Species Abundance and Diversity

• Terms

  – Community – an association of different species in a particular area

  – Community Structure – refers to kinds of species in a community along with things such as their abundance and relative abundance

  – Guild – a group of organisms that all “make a living” in the same ecological manner (ie fruit eating birds, seed eating mammals, filter feeders in a stream) – may be closely related species or can differ significantly

  – Life Form – the plant equivalent of a guild (ie tree, shrub, grasses, mosses etc.)
• **Species Abundance and Diversity**

• **Log Normal Distribution**
  - Preston – viewed abundance in a relative fashion, where one species is 2X more abundant than another – after doing this he plotted his data on a $\log_2$ scale, using the number of species in each class – upon doing this he observed that he had produced normal graphs

![Lognormal distributions of (a) desert plants, and (b) forest birds.](image)
Species Abundance and Diversity

Many data sets show only a partial bell curve – it is believed that this is a factor of small sample size – the more data the graph fills in and resembles a bell shaped curve. It takes a great deal of effort to do this.

In general, taking larger samples will show more of a lognormal distribution.

For instance, a sample of 87,000 moths from the Canadian prairie reveals only part of the lognormal distribution.

A sample of 300,000 moths reveals more of the distribution.

Sample size and the lognormal distribution.
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- **Terms**
  - Species Diversity – composed of two factors
    - Species Richness – number of species in a community
    - Species Evenness – relative abundance of each species

**Species evenness and species diversity.**

Communities $a$ and $b$ both contain five tree species. However, because community $b$ has greater species evenness, it has higher species diversity.

Community $a$ is dominated by one of its five species and so has lower species diversity than...

...community $b$, which has the same five species but in equal proportions.
Species Abundance and Diversity

- Index of Species Diversity – there are many kinds of these indexes, a common one is the Shannon-Weiner Index

\[ H' = \text{the diversity index} \]

\[ p_i = \text{the proportion of the } i^{\text{th}} \text{ species} \]

\[ \log_e = \text{natural log} \]

\[ s = \text{number of species in the community} \]

\[ H' = - \sum_{i=1}^{s} p_i \log_e p_i \]
Table 16.1

Calculating species diversity ($H'$) for two hypothetical communities of forest trees

**Community a**

<table>
<thead>
<tr>
<th>Species</th>
<th>Number</th>
<th>Proportion ($p_i$)</th>
<th>$\log_e p_i$</th>
<th>$p_i \log_e p_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21</td>
<td>0.84</td>
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$$H' = -\sum_{i=1}^{s} p_i \log_e p_i = 0.662$$

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Species Abundance and Diversity

- Rank Abundance Curves – diversity can be visualized by plotting proportional abundance vs abundance rank

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These rank–abundance curves show that community a is dominated by one of five tree species, while the five species in community b are present in equal proportions.

Greater evenness indicated by lower slope.
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Rank–abundance curves for caddisflies, order Trichoptera, of two aquatic habitats in northern Portugal.

These rank–abundance curves show that the mountain stream caddisfly community has higher species richness and greater species evenness.

Proportional abundance

Abundance rank

Mountain stream
Greater richness and species evenness.

Coastal ponds
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Rank–abundance curves for two reef fish communities

The fish community of the central Gulf of California is more diverse mainly because it has higher species evenness.

Central Gulf
Greater evenness, slightly higher richness

Northern Gulf
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- Forest Complexity
  - MacArthur (1958) – studied the relationship between the volume of vegetation above 6 m and the abundance of warblers – he found that the number of species increased with an increase in foliage volume – he observed a similar relationship upon looking at foliage height diversity.
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• Niches, Heterogeneity and the Diversity of Algae and Plants – at first glance algae and plants present what appears to be a contradiction – Why don’t algal communities and tree stands become monotopic?

• Niches of Algae and Terrestrial Plants
  
  – Tilman (1977) – found that two species of diatoms can appear to coexist, violating the competitive exclusion principle – the reason for this is the availability of silicon dioxide and phosphate
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The ratio of silicate ($\text{SiO}_2$) to phosphorus ($\text{P}$) and competition between the diatoms *Asterionella formosa* and *Cyclotella meneghiniana*.

- **Asterionella** dominates where phosphorus is most limiting to population growth.
- The two species coexist where the population of each is limited by a different nutrient.
- **Cyclotella** dominates where silicate is most limiting to population growth.

The graph shows the flow rate (turnover per day) on the y-axis and the nutrient ratio (Si/P) on the x-axis, with different color-coded regions indicating dominance and coexistence of the two species.
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- Complexity in Plant Environments
  - Lebo (1993) – found a large degree of variation in a lake with respect to nutrient distribution

Concentrations (µg/L) of nitrate (NO₃) and silicate (SiO₂) in the surface waters of Pyramid Lake, Nevada.

- The concentration of NO₃ varies more than fourfold across Pyramid Lake.
- Silicate concentrations also vary substantially across the lake.
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- Similar results were observed in agricultural fields by Robertson (1988)

*Variation in nitrate (NO$_3$) and soil moisture in a 4.761 m$^2$ area in an old agricultural field.*
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- Soil and Topographic Heterogeneity and the Diversity of Tropical Forest Trees

Variation in vegetation along a gradient of soil and moisture conditions.

Changes in soil type and depth to groundwater produce differences in vegetation over short distances.

Compare with our studies at Mohonk
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- Algal and Plant Species Diversity and Increased Nutrient Availability
  - The rule is that, as nutrient availability increases, species diversity decreases

When nutrient levels are high a few specialists can outcompete the others
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• Question – How can there be such a large amount of diversity in areas that appear so similar, i.e. rain forests? The answer lies in disturbance.

• The Nature and Sources of Disturbances – hard to define since organisms in an area are adapted to exist in an average environment that may have a large range
  
  – White and Pickett (1985) – define disturbance as any event that disrupts the ecosystem, community, or population

• Intermediate Disturbance Hypothesis –
  
  – Connell (1975, 1978) proposed that it is the constant intermediate disturbance that maintains species diversity
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The intermediate disturbance hypothesis.

The hypothesis predicts that species diversity will be highest at intermediate levels of disturbance.

High levels of disturbance reduce diversity.

Low levels of disturbance allows competition to reduce diversity.
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- Disturbance Diversity in the Intertidal Zone – periodic high waves turn over boulders, obviously size is a factor – although competing for a single resource, space, exclusion is prevented by intermediate disturbance (Sousa 1979)
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- Disturbance and Diversity in Temperate Grasslands (Tilman 1994)

Disturbance by prairie dogs and patchiness of vegetation.

Prairie dog colonies dot the landscape of Wind Cave National Park.

Disturbance by prairie dogs creates distinctive patches of vegetation.

Wind Cave National Park

Prairie dog colony

Forb/shrub

Grass

Grass/forb

Uncolonized grassland

Disturbance by prairie dogs and plant species diversity.

Plant species diversity is highest at intermediate levels of disturbance, which allows a high diversity of both grass and forb species.
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- Human Disturbance

Pollen and charcoal in Lake Wodehouse indicate a human presence and agriculture around the lake beginning after 3,900 BP.

Pollen and spores of plants associated with disturbance increases after 3,900 BP.

Corn pollen appears in sediments after 3,900 BP.

Particulate carbon also increases substantially after 3,900 years BP.