1 Ecocsystems: Energy Flow and Materials Cycling

EVPP 111 Lecture

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Energy Flow and Matter Cycling

- Energy flow s through ecosystems
  - ecosystems
  - global energy budget
  - physical laws governing energy transformations
  - energy transformations in ecosystems
    - trophic levels, food chains, food webs, primary and secondary production
- Matter Cycles through ecosystems
  - types of cycles
  - types of reservoirs
  - major cycles (names)

3 Main Topics

- Movement through ecosystems of
  - energy
    - flows
  - matter
    - cycles

4 Ecosystem

- Defined
- In context

5 Ecosystem

- Defined
  - an ecosystem is
    - a community of different species interacting with one another and with their nonliving environment of matter and energy

6 Ecosystem

- In context
  - of levels of organization of matter in nature

7 Ecosystem

- Levels of organization of matter in nature
  - atom
  - molecule
  - cell
  - organism
  - species
  - population

- community
- ecosystem
- biosphere

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9 Ecosystems
- differ in many ways
  - abiotic (nonliving) components
  - biotic (living) components
- have in common the most basic processes
  - energy flow
  - matter cycling

10 Energy Flow Through Ecosystems
- solar radiation as energy source
  - global energy budget
- principles that govern all energy transformations
- direction of flow of energy in ecosystems
- role of organisms in energy transformations in ecosystems
- productivity

11 Energy Flow Through Ecosystems
- Solar radiation
  - most life depends on solar radiation for energy

12 Energy Flow Through Ecosystems
- Solar radiation
  - global energy budget

13

14 Energy Transformations
- Life depends on the fact that energy can be converted from one form to another
  - energy transformations

15 Laws of physics govern energy transformations
- thermodynamics

- Laws of Thermodynamics

16 Two laws govern energy transformations
- First Law of Thermodynamics
- Second Law of Thermodynamics

17 Two laws govern energy transformations
- First Law of Thermodynamics
  - total amount of energy in the universe remains constant

18 Two laws govern energy conversion
- Second Law of Thermodynamics

- disorder (or entropy) in the universe is continuously increasing
  - heat is one form of disorder

19 Energy transformations
- Global energy budget
  - we can potentially trace all the energy
    - from
      - its input as solar radiation
    - to
      - its release as heat

20 Energy transformations
- Global energy budget
  - energy
    - enters “earth system” as
      - visible light, infrared, UV radiation
    - undergoes transformations
      - degrade its form to heat
    - leave “earth system” as heat

21 Trophic structure is a key factor in ecosystem dynamics
- Feeding relationships between organisms of an ecosystem
  - determine routes of energy flow and chemical cycling in an ecosystem

22 Trophic structure is a key factor in ecosystem dynamics
- Ecosystems include
  - producers (autotrophs)
  - consumers (heterotrophs)

23 Trophic structure is a key factor in ecosystem dynamics
- producers (autotrophs)
  - usually photosynthetic
    - CO_2+$H_2$0 ---> $C_6H_{12}O_6$ +O_2
    - includes
      - plants, algae, some bacteria, some protists

24 Trophic structure is a key factor in ecosystem dynamics
- consumers (heterotrophs)
  - organisms that must obtain organic molecules synthesized by autotrophs
  - includes
    - animals
    - fungi
    - most protists

- most bacteria

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26 Trophic structure is a key factor in ecosystem dynamics
- several levels of consumers exist
  - primary consumers
    - herbivores
  - secondary consumers
    - carnivores
  - decomposers
    - detritovores

27 Trophic structure is a key factor in ecosystem dynamics
- Energy transformations in an ecosystem
  - can be followed by grouping the species in a community into trophic levels

28 Trophic structure is a key factor in ecosystem dynamics
- food chain
  - a stepwise flow of energy and nutrients
    - from plants (producers)
    - to herbivores (primary consumers)
    - to carnivores (secondary and higher-level consumers) as one organism feeds on another, energy flows through the series

29 Trophic structure is a key factor in ecosystem dynamics
- food chain
  - in general, from one level to the next
    - amount of total energy passed on decreases
    - number of organisms decreases
    - total biomass decreases

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31 Trophic structure is a key factor in ecosystem dynamics
- food web
  - interacting food chains
  - defines feeding relationships among organisms

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33 Figure 54.10 Energy partitioning within a link of the food chain

34 Trophic structure is a key factor in ecosystem dynamics
- passage of energy through ecosystems
  - relatively small percentage of energy ingested at one trophic level reaches next trophic level
    - ~10% on average
      - ~5% for carnivores

- ~20% for herbivores

35 Trophic structure is a key factor in ecosystem dynamics
- Energy in food chains
  - stepwise energy loss
    - limits most food chains to 3 - 5 levels

36 Trophic structure is a key factor in ecosystem dynamics
- Community energy budgets
  - example seen in study of flow of energy in freshwater ecosystem at Cayuga Lake

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38 Energy flows through ecosystems
- Ecological pyramids
  - Graphic representations of the relative energy amounts at each trophic level
  - 3 types of Pyramids
    - Pyramid of Energy
    - Pyramid of Biomass
    - Pyramid of Numbers

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42 Energy flows through ecosystems
- Ecological pyramids
  - inverted pyramids
    - occur in some aquatic ecosystems
      - biomass of consumers can exceed that of producers

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44 Freshwater Aquatic Food Chain
Energy Pyramid

45 Grassland Food Chain
Numbers of Organisms

46 Tropical Rain Forest
Biomass Pyramid

47 Energy flow through ecosystems
- Ecosystem productivity
  - An ecosystem's energy budget depends on primary production

48 Energy flow through ecosystems
- Primary production or primary productivity

- amount of organic matter produced from solar energy by autotrophs in a given period of time
- gross versus net primary productivity

49 Energy flow through ecosystems
- Primary productivity
  - gross primary productivity (GPP)
    - total amount of light energy that is converted into chemical energy in a community in given time

50 Energy flows through ecosystems
- Primary productivity
  - net primary productivity (NPP)
    - amount of organic matter produced in a community in a given time that is available for heterotrophs
    - NPP = GPP – R
      - respiration (R)

51 Energy flows through ecosystems
- Primary productivity
  - biomass
    - net weight of all organisms living in an ecosystem (or trophic level)
    - increases as a result of net production

52 Energy flows through ecosystems
- Net primary productivity varies among ecosystem types

53 Energy flows through ecosystems
- Net primary productivity by ecosystem type
  - tropical forests ~1500-3000 g/m^2/yr
  - wetlands ~1500-3000 g/m^2/yr
  - temperate forests ~1200-1300 g/m^2/yr
  - savanna ~900 g/m^2/yr
  - deserts ~90 g/m^2/yr

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56 Energy flows through ecosystems
- Major limits to primary productivity
  - in terrestrial ecosystems
    - temperature, moisture, nutrients
  - in aquatic ecosystems
    - light, nutrients

57 Energy flows through ecosystems
- Secondary productivity
  - rate of production by heterotrophs
  - amount of chemical energy in consumers' food that is converted to their own new biomass during a given time period

58
- One way to understand secondary production is to examine the process in individual organisms.

59
60 Energy flow vs. Matter Cycling
- energy flows through the earth system
- Matter cycles through the earth system

61 Matter cycles within ecosystems
- Organisms depend on the ability to recycle basic "components" of life

62 Matter cycles within ecosystems
- Matter cycles through both biotic and abiotic components of ecosystems
  - called biogeochemical cycles.
    - cyclic pathways involving biological, geological and chemical processes

63 Matter cycles within ecosystems
- There are many biogeochemical cycles
  - unified by the involvement of the four reservoirs of earth system through which matter cycles
    - lithosphere (rocks and soils)
    - atmosphere
    - hydrosphere(oceans, surface waters, groundwaters, glaciers)
    - biosphere (living organisms)

64 Matter cycles within ecosystems
- Chemicals in these reservoirs have different average times of storage or cycling
  - depending on two main determinants
    - chemical reactivity of the substance
    - whether it has a gaseous phase at some point in cycle

65 Matter cycles within ecosystems
- Generalized average times of storage or cycling based on reservoir
  - long
    - lithosphere (rocks and soils)
  - intermediate
    - hydrosphere(oceans, surface waters, groundwaters, glaciers)

- biosphere (living organisms)
- short
  - atmosphere

66 Matter cycles within ecosystems
- 3 main categories of biogeochemical cycles
  - Hydrologic
  - Gaseous
  - Sedimentary

67 Matter cycles within ecosystems
- Gaseous
  - involves exchanges among the atmosphere, biosphere, soils and oceans
  - include
    - Carbon Cycle
    - Oxygen Cycle
    - Nitrogen Cycle

68 Matter cycles within ecosystems
- Sedimentary
  - Involve materials that move from land to oceans and back
  - include
    - Phosphorous cycle
    - Sulfur cycle

69 Matter cycles within ecosystems
- Main biogeochemical cycles
  - water cycle
  - carbon cycle
  - oxygen cycle
  - nitrogen cycle
  - phosphorous cycle

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71 The End