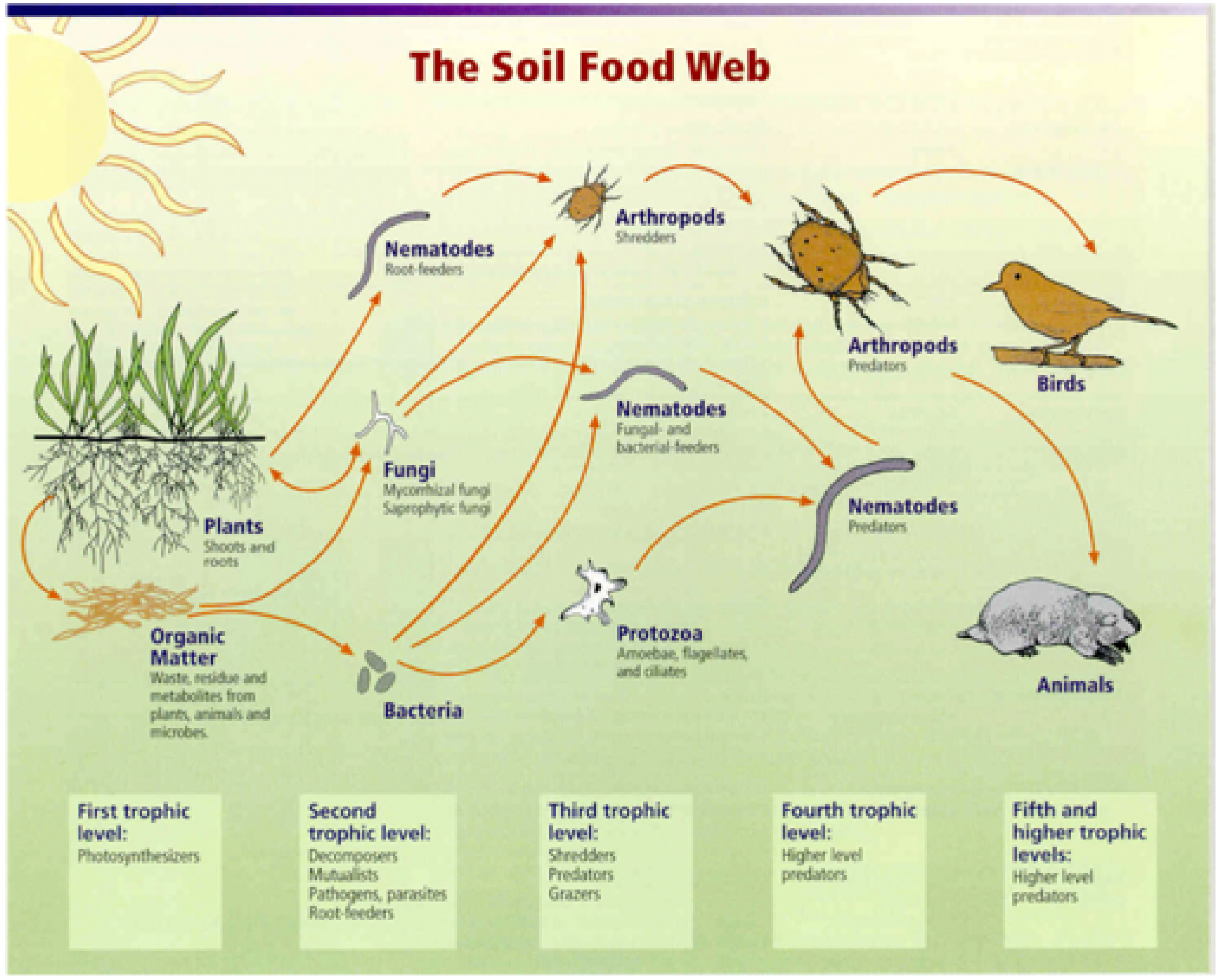
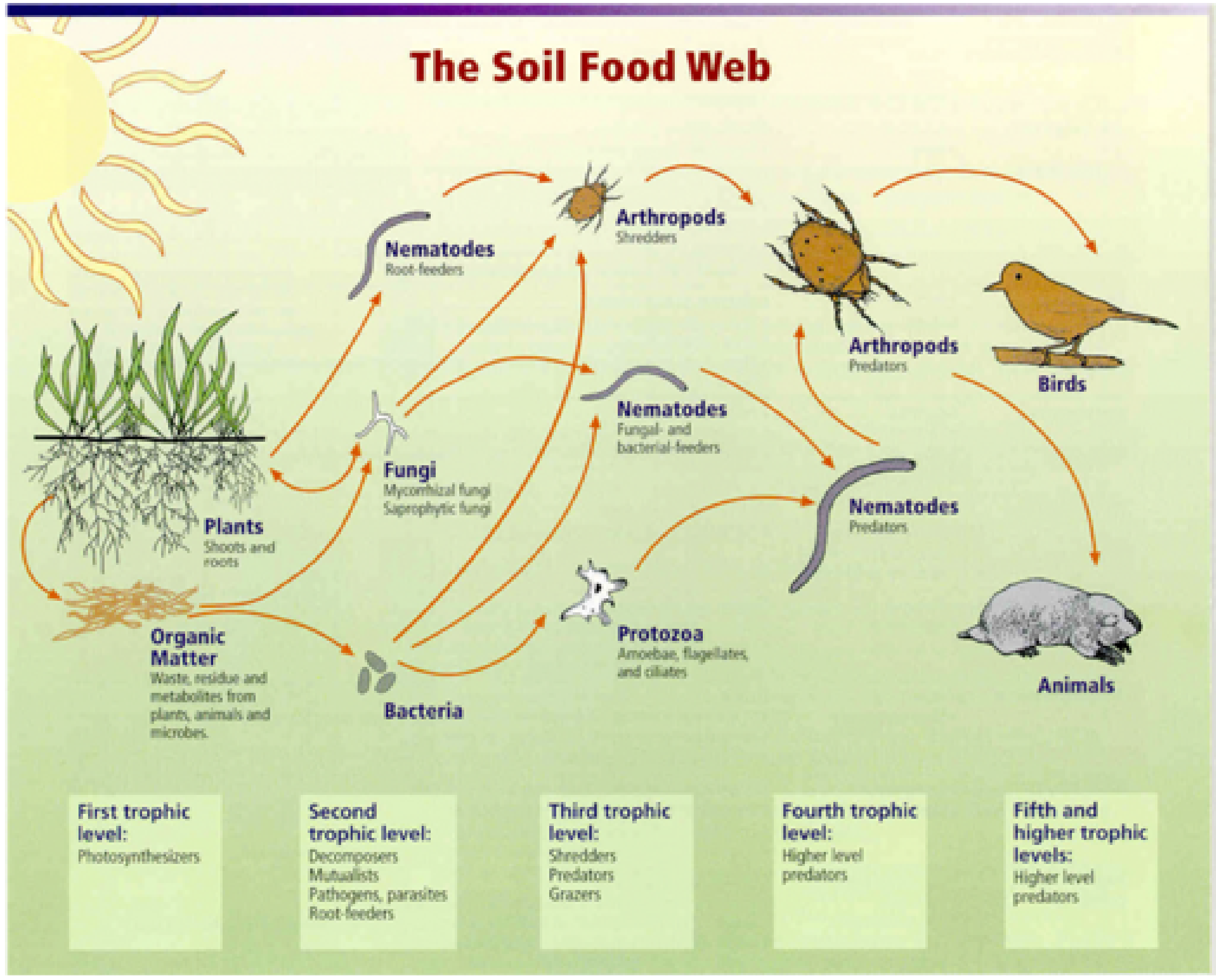
Species and trophic dynamics

What is the purpose of a food web?



Relationships between soil food web, plants, organic matter, and birds and mammals
Image courtesy of USDA Natural Resources Conservation Service
http://soils.usda.gov/sqi/soil_quality/soil_biology/soil_food_web.html.

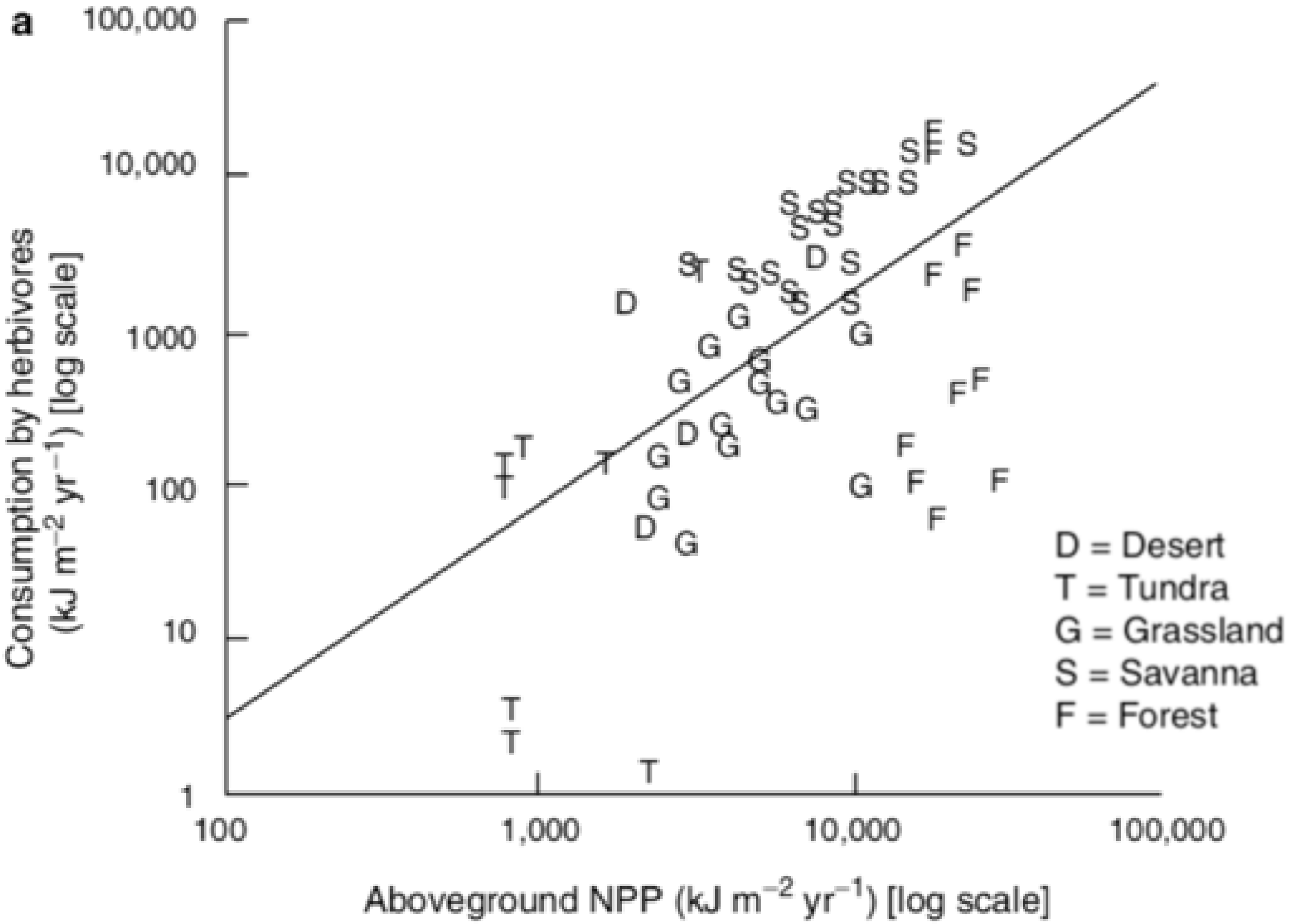
Who controls these interactions?



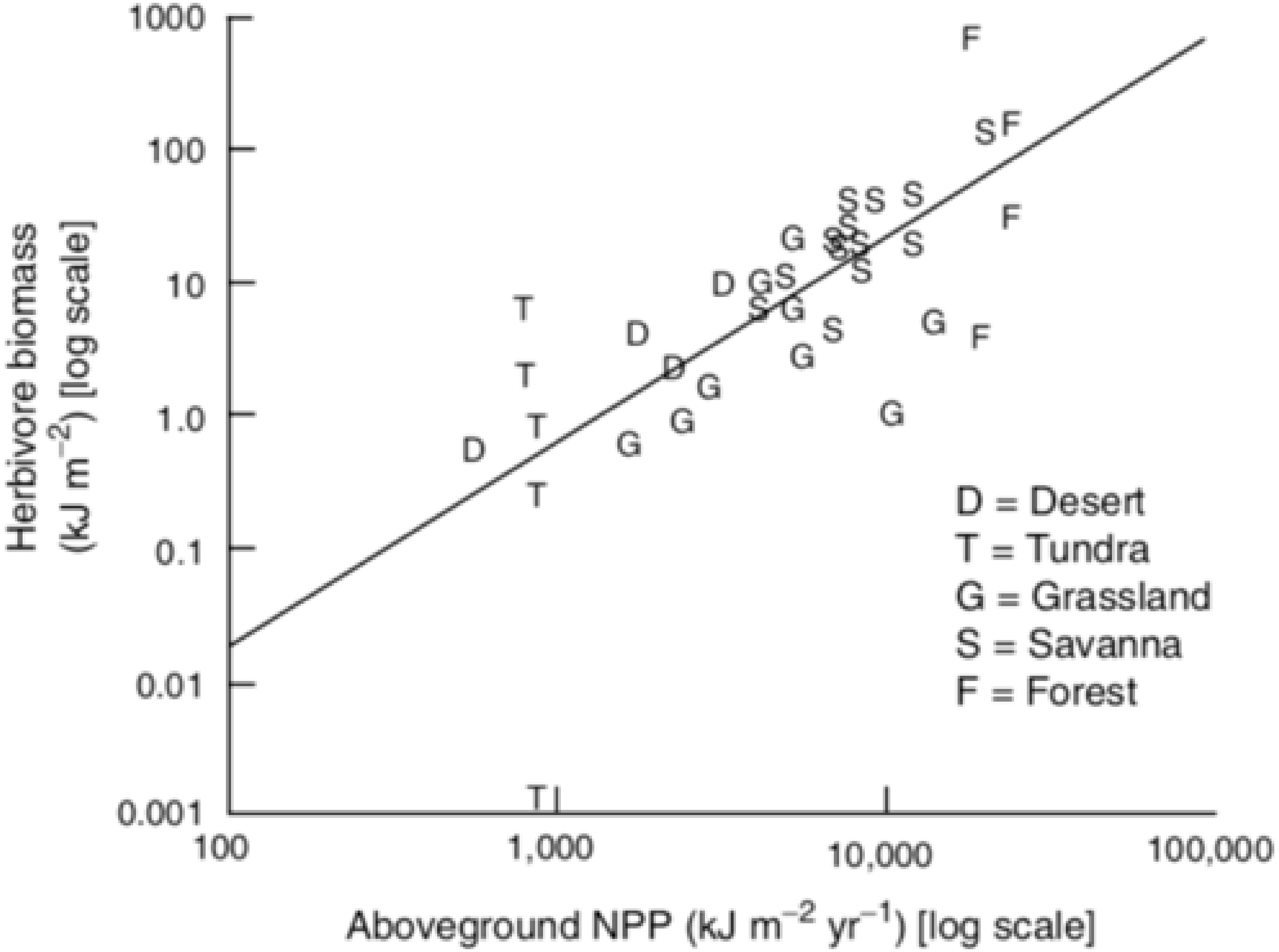
Relationships between soil food web, plants, organic matter, and birds and mammals
Image courtesy of USDA Natural Resources Conservation Service
http://soils.usda.gov/sqi/soil_quality/soil_biology/soil_food_web.html.

Bottom up controls

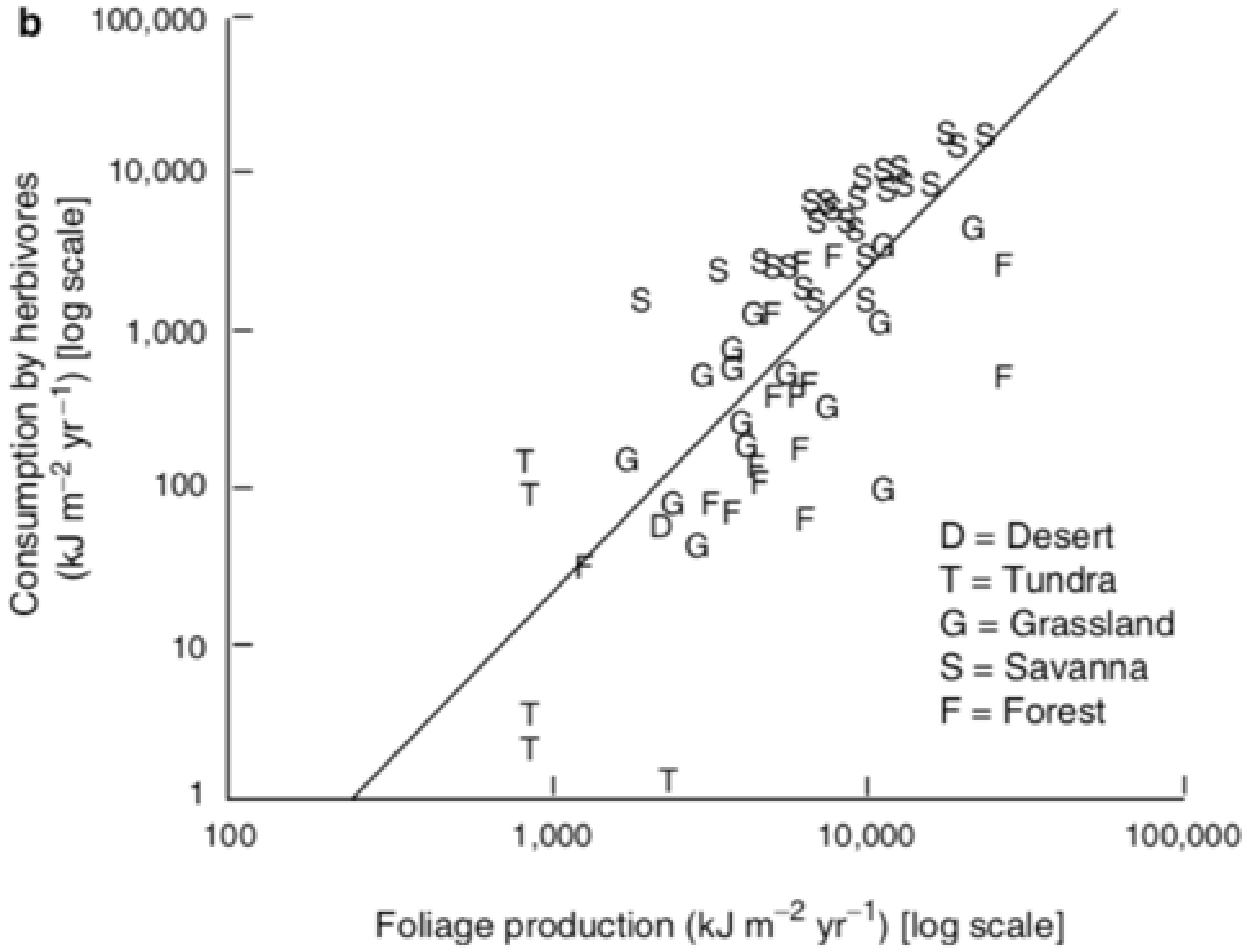
Herbivory increases with NPP



Herbivore biomass increases with NPP



Actually driven by leaf production



Why?

Leaf traits influence herbivory

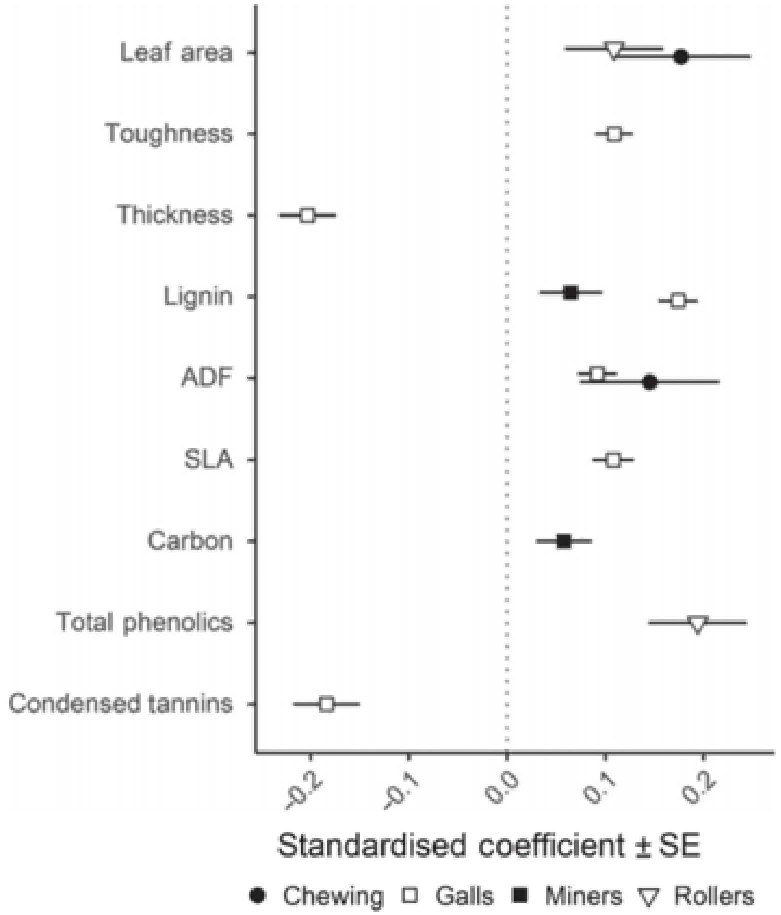


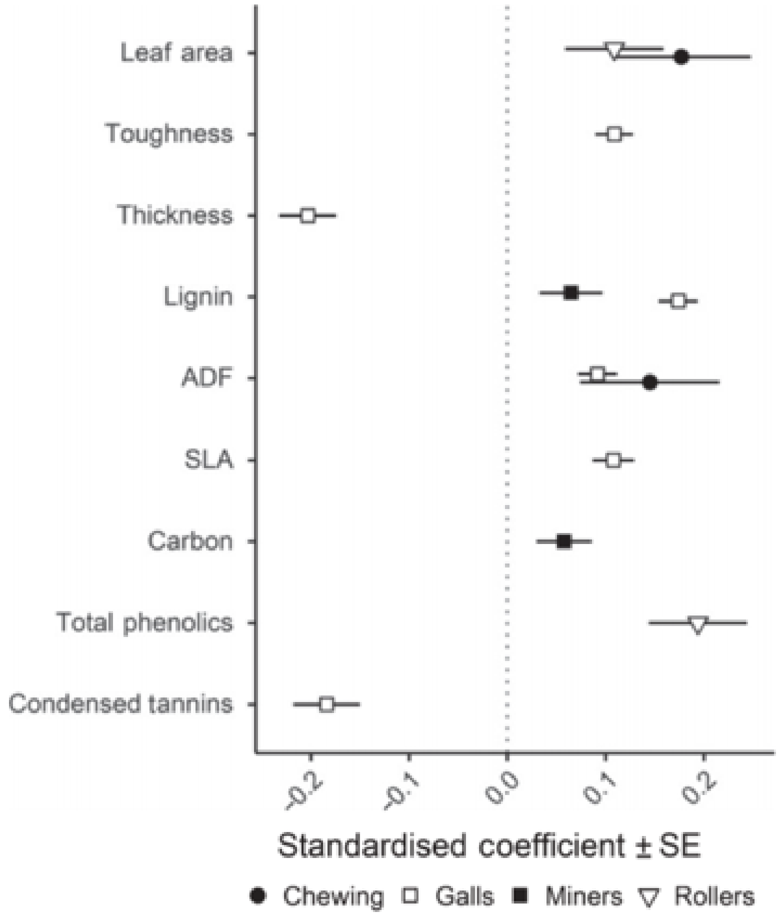
Fig. 3 Effects of birch leaf traits on herbivory. Scaled estimates (± SE) from Lasso regression analyses indicate the relative effects of each trait on chewing damage and the abundance of leaf galls, miners and rollers. Only significant effects are shown for clarity. ADF, acid detergent fibre; SLA, specific leaf area.

Muiruri et al. (2019) New Phytologist

Why do we care about anything other than plants and microbes?

- Dominate energy (>95%) and nutrient transfer in terrestrial ecosystems
- NPP uncertainty is greater than energy transfer from plants to animals

Leaf traits influence herbivory



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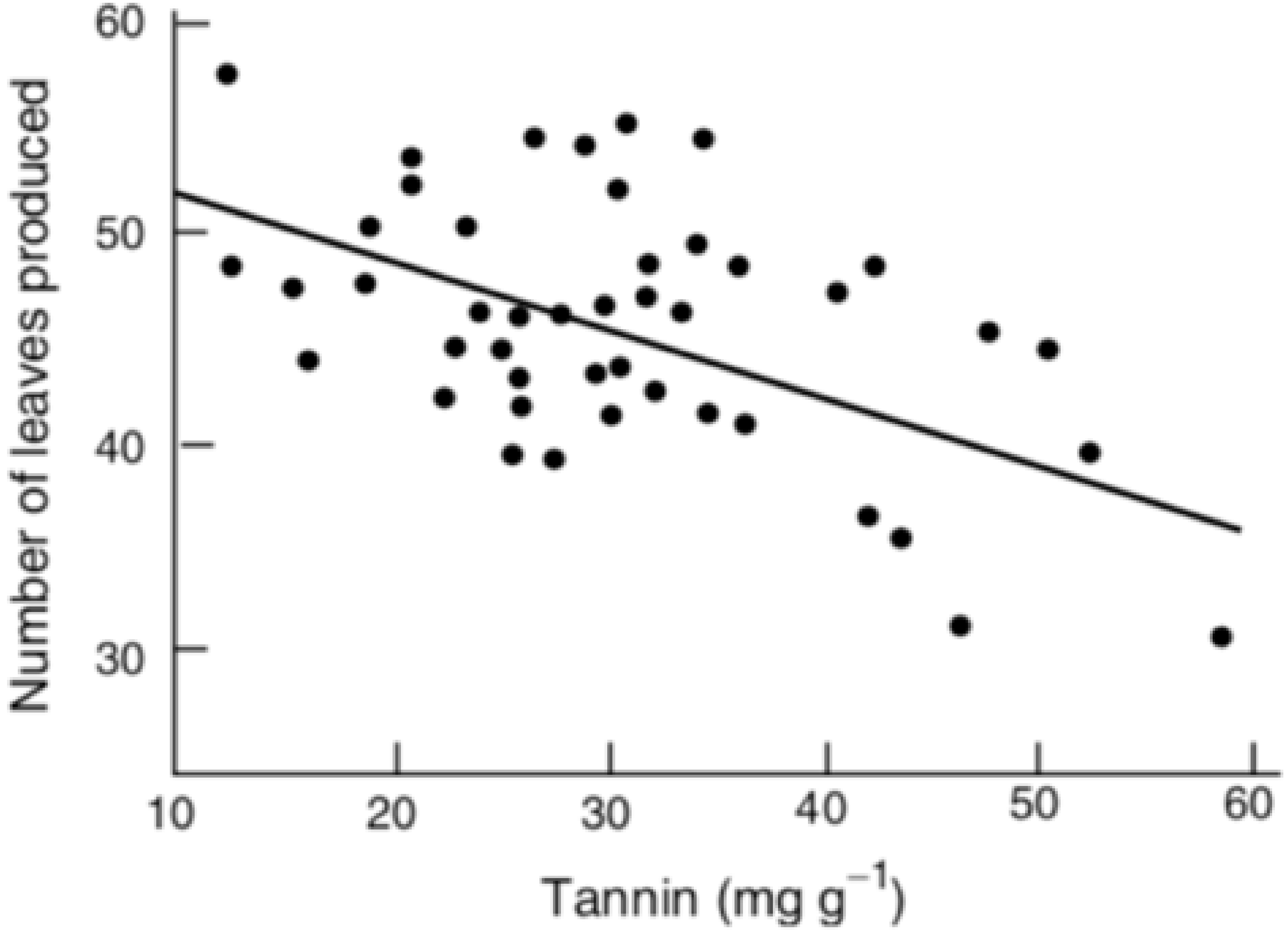
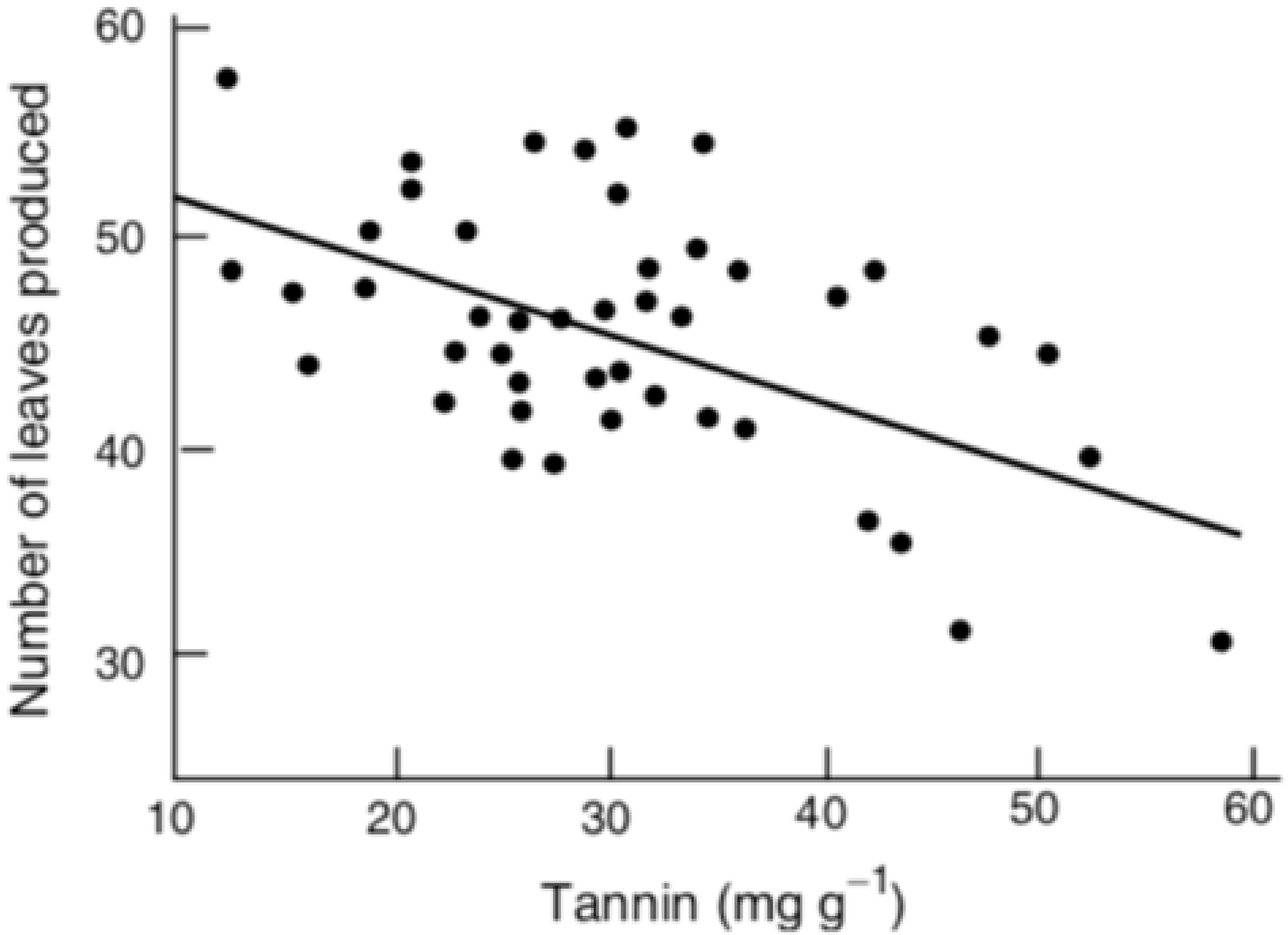
Muiruri et al. (2019) New Phytologist

Trade-off between herbivory protection and leaf productivity



Trade-off between herbivory protection and leaf productivity



So maybe plants aren’t fully driving these interactions!

Top down controls

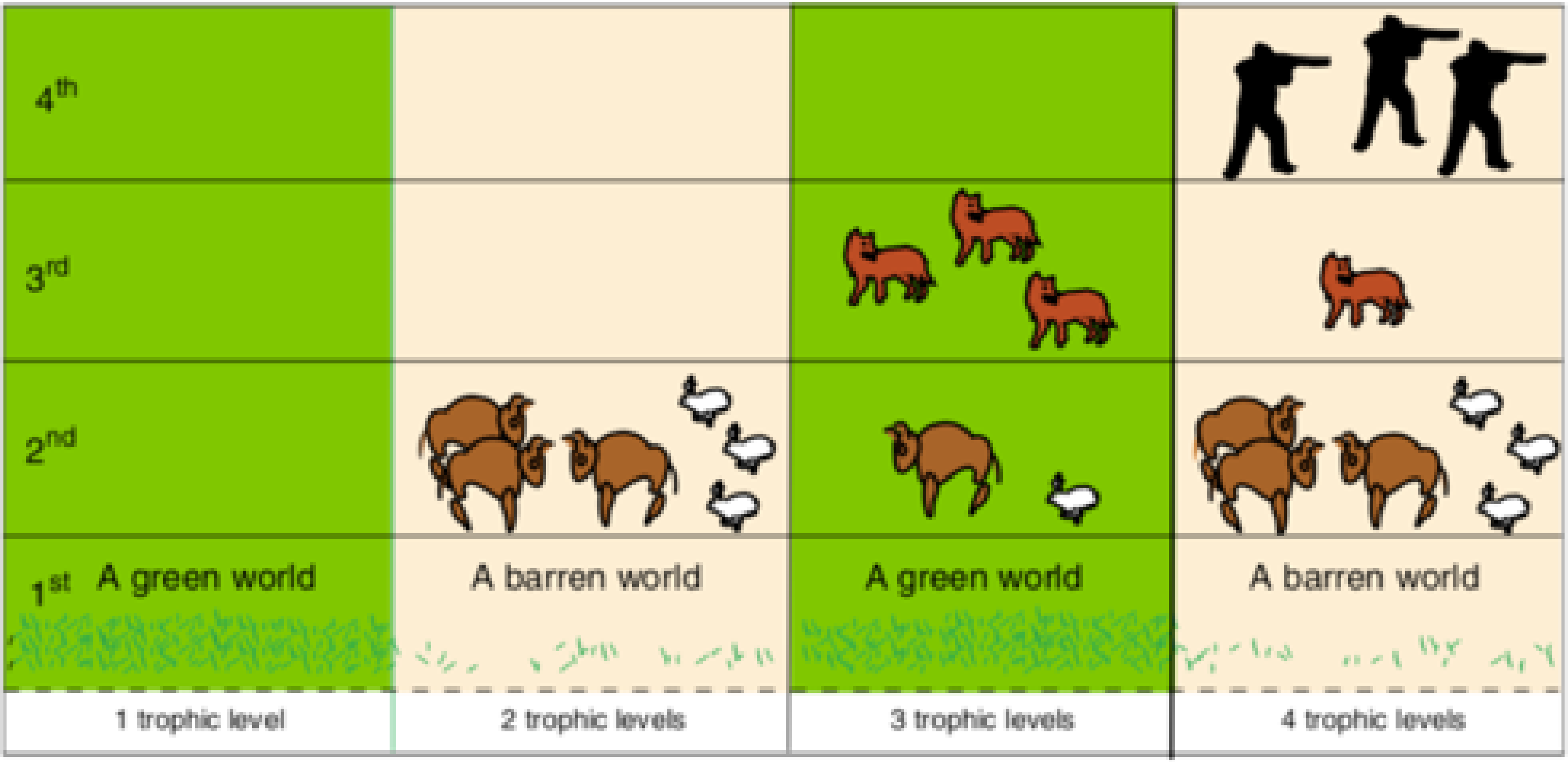
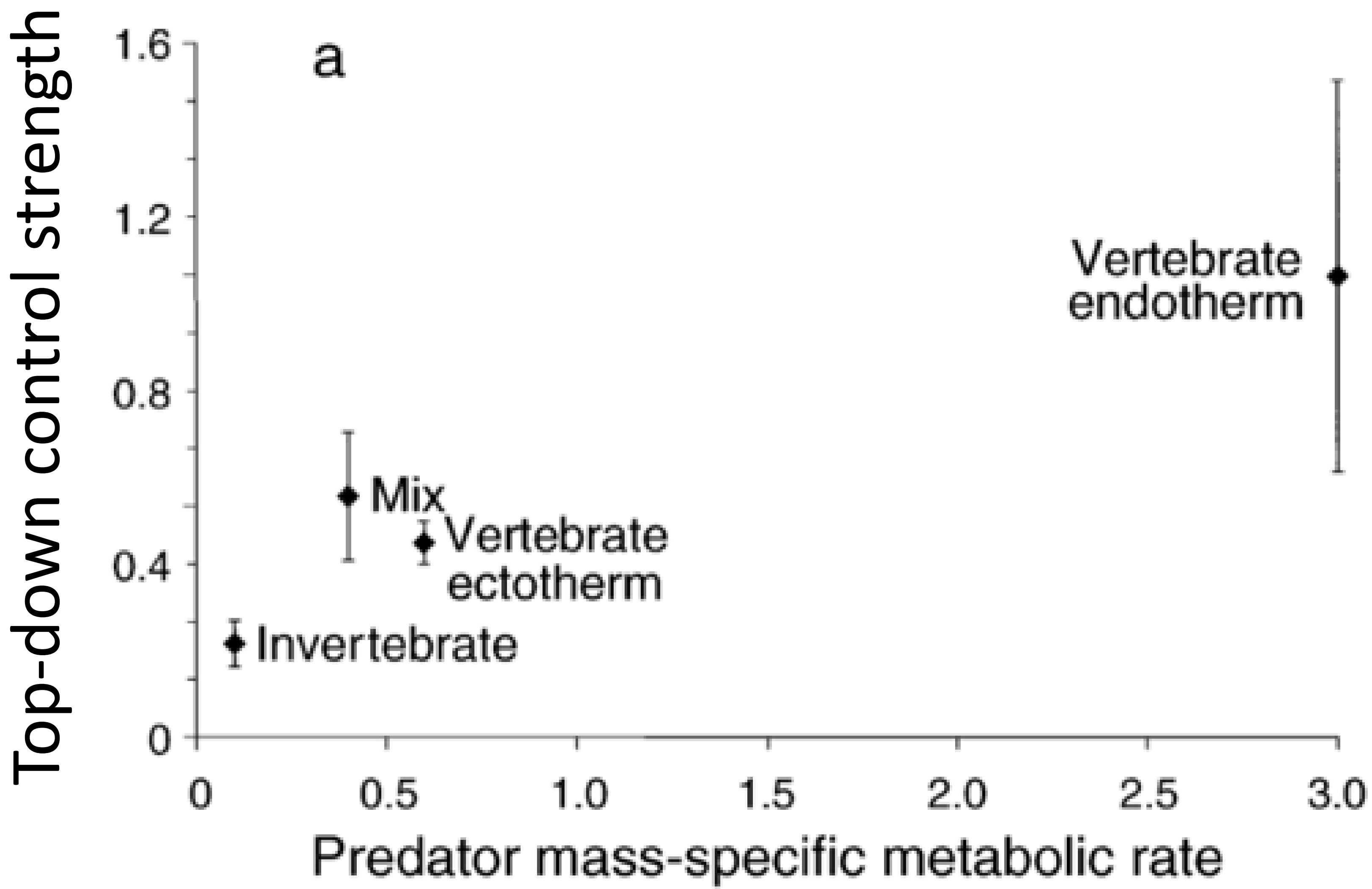


Fig. 10.8 Effect of food chain length on primary producer biomass in situations where trophic cascades operate. Plant biomass is abundant where there are odd numbers of trophic levels (1, 3, 5, etc.) because these have a low biomass of herbivores; plant biomass is reduced where there are even numbers of trophic levels (2, 4, 6, etc.) because these have a large biomass of herbivores

What types of organisms exert the strongest top-down controls?



Borer et al. (2005)

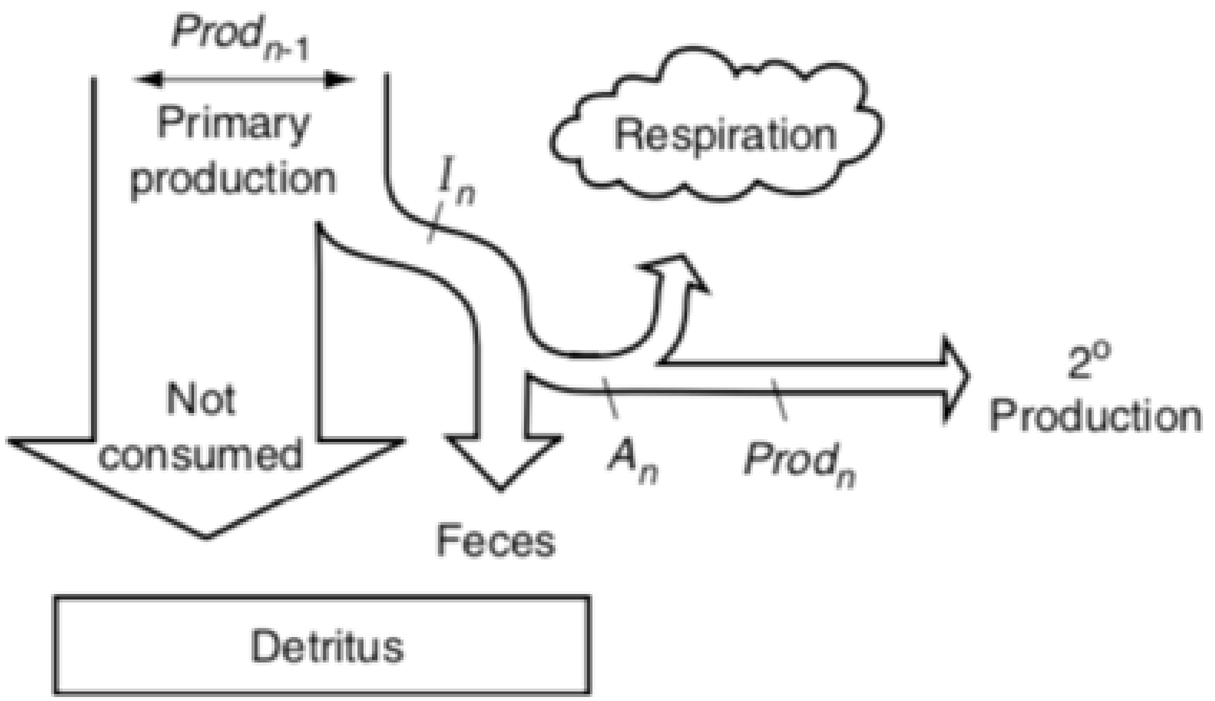
Energy flow through trophic levels

$$\text{Consumption efficiency } (E_{\text{consump}}) = \frac{I_n}{Prod_{n\text{-}1}}$$

$$\text{Assimilation efficiency } (E_{\text{assim}}) = \frac{A_n}{I_n}$$

$$\text{Production efficiency } (E_{\text{prod}}) = \frac{Prod_n}{A_n}$$

$$\text{Trophic efficiency } (E_{\text{troph}}) = (E_{\text{consump}}) \times (E_{\text{assim}}) \times (E_{\text{prod}}) = \frac{Prod_n}{Prod_{n\text{-}1}}$$



$$\boxed{\text{Consumption efficiency } (E_{consump}) = \frac{I_n}{Prod_{n-1}}}$$

Percent production by lower trophic level that is consumed by the higher trophic level

$$\text{Assimilation efficiency } (E_{assim}) = \frac{A_n}{I_n}$$

$$\text{Production efficiency } (E_{prod}) = \frac{Prod_n}{A_n}$$

$$\text{Trophic efficiency } (E_{troph}) = (E_{consump}) \times (E_{assim}) \times (E_{prod}) = \frac{Prod_n}{Prod_{n-1}}$$

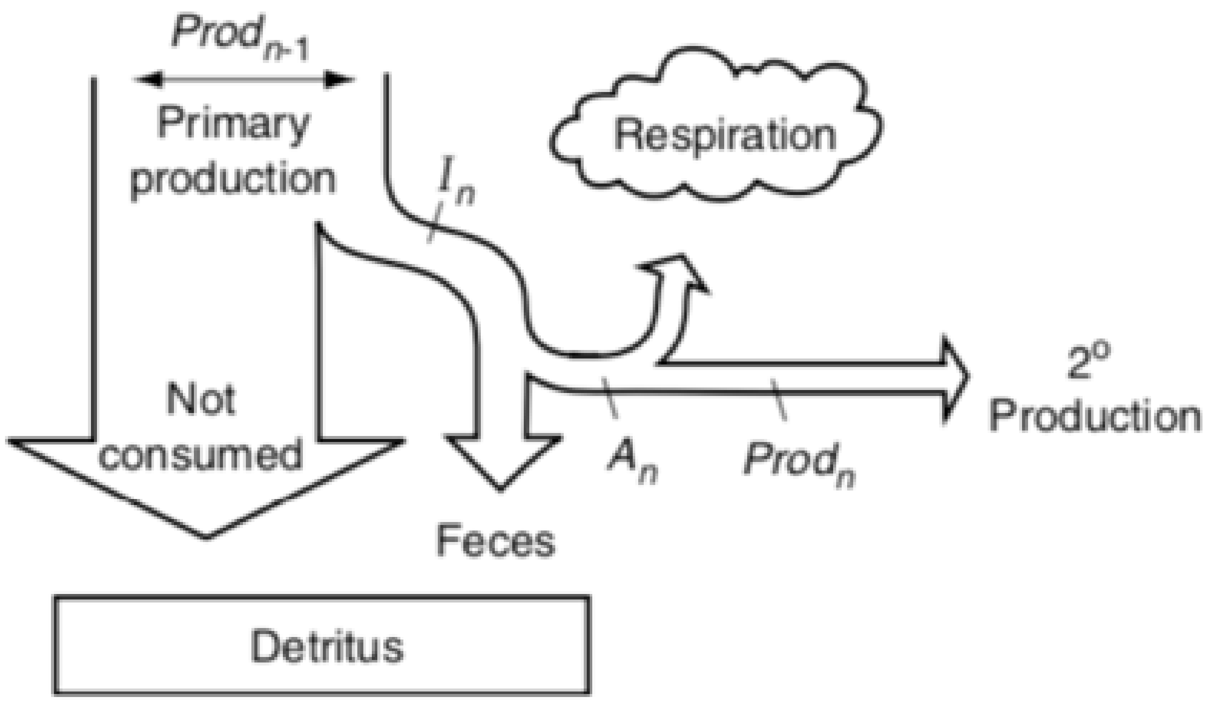


Table 10.1 Consumption efficiency of the herbivore trophic level in selected ecosystem types[a]

Ecosystem type	Consumption efficiency (% of aboveground NPP)
Ocean	60–99
Managed rangelands	30–45
African grasslands	28–60
Herbaceous old fields (1–7 year)	5–15
Herbaceous old fields (30 year)	1.1
Mature deciduous forests	1.5–2.5

[a]Data from Wiegert and Owen (1971) and Detling (1988). Terrestrial estimates emphasize consumption by above-ground herbivores and may not accurately reflect the total ecosystem-scale consumption efficiency

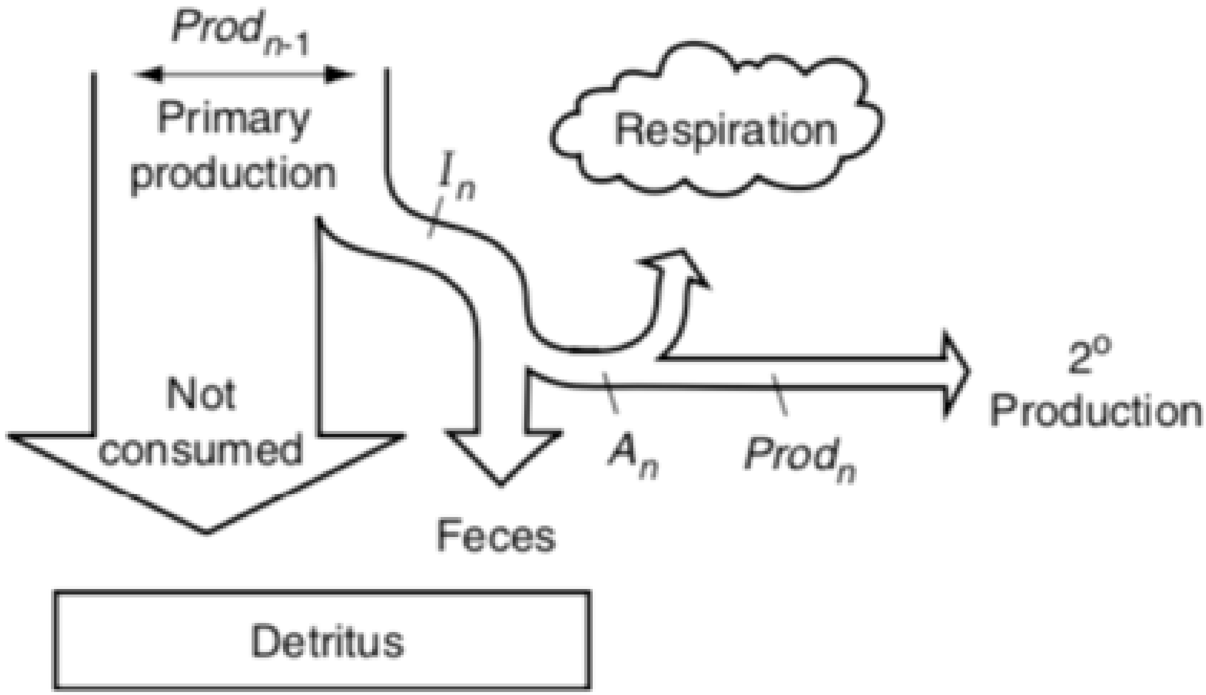
$$\text{Consumption efficiency } (E_{consump}) = \frac{I_n}{Prod_{n-1}}$$

$$\boxed{\text{Assimilation efficiency } (E_{assim}) = \frac{A_n}{I_n}}$$

The amount consumed that is assimilated into the organism (not pooped out)

$$\text{Production efficiency } (E_{prod}) = \frac{Prod_n}{A_n}$$

$$\text{Trophic efficiency } (E_{troph}) = (E_{consump}) \times (E_{assim}) \times (E_{prod}) = \frac{Prod_n}{Prod_{n-1}}$$



Carnivores have 4x greater assimilation efficiencies than herbivores. Why?

$$\text{Consumption efficiency } (E_{consump}) = \frac{I_n}{Prod_{n-1}}$$

$$\text{Assimilation efficiency } (E_{assim}) = \frac{A_n}{I_n}$$

$$\boxed{\text{Production efficiency } (E_{prod}) = \frac{Prod_n}{A_n}}$$

The amount assimilated that is not respired

$$\text{Trophic efficiency } (E_{troph}) = (E_{consump}) \times (E_{assim}) \times (E_{prod}) = \frac{Prod_n}{Prod_{n-1}}$$

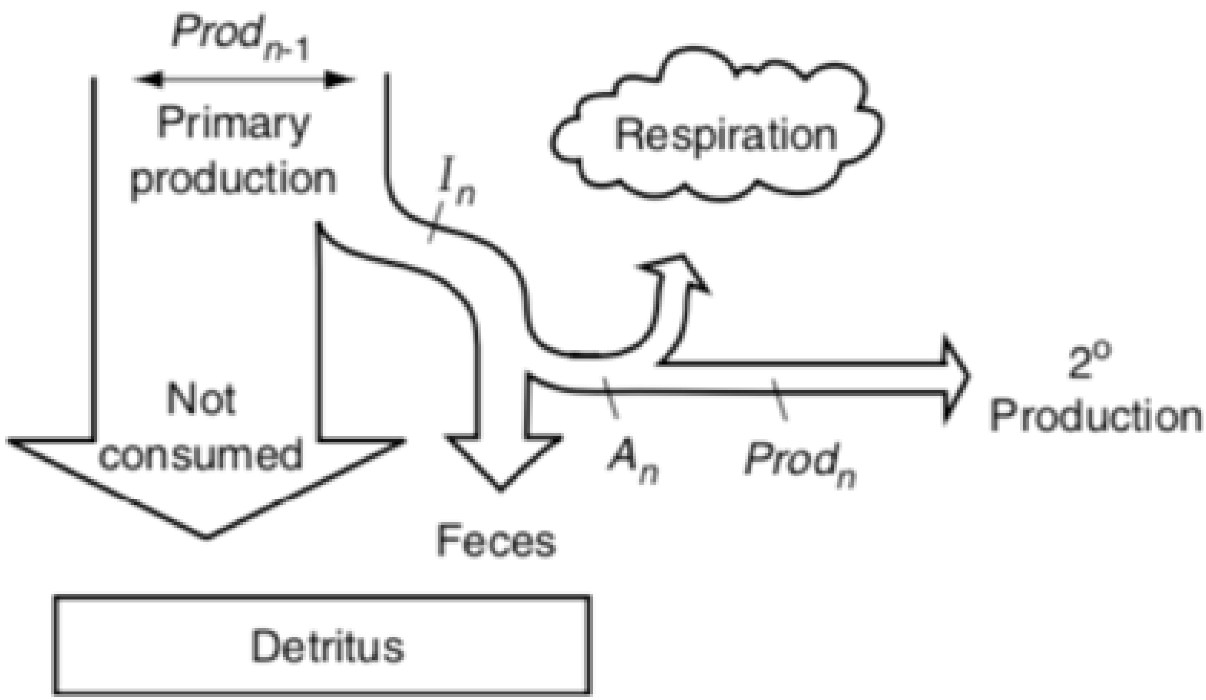


Table 10.2 Production efficiency of selected animals[a]

Animal type	Production efficiency (% of assimilation)
Homeotherms	
Birds	1.3
Small mammals	1.5
Large mammals	3.1
Poikilotherms	
Fish and social insects	9.8
Nonsocial insects	40.7
Herbivores	38.8
Carnivores	55.6
Detritus-based insects	47.0
Noninsect invertebrates	25.0
Herbivores	20.9
Carnivores	27.6
Detritus-based invertebrates	36.2

[a]Data from Humphreys (1979)

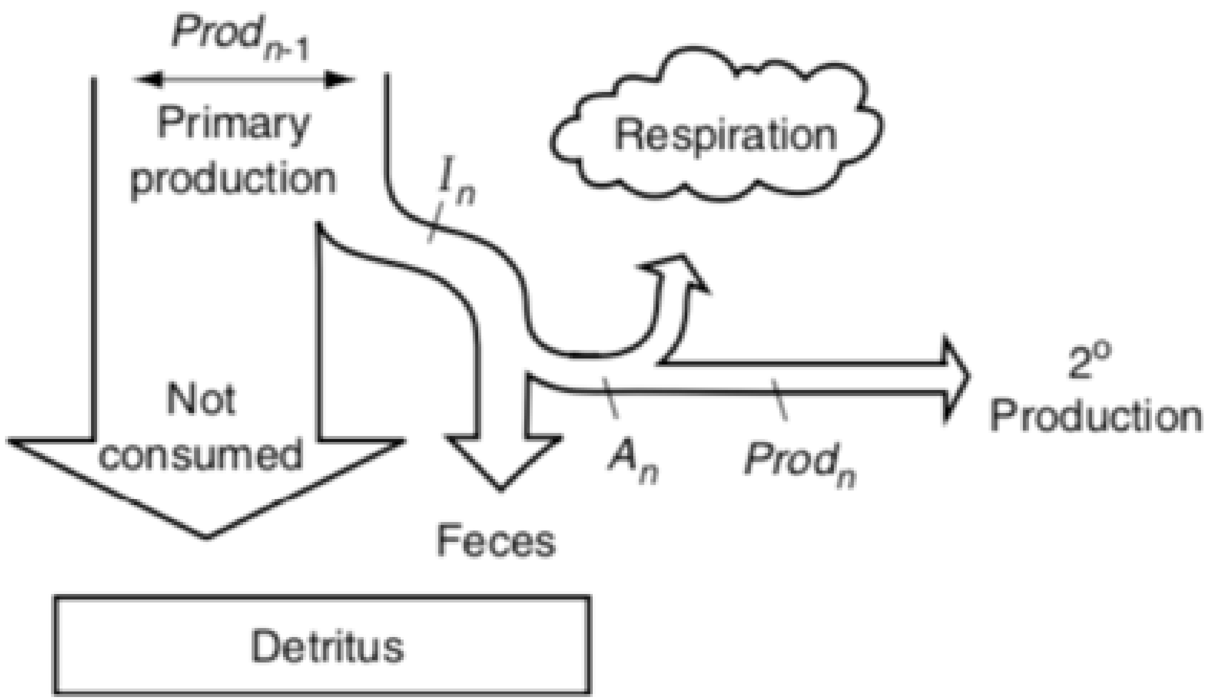
$$\text{Consumption efficiency } (E_{consump}) = \frac{I_n}{Prod_{n-1}}$$

$$\text{Assimilation efficiency } (E_{assim}) = \frac{A_n}{I_n}$$

$$\text{Production efficiency } (E_{prod}) = \frac{Prod_n}{A_n}$$

$$\boxed{\text{Trophic efficiency } (E_{troph}) = (E_{consump}) \times (E_{assim}) \times (E_{prod}) = \frac{Prod_n}{Prod_{n-1}}}$$

Efficiency of the trophic level



Activity: what is the largest food chain you can create?

Activity: what is the largest food chain you can create?

What is characteristic about the longest ones?

How does nutrient and energy flow differ?

Herbivores speed nutrient flow

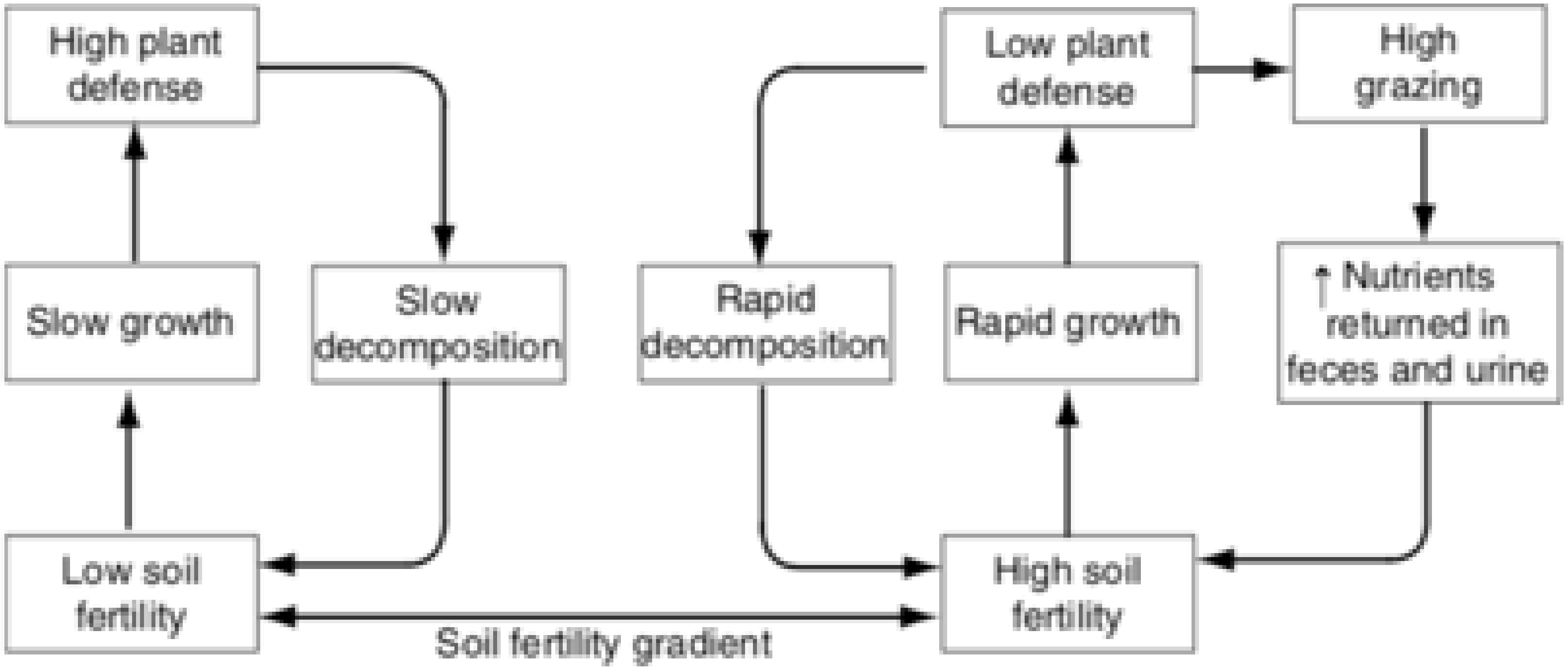
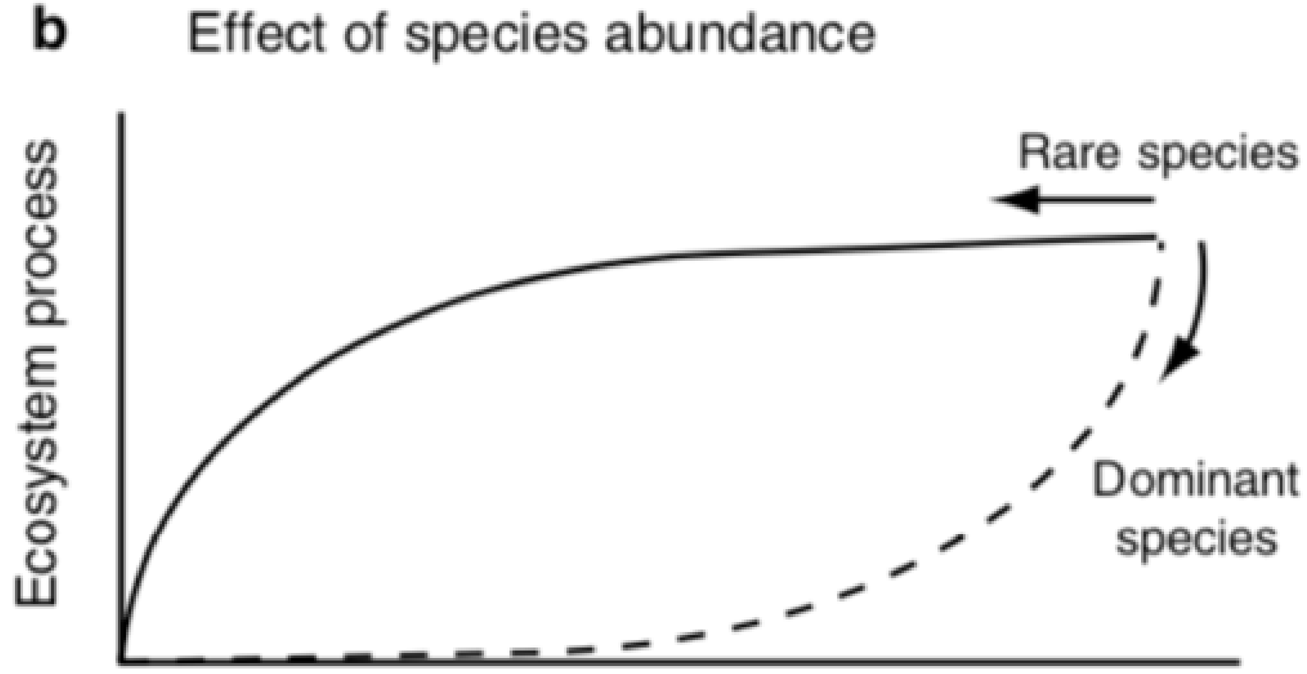


Fig. 10.9 Feedbacks by which grazing and plant defense magnify differences among sites in soil fertility. In infertile soils, herbivory selects for plant defenses, which reduce litter quality, decomposition, and nutrient supply rate. In fertile soils, herbivory speeds the return of available nutrients to the soil. Based on Chapin (1991b)

Species-level impacts

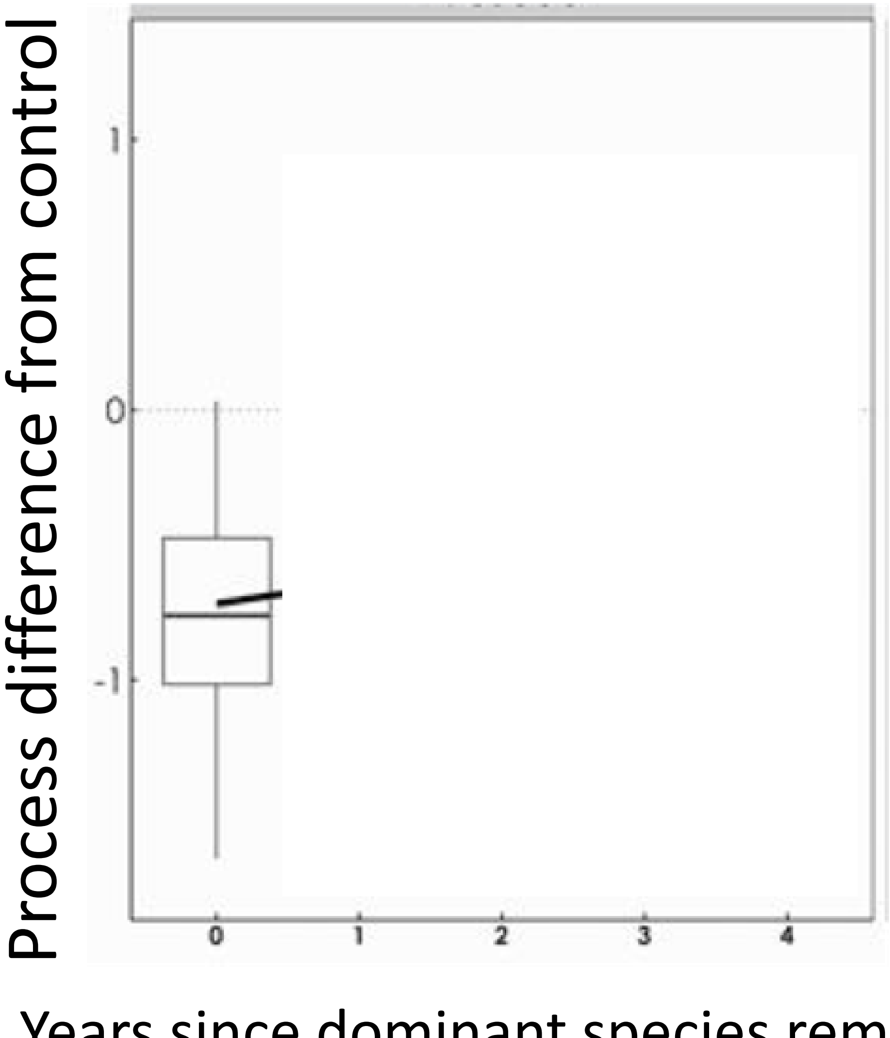
Some species have larger impacts on ecosystem processes than others. Agree/disagree? Why?

Dominant species drive ecosystem processes



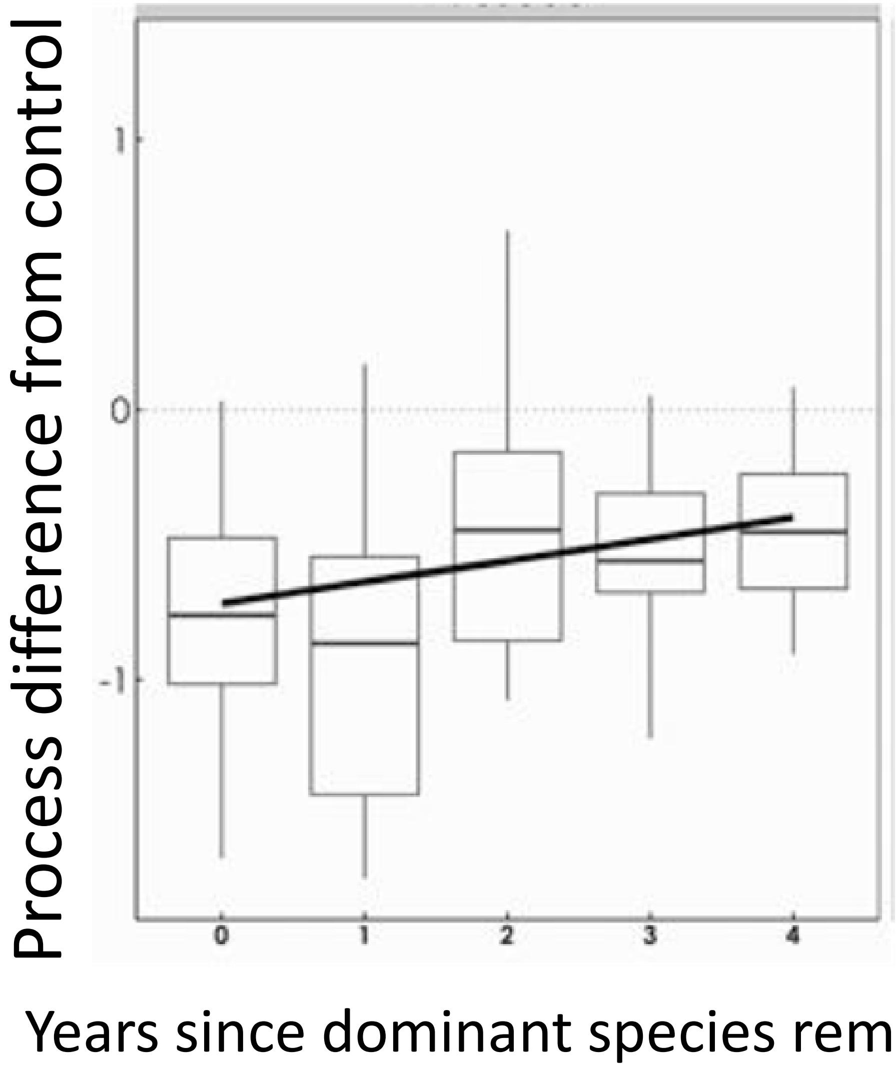
Species Richness

Effect might be dependent on time



Read et al. (2017)

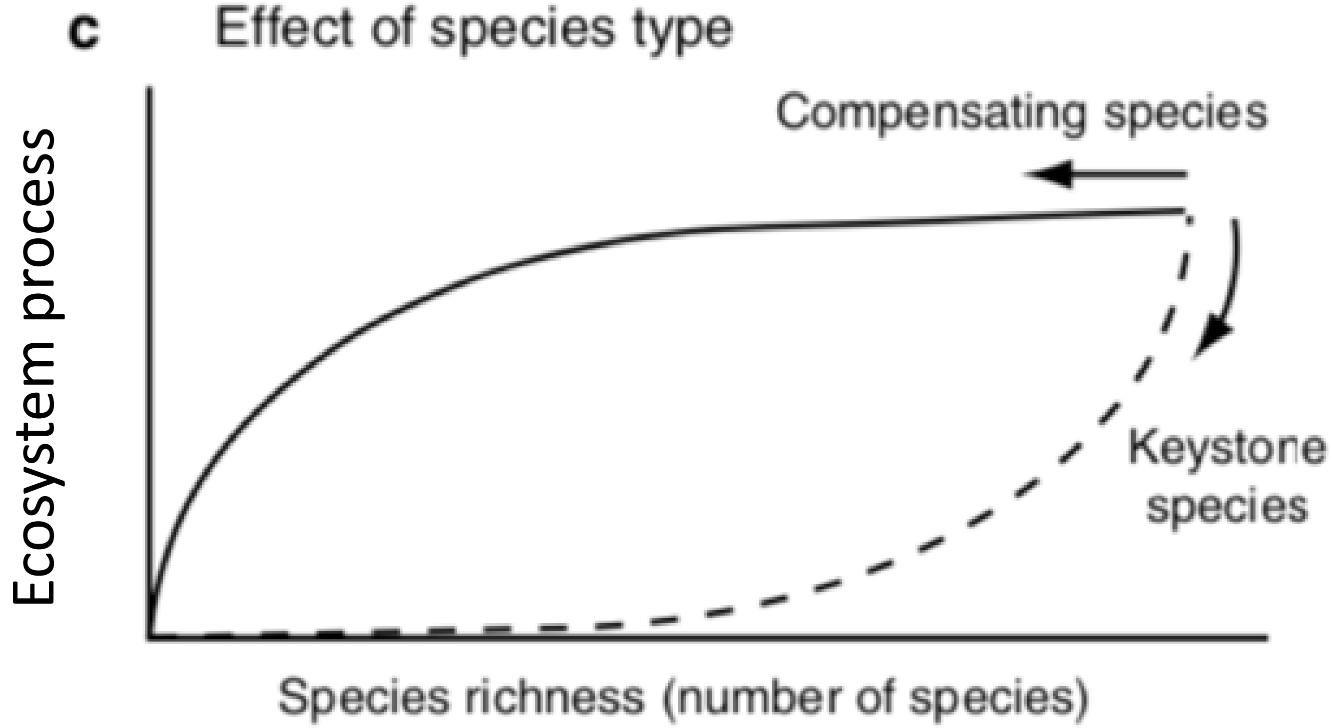
Effect might be dependent on time



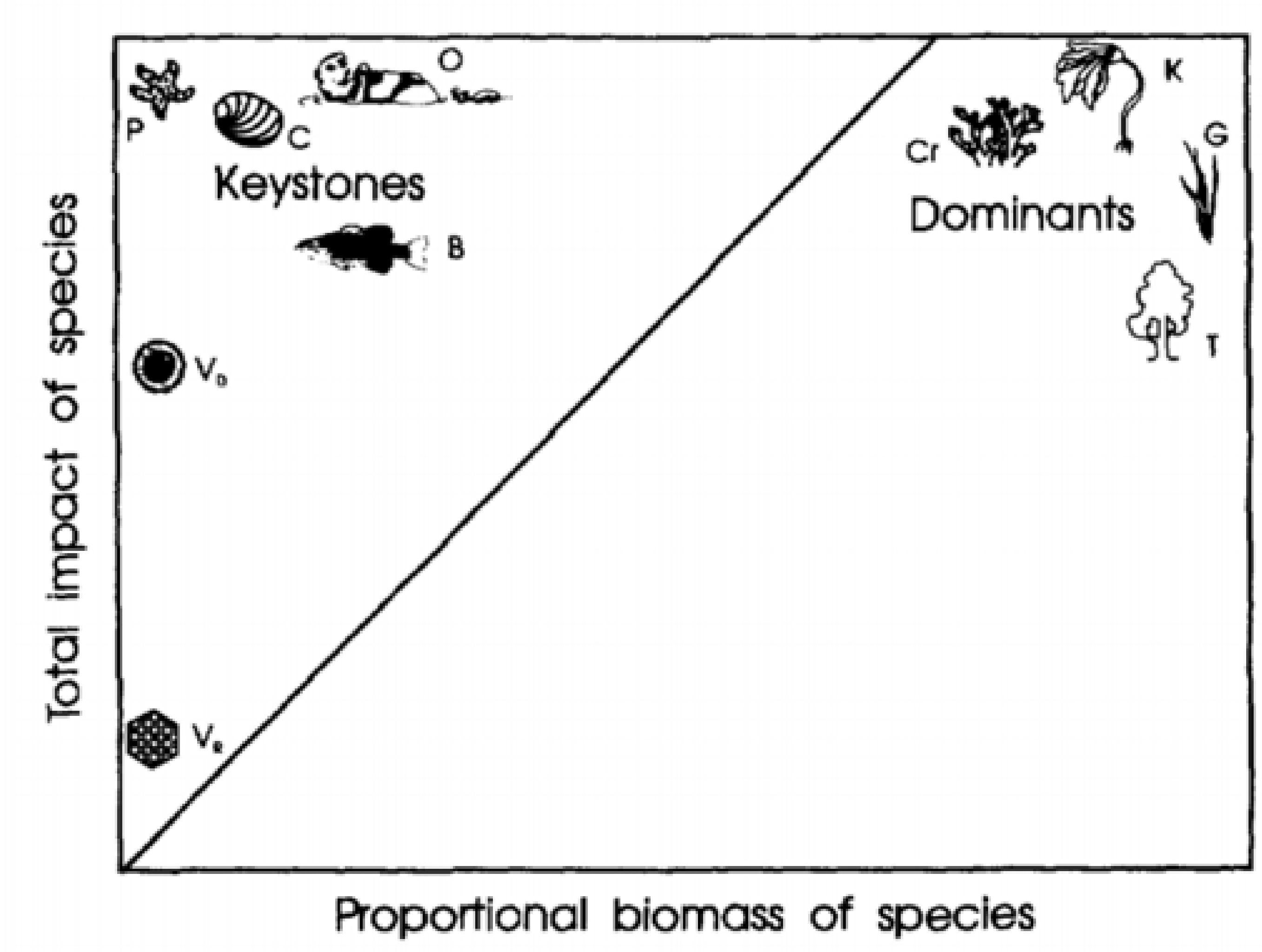
Community is filling the niche of the dominant species

Read et al. (2017)

Keystone species drive ecosystem processes



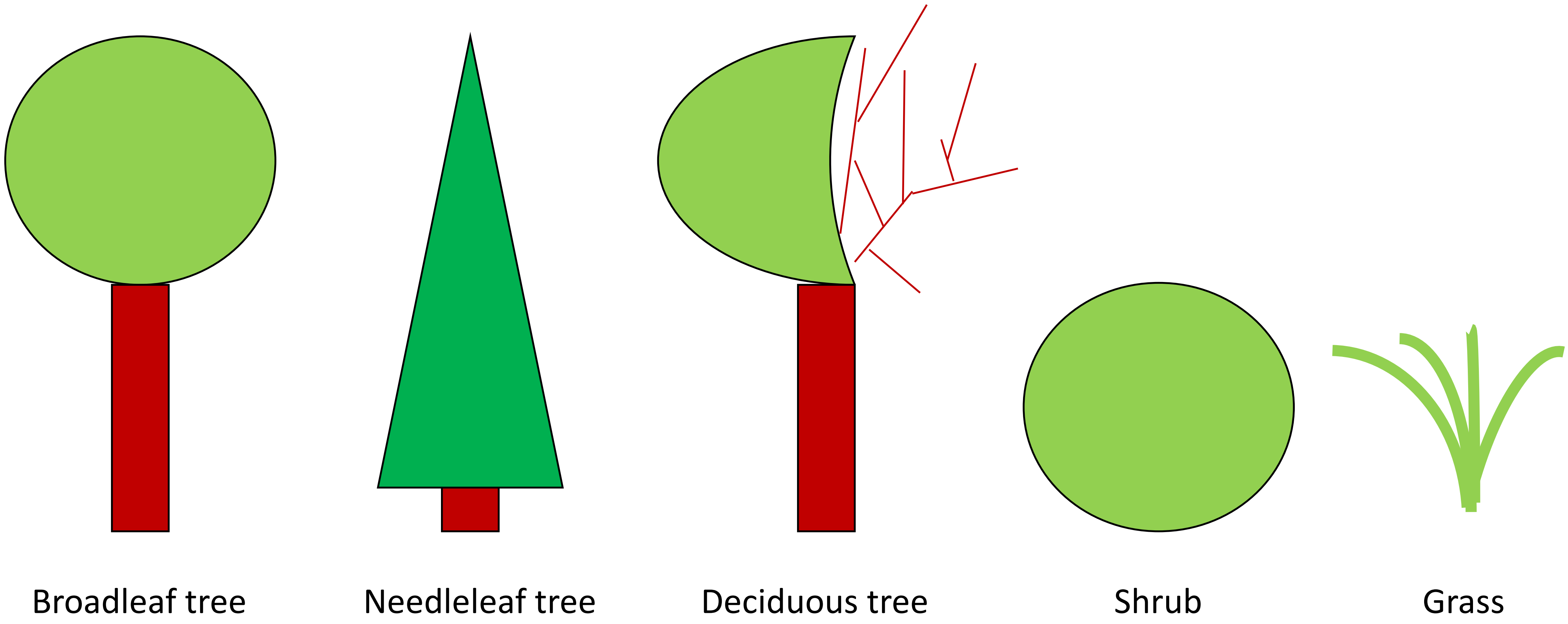
Keystones have importance that outweighs abundance



Power et al. (1996)

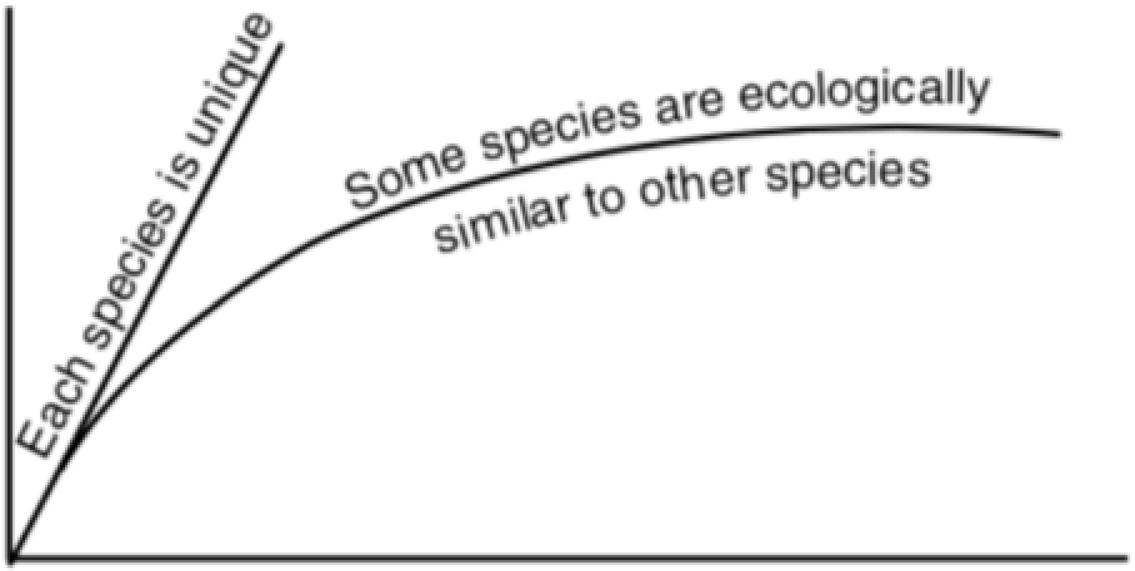
Functional types

Functional types describe the life history strategy of a species…



…and this can influence ecosystem processes…

Ecosystem Process



Number of species

…such as biomass…

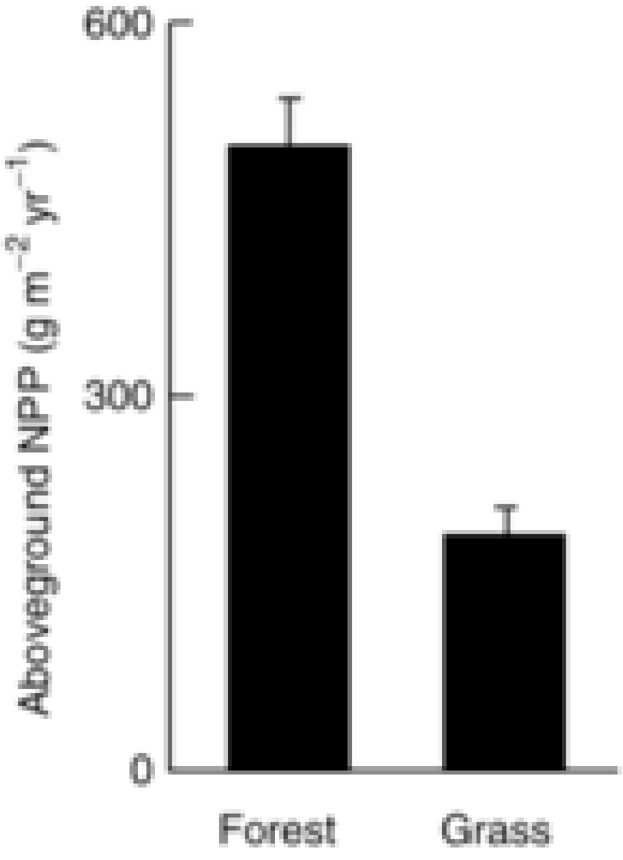


Fig. 11.4 Comparison of ecosystem processes between two exotic communities that differ in rooting depth: annual grassland and *Eucalyptus* forest in California. Data are averages ± SE (Robles and Chapin 1995)

…nutrient supply…

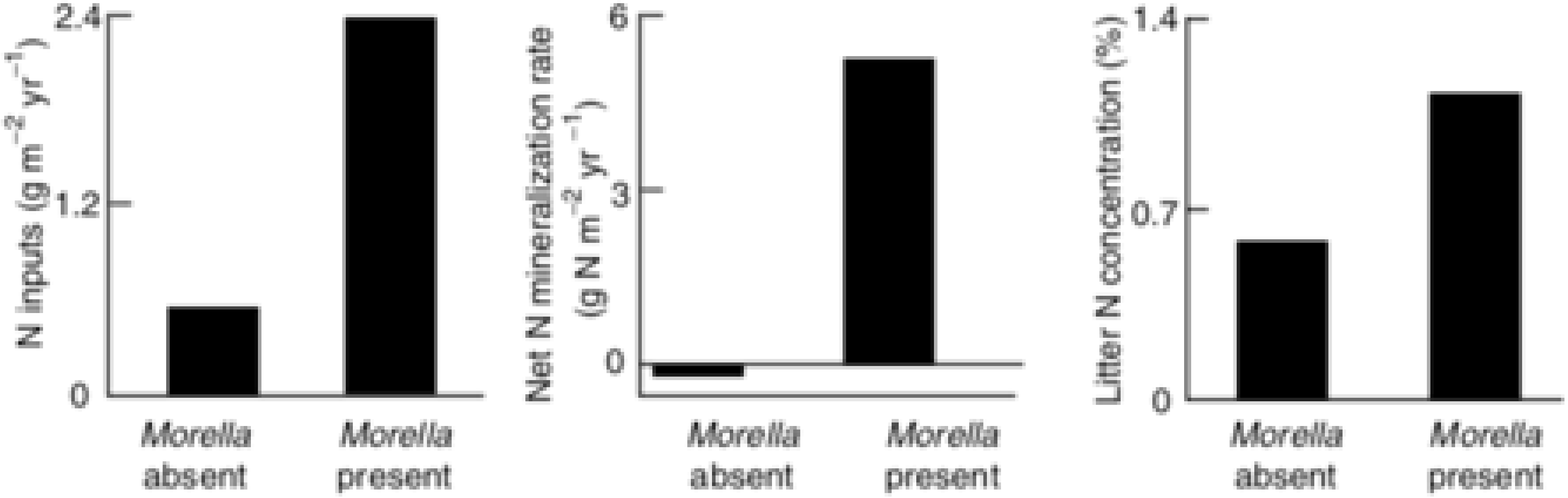


Fig. 11.3 Impact of the nitrogen-fixing tree *Morella faya* on nitrogen inputs, litter nitrogen concentration, and nitrogen mineralization rate in a Hawaiian montane forest. Data are averages ± SE (Vitousek et al. 1987)

…nutrient turnover…

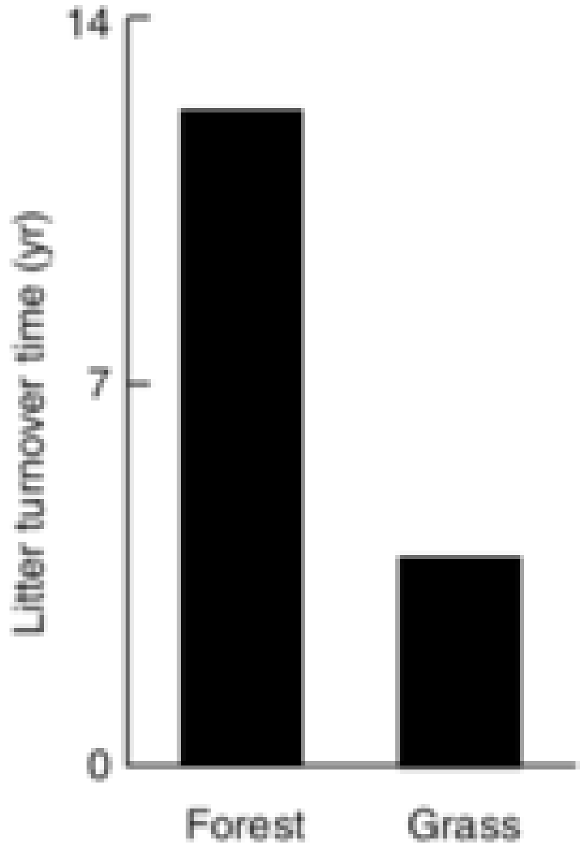
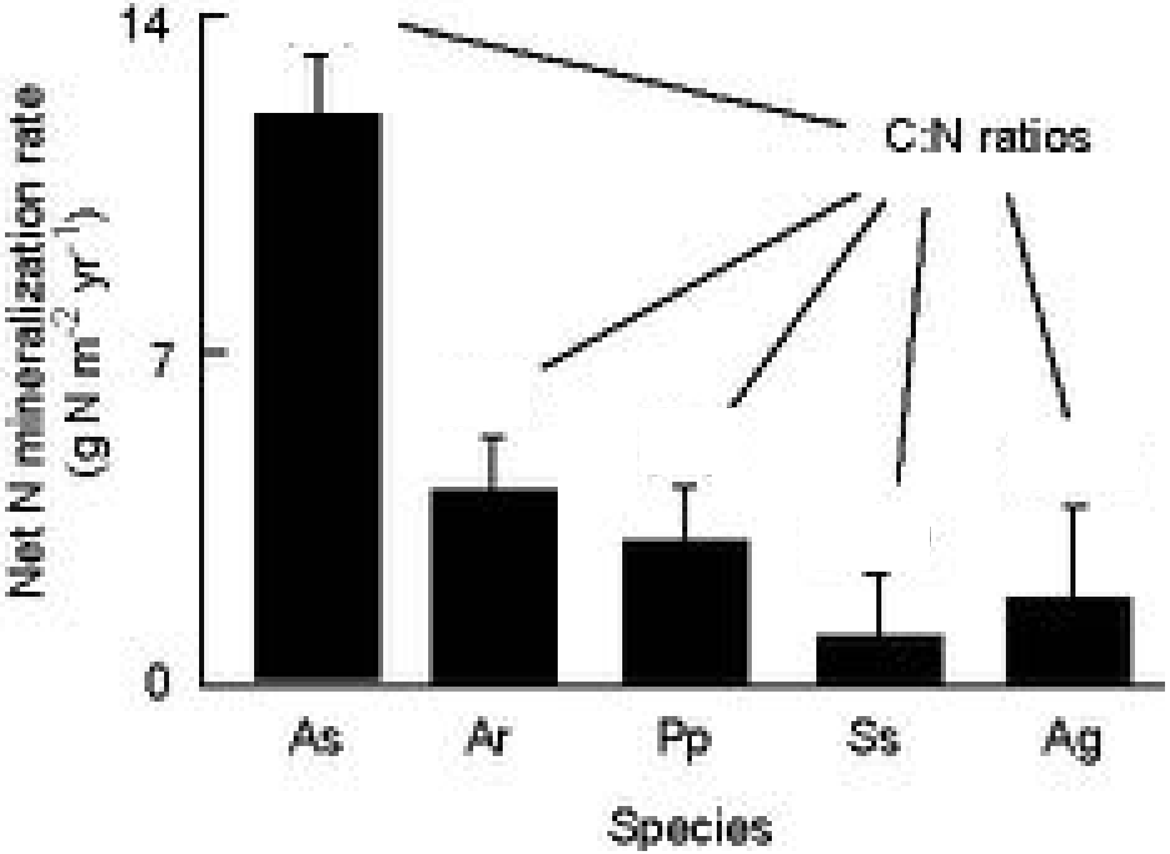
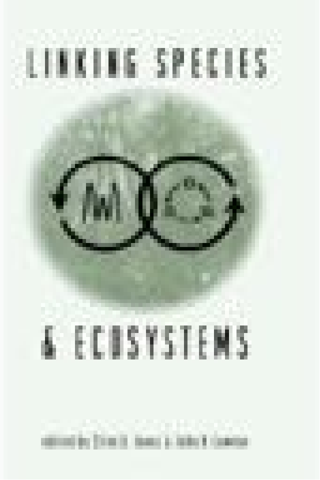


Fig. 11.4 Comparison of ecosystem processes between two exotic communities that differ in rooting depth: annual grassland and *Eucalyptus* forest in California. Data are averages ± SE (Robles and Chapin 1995)

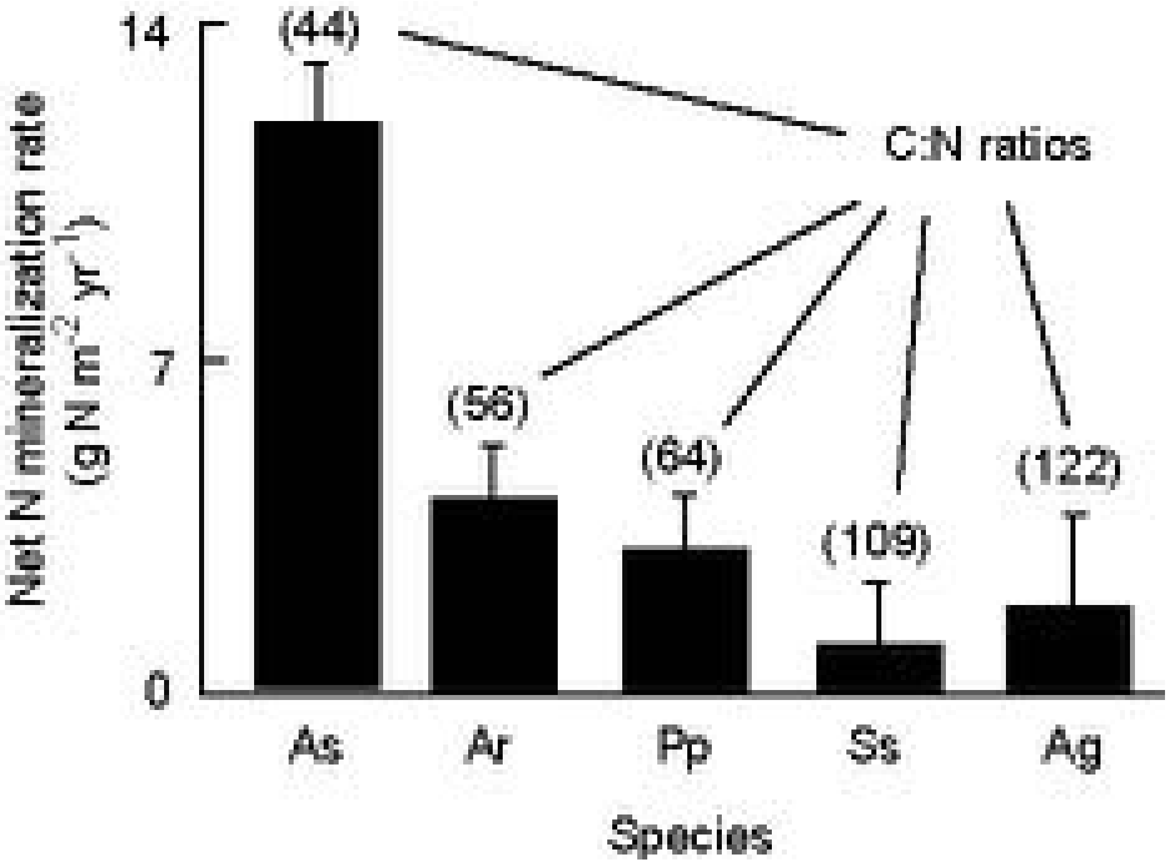
…nutrient turnover…

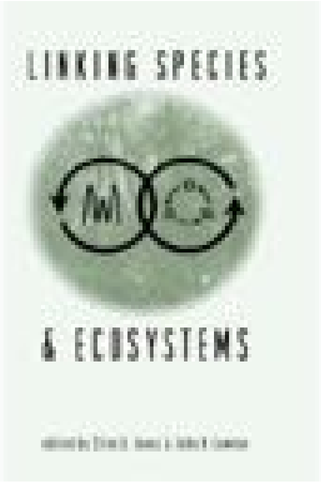




(Jones & Lawton 1995)

…nutrient turnover…





(Jones & Lawton 1995)

…biophysics…

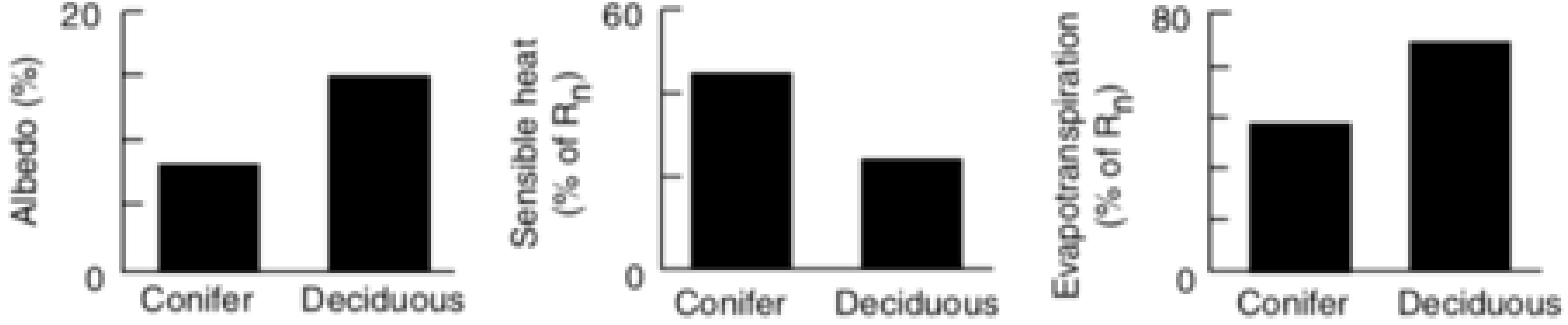


Fig. 11.6 Sensible and latent heat fluxes from deciduous and conifer boreal forests. Data are from Baldocchi et al. (2000)

…trophic dynamics…

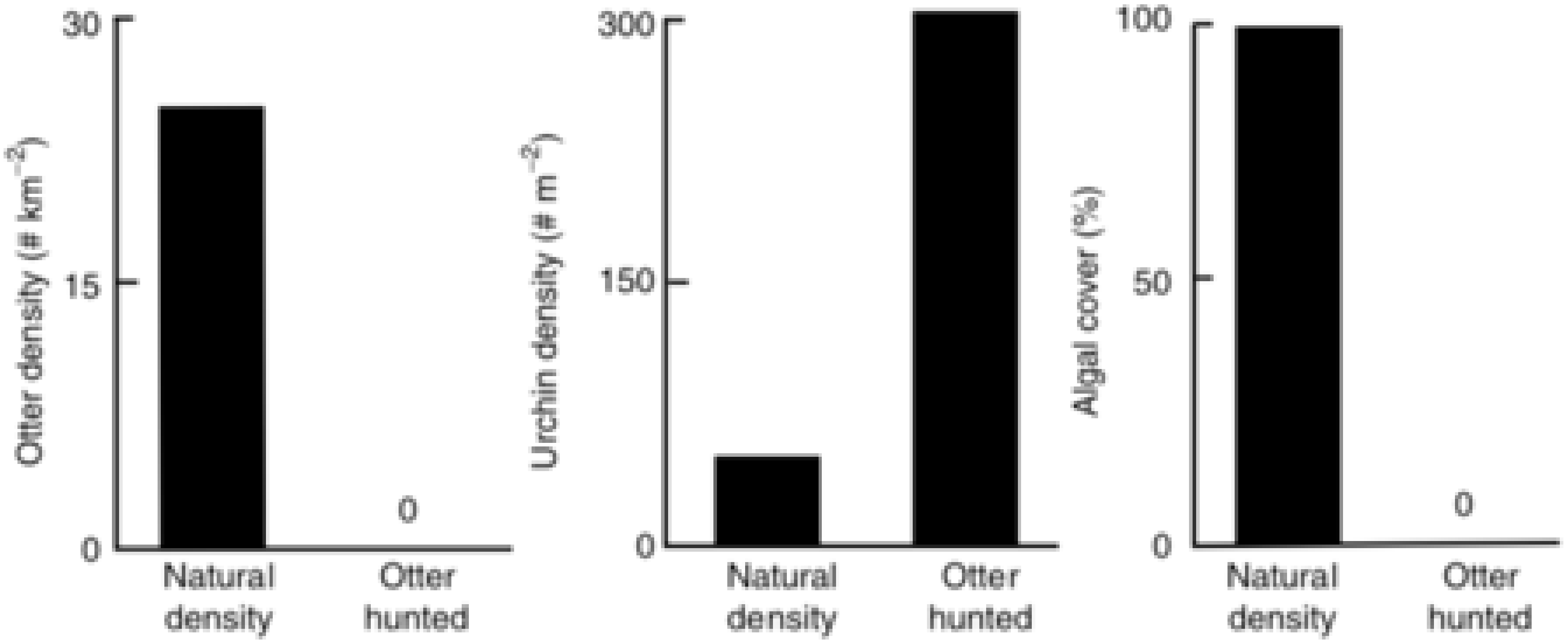


Fig. 11.7 Density of sea otters and sea urchin, and percentage cover of macroalgae in the Aleutian Islands of Alaska. Sites differed in otter density due to differential hunting pressure 300 year previously. Data are from Estes and Palmisano (1974)

…and disturbance regimes

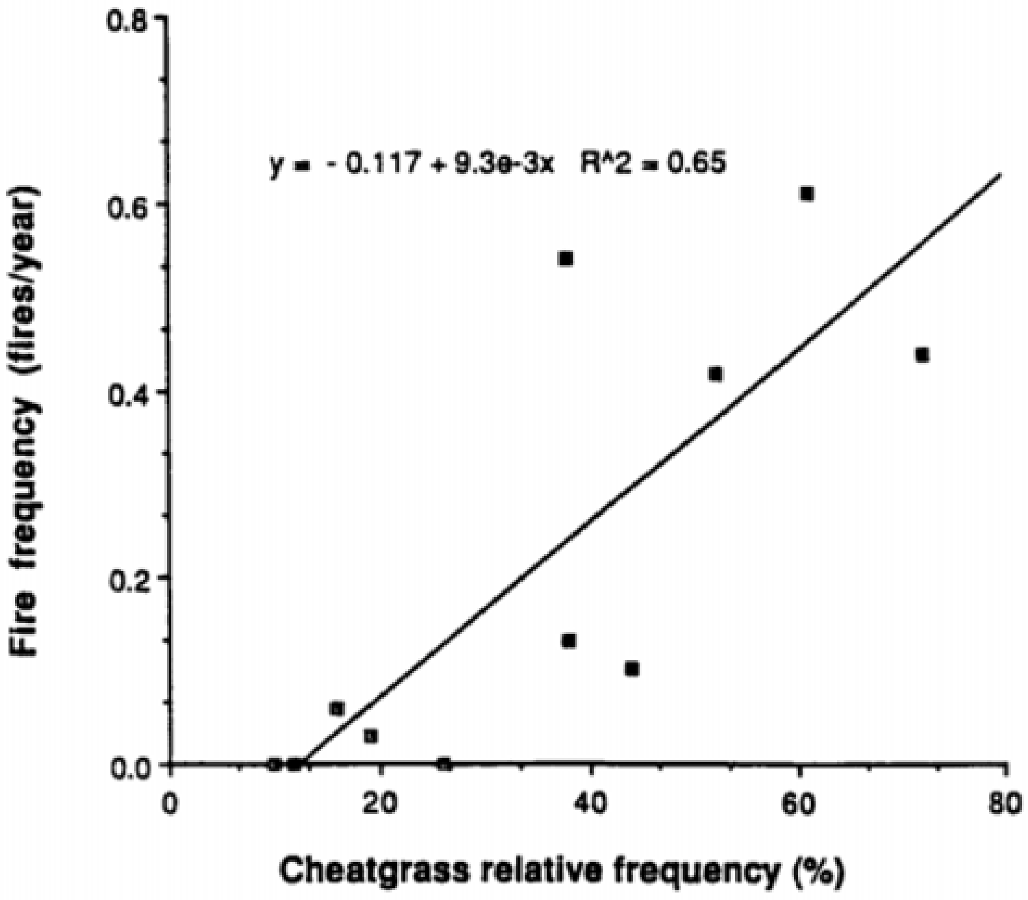


Figure 2—Relationship between relative frequency of cheatgrass in the community and fire frequency.

Bromus tectorum (cheatgrass)

Sagebrush steppe

Whisenant (1989)

Biodiversity

Biodiversity – some definitions

- Richness (R): total number of species in a given area
- Evenness (E): relative abundance of the species present
- Species diversity (D): a combination of richness and evenness (D = R * E)
  - Larger if more species
  - Larger if species are evenly distributed

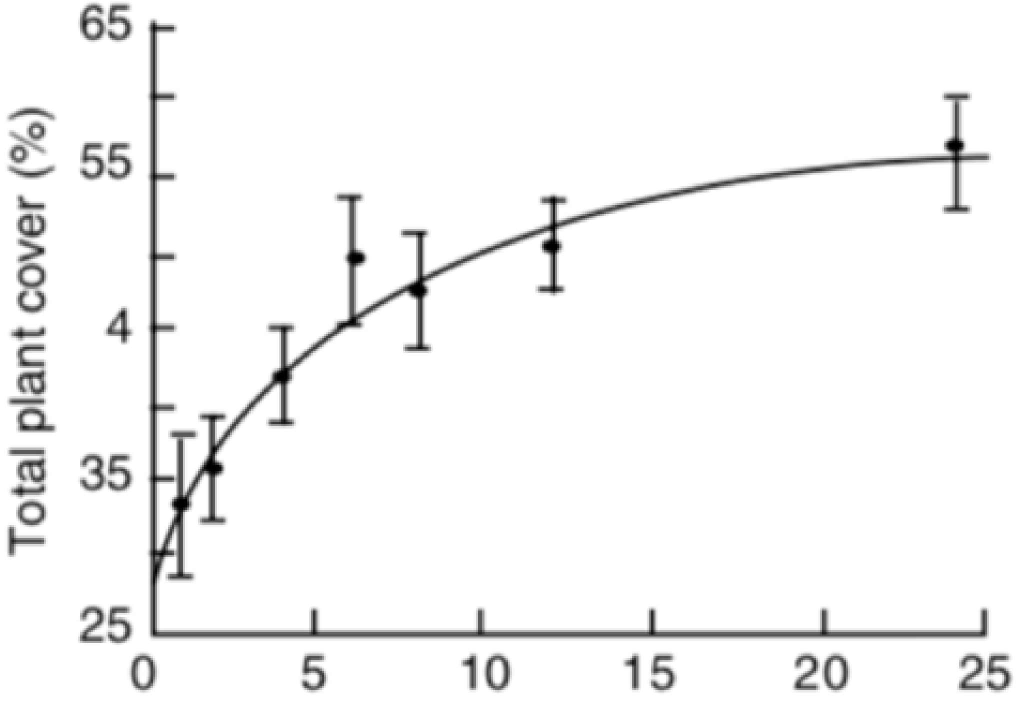
	Community A	Community B
Species 1	5	10
Species 2	60	10
Species 3	0	10

Which community has higher richness?
Which community has higher evenness?
Which community has greater diversity?

	Community A	Community B
Species 1	5	10
Species 2	5	10
Species 3	0	10

Which community has higher richness?
Which community has higher evenness?
Which community has greater diversity?

How does diversity influence ecosystem services?

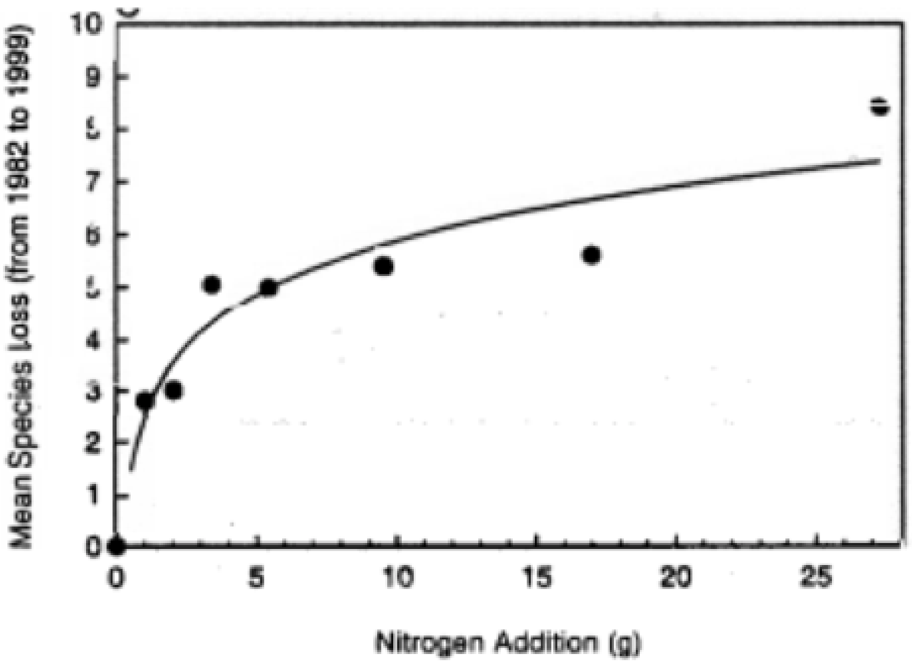


Species richness

Tilman et al. (1996)

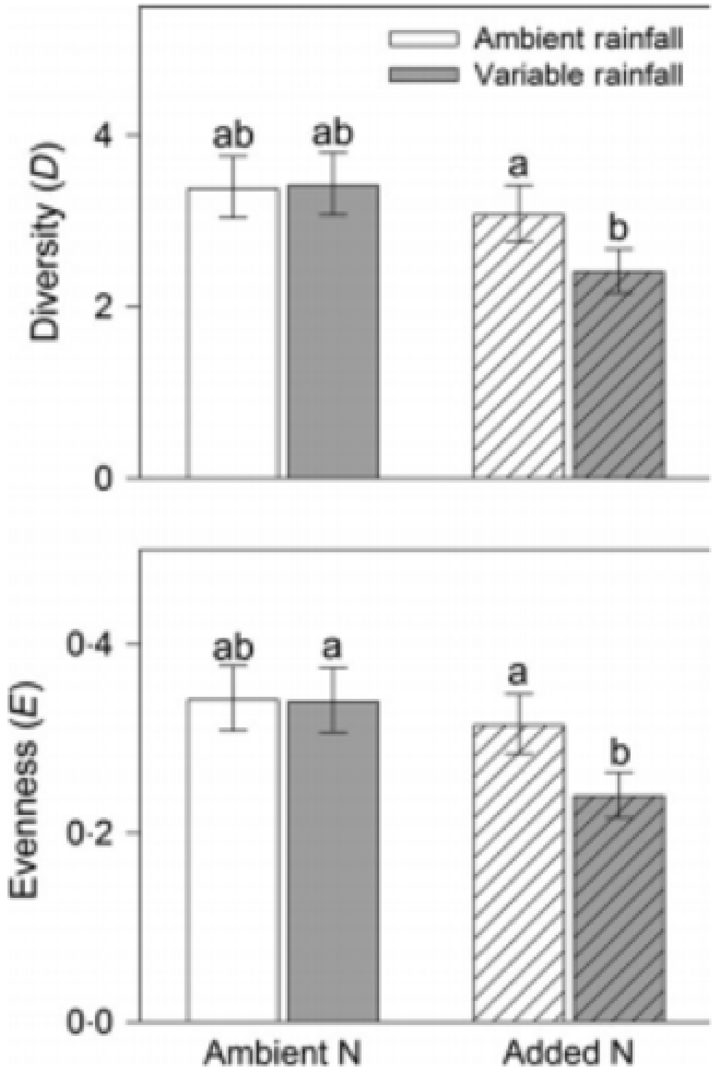
Threats to biodiversity: Eutrophication

- Competition can increase biodiversity
- Eutrophication is the increase of nutrients to natural ecosystems
  - Reduces competition
  - Enhances the dominance of a few species



N addition causes species loss in Minnesota (Tilmann et al. (1994))

Threats to biodiversity: Eutrophication



Smith et al. (2016)

Threats to biodiversity: Invasive species

- Sometimes the competitors are too good, and biodiversity decreases
- Invasive species possess traits that native species do not have
  - Enhanced tolerance
  - Fast reproduction
  - No predators
  - No competitors
- Diversity decreases invasion, invasion decreases diversity

Kudzu in SW US

Take home: to fully understand ecosystem processes, we need to understand the underlying species level processes