (the amount of water that evaporates and transpires from a landscaped/year, mm H₂O/yr)

**Actual evapotranspiration and net aboveground primary production in a series of terrestrial ecosystems.**

**Terrestrial primary production increases with actual evapotranspiration.**

**AET is effected by both precipitation and temperature, therefore, low temperatures or low precipitation greatly affect net primary production.**
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- Sala (1988) looked at variations in net primary production in similar ecosystems.

Influence of annual precipitation on net aboveground primary production in grasslands of central North America.

Primary production in grassland increases with greater annual precipitation.

In these studies precipitation was the determining factor. Why not temperature related?
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What can cause variations in net primary production among similar ecosystems with similar precipitation or AET?

- Soil Fertility and Terrestrial Primary Production – soil fertility plays a very important role, one need only to look at farming
  - Leibig (1840) – identified that the necessary nutrient found in the least amount was called the limiting factor “Leibig’s Law of the Minimum” – in reality it has been found that several factors in conjunction can limit primary production – this has been demonstrated via experiments using enriched soils
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Adding nitrogen, phosphorus, and potassium to net aboveground primary production in Arctic tundra.

Adding fertilizers nearly doubled primary production in these tundra study plots.

Adding phosphorus (P) and/or nitrogen (N) to aboveground primary production in alpine tundra.

Adding nutrients increased primary production in both dry and wet meadows.

- Dry meadow
- Wet meadow
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- Patterns and Models - studies in Japan and the Northern Hemisphere have shown a relationship between total phosphorous and algal biomass, which in turn is related to the rate of primary production.

Phosphorus concentration and algal biomass in north temperate lakes.

As algal biomass increases so does the rate of primary production.

Algal biomass and rate of primary production in temperate zone lakes.
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- Whole Lake Experiments on Primary Production – researchers took an entire lake and divided it into distinct areas using vinyl curtains – they then applied fertilizer to some of these areas.

A whole lake experiment shows the effect of nutrient additions on average phytoplankton biomass.

- Before fertilizing, the two lakes supported similar phytoplankton biomass.
- After fertilization, phytoplankton biomass increased in the experimental lake.
- When fertilizing stopped, phytoplankton biomass decreased in the experimental lake.
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- Marine Primary Production – looking below it is obvious those that are most productive are those that are most fertile (coastlines)
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- Little experimental evidence, of those studies done, nitrogen appears more important than phosphorous.
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- The effect of consumers on primary control – up to this point we have concentrated on abiotic factors – we will now look at biotic factors such as consumers

  - Bottom Up Controls – the effects of physical and chemical factors on an ecosystem

  - Top Down Controls – influences of consumers on an ecosystem
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- Piscivores, Planktivores, and Lake Primary Production

  - Trophic Cascades – the effects coming from consumers “down” through a food web – similar to keystone species, however now the effect is on primary production not species diversity (Carpenter and Kitchell, 1988)
The trophic cascade model predicts that manipulating piscivore biomass will lead to changes in biomass and production of planktivores, herbivores, and phytoplankton.

Effects of piscivores on planktivore, herbivore, and phytoplankton biomass and production.
Primary Production and Energy Flow
• Experimental Evidence by Carpenter and Kitchell

![Diagram illustrating primary production and energy flow](image)

- **Experimental manipulations**
  - Reduced piscivore (bass) biomass
  - Increased planktivore biomass
  - Increased piscivore (bass) biomass
  - Decreased planktivore biomass

- **Responses**
  - Decreased herbivores
  - Increased phytoplankton
  - Increased herbivores
  - Decreased phytoplankton

The responses of herbivores and phytoplankton to manipulations of piscivore and planktivore biomass support the trophic cascade model.
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- Grazing by Large Mammals and the Effect on Primary Production of the Serengeti – an interesting relationship amongst factors

Soil Fertility and Rainfall increase primary production

Moderate grazing animals also effect water, fertility and plant production (McNaughton, 1976)
Primary Production and Energy Flow
- Causes of increased primary production – *Compensatory Growth* – Why?

- Lower rates of respiration, the result of reduced biomass
- Reduced self shading
- Reduced leaf area, reducing transpiration
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- Primary production can affect the number of trophic levels, because of thermodynamics, the lower the primary production the what the number of trophic levels?

- A Trophic Dynamic View of Ecosystems – Lindeman (1942) – proposed that because of the loss of energy at each level a pyramid shaped distribution would result.

![Graph showing energy distribution between trophic levels for Cedar Bog Lake and Lake Mendota.](image-url)
Primary Production and Energy Flow

- Energy Flow in a Temperate Deciduous Forest – Hubbard Brook Experimental Forest