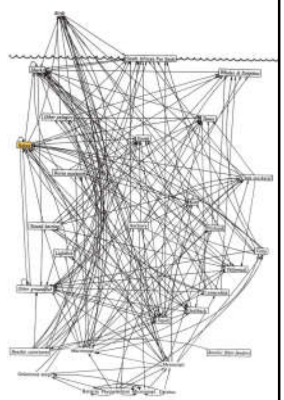
Food Webs and Ecological Networks

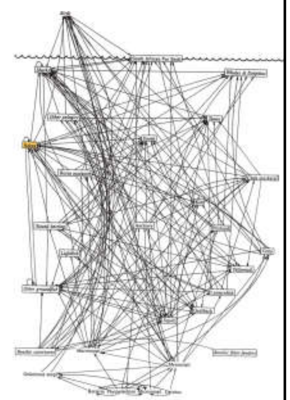
- Communities feature numerous species with the potential for a large number of interactions.
- Taxonomic bias
- Species sometimes grouped into functional categories or guilds
- Very few examples well documented
- Historically, arrows represent prey → predator with most important species (keystone) viewed as top predators.



COMMUNITY ECOLOGY, Figure 10.2

Food Web Structure

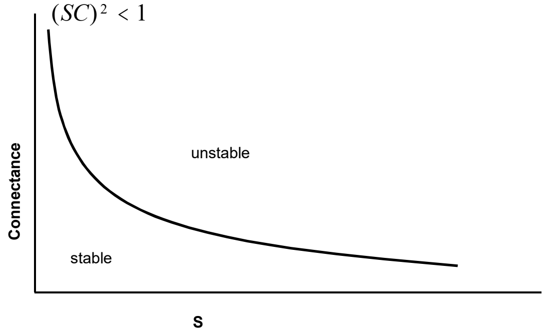
- Connectedness webs – interactions (predator/prey) indicated but no strength of interactions.
- Green vs. brown webs
- "fast" vs. "slow" webs
- Food web metrics
  - S
  - # trophic levels
  - Connectance and complexity (May 1972)
  - Network topology



COMMUNITY ECOLOGY, Figure 10.2

Models of stability (May 1972)

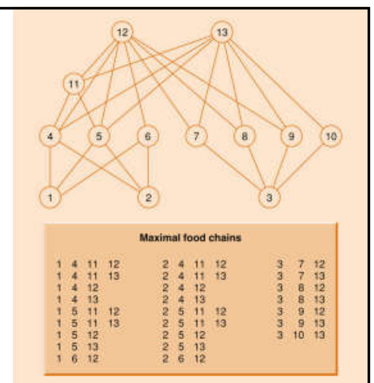
$$(SC)^{\frac{1}{2}} < 1$$



Increased diversity and/or complexity decrease stability.

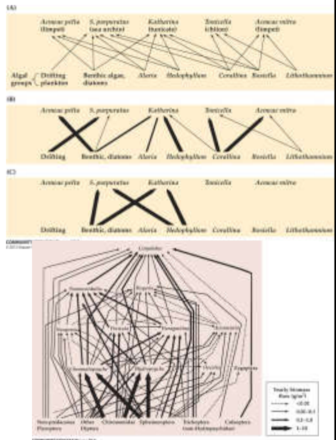
Maximal food chains

- Attempt to quantify the "length" of food webs
- Average number of links between a consumer and top predator
- Generally, more productive systems support longer chains



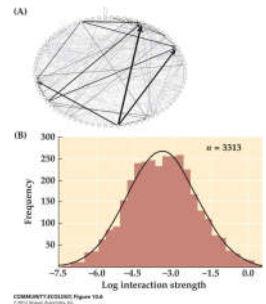
Energy Flow and Functional Webs

- Paine suggested connectedness webs (A) missed too many pertinent biological functions.
- **Energy flow** (B) estimates the flow of biomass (energy) between components
- **Functional webs** (C)– connections represent the **strength of interactions**



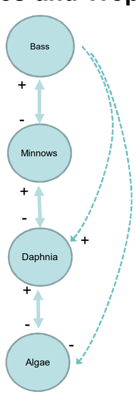
Interaction Strength

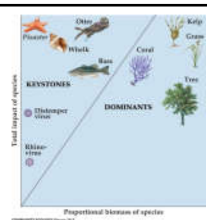
- Strong vs. weak interactors
- Keystone species
- Largely determined through removal experiments
- Metrics (table 10.1)
  - Raw: $\frac{N-D}{Y}$
  - Paine's Index: $\frac{N-D}{DY}$
  - Comm. Importance: $\frac{N-D}{Np_y}$
  - Dynamic Index: $\frac{\ln(N-D)}{Yt}$

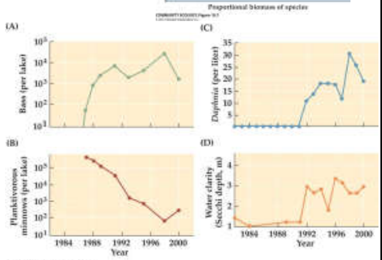


- Where
  - N – prey abundance with predators
  - D – prey abundance without predators
  - Y – predator abundance
  - P_y – proportional abundance of predator
  - t - time

Keystones and Trophic Cascade

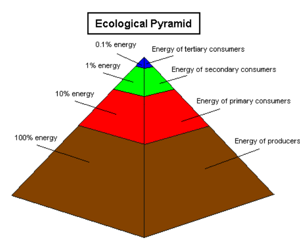






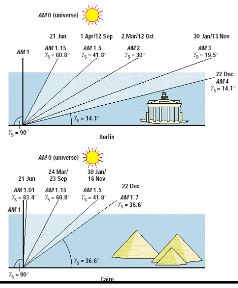
Food Web Energetics

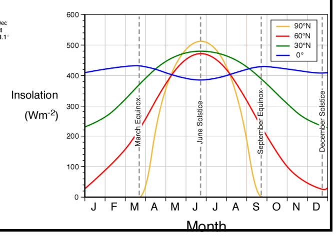
- Elton first observed that biomass decreased at higher levels in food webs.
- Eltonian Pyramid
- Longer chains require greater productivity, unless energy transfer efficiency increased.



Primary production efficiency

- How much energy is available?
  - Solar constant 1366 watts/m^2 (1.96 cal cm^{-2} min^{-1})
- What percentage converted to usable carbohydrate energy?
  - 1-2% on land 3-4% for algae
  - Efficient solar panels = 15-30%

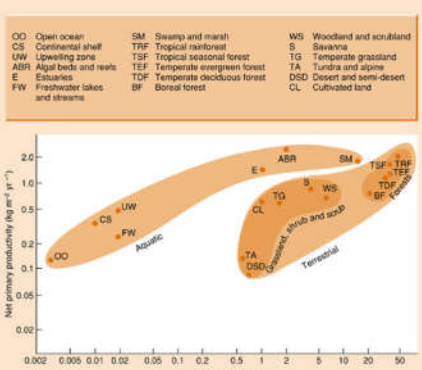




Net Global Primary productivity

Marine	NPP	Terrestrial	NPP
Tropical and subtropical oceans	13.0	Tropical rainforests	17.8
Temperate oceans	16.3	Broadleaf deciduous forests	1.5
Polar oceans	6.4	Mixed broad/needleleaf forests	3.1
Coastal	10.7	Needleleaf evergreen forests	3.1
Salt marsh/estuaries/seaweed	1.2	Needleleaf deciduous forests	1.4
Coral reefs	0.7	Savannas	16.8
		Perennial grasslands	2.4
		Broadleaf shrubs with bare soil	1.0
		Tundra	0.8
		Desert	0.5
		Cultivation	8.0
Total	48.3	Total	56.4

Ecosystem Productivity per unit Biomass



Why so inefficient?

- Laws of thermodynamics:
  - First law of thermodynamics – conservation of energy
  - Second law of thermodynamics – entropy
- Plant productivity limited by:
  - Limited wavelengths used
  - Energy spent conducting photosynthesis or respiration (~30%)
  - Most ecosystem energy "lost" as kinetic energy or heat
  - Limitations to productivity
    - Patchy distribution of water and nutrients
    - Growing season length
    - Temperature
    - Soil depth