THE IMPORTANCE OF ECOLOGY FIELDWORK IN ENGLISH SECONDARY SCHOOL CURRICULA

R. Tynan

Liverpool John Moores University (UNITED KINGDOM)

Abstract

A government white paper in 2010 [1] re-established school subject knowledge as the foundation for curriculum design in English schools, and written end-tests as the only assessment tool for public examinations. Course work, practical tests and modular tests could no longer contribute to most external qualifications aimed at 16-year-olds and 19-year-olds.

The examination specifications for science subjects specify that learners experience a number of required practicals to develop their experimental research skills [2] [3]. However, those skills are only tested on the final written examination, through questions referring to the required practicals [2] [3]. Ecology concepts are important components of English examination board biology specifications [2] [3], but the position of fieldwork has weakened despite having many educational advantages [4].

The fieldwork needed has been reduced to estimating the population size of a common species in a habitat [2] for the General Certificate of Secondary Education (GCSE) and investigating the effect of a named environmental factor on the distribution of a given species for General Certificate of Education (GCE) A-Level [3]. This is a minimum requirement, and it can be argued that a critical approach to these activities will lead to a discussion of a wide range of field work sampling and measurement techniques.

This paper discusses the ecology subject knowledge and required practicals in the AQA examination specifications [2] [3] and learning, teaching and assessment (LTA) activities developed after centre and teacher-led field work at Field Studies Council field centres [5]. These have been adapted in order to utilise sand dune and saltmarsh ecosystems local to teachers in Liverpool and Merseyside schools. It also describes pre-service science teachers' introduction to these ecosystems during their initial teacher education programme at a Higher Education (HE) qualified teacher status (QTS) provider.

Keywords: ecology, biology, science, required practicals, examination, investigation skills, teacher subject knowledge, fieldwork, sampling, estimating populations.

1 INTRODUCTION

The United Kingdom (UK) education White Paper of 2010 [1] initiated major reforms to school curricula, assessment, and public examinations for secondary school and college learners in England. Moving away from what was, arguably, a generic skills-based 14-16 curriculum based upon the English National Curriculum, knowledge about subjects or disciplines was re-established as the unit for curriculum design for school curricula. Course work and modular examinations would no longer contribute to final grades for General Certificate of Secondary Education (GCSE) or General Certificate of Education Advanced Special and Advanced (GCE AS and A-level) qualifications. Only skills that could be assessed on a written examination would be measured. This had serious implications for the learning, teaching, and assessment (LTA) of Science, Technology, Engineering and Mathematics (STEM) subjects like Biology. Delivering STEM education can be expensive and only likely to receive sufficient funding in schools for practical aspects if those are linked to external assessment contributing to the grades for nationally recognised qualifications [4]. Still, these reforms [1] received qualified approval across the political spectrum [6] [7] and were adopted.

Organisations like the Field Studies Council [5] and Council for Outdoor Education [7] have long argued the case for field work and other types of education outside the classroom. They claim there are obvious and demonstrable positive social, psychological and health benefits to education outside the classroom, but they would also argue that there are cognitive benefits as well for learners trying to understand and remember complex and interrelated concepts. However, from personal experience biology (ecology in particular) field work has always been difficult to promote in secondary schools in England. Historically, external examination specifications have always recommended field work for the understanding and learning of ecological concepts and the development of experimental investigation skills, but they always stopped short of making it a compulsory component of the specification. The situation has not been improved by the change in status associated with the new examinations [4].

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Changes to the LTA of ecology in secondary school biology curricula in England were inevitable following the education white paper of 2010 [1], and for the purposes of this paper, the Assessment and Qualifications Alliance (AQA) provide an example of the current non-modular, end-test examination biology specifications in England that were written for first teaching in 2015 and 2016 [2] [3]. These indicate the reduced status of practical fieldwork and investigation in secondary school biology [4] but they also ensure that some practical ecology is now a required learning experience for secondary school learners. This is because they list the required practicals teachers must accredit their learners have experienced and could be used to test experimental investigation skills on written end-test examinations [2] [3]. However, the wide range of ecology investigations available to biology teachers for ecology field work in GCSE Biology has been reduced to: estimating the population of a species, and using sampling techniques to investigate the effect of an environmental factor on the distribution of a species [2]. There is no required practical associated with GCE AS-Level but at A-Level an investigation into the effect of a named environmental factor on the distribution of a given species is required [3]. These involve important investigational skills and allow the exploration of a range of ecological concepts but reduce greatly the potential impact of ecological investigations in helping learners understand and remember a complex subject. The concern would be that the required practical in current examination specifications should be sufficient for two purposes: to support the understanding and learning of the ecology concepts set out in the specifications and to support the experimental investigation skills that will be tested in the final written examinations [2] [3]. This leads to the first question this paper raises: Can the required practical component of GCSE and GCE AS/A-Level specifications support the understanding and learning of the ecology theory and investigational skills required for the assessment?

In addition, in England, there has also been a move away from visiting ecologically interesting field sites in favour of investigating the ecology of the school or college environment. This reduces costs, avoids travel and overnight stays, and simplifies all aspects of risk assessments. It is also the case that most of the ecology concepts in the examination specifications can be demonstrated using the school playing field and ornamental areas, but it is also true that this reduces the opportunity to inspire learners through interactions with unfamiliar places and ideas, and expert adults other than teachers. So, this paper also considers the use of a managed ecosystem that demonstrates succession: the change in communities of organisms over time at one location. This is a difficult concept for learners to grasp but it can be demonstrated clearly when visiting sand dunes. Here land formation has occurred due to the accretion of sand, and the colonisation and stabilising of the soil by changing communities of living organisms, resulting in a stable climatic climax community. However, in dunes ecosystems, each seral stage occurring over time is also set out linearly in space behind the previous stage. Teachers do need to distinguish clearly the difference between what has happened on sand dunes and the zonation found on, often nearby, salt marshes where the stable synchronous communities simply track environmental factors such as salinity and frequency of immersion in water. Pre-service teachers visited the Ainsdale sand dune system as part of their ITE programme leading to QTS. This is local and easily accessible to teachers in the Northwest of England. This was an exploratory visit to Ainsdale National Nature Reserve to establish if it would be suitable for GCSE and/or GCE A-level fieldwork. Background information on the area was available from a major research seminar on the Sefton Coast Sand Dune system in 1991 [9]. The second question raised here is: Is the Sefton Coast Sand Dune Ecosystem suitable for the out-of-classroom learning and teaching of AQA biology examination specifications?

2 METHODS

This was a pedagogical study requiring only a literature review, document analysis and some personal observations and evaluations of the sand dune ecosystem visited, and materials produced at the time. It took place during the normal activities undertaken as part of an ITE programme in the northwest of England. No primary data was collected from other participants. As such there were no ethical issues in the anonymous reporting of the findings [10]. The full list of documents referred to can be found in the References section at the end of the paper. The AQA Biology Specifications for GCSE and GCE AS/A-Level [2] [3], often referred to here, were last downloaded from the AQA website on April 30th, 2023.

3 MAIN ARGUMENTS

3.1 General

Fig. 1 shows the ecology discipline conceptual framework used with pre-service teachers at a QTS provider in the northwest of England. On the synecological side of the diagram, each level is comprised of components of the level below. The examination specifications [2][3] also include energy transfers, cycles of matter, and applied aspects exemplified by the impact of human activities on ecosystems. These are linked to the general concepts as appropriate in ITE programme subject knowledge enhancement sessions.

The discipline of ecology asks three simple questions: What species are present? How many? Why? So, it is not surprising that faced with selecting the most representative practical investigation for the required practical lists, examiners chose to estimate a population and link its distribution to other environmental factors [2][3]. This is an autecological, rather than synecological, approach, presumably adopted to simplify the complexity of the true situation (Fig. 1) whilst undertaking practical work.

The required practicals [2][3] could illustrate and help develop different parts of the framework (Fig. 1) depending on the species and environmental factors chosen for study. However, depending on the learners, their organisation in the field, and the location of the field work, it is possible to look at more than one species and environmental factor simultaneously during a site visit. This could also be an opportunity for adaptive teaching where all learners achieve the same learning outcomes associated with completing the required practical and developing investigational skills, but the level of challenge is different, again depending upon which species is selected and whether an abiotic or biotic factor is selected. Both GCSE and GCE A-Level specifications suggest random and systematic sampling methods involving transect and belt transect lines, which assume linear changes in communities.

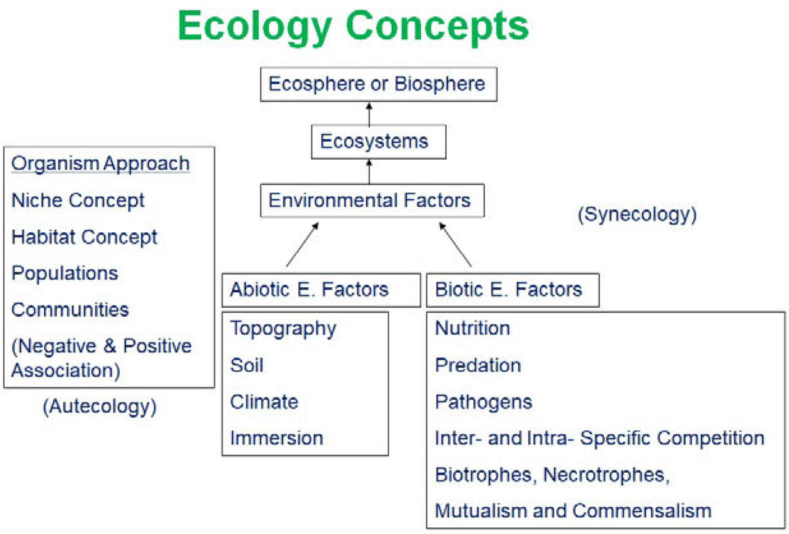

Figure 1 Ecology Conceptual Framework currently used with pre-service science teachers at a QTS provider in the northwest of England.

3.2 GCSE Ecology Content

The ecology content of the AQA GCSE Biology specification [2] is wide-ranging and touches on all the concepts set out in Fig. 1. It is set out in five sections and twenty-one bullet-pointed sub-sections. It has a preceding description and a final summary of nine key ideas. It emphasises the role of living organisms for the cycling of materials and the transfer of energy through the ecosphere as an open energy system, which ultimately relies on autotrophes transducing energy from the sun. It covers both general and applied ecological ideas and addresses the human impact on the environment, both positive and negative, including the effects of intensive agriculture. It would be appropriate to describe the ecology specification as content heavy, complex, and challenging to learners of all abilities. The required practicals (estimating a population and using sampling techniques to link distribution to environmental factors [2]) underpin the theoretical content regarding abiotic and biotic environmental factors and the distribution of organisms [2]. This is a reasonable compromise as it would appear almost impossible to support all areas of the theoretical ecology content with practical exercises within the time constraints of the GCSE curriculum.

3.3 GCE AS-Level Content

The content for AQA AS/A-Level Biology is grouped thematically to include traditional biology subject discipline areas in the same sections. It should be noted that the AS-Level content is also the first-year content for a full A-Level allowing AS and A-Level cohorts to be taught together. The AS (and A-Level first-year) content covers macromolecules, protein synthesis, aspects of cell biology and whole organism physiology, taxonomy, and the genetic basis for variation and diversity [3]. Ecological aspects of diversity and how to calculate a diversity index from population estimates of species found in a habitat are also covered. There is no required practical linked to this and the specification suggests that learners be provided with the necessary data (numbers of species in a habitat and their populations) to practice calculating a diversity index and compare the diversity of different habitats, including in agricultural areas. This removes the need for a site visit to collect primary data and reduces the time allocation needed for this topic on the AS/A-Level biology curriculum. A-Level students could revisit this topic in their second year and use primary data collected during the required practical to revise it thoroughly. However, for AS-Level students, that opportunity is lost, and the topic will probably be learned in the absence of concrete examples.

3.4 GCE A-Level Ecology Content

Due to the thematic arrangement of content, AQA A-Level ecology topics [3] can be found across several sections.

One section covers energy transfers in and between organisms. There are ecological references in subsections that otherwise mainly describe the biochemistry of respiration and photosynthesis. There are two distinct ecological subsections. One describes the efficiency of energy transfers between trophic levels in ecosystems and the calculation gross and net productivity linked to applied ecology and food production. A little confusingly, the section on energy exchanges ends with a subsection emphasising the role of micro-organisms in nutrient cycles exemplified by the nitrogen and phosphorus cycles with reference to the differences in human impact on ecosystems using natural or chemical fertilisers in agriculture.

Populations and ecosystems are covered in another section that also includes populations and genetics. This subsection is fully supported by the required practical: an investigation into the effect of a named environmental factor on the distribution of a given species. Again, curriculum time is saved here by avoiding full ecosystem survey approaches.

3.5 Utilising the Sefton Coast Sand Dune Ecosystem

The potential field work site was part of the Sefton Coast Sand Dune System that runs for approximately twelve miles between Ainsdale in the north and Altcar in the south and is approximately three miles wide in places. It is a mosaic of local and national nature reserves and sites of scientific interest with a high level of amenity use, several notable golf courses, a small airfield, and a military firing range. The site visited is known as The Fisherman's Path Freshfield/Formby, which is located north of Liverpool on the northwest coast of England [11].

The pre-service teachers (Fig. 2) arrived by car and train. The station was the start of the visit, situated at a point where it is a possible to take a short walk in either of two directions to reach an ecological site of interest. Walking north parallel to the train line is Fisherman's Path, which traverses the railway line and a golf course (risk assessment and control measures were discussed at this point) to access a sand dune system with endangered Natterjack Toads, Sand Lizards and many rare plants, Crossing the line immediately and walking directly to the coast they could access Formby National Trust Nature Reserve which contains a pine forest that is home to a remnant population of Red Squirrels. Conserving the ecosystem is the responsibility of Sefton Coastal Management and has long been the subject of much discussion [9].

Figure 2 The class of 2023 in the fixed dunes

The advantages of using this path were discussed with the pre-service teachers. It crosses the national nature reserve and parties must keep to designated metalled paths and public areas until it reaches the mobile dunes and beach. This reduces the problems that might occur managing young learners in an outside classroom. It also crosses all the seral stages in a psammosere (Fig. 3) in a short distance. Further, the path is fully accessible to most learners until it gives way to sand. The seral stages that are easily distinguished are: Bare Sand, Strandline, Embryo Dunes, Mobile Dunes, Dune Slacks, Fixed Dune (forest and dune acid heath). However, Embryo Dunes are currently scattered and isolated and the subject of management procedures (Fig. 4).

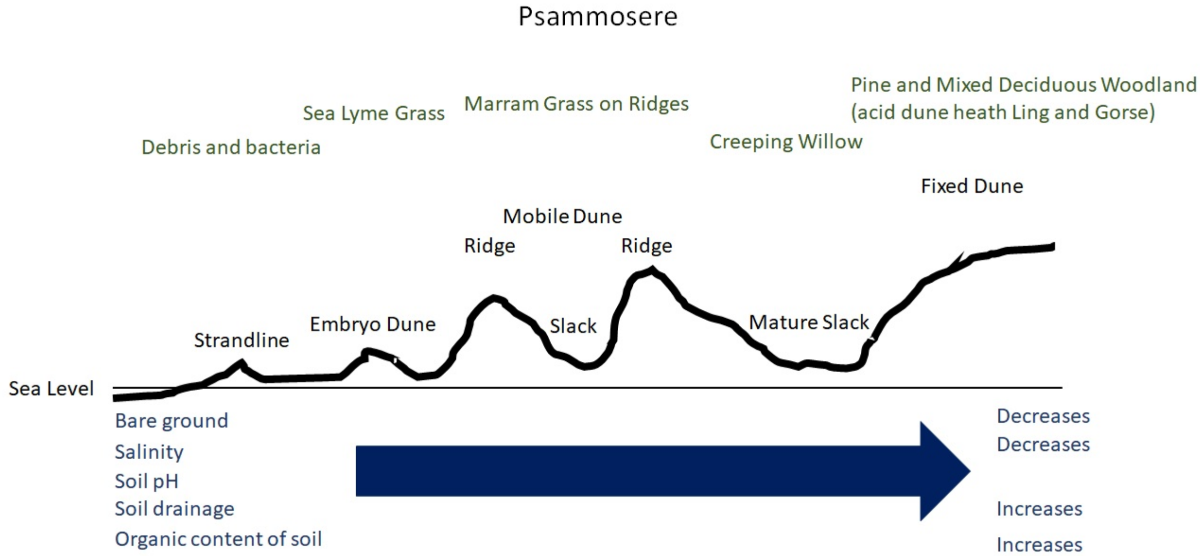

Figure 3 Typical features of a psammosere demonstrated at the Fisherman's Path

Figure 4 Bare Sand, Early and Late Mobile Dune

There are opportunities for gathering data using public access areas that demonstrate most of the stages in Fig. 3. The distinct communities associated with the seral stages are dominated by sea lyme grass on the embryo dunes, marram grass on mobile dunes, creeping willow on mature dune slacks, Scots and Corsican pine on fixed dunes, ling and gorse on dune heath. There are other easily recognisable but less abundant signature plants such as sea rocket, sea buckthorn, birds-foot trefoil, sea spurge and ragwort. All the plant species are interesting and could be selected as the subject for required practical work. Non-protected animals may also be selected for study. The Cinnabar Moth is interesting because it is unmistakable in both its larval (black and yellow hooped caterpillars) and adult (black wings with a red stripe at the front edge) forms. Just after its eggs hatch, there is no need for the ‘mark and recapture’ method suggested in the specifications [2][3] (Fig. 5) as its sole food source is ragwort and the population in an area can simply be counted on the ragwort plants where the eggs were laid.

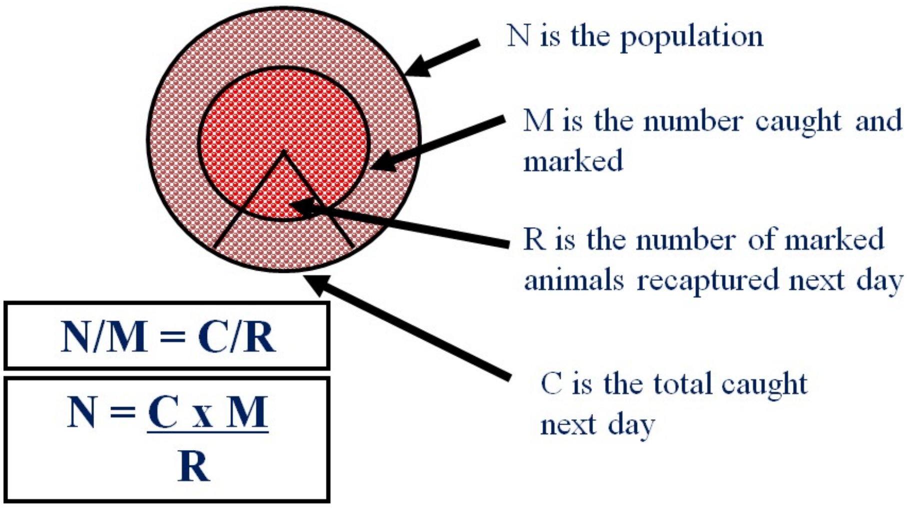

Figure 5 The diagrammatic explanation of the mark and recapture technique

The specifications [2][3] do not designate that only biotic or abiotic environmental factors should be investigated and linked to the distribution of the species selected. Abiotic factors may be easily measured quite accurately on-site using salinity and pH sensors, plastic beakers and de-ionised water bottles, and samples can be labelled and transported back to school for future practical work in the laboratory. On sand dune systems there are measurable decreases in salinity and soil pH as readings are taken moving away from the beach. Salinity changes can be explained in terms of increasing distance from salt spray. The decrease in pH is due to a decrease in the calcium-rich (due to shell fragments) sand component of the soil accompanied by an increase in the humus or organic material present. The decomposition of the organic material releases organic acids. The transition to acid podsol is accelerated in areas under pine trees with a continuous supply of slowly decomposing needles. If trees are removed this may lead to dune heath formation with acid soil indicator plants such as ling and gorse. Other abiotic factors that can be easily measured are soil drainage and humus content. A simple pattern of distribution linked to a similar change in a physical factor is needed at GCSE level to establish a link. However, similar studies at A-Level should involve statistical analysis such as correlation coefficients or t-tests for comparing means if random sampling of two locations is involved.

The effect of abiotic factor on distribution is more difficult to investigate and demonstrate, requiring that two organisms are found apart or together more often than expected if they were randomly distributed (negative or positive associations). If established, this alone gives no clues to the cause of the association. Other means are needed to establish if this is a predator/prey relationship, mutualism, inter specific competition or another explanation. As this requires the use of Chi-squared analysis using contingency tables, it is probably best left to GCE A-Level (Fig. 6).

Do these organisms occur together, apart or are they independently distributed?

Organisms which have overlapping niches are inter-related in some way (e.g. pred/prey, overlapping abiotic factors required to survive). They tend to occur together more often than you would expect and form communities.

Organisms which have completely different niches tend to 'avoid' each other i.e. occur together less often than expected.

Organisms which are distributed independently of each other may have partially overlapping niches would still be found together sometimes.

An ecologist needs an objective way of deciding if organsims are positively or negativively **Associated** or independently distributed?

Let's look at two plants, A and B, which you think are growing together in an area - Positive Association. Place 50 quadrats using a random sampling method. For each quadrat record if the two plants plants occur in it. There will be only four possible results. In each you will find either: Both A and B, A only, B only or Neither.

Here's a typical set of results:-

Outcome	Number of quadrats
A and B	27
A only	7
B only	9
Neither	7
Total	50

The probability of finding A in your next quadrat would be 27 + 7 = 34 out of 50 or 0.68.
The probability of finding B in your next quadrat would be 27 + 9 = 36 out of 50 or 0.72.
The probability of finding both in your next quadrat would be 0.68 x 0.72 = 0.49.
We would expect to find A and B growing together in 0.49 x 50 = 25 quadrats even if they were randomly distributed..

We can use this data to construct a contingency table:-
(Expected values in brackets.)

		B Found	Not found	Totals
A	Found	27(25)	7(9)	34
	Not Found	9(11)	7(5)	16
	Totals	36	14	50

Use the Chi Square Calculation to test how different the observed results are from the calculated results expected if the two plants are both randomly distributed:-

Observed	Expected(e)	Difference (d)	Yates' Correction	Cor d^2	Cor d^2/e
27	25	2	1.5	2.25	0.083
9	11	-2	-1.5	2.25	0.25
7	9	-2	-1.5	2.25	0.321
7	5	2	1.5	2.25	0.321
				Total	**0.975**

Althought A and B are together in 27 quadrats they are not associated because the chance of being wrong if you say they are is greater than 5%. There is more than 5% chance of getting a figure of 0.975 from this calculation if the plants grow independently. You find this out from prepared statistics tables. (1 df, cv 5% 3.84)

Figure 6 An A-Level sheet explaining how to investigate the effect of a biotic factor (another species) on the distribution of a named species by looking for positive, negative or no association

It is suggested [2][3] that GCSE and A-Level learners can sample randomly, systematically, or representatively along transect lines and belts (Fig. 7) and this is certainly appropriate where the transect line crosses zones or seral stages that change linearly in space. Kite diagrams (Fig. 8) can be used to record the changes in population. The sand dune ecosystem is suitable for transect line sampling and, when dealing with a selected species, the transect line does not have to be too long. Quarter square metre quadrats are suitable for percentage frequency estimates of plant distribution, and point quadrats can estimate percentage cover.

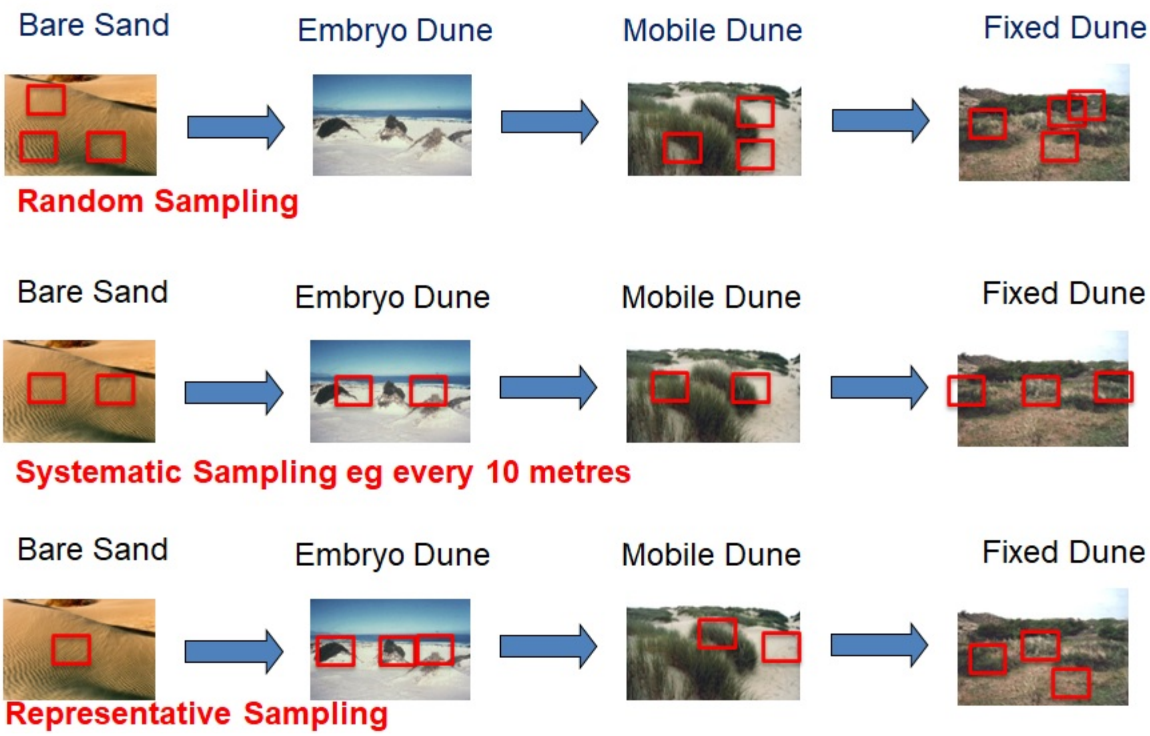

Figure 7 Ways of sampling sand dunes along a transect line

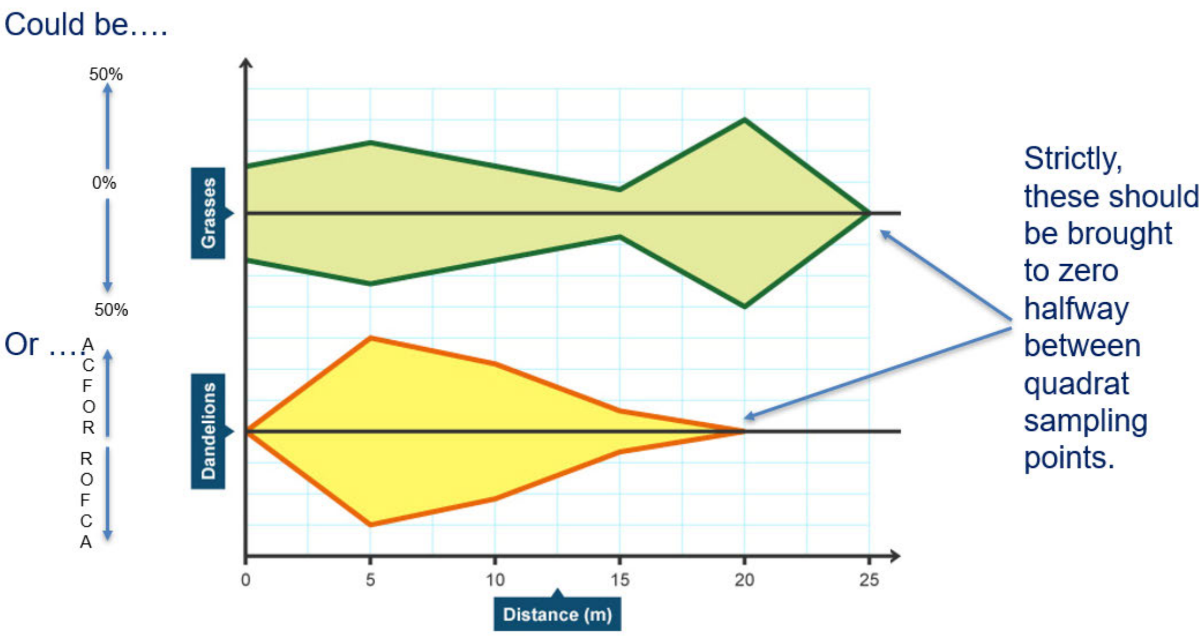

Figure 8 Using Kite diagrams to demonstrate the distribution of organisms along a transect line or belt

A-level learners can use other random sampling techniques and point quadrating to look for positive and negative associations between plant species and realised niches that overlap and are distinct. There are several adaption narratives to use with learners e.g., Marram Grass has many xerophytic features such as deep roots, stomata on the upper leaf surface and leaf curling. It is also able to grow rapidly

and survive high rates of accretion and burial. However, it is less tolerant of salt than sea lyme grass and is unable to colonise embryo dunes. They should demonstrate a negative association explained by interspecific competition. A standard A-level explanation would be that both plants are adapted for harsh beach conditions and have a partially overlapping niche. They could grow in the same locations in the absence of the other. In regions of higher salinity, the more tolerant lyme grass can outcompete any marram. However, as the embryo dune transitions into mobile dune, the drop in salinity and higher sand accretion rates begins to favour the marram grass over the now slower growing lyme grass.

4 CONCLUSIONS

The currently required ecology practicals support the study of ecology at GCSE and GCE A-level with a generic approach that allows teachers to do more if they have time and utilise the habitats they have available [2][3].

The required practicals linked to ecology directly support specific fundamental aspects of ecology in the GCSE and GCE AS/A-Level Biology specifications [2][3]. They can be adapted to illustrate related areas of applied ecology also addressed in the specifications.

Very locally managed habitats, including the school playing field, can be utilised to illustrate most ecology concepts and to gain experience in required ecology practicals and accredit them. Learners will gain an understanding of distribution and zonation from such concrete examples,

Succession, the change in communities over time as environmental factors change, can be understood concretely through records kept at a single location over time or where land accretion leads to seral stages spread over space as well as time. Sand dune systems are prime examples of the latter.

The Sefton Coast Sand Dune system is an easily accessible resource that science teachers in the northwest of England around the major city of Liverpool could utilise for education outside the classroom that does not require expensive travel or overnight stays. As an amenity area, the risk assessments are relatively straightforward and control measures are achievable. The dune system is very appropriate for the delivery of the required practicals [2] [3] to GCSE and A-Level learners.

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