A FRESH APPROACH TO THE TEACHING OF ECOLOGY IN NEW ZEALAND HIGH SCHOOLS

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INTRODUCTION

During 1962 the first fruits of the revision of the American High School biology curriculum reached New Zealand and some teachers began experimenting with the new materials. In 1963 and 1964 the Department of Education called two conferences consisting of university and high school teachers and Education Department inspectors to examine the adequacy of the University Entrance and Scholarship syllabuses, the quality of the English texts traditionally used and the quality of the teaching in high school biology. As a result new syllabuses were drawn up and published by the University Grants Committee (1969), and a proposal that a local textbook and practical manual be written was financed by the Department of Education.

The new syllabuses, as well as being much broader than the old, required that ecological principles should permeate the whole teaching programme. The traditional position of ecology near the end of a course, at a point reached only by an elite minority,* was considered unsatisfactory because "the benefits of ecology must come largely through wide popular understanding" (Sears, 1964).† Furthermore, the conferences stressed the importance of the spirit of genuine enquiry in the laboratory and field programmes and this attitude was strongly reinforced by the Nuffield Science Revision in Britain.

Thus, a critically important item in the project was to devise field exercises that laid the foundation for an ecological approach for the rest of the course but which did not require extensive preliminary biological and taxonomic knowledge. The exercises also had to meet the criteria for a modern science curriculum which emphasises the importance of principles derived from personal investigation.

TRADITIONAL APROACH

The traditional approach to ecology has been largely confined to making a species list for an area and drawing up a map to show the position of either individual organisms or species. When such studies are made in major communities the natural population boundaries of most species can seldom be observed, thus any useful discussion about the nature of limiting factors becomes almost impossible. This kind of survey relies heavily on systematics and this has deterred many teachers or caused them to lose status in the eyes of pupils when naming had to be handed over to a specialist taxonomist. Usually, communities with a rich and varied biota were chosen, thus making the unravelling of biotic interactions extraordinarily difficult; so difficult, indeed, that the construction of food chains and webs was well beyond the capacity of the student.

In general, the questions which the techniques of the professional ecologist are designed to answer are inappropriate for class work because the time and circumstances prevent adequate data from being gathered. Teachers have tended to take over in unmodified form the techniques of full-scale and long-term ecological enquiries of professional ecologists. As an example, there is the very extensive misuse of the quadrat technique: Essentially a sampling procedure for systematic comparison between a series of study areas or for studying changes that occur in the same area over a period of time, the quadrat cannot produce results unless the data are treated as samples. Especially useless and misleading, but quite common, is the single quadrat recorded in minute detail on only one occasion. It is fair to say that there has grown up a rather widespread dissatisfaction among high school teachers at the quality of the product of field work under such circumstances.

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* Under the old syllabus ecology was specified for University Scholarship.

† There are approximately 10,000 pupils studying biology in N.Z. sixth forms making it the most popular science subject in our high schools.

One of the most difficult problems facing the teacher and, especially, the examiner of traditional descriptive ecology in New Zealand is the great diversity of ecological situations available for study.

OBJECTIVES

Under these circumstances it was necessary to define the precise purposes of ecological work in the syllabus. An important point, perhaps not always realised by university teachers, is that only a very small minority of pupils who study lower sixth form biology have any intention of continuing this study into their university life. In fact only one pupil in five persists with biology from 6B to 6A and very few students enter university after their Entrance examination year. Consequently 6B biology has changed from being a pre-university training to being the last contact with science for a very substantial group of citizens, most of whom do not take a degree at all.*

The descriptive ecology of large communities, enormously variable as they are in New Zealand, seems to offer much less of permanent value to the future citizen than a knowledge of the structure of communities and the way in which they are organised — aspects which are more or less universal in communities irrespective of their species composition. The conviction that it is the general features which should be the major preoccupation of sixth form ecology led to the following list of concepts and processes being chosen for demonstration in the field:

(a) the ecological niche, (b) the species population, (c) adaptation, co-existence and competition, (d) dependent relationships as seen in food chains, predation, parasitism, etc., (e) community organisation, (f) major patterns in time and space; stratification, zonation and succession.

Two types of ecological exercises have been tested and are offered to teachers as ways of achieving these objectives: (1) the study of the ecology of simple communities, and (2) the single concept exercise. Both stress the importance of studying small, uncomplicated ecological situations and both are based on the idea of proposing an hypothesis about which the students are asked to gather evidence. The essence of the approach is that if the data recorded run contrary to expectations then this outcome must be accepted. This kind of practical work, because there is often no "correct answer", has much to offer in conveying the concept of intellectual honesty in science. However, pupils and teachers do not always welcome an approach in which the certainties of the well-trodden path are no longer comfortably to hand.

THE RESTRICTED COMMUNITY APPROACH

Starting from the proposition that, in a functional sense, any set of interacting populations constitutes a community, situations were sought in which a restricted number of interacting species could be studied conveniently and intimately. A number of plants which carry an abundance of small and frequently specialised herbivores were investigated and it soon became obvious that this kind of simple community, (animals dependent directly and indirectly on a single species of plant) had much to offer to the solution of our problems.

Flax (*Phormium tenax*) proved to be ideal because it has several species either restricted to it (two hover-fly larvae, one a herbivore and the other a predator, and a midge larva) or highly characteristic of it (leaf-eating and seed-eating caterpillars). The more sedentary species have highly characteristic feeding and shelter sites and are usually sufficiently numerous to allow the student to grasp the concept of a population and its distribution.

Initially, it was suggested that pupils subdivide the plant into microhabitats and record the species present and their relative abundance; but this approach to the study of concepts, starting in the conventional way with a description and subdivision of the environment, proved unrewarding because no appreciation of the ecological niche or other objectives grew out of it. Consequently, it was completely abandoned in favour of an approach through the study of the population of each species. This is a very important distinction and such success as this work has had derives, I am convinced, from the initial concentrated study of the animals as populations.

Two reasons seem to underlie this method's success. The first is that only the physical and biotic factors relevant to each species need be

* It is now quite clear that the University Entrance examination is not what its name suggests, since a large and increasing number of students take a 6A year before entering University.

studied, so making the study of organism-environment relationships more real, intimate and convincing. The second is that the population is presented as a dynamic entity tending to expand but held in check by environmental limitation.

That only relevant physical factors need be considered, is of great importance in this approach. It may well be that some of the failures of the traditional class methods of studying ecology may, in part, be attributed to the practice of making a general description of the physical environment first and then using this in discussions relating to the success of the many different species present. As is now well recognised, each species is living in a world of its own, with a specific environment consisting of the conditions and resources that actually impinge on it. These specific environments may differ for species living only a distance of inches apart. Whatever exists outside a species' usual environment — the food it cannot eat, the degree of moisture it cannot tolerate, the predators that do not prey on it — are quite irrelevant.

After a series of trial versions the introductory ecological work has been cast in the form of five hypotheses:

(1) *Each species living on the (flax) plant occupies a typical site.*

The pupil searches the plant for evidence relating to this proposition and it does not take him long to see that no matter which species he starts with, provided it is numerous, each has a neatly specifiable site and distribution, and there are concentrations of abundance which tail off in two directions. The recognition of patterns in nature often depends on the scale of the observations. On a single plant the pupil can get a good qualitative picture of one species' distribution at a glance or, at the most, in a few minutes work; consequently, the question as to why the distributions occur as they do arises naturally and quickly.

(2) *The distribution of each species is determined by a specific set of conditions and resources.*

The pupils are asked to look for evidence that there is some change of conditions associated with the thinning out of abundant and fairly sedentary species such as aphids, coccids, rat-tailed maggots or collembolans. Gradients of factors such as moisture, age of leaf, light and shelter are explanations suggested as possible and a bell-shaped curve is suggested as a useful distribution model to keep in mind. (Although not all distributions are neatly Gaussian, it is the statistical way of thinking about a population that is considered important). Once this approach has been achieved, useful discussions can arise about the idea of limitation and the concept of adaptation. The aim is to establish in the pupil's mind the dynamic view of a population subject to the controlling action of different influences.

It will become obvious during this work that some species do, in fact, have the same distributions on the plant as others. How then can each species have a distinctive mode of life, its own ecological niche wherein it may be ecologically segregated? This opens the way to setting up the hypothesis that:

(3) *Species with the same distributions differ ecologically in some other way.*

Pupils are then asked to look at food habits, size in relation to available shelter and so on. Mouth parts, gut contents, feeding postures and behaviour, periodicity of feeding, chew marks and faeces are examined to see if they separate two similarly-distributed species. Recourse to textbooks and monographs may be necessary at this stage.

This kind of investigation has worked on a number of different plants where the division into herbivores with different food sources, predators and parasites is not difficult but is very instructive. The idea that ecological differentiation is closely concerned with co-existence arises in discussion of these results and gives an excellent basis for a discussion of the nature of adaptation. Experience with this exercise has shown that the concept of adaptation makes very good sense when a number of species are studied *within* the same small community and that it is superior to the traditional practice of taking scattered examples of bizarre and extreme specialisation.

Some insight into the more detailed aspects of adaptation may be afforded pupils by next proposing the hypothesis that:

(4) *Co-existence may be achieved by very small differences of adaptation.*

This step is feasible only if there happens to be present two similar species differing only slightly in their ecology. On flax, two such species are the caterpillars of a geometrid and a noctuid moth, both of which feed on the leaf blades, but in characteristically different parts of the leaf. One eats V-shaped notches in the edge and the other makes long "windows" in the blade. By measuring the depth of the notches and the distances of the "windows" from the edge it is possible to show graphically that there is only slight overlap in the areas of the leaf used by the two species and, consequently, only a small degree of competition between them for food. The adaptive feature involved here appears to be a behavioural one as it seems unlikely that the shape of the mouth parts is responsible. Similar exercises based on the distribution of aphid and barnacle species have been highly successful.

There follows at this point a general summary of the conclusions arising out of these four exercises. The concept developed from the summary is that of the *ecological niche* which is defined, in this context, as the more-or-less specialised role of a species in a biotic community, as described by the resources it depends on, the adaptive features that give effect to that dependence and the effects the species has in modifying the environment of other species. By approaching the study of ecology through the concept of the ecological niche one is stressing ecological differences between species. It now remains to enquire how these different species are organised within communities by posing a final hypothesis concerning the organisation of communities:

(5) *A model of a community may be built which is based on the integration of ecological niches.*

This does not involve extra field work but, rather, the construction of probable, and some proved, food chains and a food web for the community. The relative abundance of herbivores and predators found from the earlier data may be presented graphically in the form of pyramids and the general features of community organisation and the flow of energy discussed.*

SINGLE CONCEPT STUDIES

Much can be achieved using these simple communities, but a number of important concepts such as stratification, zonation and succession cannot be conveniently studied on such a small scale. Therefore, the proposal has been made that these ideas be studied separately, each in a community in which it can be most clearly seen. Hypotheses relating to zonation, for example, are probably best studied on a rocky shore by concentrating on the distribution patterns of one or two species.

CONCLUSIONS

A very successful innovation in this programme has been the identification sessions held before the field work starts. Named specimens of all the species that occur on the plant are provided and in effect the pupil passes through the "species-list stage" before the ecological work proper starts. No ecological information is provided at these sessions because it is this kind of information that constitutes the element of enquiry and discovery in the field.

Pupils learn to identify a set of species with astonishing speed when they know that the information is to be used immediately for some larger purpose in the field; and this, combined with the simplicity of the species structure of such communities, has effectively put an end to the identification bogey, real or imagined, that has deterred many teachers from ecological work in the past.

Teachers who have made small-scale studies first have found that if they later made studies of more complex communities these were far more rewarding and quicker because the pupils had a conceptual model of community organisation and so knew what sort of questions it was useful to ask. However, the biggest gain seems to come from the fact that what were formerly rather useless anecdotal snippets of observation in the field take on a new significance in that they cumulatively contribute evidence for or against some major generalisation. We should face the fact that most field observations are, as isolated items, trivial and that they can take on stature only insofar as they contribute to a broader picture. The contention of this paper is that there is no better or quicker way of establishing the framework of that picture in the pupil's mind than by the study of a very simple community based on a single species of plant.

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* Other plants that may be used successfully for these exercises are ragwort, sowthistle, cabbage, oak, nasturtium and gorse, but investigation is necessary to ensure that enough species and individuals are present on the plants.

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