Table 3. SUMMARY OF STEPWISE MULTIPLE LINEAR REGRESSION ANALYSIS.

	Regression coefficient	s.e. of regression coeff	R	ΔR^2
Chl a	0·00325	0·00048	0·800	0·6392
Depth	0·00079	0·00023	0·853	0·0889
Cell number	−0·00671	0·00176	0·896	0·0747
NO_3	−0·00477	0·00165	0·918	0·0398
PO_4	0·02935	0·01412	0·926	0·0141
Spp. diversity	0·00156	0·00293	0·928	0·0034
c/a	0·00225	0·00358	0·928	0·0019
Carbon	−0·00001	0·00001	0·929	0·0012
P/R	0·00020	0·00072	0·929	0·0005
Age	0·00006	0·00018	0·929	0·0004
Constant term	−0·1975			

Analysis of Variance

	d.f.	Sum of squares	F ratio
Regression	10	0·009	21·45
Residual	34	0·001	

Dependent variable is k_b. Quantity R is the multiple correlation coefficient. ΔR^2 is the increase in the amount of the variance of k_b which is explained by including a particular variable in the regression. The standard error of the estimate is 0·0065.

best correlation with inorganic nutrients, but no correlation with species diversity (Table 2). The difference between this and the previous interpretation is in the amount of emphasis placed on the system itself compared with the importance attached to the organisms and their interactions.

If the only object had been to establish a predictive equation for primary production, it seems that much less work could have been done at the sacrifice of only a little information. Table 3 summarizes the stepwise regression calculation. The square of the multiple correlation coefficient is the fraction of the variance in k_b explained by the regression. Concentration of chlorophyll a could account for 64 per cent of the variation in k_b. Depth accounted for a further 9 per cent of the variance, cell number 7 per cent and nutrients 4 per cent. The other six quantities measured accounted for only a further 2 per cent of the variation in k_b. This is not to deny the importance of these six quantities; the point is that they made little further refinement to prediction of k_b, once changes in chlorophyll, depth, cell number and nutrients had been taken into account. This supports the argument of Platt[5] that changes in the chlorophyll content of algal cells in response to nutrients, temperature and other environmental factors enhance rather than detract from the value of chlorophyll as a standing stock index in the prediction of primary production.

We have thus found some empirical justification, in natural conditions, for Margalef's hypothesis of ecosystem dynamics. The chief difficulty we find in trying to apply the ideas to real situations is a lack of clarity concerning the various time scales involved; for example, values of P/B could be quite different, depending on the times over which P and B are averaged. The main weaknesses we find in our own treatment are, first, that the inadequacies of the linear model may have obscured some important information and, second, that we have ignored Margalef's timely hint of the importance that derivatives (in the sense with which the word is used in calculus) must play in the future progress of ecological understanding.

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Distribution Pattern of the Duplication of Discoveries

PRICE[1] conjectured that a Poisson distribution might be a good fit for the pattern of incidence of multiple discoveries. We have fitted a modified Poisson distribution to the frequency of duplication of discovery of antibiotics.

We have considered the discovery of an antibiotic to have been duplication if it was identified with another antibiotic and so reported in published documents, irrespective of whether the compounds were produced by one and the same or different species of microorganisms[2]. We used the data reported earlier[2] on the frequency and duplication of discovery of antibiotics during 1907–1966 after correcting a few minor discrepancies. As there was practically no duplication of discovery of antibiotics from bacteria, we have dealt only with the pattern relating to two groups: (1) fungi, algae and lichens, and (2) actinomycetales.

A normal Poisson distribution did not fit the distribution pattern of duplications, but a modified version[3] did. For such a distribution, the p.d.f. is

$$\left(\frac{c}{c+1}\right)^p \left\{ \frac{p(p+1)(p+2)\dots(p+(r-1))}{(r-1)!\ (r+1)^r} \right\} \quad (1)$$

where p and c are constants to be estimated using the following relations

$$\text{mean of } X = p/c \quad (2)$$

$$\text{var } (X) = p/c + p/c^2 \quad (3)$$

Using equations (2) and (3), p and c were estimated separately from the data on antibiotics derived from the two groups of organisms and for the pooled data. Using formula (1), the expected frequencies were computed. A χ^2 test was done. To fit the distribution, the upper tail of the distribution from duplication frequency 8 and above was omitted. Table 1 gives details of the goodness of fit. In all three cases, the goodness of fit was confirmed.

Table 1. OBSERVED AND EXPECTED FREQUENCIES OF DUPLICATION, AND TEST OF GOODNESS OF FIT

No. of times duplicated	No. of antibiotics from fungi, algae and lichens		No. of antibiotics from Actinomycetales		Total	
	Observed	Expected*	Observed	Expected*	Observed	Expected
0	371	364·2	1,018	1,011·6	1,380	1,380·5
1	39	44·3	79	81·9	118	121·5
2	12	15·8	20	29·5	32	44·2
3	7	6·9	15	13·3	22	20·2
4	2†	3·3	7	6·7	9	10·1
5	4†	1·6	7†	3·5	11	5·4
6	2†	0·8	4†	1·9	6†	2·9
7	1†	0·4	1†	1·1	2†	1·7
	2·98		8·23		12·25	
χ^2_{cal}	9·49 for 4 df		12·59 for 4 df		12·59 for 6 df	

* Value corrected to first decimal place.
† Grouped data used.

There thus seems to be predictable regularity in duplications, and Price's conjecture about the pattern of distribution of multiple discoveries is confirmed for antibiotics, even in cases where there are no duplications.

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