**Diversity of Ecological Communities**

**Species Number, Richness, Diversity**

**Species Abundance Patterns**

**Geography of Species Number**

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**Species Diversity**

**Diversity: Measure Variability of Identity**

**"Qualitative Variance"**

**Species (Taxon): *Qualitative* Identity**

**Species Diversity of Community:**

***Variability Of identity, by Species,***

***Among Individuals in Community***

**Estimate Diversity (Variability by Identity)**

**S:** ***Species Number*** **(simplest)**

**R:** ***Species Richness*****, Sample N Individuals**

**$R = S/N^{1/2}$ $R = (S - 1)/\ln N$**

**Species Diversity:**

1. **Species *Number***
2. ***Relative Abundances* of Species**

**Scalar Diversity Estimate**

$$H' = -\sum_{i=1}^{S} p_i \ln(p_i)$$

**Species i = 1, 2, ..., S**

**$p_i$ Proportional Abundance Sp i**

**$N_i$ individuals, species i; i = 1, 2, …, S**

| | |
|---|---|
| **Total individuals** | $N = \sum_{i=1}^{S} N_i$ |
| **Relative abundances** | $p_i = N_i / N$ |

$$H' = -\sum_{i=1}^{S} p_i \ln(p_i)$$

**ln: Base e; log: Base 10**

**$N_1$ = 50, $N_2$ = 30, $N_3$ = 20**

**N = 100 Total individuals**

**$p_1$ = 0.5, $p_2$ = 0.3, $p_3$ = 0.2**

**N.B., $p_i$ sum to unity**

$\ln p_1 = \ln 0.5 = -0.693$ $\ln p_2 = \ln 0.3 = -1.024$

$\ln p_3 = \ln 0.2 = -1.609$

$p_1 \ln p_1 = (0.5)(-0.693) = -0.347$

$p_2 \ln p_2 = (0.3)(-1.024) = -0.361$

$p_3 \ln p_3 = (0.2)(-1.609) = -0.322$

$$H = -[-0.347 - 0.361 - 0.361] = 1.03$$

max $H = \ln S = \ln 3 = 1.099$

**Each species' relative abundance 1/S**

**Evenness** $= J = H/(\max H) = H/\ln S = 1.03/1.099 = 0.937$

**H, J: "Numbers"**

***Only useful if compare communities meaningfully***

$$H' = -\sum_{i=1}^{S} p_i \ln(p_i)$$

## Physics: Negative of Entropy

Entropy: Disorder

Second Law Thermodynamics:

Open Systems Lose Energy, More Disordered

Different States Equally Likely

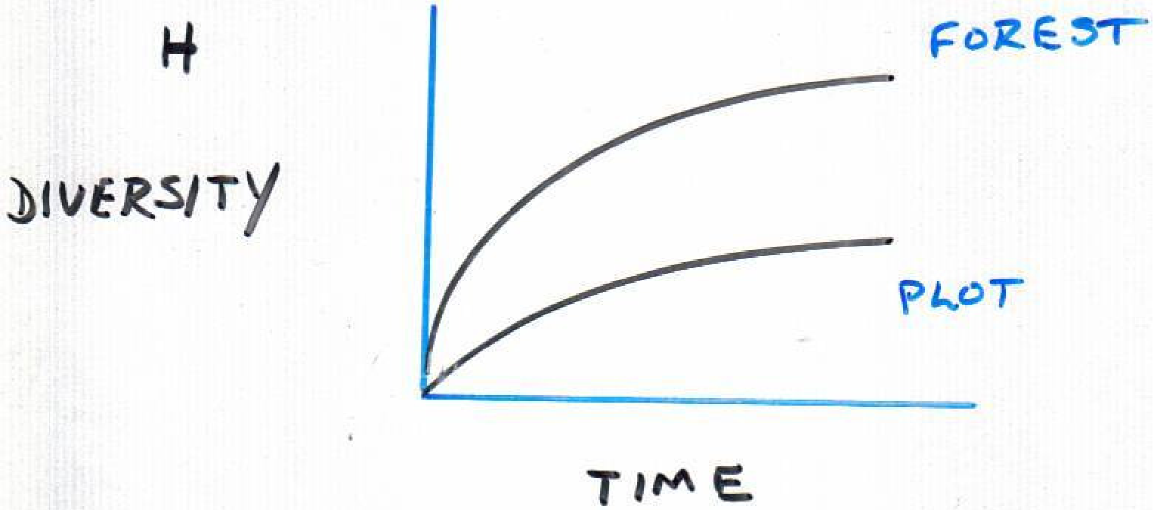
## Comunication Theory

Sequence of Symbols; Guess Next?

**Ecology**: Identity, Next Individual Sampled from Community

Diverse Community, Identity Uncertain

Many Diversity Indices




"PATCHINESS", SPATIAL VARIABILITY INCREASES

GENERALIST SPP REPLACED BY MORE SPECIALIZED SPP DURING SUCCESSION

**Species Abundance Patterns**

*Niche Preemption*

Small communities, harsh environments

Extreme weather, low-nutrient, serpentine soils

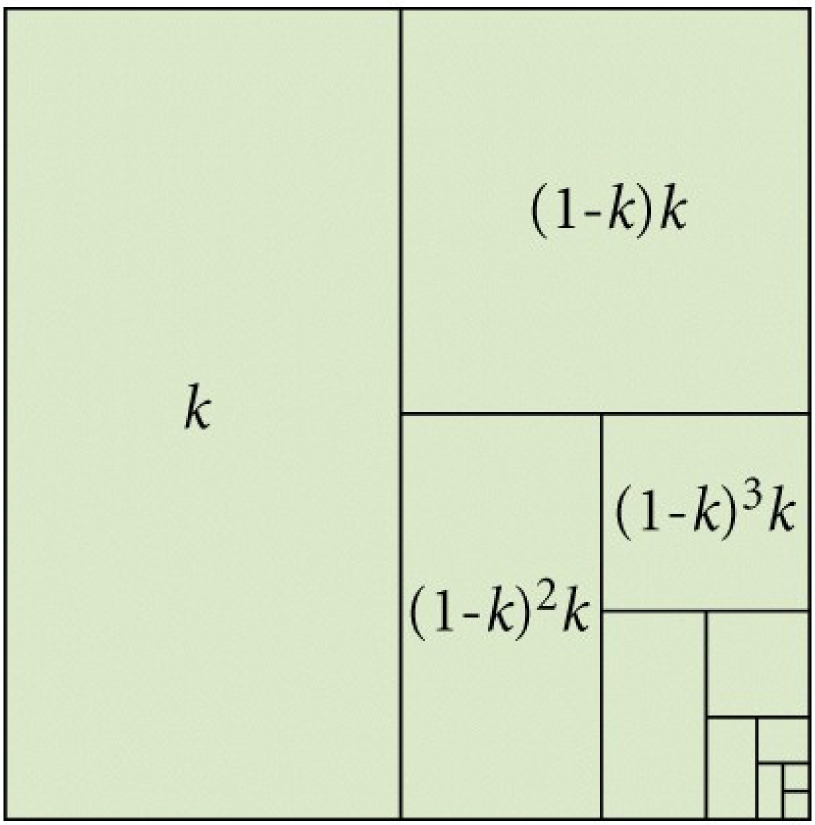
*Each species takes fraction k of available resource*

(As if) Species arrive sequentially

Available resource declines

Relative abundance sp i = fraction of resource acquired

Niche preemption of total resource




Proportional abundance of i-th ranked species

$$p_i = k\left(1-k\right)^{i-1} \quad ; i = 1, 2, \ldots$$

Geometric series

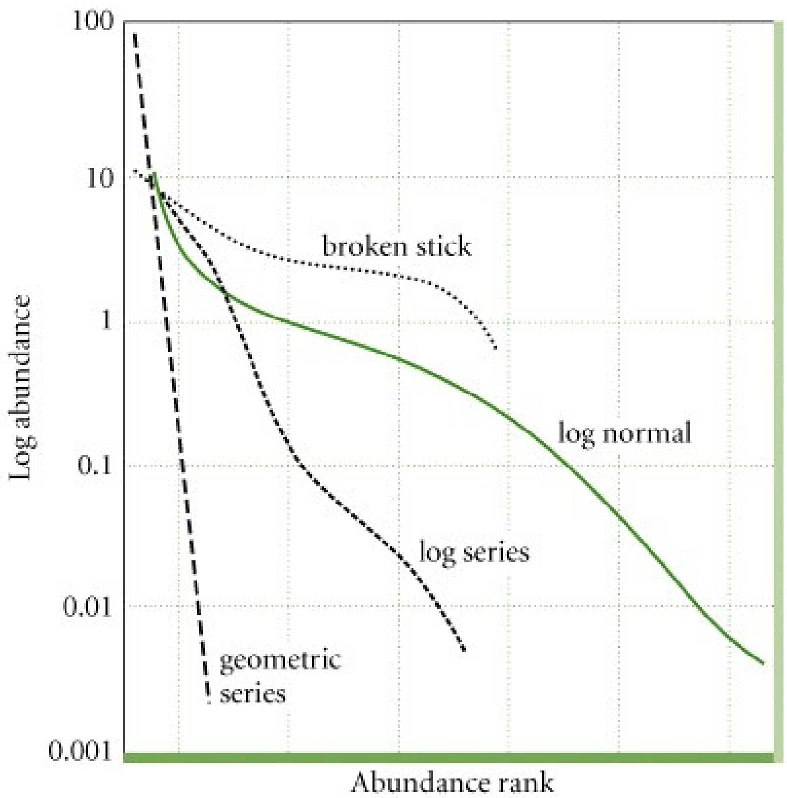
**Importance Plot**

*Ln Importance*

Relative abundance, biomass, …

*Rank abundance*

1 (most common), 2, … , S (least common)

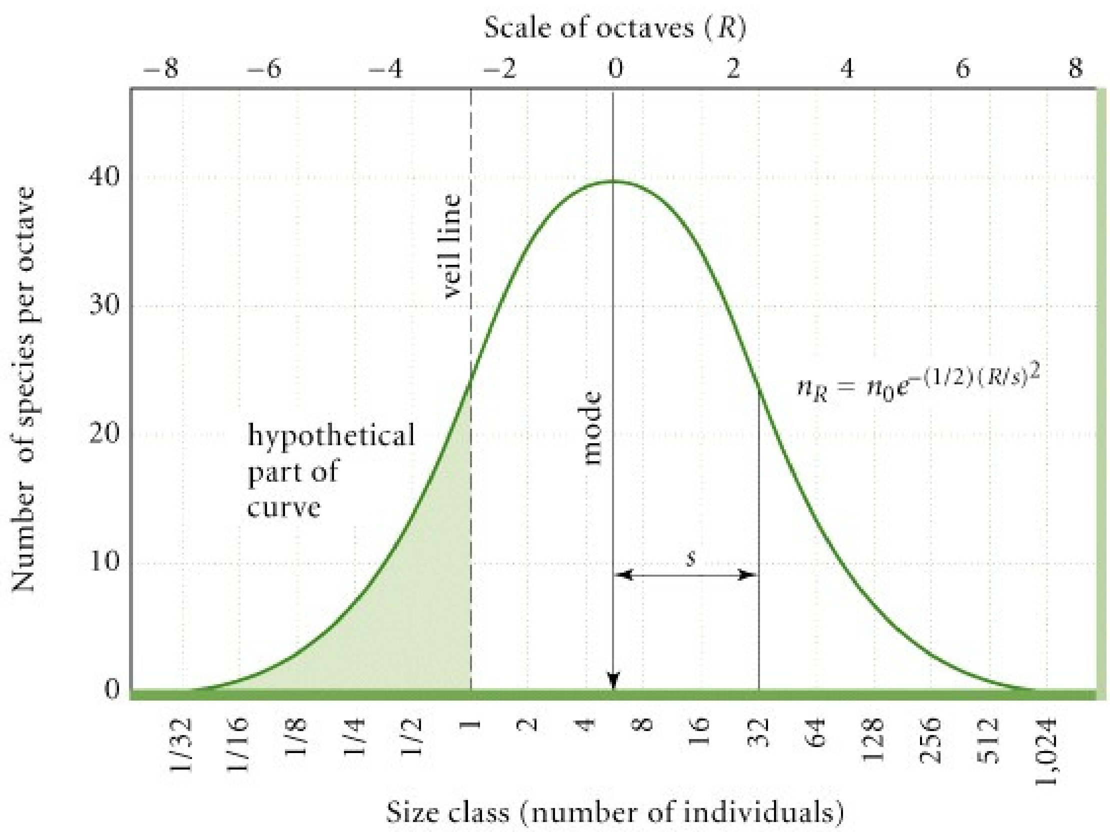


*Lognormal abundance*

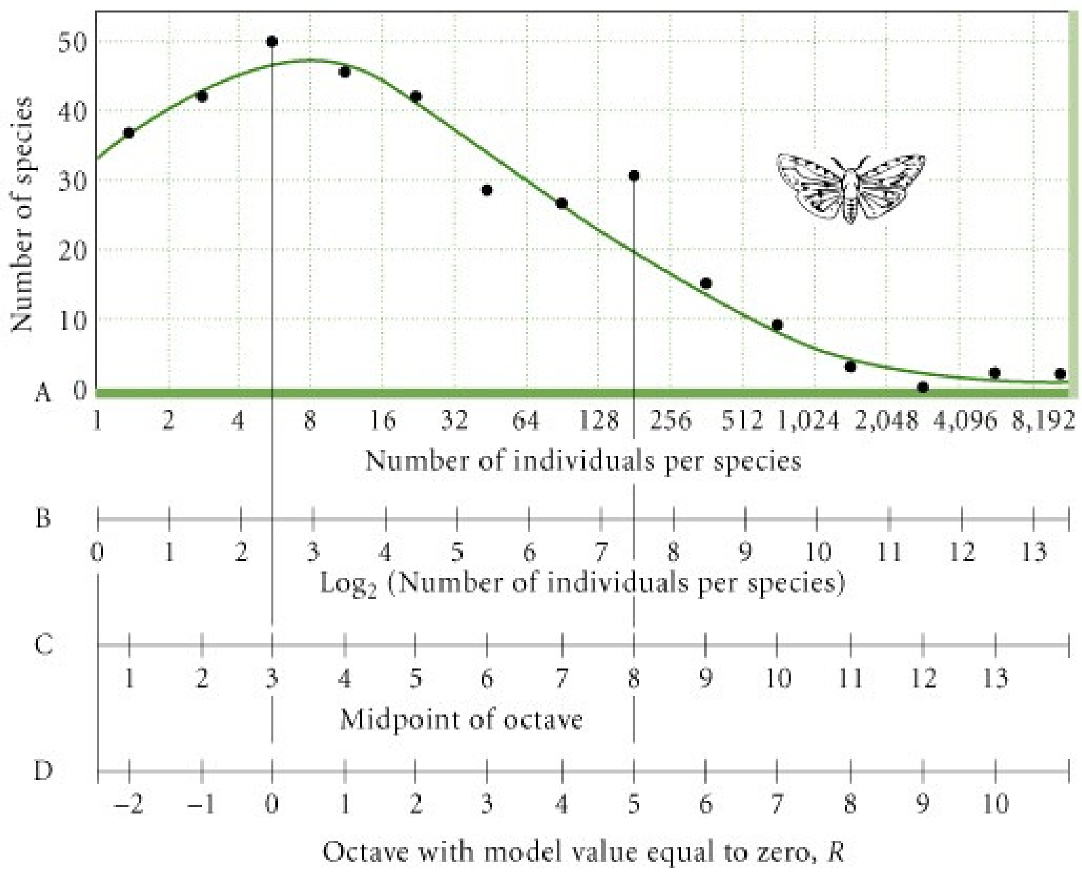
Large communities, productive environments

Biotic interactions important

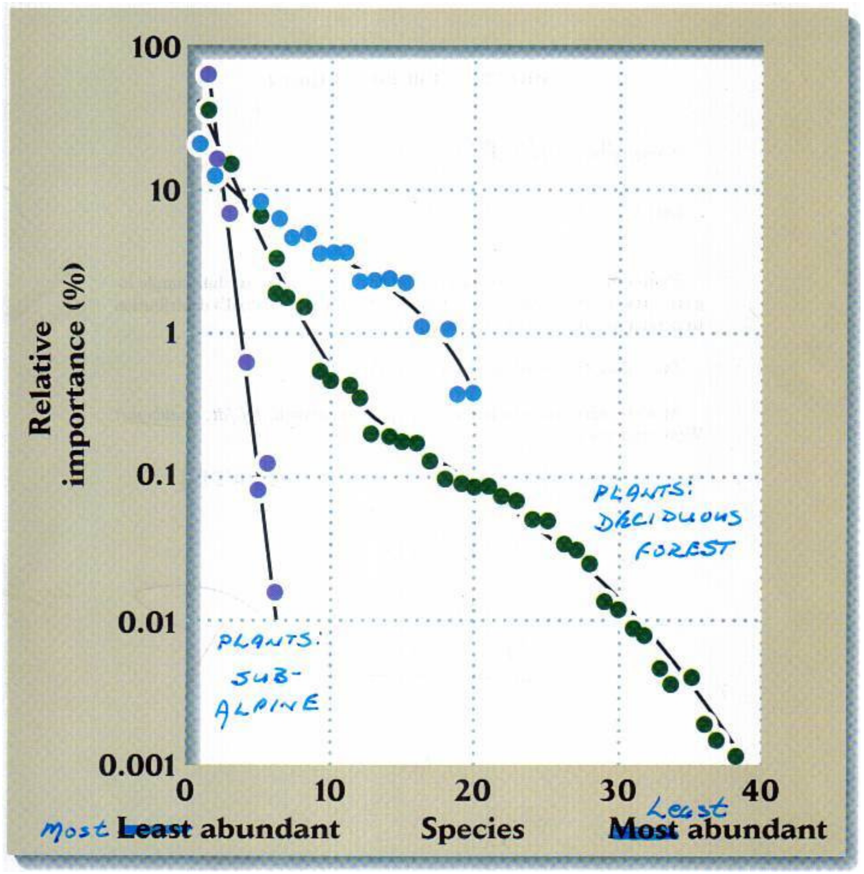
Count (estimate) number of species in different abundance classes




Note abscissa logarithmic, ordinate linear




Compare importance plots: space & time




Harsh environment: Fewer species, less evenness;

linear importance plot

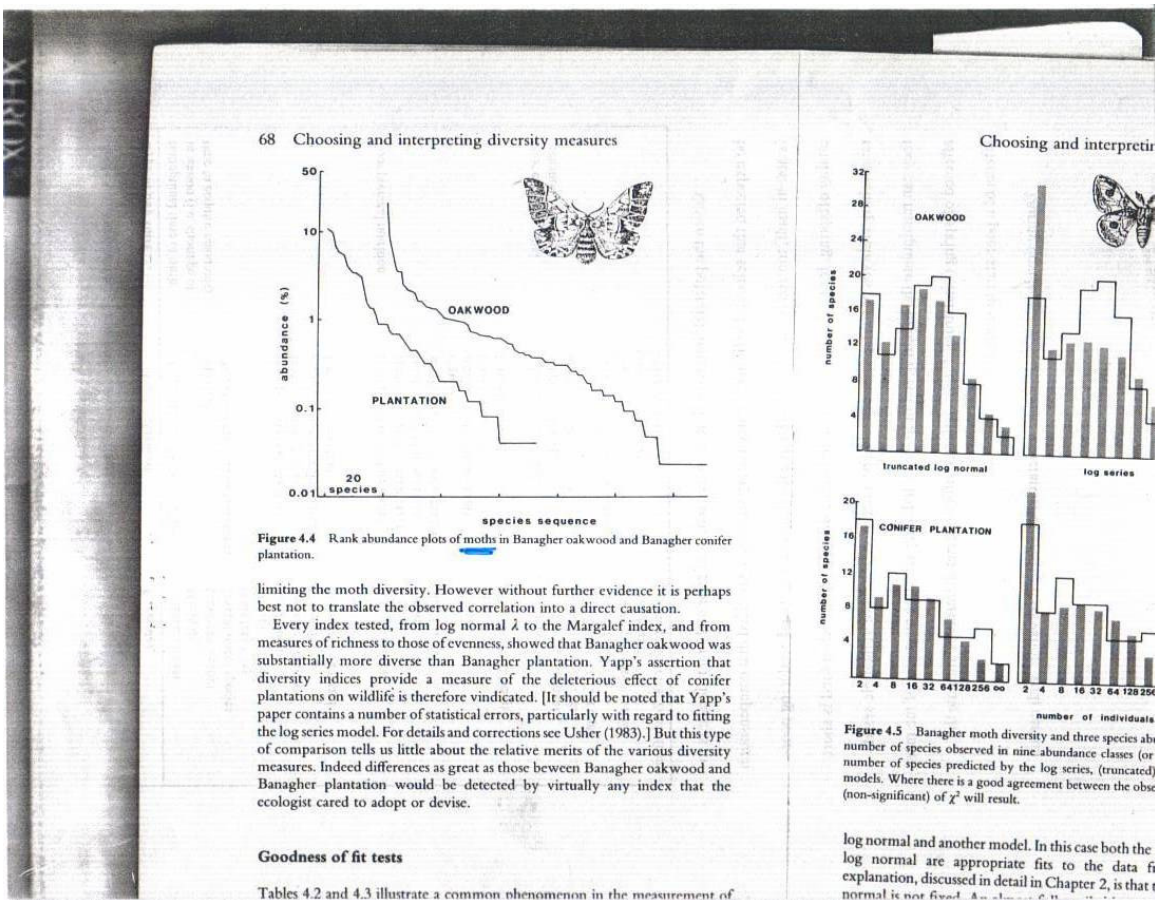

68 Choosing and interpreting diversity measures



**Figure 4.4** Rank abundance plots of moths in Banagher oakwood and Banagher conifer plantation.

limiting the moth diversity. However without further evidence it is perhaps best not to translate the observed correlation into a direct causation.

Every index tested, from log normal $\lambda$ to the Margalef index, and from measures of richness to those of evenness, showed that Banagher oakwood was substantially more diverse than Banagher plantation. Yapp's assertion that diversity indices provide a measure of the deleterious effect of conifer plantations on wildlife is therefore vindicated. [It should be noted that Yapp's paper contains a number of statistical errors, particularly with regard to fitting the log series model. For details and corrections see Usher (1983).] But this type of comparison tells us little about the relative merits of the various diversity measures. Indeed differences as great as those beween Banagher oakwood and Banagher plantation would be detected by virtually any index that the ecologist cared to adopt or devise.

**Goodness of fit tests**

Tables 4.2 and 4.3 illustrate a common phenomenon in the measurement of

Choosing and interpretin



**Figure 4.5** Banagher moth diversity and three species ab
number of species observed in nine abundance classes (or
number of species predicted by the log series, (truncated)
models. Where there is a good agreement between the obse
(non-significant) of $\chi^2$ will result.

log normal and another model. In this case both the
log normal are appropriate fits to the data fi
explanation, discussed in detail in Chapter 2, is that

# Plantation: Fewer moth species, reduced evenness

# Does (ground) plant diversity correlate?

Adjacent to Banagher oakwood is a recently established and typical conifer plantation (Figure 4.2) covering an area of over 1000 ha. Pure stands of sitka spruce (*Picea sitchensis*) extend across 72% of the plantation. Over 85% of the planting took place between 1945 and 1965, much of it concentrated in two short periods, 1946–9 and 1960–4.

The variety and abundance of species of ground flora in the two woodlands was measured using randomly sited point quadrats (Chapter 3 and see Magurran, 1981, for details) while moth diversity was assessed by means of portable light traps (Magurran, 1985).

Rank abundance plots of the ground flora (Figure 4.3) show that the relic oakwood has more species and less dominance. The selection of diversity

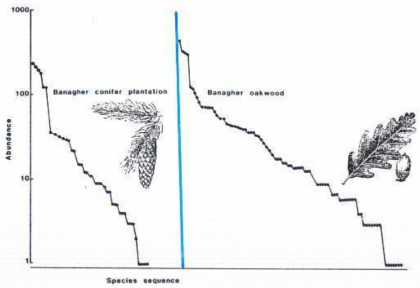



**Figure 4.3** Rank abundance plots of ground vegetation in Banagher oakwood and Banagher conifer plantation.

indices listed in Table 4.3 confirms this first impression: in all cases the oakwood is considerably more diverse than the plantation. With so much evidence for the greater richness of the oakwood is it necessary to complete the laborious task of fitting the various models? The answer, perhaps surprisingly, is yes for it is only the conifer plantation that conforms to a log series distribution of species abundances (Table 4.3). This immediately arouses a suspicion that one factor is important in determining the number and



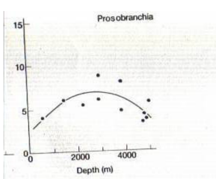
**Table 4.3** Diversity of the Banagher woodlands. (A) models.

| | *Oakwood* |
|---|---|
| (A) Diversity | |
| Species richness ($S$) | 86 |
| Individuals ($N$) | 3666 |
| Margalef | 10.44 |
| Berger–Parker ($N_{\infty}$) | 8.43 |
| Simpson ($1/D$) | 19.67 |
| Shannon | 3.54 |
| Shannon evenness | 0.80 |
| Log series ($\alpha$) | 16.15 |
| Log normal ($\lambda$) | 129 |
| (B) Fit of models | |
| Log series | No |
| Log normal | Yes |
| Broken stick | No |

abundance of species of vegetation in the plantatio
amount of light penetrating the canopy in the sp
critical factor (Magurran, 1981). By contrast th
describes the oakwood is the truncated log norn
diversity of the vegetation in the deciduous woodl
influences. Support for this hypothesis comes
combination of soil pH, light, slope, degree of wate
important in determining the level of species rich
Large differences between the oakwood and the
by the moth data (Magurran, 1985). Here again
(Figure 4.4) show the oakwood to have a greater r
three models are formally tested the pattern is iden
the ground flora (Figure 4.5). The log series is
plantation while the truncated log normal fits both
poor fit to the data because for both habitats it pred
were recorded. Conversely, the log series provides
oakwood data because it predicts too many rare sp
show that the moth fauna of the oakwood is the mo
the log normal index, estimates the diversity of the
the diversity of the plantation as $\lambda = 97.4$. The correl
the vegetation is striking. Many caterpillars have s
and it may be that the low diversity of the veget

Plantation plants: less diverse

Through Successional time (1 - 40 years)




(Sanders, 1968). At greater depths, beyond
ess declines again, probably because of the
n abyssal regions.

ities have indicated a gradual increase in
. This increase either continues through to
as some late successional species disappear.
during an old-field succession changes with
ease in species richness is accompanied by a
nk–abundance curve, with a high level of
bution of ground cover among the species,
v studies which have been carried out on
parallel increase in species richness. Figure
d insects associated with different old-field

essional gradient is a necessary consequence
rea by species from surrounding communities
ges, i.e. later stages are more fully saturated
vever, this is a small part of the story, since
replacement of species and not just the mere

, there is bound to be a cascade effect with
to think of succession as being this cascade
cies will be those that are the best colonizers
n space. They immediately provide resources
it, and they introduce heterogeneity that was
ample, the earliest plants generate resource-
h inevitably increase the spatial heterogeneity
mselves provide a new variety of microhabitats,
t feed on them they provide a much greater
ncrease in herbivory and predation may then
increases in species richness, which provides

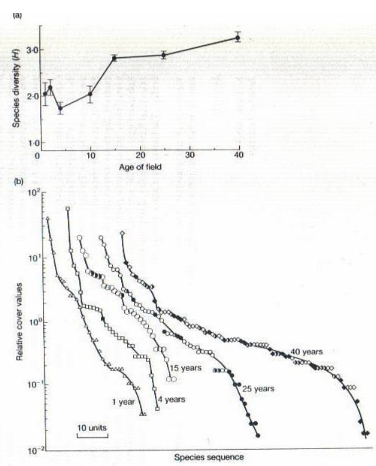



**Figure 24.20.** (a) Relationship between plant species diversity ($H$) and time in succession in old fields in southern Illinois, USA. (b) Rank–abundance curves for plants in old fields of five different ages. Symbols are open for herbs, half-open for shrubs and closed for trees. (After Bazzaz, 1975.)

exposed early successional stage, and the enhanced constancy of the environment may provide a stability of conditions and resources which permits specialist species to build up populations and persist (see, e.g. Parrish & Bazzaz, 1979, 1982; Brown & Southwood, 1983).

As with the other gradients, the interaction of many factors makes it difficult to disentangle cause from effect. But with the successional gradient of richness, the tangled web of cause and effect appears to be of the essence.

**24.4.5 Patterns in faunal and floral richness in the fossil record**

The imperfection of the fossil record has always been the greatest impediment to the palaeontological study of evolution. Incomplete preservation, inadequate sampling, and taxonomic problems combine to make the accurate assessment