UNIVERSITY OF SOUTHAMPTON

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Department of Biology

A PARTIALLY OBJECTIVE METHOD FOR THE ECOLOGICAL EVALUATION OF BIOLOGICAL COMMUNITIES

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UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF SCIENCE

BIOLOGY

Doctor of Philosophy

A PARTIALLY OBJECTIVE METHOD FOR THE ECOLOGICAL EVALUATION OF BIOLOGICAL COMMUNITIES

By John Raymond Peat

The range of existing techniques of ecological evaluation and their use in environmental planning in the United Kingdom is reviewed. It was concluded that there remains considerable scope for the use of ecological evaluations. There is a particular need for objective schemes which will generate data which are useful at the level of producing detailed 'local' plans. Examination of three planning documents highlighted the confused manner in which 'the ecological argument' is presented at planning inquiries. It is suggested that ecological evaluations will help clarify the presentation of ecological data and shift the argument away from a preoccupation with rare species.

Following a review of the three different approaches (schools) to ecological evaluation and an examination of the range of criteria measured a method is proposed of evaluating biological communities. Assessments of area, floral species richness, ground invertebrate diversity and rarity are used to calculate a community aggregate score. The maximum value for the C.A.S. is four and weighting is explicitly excluded from the formula.

The order of results obtained for the C.A.S. were found to agree with a broader more subjective ecological evaluation of the study area. Sites enjoying statutory protection such as National Nature Reserves and Sites of Special Scientific Interest generally obtained the highest scores. The average community aggregate scores for each community type agreed with the generally expected results, e.g. coniferous plantations consistently obtained low scores.

Because of fundamental objections to the type of formulae often used in ecological evaluations and the elusive notion of ecological value an alternative approach is explored. It is suggested that techniques of multivariate analysis have a contribution to make to this study area.

These multivariate techniques may have severe limitations, when applied to this field of work, owing to their development from the calculation of correlation coefficients. Nevertheless, finally, alternative clustering techniques are briefly discussed which may have a role to play in ecological evaluation.

It should be recognised that there are some who would not wish to shift the emphasis away from rare species, and see their preservation as the legitimate goal of ecological evaluation.

PREFACE

"The technological and sociological progress of mankind takes place at the expense of nature and its resources; no one doubts any longer that this evolution creates conflicts and thus it is urgent to intervene in order to channel this evolution ...

(there is a) need for preliminary studies of the natural environment each time it is desired to change it ..... in response to this necessity scientifically valid methods (of ecological evaluation) are required."

(Froment and Nef, 1976)

CHAPTER 1

1. INTRODUCTION

1.1 Ecological evaluation and environmental planning

The work in this thesis is concerned with the topic of the ecological evaluation of biological communities. The aim of ecological evaluation is to provide in a concise and generally comprehensible way a quantitative statement of the worth which a competent ecologist attributes to a particular biological system (O'Connor 1974).

There are several quite different approaches to ecological evaluation in the literature. This reflects the different schools of thought which have developed in recent years. On the one hand there are those workers who evaluate parameters such as species diversity and rarity and on the other there are those who seek to evaluate the benefits man derives from wildlife.

Irrespective of approach one of the purposes of these methods is to standardise the input of ecological data into the planning process. It is not suggested that ecological evaluation should replace the vast wealth of data presented at the moment but rather the evaluation will highlight potentially important areas and emphasise the need to look closely at the available data for those areas.

It is to be hoped that one of the major uses of an objective method of ecological evaluation will be within Environmental Planning. When any decision is made on a planning matter there are numerous considerations, for example the quality of the agricultural land, socio-economic factors, the quality of the landscape and the ecological value of the proposed development site. Perhaps the most unsatisfactory input into the planning process is the latter where information is often presented in such a way as to make accurate comparisons difficult if not impossible. The worth of listing the rare species in different areas would appear to be of limited value if one is trying to decide on which site to develop if both alternative sites contain rare or interesting species. The comparison of different sites would be made easier if there was some standardisation of the form of the information input. Such standardisation would appear to be additionally desirable with the increased use of Environmental Impact Statements. Equally, such a standardisation would help the planner if he is not to be overawed

by a large amount of complex ecological data. The standardisation of the ecological input lags far behind work done in other fields. There is a satisfactory method for classifying agricultural land and advances are being made in evaluating landscapes. Lovejoy (1973) has reviewed the methods used in Germany, in Great Britain and in the U.S.A., most of these methods are qualitative, classifying the quality of the landscape in the absence of numerical data.

1.2 Species evaluation

If species whose existence is threatened are to be protected and conserved, in many cases this will only be achieved through a protection of their habitats. It is fair to say that in wildlife conservation the emphasis must lie in protecting the habitat wherever this can be achieved. The subject of species evaluation falls outside this study. Spellerberg (1980) presented an informative and comprehensive review of this topic. The papers of Adamus and Clough (1978) and the approach of the British Red Data Book (vascular plants) (Perring and Farrell 1977) are arguably significant contributions to this study area. The approach used in New Zealand to species evaluation makes an interesting comparison and the details have been published by Given (1979).

1.3 General discussion on the potential contribution of ecological evaluation to planning

1.3.1 The potential contribution of ecological evaluation to planning

The advantages of standardising the ecological data used by planners become evident on studying selected planning issues. For the purposes of this thesis three planning documents relating to specific case studies were examined in detail. These documents were:

1) The Public Inquiry into the appeal by the English China Clay Company against the refusal of the Dorset County Council to permit the winning and working of ball clay at Russel Quay, Arne, near Wareham in Dorset. (Appendix A).

2) Report of the Working Party on the environmental implications of an exploration well site for oil or gas on the Goathorn Peninsula near Wareham, Dorset. (1979) (Appendix B).

3) Purbeck Heritage Coast Reports and Proposals (1977) (Appendix C).

These three reports were selected because they are typical of the type of document used by planners in developing planning policy. They were readily available and typified the principal environmental pressures upon the countryside today. A variety of evidence was presented at these enquiries but for the purposes of this study only the ecological evidence was considered and has been included within appendices A, B and C.

1.3.2 Some comments on these three selected planning reports

In two of the documents studied (the Goathorn Peninsula Working Party and the E.C C. Ball Clay Inquiry) an ecological evaluation would have helped to clarify the ecological issues. Both areas were relatively small; 1.54 ha (3.8 acres) and 19.67 ha (44 acres) respectively. The time required to carry out a study of these two areas would be relatively short and given the evidence that there was little data available on both sites such a study would appear to be essential. A great deal of information was presented at both of these Inquiries, not all of it relevant to the sites under study but much of it relating to the surrounding area. Information was presented in a variety of formats and the desirability of standardising the format of the presentation of the data would appear to be overwhelming. Generally the ecological information was descriptive and lacked quantitative information. Too often there appeared to be a preoccupation with rare species, the implication almost being that sites are only worth conserving if they contain rare species. One section in the E.C.C. Ball Clay Inquiry contains the following statement: "They contained no important species". All too often 'rarity' is used in a subjective manner or at least not defined. One cannot help but come to the conclusion that the ecological issues would have been discussed with greater clarity and greater ease if the information had been presented in the form of a reliable ecological evaluation. It is interesting to note that reference was made to an ecological evaluation in the E.C.C. Ball Clay Inquiry.

"In an evaluation made for the Dorset Naturalists Trust only 17% of the total land surface in South East Dorset had been classed as of above average grade 1 or 2 ecological significance. The exceptionally high pace of development in South East Dorset highlighted the importance

of retaining intact the Arne Peninsula as a nature conservation area."

The evaluation was used in a confusing manner and since it was largely based on very subjective criteria it was as a methodology perhaps of limited value within the context of a Public Inquiry.

The Purbeck Heritage Coast Study covered a much larger area than the above two studies (in excess of 150 sq. km.). The amount of ecological information used was limited considering the size and the number of S.S.S.I.s and N.N.R.s in the area. Given these facts a broad ecological evaluation would have helped in discriminating between those areas which should receive Intensive Use, Medium Intensive Use, Low Intensive Use and Quiet Areas. Such a categorisation of levels of recreational use is probably inversely related to ecological value. That is to say one would want to achieve a very low level of recreational use in ecologically important areas and vice versa for ecologically unimportant areas. An ecological evaluation thus could have played a unique role within this study. Further to this point an ongoing series of ecological evaluations could ascertain whether the chosen management policies were working and to what extent if any a particular area was suffering from the level of recreational use planned for it. This would appear to be a further use of ecological evaluations in ascertaining the effectiveness of planning policies. A time sequence of evaluation would help in ascertaining whether ecologically a habitat was deteriorating, or improving.

There is undoubtedly a sense of unease when qualified and experienced biologists differ often so markedly in the evidence they present at Public Inquiries. Whilst one would expect individuals to differ in their interpretation of data, and there may be errors of judgement, the facts should remain constant. Since the primary function of a Public Inquiry is to ascertain the facts through evidence the concern about the different interpretation of a body of ecological data should not necessarily arise but witnesses are frequently asked by Counsel to advise the Inspector on a 'reasonable' interpretation of the evidence. Nevertheless Yapp (1973) recorded an instance when two biologists differed dramatically in the interpretations they gave when presenting evidence of the 'best' route for a proposed road. Cain (1968) described a number of ill fated non-ecological planning decisions on a worldwide scale arising out of such disagreements between ecologists.

The wide scale adoption of a universally agreed method of ecological evaluation would help diminish public disagreements between ecologists on what should be uncontestable facts, thus avoiding causing incalculable damage to the status of the ecological contribution to planning decisions.

1.3.3 The global perspective of local issues

The above arguments and justifications for the wide scale use of ecological evaluation as a tool in conservation is very much developed at the local level. Conservation however has a global perspective and small scale local issues are symptomatic of the broader problems facing the biosphere which ecologists and conservationists seek to ameliorate. These problems were drawn to the attention of many by Rachel Carson's "Silent Spring" and "The Limits to Growth" (Meadows et al.1972).

As Caldwell (1970) noted, "On earth, ecological criteria will increasingly modify or replace other indices of value as the constraints of the closed system environment of Spaceship Earth become increasingly clear." Some of the case studies examined specifically illustrate these global trends. The Goathorn Peninsula Study into the location of an oil exploration well site exemplified the world demand for energy and this demand in turn relates to our technology and population level. The Purbeck Heritage Coast Report is a consequence of an increased recreational demand which amongst other things is related to population size. It can be argued then that the use of such techniques as proposed in this study whilst being justified at the local level have a role to play in the overall conservation of the biosphere in seeking to modify and minimise the pressures thereon.

1.4 The role of ecological evaluation in planning

One of the principal uses of ecological evaluation is to enable an ecologist to make an objective statement of the relative or absolute value of ecological characteristics. Such an assessment would enable planners and other interested bodies to rank habitats in the order of their ecological value. If a suitable technique was developed and widely accepted this would have the benefit of standardising the form of ecological data used in planning decisions. If a system could be developed which scored habitats say on a range of one to four this would

allow broad policy decisions to be made very much along the lines on which the Agricultural Land Classification Scheme is based. Many County Planning Authorities make a policy decision not to develop on Grade 1 agricultural land and include this decision in their Structure Plans. It is not difficult to envisage a similar statement being made in terms of ecological grades as specified by a specific methodology. Such a system would support and supplement the current statutory designation, particularly in the case of S.S.S.I.s which have very limited protection. It has also been mentioned previously that one possible additional use of ecological evaluations is that of monitoring policy decisions to check if a certain policy is resulting in a deterioration or improvement of a particular site.

There is considerable scope for the development and use of such techniques based on a scientifically valid methodology. Evaluation methods are indispensible for good environmental management. Froment and Nef (1976) in a review of the status of the ecological argument in planning decisions in Belgium came to very similar conclusions. If there is to be an effective contribution from ecology, the issue of the presentation of biological data must be resolved. The qualities of the natural environment can no longer be expressed in terms of such adjectives as rare, unique and precious. Data must be presented in a form accessible to the planner, if possible by attributing a numerical evaluation. This scale of values would allow choices to be made in full awareness of the facts.

1.5 The uses of ecological evaluation outside of the U.K.

The United Kingdom with its small surface area relative to its large population has tremendous conflicts of land use not at all dissimilar to the problems experienced in the Netherlands. In the Netherlands the use of ecological evaluations is much more widely accepted than in the U.K. and van der Ploeg and L. Vlijm (1978) review ten case studies. From these ten case studies it is possible to identify four types of evaluation studies.

1) Studies aiming at an environmental survey of large areas (71,000 sq.km.)

2) Studies aiming at an ecological evaluation of areas or regions because of possible threats i.e. they show the educational and scientific

importance of an area. One such study, "The Colours of South-West Netherlands"; Zuidwest Nederland Werkgroep (1972) had as its aims to

i) Present an environmental atlas of the region.

ii) To make a comparative inventory of the present plus prognosis for the future.

iii) To produce a hard input from the field of nature conservation and environmental management for policy making.

3) Studies aiming at ecological evaluation of regions because of land use proposals.

4) Studies aiming at ecological evaluation of a limited area because of specific threats. These were study areas ranaging from 0 - 100 sq.km.

Van der Maarel and Stumpel (1974) make the observation that the first projects done in the Netherlands originated from world-action-group initiatives or from ecological circles and gradually the authorities became convinced that ecological mapping and evaluation should be an essential element in the planning system and they are now demanded by the planning authorities. Since 1970 about sixty projects have been completed in the Netherlands. Their general use appears to be along the following lines; the results of the ecological evaluation are presented on a scale of 5 to one, a value of five pertaining to a very valuable habitat. Then expert opinions are presented on the effect of specific encroachments and finally recommendations are drawn up.

In New Zealand a recent 'Biological Workshop' (Commission for the Environment 1979) attended by biologists and planners resulted amongst other things in the establishment of a working group to investigate and develop systems of ranking.

It is interesting to note that one of the major problems encountered in New Zealand is that since the assessment of some of their factors was to some degree subjective this gave field officers considerable freedom of expression and the data was difficult to analyse and not suitable for computerisation. Imboden, Coker and Ogle (1979) are working on a more objective habitat ranking system which gives scores to various criteria. Nevertheless, there is no agreed procedure in New Zealand for evaluating and ranking examples of threatened communities (Kelly 1979). Kelly has outlined an embryonic system for evaluating

Nature Reserves (1979) but this does not represent a sophisticated technique and Wright's (1977) proposals are more detailed.

In the United States Klopatek et al. (1981) have developed a scheme of ecological analysis with the objective of identifying potential conflicts between desirable wilderness areas and the development of energy resources. They succeeded in highlighting the existence of tracts of land which have both unique ecological resources and significant energy resources and they concluded that before making any decisions on the future status of these tracts, 'site-specific' investigations need to be conducted. In the United States schemes developed by Tans (1974) and Gehlbach (1975) have been used by the state planning boards.

1.6 The uses of ecological evaluation in the U.K.

In the United Kingdom we have little to compare with the level of sophistication we find in the Netherlands. From the point of view of identifying valuable conservation sites Peterken (1974) has developed a method for assessing woodland flora and Ward and Evans (1976) have developed a scheme for assessing British Limestone Pavements. Ratcliffe (1977) has discussed the criteria used by the Nature Conservancy Council in selecting sites of national biological importance, but these criteria do not together constitute an evaluation scheme. On a large scale Tubbs and Blackwood (1971) have applied their method to several counties in the South of England and their evaluation maps are taken into account in the production of structure plans. Specifically this scheme was used in a novel planning study in the East Hampshire Area of Outstanding Natural Beauty. Helliwell (1969) carried out a survey of Severnside and developed a method of evaluating the conservation values of large areas, the results of which were used by a planning team preparing a strategy plan for urban development in the region. West Sussex County Council (1977) carried out an ecological appraisal of the county using a subjective system developed by the local Nature Conservancy Council.

The Nature Conservancy Council has carried out an ecological evaluation of the New Forest (1971) as a contribution to the study, 'The Conservation of the New Forest' (1971) which principally sought to reconcile the conflicts between recreation and conservation. Wright

(1977) developed a site evaluation scheme for use in the assessment of potential nature reserves. For identifying sites of particular interest on coastlines Ranwell (1969) has used a semiquantitative index for the comparative biological value of sites in Great Britain.

Yapp (1973) has developed a specific method for evaluating linear landscapes; the data from which he presented at a public enquiry.

It will be seen from this short review of the uses of ecological evaluations that their use in planning in the U.K. is very limited and only Tubbs and Blackwood's (1971) method has been used to any great extent. However the scale of their work is such that it is only of use at the level of producing structure plans or other large scale evaluations. The requirements of a small localised issue would not necessarily be met by this method.

There is then in the United Kingdom a need for a sensitive scheme of ecological evaluation which can be used in planning decisions on small scale issues and which optimistically would be adopted on the scale of use found in the Netherlands.

A plausible model for the use of ecological evaluation within the total planning machinery has been suggested by Dearden (1978) and van der Ploeg (1978) both arguing that evaluation methods are indispensable for good environmental management. The 'political' power should have at its disposal all the information necessary to make the best decision. A systematic application of such methods over the whole country would provide information which would be empirical and objective.

1.7 The aims of this study

1.7.1 To develop an acceptable technique for evaluating wildlife habitats

The broad intention of this study is to review and investigate the methods available at present. Having effected this review the intention is then to propose and test the feasibility of a technique of ranking communities which will combine the strengths of existing schemes without their attendant weaknesses. Any new technique developed must have as one of its prime objectives that of the ability to produce similar results when used by different workers and have a broad applicability over a wide range of habitat types.

1.7.2 To develop a technique which satisfies the requirements of the ecologist and fulfils the needs of the planners

Ecological research for planning purposes must focus on planning goals rather than scientific ideals. The process of ecological evaluation would be more efficient, justifiable and useful if such enquiries were conducted with specific planning needs in mind (Dearden 1978). One of the challenges of this type of work is to develop a scientifically acceptable and objective method which is not too expensive in terms of man hours and yet can be applied to relatively large areas and generate useful information. The subjective element of many existing techniques seriously undermines their value within this context. At best it should be possible to develop a partially objective scheme; the selection of the ecological parameters to be measured is in itself a subjective exercise but the measurement of those parameters can be done empirically.

i.e. assessed on a linear equal numeric scale.

1.7.3 To effect a comprehensive ecological evaluation of an area

The method proposed in this study was tested on a large area. This would also contribute to the amount of such information presently available to planners.

1.8 Layout of the thesis

The theoretical considerations implicit within this area of study are discussed in Chapter 2,and Chapter 3 examines the different approaches to this area of study. Having discussed the criteria used for evaluating communities, those to be included in the method adopted in this thesis are selected in Chapter 4. This chapter concludes with a discussion on the applicability of ecological indices. Chapters 5 and 6 detail the method and results obtained respectively including a multivariate analysis of the data. In Chapter 7 the approach suggested here is compared critically with three similar methods. Finally in Chapter 8 suggestions for further work are made along with some suggested improvements in the recommended technique.

CHAPTER 2

2. SOME THEORETICAL CONSIDERATIONS

2.1 Towards a concept of ecological evaluation

The last five years have seen a lively discussion on the nature of ecological evaluation and it is right and proper that there should be an ongoing dialogue into the philosophical underpinning of any new study area. This is particularly important with a topic like this which lies at the interface of ecology and conservation. Van der Ploeg (1978) has argued that since science does not attach value judgements to the objects of study the activity called 'ecological evaluation' cannot be a scientific activity. There is undoubtedly a lot of confusion in the literature and this appears to arise from a lack of clear definition of the principal terms involved. It is therefore fundamental to state clearly the definitions of the terms used and this is especially important for the word 'value' for which the Oxford Dictionary lists numerous meanings. It has been suggested accordingly that there may be some merit in dropping the use of the word 'evaluation' altogether and Goldsmith (1974) uses the term 'assessment'. There is a rapidly developing literature on this topic and there would appear to be few good reasons for such a step as long as the term is clearly defined.

A discussion on the nature of ecological evaluation (see Holdgate 1975) should not take place in a vacuum, but one should bear in mind the uses to which such work is likely to be put. Discussions on the virtues of pure and applied science are not new but with the current cutbacks in research grants and university grants, the merits of applied science have received a boost. Likewise in many ways ecology is an applied science having numerous applications, particulary but not exclusively by any means in the field of conservation, or more generally Environmental Planning. Ecology and conservation are different entities and it has to be acknowledged that ecological evaluation is very much a bridge between these two bodies of knowledge. The data provided by a reliable method of ecological evaluation can be of great use to conservationists and environmental planners.

2.2 Some definitions

In this study the terms listed below are understood by the following definitions:

2.2.1 Definition of ecology

Today the word 'ecology' is used in a broad sense. As our understanding of ecology has grown, different and sometimes improved definitions have been offered.

"Scientific natural history" (Elton 1927)

"The structure and function of nature" (Odum 1963)

"The scientific study of the distribution and abundance of organisms" (Andrewartha 1961)

2.2.2 Definition of conservation

As far as nature or biological conservation is concerned, this has been defined by Warren and Goldsmith (1974) as "The custody of natural resources". Since there is implicit within conservation the idea of management and scarce resources, an alternative definition might be "Biological conservation is the prudent management of scarce biological resources". Odum (1971) has suggested that the aims of conservation are:

1) To ensure the preservation of a quality environment that considers aesthetic and recreational as well as product needs.

2) To ensure a continuous yield of useful plants, animals and materials by establishing a balanced cycle of harvest and renewal.

2.2.3 Definition of the word 'value'

The Concise Oxford Dictionary offers at least eight quite different meanings. As far as this study is concerned it refers to the numerical measure of a quantity and it is therefore quite capable of being objectively quantified by empirical means. It is not used in the sense of a value judgement i.e. a principal or standard of ones judgement of what is valuable or important in life (see van der Ploeg 1978).

Clearly then, ecological evaluation does exist as a science if the

word 'value' is being used in the former sense but not if it is being used in the latter sense.

2.2.4 Definition of the word 'evaluate'

Taking the meaning of the word 'value' to be a numerical measure of a quantity, then 'evaluation' is to ascertain the amount of, or find the numerical expression for, that value (Concise Oxford Dictionary). Fowler's Modern Dictionary (1965) gives that 'evaluate' is a term of mathematics meaning to find a numerical expression for, hence more generally to express in terms of the known.

These evaluations can then be used to rank habitats i.e. to classify them by applying certain grades derived from the evaluation.

2.3 Relationships between ecology, ecological evaluation and conservation

It has been suggested by van der Ploeg (1978) that ecological evaluation is not a scientific study since science does not attach values to entities. As has already been noted, this largely depends on the sense in which the word 'value' is being used. However, ecology is a scientific discipline and conservation is not; conservation represents a goal to achieve and in working towards this goal one uses ecological data and ecological methods. Conservationists make a value judgement as to the order of their priorities, that is to say they attach high values to certain factors (e.g. rare species) and lower values to other factors (e.g. abundant species).

Since conservation is in the very real sense of the word a political activity, it has been suggested by Braat et al. (1979) that that branch of ecology which is the application of scientific ecological information for political objectives, such as nature conservation, be called Political Ecology. Ecology within this field of study is impartial, conservation has within it inherent biases determined by the values attached by society to rare species etc. Ecological evaluation could be a valuable tool for conservation and whilst Political Ecology represents a bridge between conservation and ecology, ecological evaluation is an objective entity located within Political Ecology.

A similar observation by Margules and Usher (1981) led them to comment that the confusion surrounding the 'concept' and 'value' aspects

of an ecological parameter has hindered the development of universally acceptable methods of assessing conservation potential. Whilst the concept is unlikely to change, the value placed by society will change both in place and time.

2.4 The essential partnership between ecologist and planner

Thompson (1979) has commented that whilst ranking systems have many attractive features, a ranking system compiled by an amateur or by a planner with insufficient primary data at his disposal, can be meaningless, misleading or even absurd and yet still retain all its attractive features. He concludes that ranking systems are valuable management tools but, since they represent the ultimate condensates of the raw data, it is imperative that this type of display for comparing land use priorities be passed before appropriate specialists for comment. Certainly few planners have the knowledge to assess the full consequences of modifying ecosystems.

One highly experienced planner has suggested there are two levels of evaluation, firstly interpretation of the resources to simplify and code basic information - this being the task of biologists and secondly synthesis by the user of the evaluation - the task of the planner (Henderson 1979). The former should be an objective exercise whilst the latter, which involves social values and the aspirations and needs of man, will be subjective. Henderson states that in his experience biological scientists are often reluctant to release information and there is a close guardianship of information which when presented is in a very complex format. Biological resource material must be produced simply and clearly; bad planning decisions do adversely affect the biosphere. Planning is not a science, but it is concerned with the application of science to policy and administration. In any circumstances it is a process of making choices in situations of uncertainty. One of the causes of uncertainty is our knowledge of the environment and our presentation of that data (Lewthwaite 1979). At the moment to carry out planning, a considerable number of judgements are made based on very limited data. This is a situation which all ecologists should find unacceptable.

It is naive to think that land use decisions will ever or should

ever be made on purely ecological criteria. Ecological input must be considered in conjunction with the economic and social concerns that have traditionally dominated planning. However ecological input should be considered mandatory in all land use decisions (Dearden 1978).

CHAPTER 3

3. THREE APPROACHES TO THE EVALUATION OF WILDLIFE

3.1 Introduction

There are several divergent approaches to the evaluation of wildlife. It appears that these approaches can be very broadly allocated to two schools of thought. Firstly there are those investigators who seek to measure certain ecological and conservation parameters such as rarity, habitat diversity and fragility and combine these parameters within a stated formula (e.g. Gehlbach 1975, Tans 1974 and Goldsmith 1975). Secondly there are those workers who have identified certain values or uses which nature fulfils for man, this anthropocentric approach is characterised by the work done in the Netherlands in evaluating the 'Functions of Nature' (Braat et al. 1979). However the work of Froment and Nef (1976) in Belgium very much bridges these two schools of thought and it is not easily allocated to either, their techniques having characteristics in common with both approaches.

The international nature of the work currently in progress in this field and particularly the languages in which the results have been published (for example the great quantity of work published in Dutch) has not facilitated this study.

3.2 The 'Functions of Nature' approach

This is an approach which seeks to measure certain criteria which are related to the functions which nature or wildlife fulfils for man. In other words it measures the benefits derived by man from wildlife. This assumes that there are identifiable or potentially identifiable benefits to be derived through conservation. Frankel (1970) described the importance of genetic diversity to the development of food resources and Vida (1978) warned of the long term dangers of lower genetic diversity leading to reduced polymorphism in natural populations. Helliwell (1969, 1973) and Everett (1978) have stressed the economic value of wildlife.

Within the school of thought which evaluates the 'Functions of Nature' it is possible to identify three different approaches:

a) Economic evaluations

b) Economic - ecological evaluations

c) Ecological evaluations

3.2.1 Economic evaluations

These are techniques which principally use the science of economics. They fundamentally involve the attachment of monetary values to the benefits of wildlife.

Langford and Cocheba (1978) have written a critical review of these economic assessments. The aim of these techniques is to provide information which can be used in making wildlife management decisions principally in connection with optimising the revenue from hunting. The central issue in these economic assessments is that wildlife permits people to participate in certain activities which produce varying amounts of satisfaction or utility. This benefit of wildlife can be measured in economic terms, it is argued that even the aesthetic value of wildlife is amenable to this sort of evaluation. The following are identified as the main sources of wildlife value.

i) Recreational hunting

ii) Non-hunting activities: these activities can be further sub-divided:

   a) wildlife based activities

   b) wildlife-related activities (e.g. camping, picnicing, hiking, canoeing)

   c) endemic wildlife activities (e.g. observing flights of migrating water fowl from one's own garden)

   d) recording wildlife based activities (e.g. wildlife films, wildlife painting and carving).

iii) Existence value; this value is derived from the comfort gained by people in being simply aware of the existence of wildlife. This contemplation attributed to the existence of wildlife is defined as a contemplative wildlife activity. By definition this contemplation occurs in the absence of sensory contact with wildlife.

iv) Option value; this exists when an individual places value on having the option for himself or others to participate in an activity in the future.

These values are very individualistic and related to private consumption. Values of wildlife such as an input into research processes and as a pool of genetic materials which are related to public value fall outside the scope of these studies.

The dilemma within this approach is that it is the activities rather than the wildlife which is valued and to be accurate the wildlife only helps to produce the activity which is valued. In the case of shooting water fowl, for example, there are other inputs such as transportation, the natural surroundings, decoys and guns etc. The hunter has a clear idea of the value of all these inputs other than the wildlife and the problem to be solved is that of isolating the value of wildlife from the other sources of value.

Langford and Cocheba (1978) concluded that the economic quantification of wildlife value remains a formidable challenge and there are no available valuation techniques which are without serious limitations.

3.2.2 Economic - ecological evaluations

Helliwell (1969 & 1973) devised a method which attached notional monetary values to various benefits that wildlife has for man. These benefits fall into these four categories:

i) Actual production e.g. hunting, shooting, fishing, berry picking
ii) Potential production
   a) maintenance of a genetic pool for breeding
   b) control of pest species and pollination
   c) facilities for research work and training of research workers
iii) Recreation
   a) natural history studies, photography
   b) contribution to the landscape and character of a locality
iv) Education
   a) the education of children and adults into the way in which the biological world functions.

Helliwell does not consider the 'intrinsic worth' of wild plants and animals, that is to say the moral argument which articulates the view that wildlife has of its own a right to exist. It is suggested that these seven benefits listed above can be evaluated by the following criteria.

	Benefit	Parameters Indicative of Benefit
1.	Actual production	- Direct returns, income from shooting or the value of the produce sold

	Benefit	Parameters Indicative of Benefit
2.	Genetic reserve	- The value of a particular area for this purpose will depend on the rarity of the community and its species diversity
3.	Ecological balance	- The diversity and extent of the locality will govern its value against violent fluctuation
4.	Educational value	- Accessibility to students, the availability of other suitable areas and its resistance to trampling and collecting
5.	Research	- Homogeneity, size and scarcity
6.	Natural history interest	- Scarcity, diversity, presence of attractive species
7.	Local character	- Conspicuousness, scarcity and number of people visiting a rare creature.

This technique is highly subjective and would need a lot more developmental work before it could be used equally satisfactorily by different workers. The various indices used are highly arbitrary and the implementation of this method requires the worker to make numerous highly subjective decisions. The technique has also been criticised on the grounds that species diversity is estimated in terms of plant diversity, the assumption being that there is a very close correlation between plant species diversity and animal species diversity. Hooper (1970) questioned this assumption. Research in progress at the moment (Margules pers. comm.) will hopefully contribute to our understanding of this relationship.

Braat et al. (1979) sought to use and combine the sciences of ecology and economics, since economics is the 'science of evaluation' and it pertains to the distribution of scarce goods. The key to this anthropocentric approach is that human society is judged to exist by virtue of the functions performed for it by the natural environment. Braat lists five arguments for the conservation of nature:

1. Sentimental reasons, which include ethical, cultural and hobbyistic reasons.
2. Conservation is a means to maintain the stability, integrity and functioning of the biosphere.
3. Nature has a value as an object of scientific study.
4. There are economic benefits from studying wildlife.

5. The ethical argument which suggests that every creature has a right to exist.

It is suggested that arguments 2 and 4 listed above may form the basis for scientific and quantitative analysis. Braat et al. have developed a lengthy argument as to the nature and existence of ecological value; the values which they consider useful are stability of ecosystems, contribution to the steady state of the biosphere and irreplaceability; the relationship between these values being found within the concept of the 'steady state'. They argue that the evaluation methods used by ecologists in the past decade do not really produce ecological values. The principle question for debate is not which criteria to evaluate but which criteria reflect the performance of the functions of nature.

Whilst the difficulty lies in specifying the structures and processes involved in performing a certain function, this is argued to be preferable to evaluating a 'non-delineated entity'. The functions of the natural environment have been variously defined as: 'the supply of means for human use' (Braat et al. 1979), 'a possibility to satisfy needs, as this results from the properties of the natural environment' (Van der Maarel and Dauvellier 1978).

Having so defined the functions of wildlife they have been classified in the following ways;

1. direct benefits (e.g. fisheries)
2. gene pool
3. buffer function of natural populations
4. educational value
5. research area for biologists
6. basis for interest in nature
7. "local colour".

De Smidt (1970) devised the following classification, depending on a function's "relevance for scientific research";

1. gene pool (reservoir function)
2. indicator value (signal function)
3. laboratory function
4. buffer function (of relatively stable ecosystems).

Westhoff (1971) suggested a modification. Instead of the buffer function, which he thought hard to assess, he proposed;

5. regulation function (by stable elements in a landscape)
6. educational function ("in vivo" studies of systems).

An early classification of Hueting and Morzer Bruyns dates from 1970;

1. nature as a producer for mankind
2. nature as a regulator of processes important to mankind
3. nature as a source of physical and spiritual well being
4. nature as a source of knowledge and inspiration
5. nature for its importance to itself.

Bouma (1972) developed a classification using the needs of man as his criterion;

1. functions of nature related to the needs of man (production function, welfare function, including recreation and landscape function and the science function)
2. functions of nature which are conditional functions for human needs (regulation and reservoir functions)
3. functions of nature not related to human needs (nature for itself function).

Hueting (1970) distinguished some functions of a coastal dune area as follows (this list is not complete);

1. processing of water
2. recreation
3. biological research
4. habitat of rare species
5. protection against the sea
6. educational function.

Van der Ploeg (1971) used both the actual and the potential functions of any area as a starting point. The final designation must be in one of the following categories;

1. industry
2. urbanisation and infrastructure
3. supply
4. recreation
5. education (research)
6. conservation
7. miscellaneous (for uncertain destination).

However van der Maarel and Dauvellier (1978) produced a comprehensive classification identifying the four major functions as;

1. production function
2. carrier function
3. information function
4. regulation function.

These various classifications represent five different approaches;

1. The form of use.
2. Actual and potential functions of an area.
3. The needs of man.
4. Scientific research.
5. Ethical argument.

Braat et al. have judged the third approach to be preferable for their economic/ecological approach. They suggest that a classification of the natural environment should be based on an overall framework of needs and means (services). In any evaluation of functions the interactions are of great importance.

Having identified and agreed upon a series of functions, the next step is to select criteria which when measured indicate the level of performance of that function. There are of course many problems involved in assessing the performance level of functions. Classifications are subjective and may differ from researcher to researcher and from area to area.

Van der Ploeg and Vlijm (1978) presented a framework of land use planning into which they would see their proposals fitting.

These studies are still in progress and some cover large areas, when complete they will provide the basis for the judgement of the operationality of the concept of functions.

3.2.3 Ecological evaluations

Everett (1979) discussed six functions of wildlife. These were:

1. Agricultural benefits e.g. cropping, pollinations, biological control.
2. Medical e.g. animals are used for research, wild plants as a source of drugs.
3. Research - such research should help improve man's relationship with the surrounding environment.
4. Educational.

5. Aesthetic - many species of wildlife are attractive and stimulating to watch.
6. Ethical and moral - some people benefit from knowing a species exists.

Everett has developed this discussion by attempting to isolate those factors from which the above benefits are derived. He does not, however, go on to suggest a methodology for determining those factors, although a system of weighting is suggested where those factors which make the greatest contribution to the above six factors receive the highest weighting.

3.3 The 'Measurement of Selected Ecological Parameters' approach

In this approach, certain criteria are selected and values ascribed to them. Ideally all of the elements of an ecosystem should be evaluated, but this is impractical. In practice a few elements only will be studied in the hope that the final evaluation will possess a high degree of credibility.

There has been some confusion on the point of selecting criteria which are truly ecological. Some parameters such as 'educational' and 'research use' are clearly not ecological and some workers have argued that 'rarity' and 'fragility' are conservation values and not ecological values. This is a debatable point; ecologists do concern themselves with abundance and since fragility is an intrinsic factor (or the predisposition to recreational pressure is an intrinsic factor) it may be that they can be safely regarded as ecological criteria. Nevertheless this is an important point which must be considered if subjective considerations are to be eliminated. The distinction which needs to be drawn between the relative positions of ecology and conservation have already been discussed.

Another possible weakness is that criteria are frequently estimated subjectively; this should be avoided as far as is possible in any rigorous scientific investigation. It will not be possible to produce a wholly objective scheme since the process of selecting criteria is in itself subjective. However those criteria when selected must be capable of objective empirical assessment. Rarely will it be possible to evaluate all aspects of all communities and therefore it is for this reason that the very best that can be achieved is a partial semi-objective biological evaluation.

It is arguable that this approach is seen at its best in the work of Dearden (1978) and Goldsmith (1975). There are now several examples of this approach in the literature, most of which determine species and habitat diversity and rarity. Goldsmith's (1975) approach included extent, rarity and plant and animal species richness and the values obtained were multiplied together to give an Index of Ecological Values.

Margules and Usher (1981) presented an admirable review of the criteria used in a selection of schemes. It is not always easy to make an immediate comparison because frequently one is not comparing like with like. In some schemes the objectives are to identify potential nature reserves (Wright 1977), others are very specifically aimed at evaluating a particular taxonomic group (Williams 1980), whilst others are very broad and cover large areas of the landscape (Tubbs and Blackwood 1971, Goldsmith 1975). Margules and Usher (1981) recognised three groups of criteria.

"The first, containing area and diversity, can be assessed during a site visit. The second, containing representativeness, rarity and naturalness also requires a site visit, but detailed survey data on the surrounding biogeographic region are also required. The third containing recorded history, potential value and ecological fragility, depend on case histories of the sites themselves or on the drawing of inferences from case histories of similar sites."

3.4 Froment and Nef (1976)

The work of the above authors does not really fit into either of the aforementioned schools of thought, this proposal having a great deal in common with both schools. They suggest that the aim of environmental management is in reality the optimizing of 'productions' whose vital capacity it tries to increase. These 'productions' can be classified under four headings:

i) Basic material goods (viable climate, food).
ii) Material goods that ensure comfort (shelter, communications, tools).
iii) Basic intellectual goods (recreation/leisure).
iv) Intellectual goods that ensure 'well being' (aesthetic, cultural etc.).

They go on to state that:

"It is the responsibility of the political power to maximise and perpetuate these functions. With this as a goal the environmental manager should receive from the ecologist data on the biological value of the region under consideration. Evaluation methods are therefore indispensable for good environmental management, they assert that the requirement is complete, numerical and objective information".

They argue that all the elements of the ecosystem should be evaluated but acknowledge that this is often not practical. It is desirable to evaluate the relief, the soil and the hydrology. The criteria they favour are diversity and rarity; they assert that it is imperative no matter which criteria are selected that they should allow a numerical and objective evaluation. However this alone is argued to be insufficient and a synthesis of several partial evaluations, as diversified as possible will give an acceptable evaluation. For each discipline (pedology, botany, zoology etc.) a partial synthesis is calculated on the basis of diverse criteria (rarity, diversity for example). This intermediate stage allows each of these disciplines to be given an equal weight to the final synthesis, independently of the number of partial criteria used. A final synthesis value (S) is calculated by the formula:

$$S = \sqrt{\frac{\sum_{1}^{n} v^3}{n}}$$

n = the number of partial values

v = each value

The data was finally presented in map form, the communities according a rating from 5 (the highest) to 1. An example of this system in use is given below, which was applied to a forest ecosystem covering 340 hectares.

It is difficult to see how the above formula relates to the results on the following page. The reasoning behind the formula is not readily apparent.

	Max.	Beech	Oak with Silver Birch	Pine	Spruce
A. Environmental factors					
1. Geomorphology	5	4	1	1	1
2. Pedology	5	4	3	3	2
B. Vegetation					
1. Organisation					
(a) structure	5	2	4	2	1
(b) degree of artificiality	5	4	4	2	1
(c) age/maturity	5	4	3	2	1
2. Diversity					
(a) number of species	5	3	4	2	1
(b) number of ecological groups	5	3	4	2	1
C. Fauna					
1. Number of trophic levels	5	4	5	3	2
2. Diversity/rarity of species	5	4	5	3	1
D. Functioning					
1. Cycle of organic matter	10	8	9	6	2
2. Water cycle	10	7	8	5	3
Σ	65	47	50	31	16

Whilst it is not quite clear how these figures were derived they range out of a maximum of 65, from 16 for the spruce plantation to 50 for the oak grove with silver birch.

3.5 A brief concluding discussion

One of the difficulties which one is presented with in examining proposals is that in many cases publications only include a methodology and publication of results is still awaited. Where the results of investigations are available it is far from easy to see how the data has been derived.

Certainly any appraisal of the 'Functions of Nature' approach will have to await detailed publication of results. Even then in the final

analysis the worth of any technique will be judged by the extent to which it is used by ecologists working in this field. It does appear that the greatest effort has gone into the evaluation of selected criteria. Whilst it is no comment on the merit of individual schemes there are far more publications representing the latter school of thought than there are from the Functions of Nature approach.

The large number of criteria used by different assessors is reviewed in the next chapter.

CHAPTER 4

4. REVIEW OF CRITERIA FOR EVALUATING HABITATS AND COMMUNITIES

4.1 Introduction

The aim here is to systematically and critically review those factors which either individually or jointly may be indicative of the ecological value of a habitat or a community. Confusion can arise from the multiplicity of criteria used. When these factors have been reviewed it should be possible to isolate those relevant to this study and then develop an acceptable methodology for evaluating them. Many criteria are interrelated and relatively few are independent of one another e.g. area and species diversity are clearly related in the form of the species/area curve and this has led Peterken (1974) to comment that one of the strengths of his scheme for evaluating woodlands using indicator species is that this dilemma is avoided. However ecosystems are complex units and any survey can only record a fraction of the total observable parameters. Which parameters are indicative of ecological value is the arguable point.

One of the aims of this study to produce an objective and empirical scheme of assessment which is free (as far as is possible) from subjective considerations. There are obvious scientific merits in a wholly empirical ecological assessment, however if such evaluations are to be presented as evidence at Public Inquiries a subjective assessment may come to be contentious in the hands of a well briefed Counsel.

Accordingly it is one of the objectives of this review to identify those factors capable of an objective and an empirical assessment. The criteria which are assessed and eventually enable habitats and communities to be ranked in order of importance will vary according to the intended use of each evaluation scheme. A worker concerned with identifying potential nature reserves will be likely to use quite different criteria than someone concerned with evaluating two different areas as one of the considerations in siting a potential development.

In connection with the selection of sites for nature reserves the Nature Conservancy Council in 1977 published the N.C.C. Review. This document elucidates those criteria used by the N.C.C. in the selection of their key sites. The key area concept has been defined explicitly

in Cmd. 7122 (Ministry of Town and Country Planning 1974). The Society for the Promotion of Nature Conservation (undated) adopted the list of criteria proposed by Ratcliffe (1977) in the above review in their scientific assessment of the scientific value of reserves under the management of the Conservation Trusts associated with the S.P.N.C.

4.2 Criteria

The following discussion of eighteen criteria has been developed around the framework of Ratcliffe's criteria. Diversity, extent, naturalness, rarity and fragility have been discussed in some detail because of their frequent use in many schemes.

4.2.1 Species, community and habitat diversity

4.2.1.1 Discussion

Species diversity can be interpreted in several ways, meaning either a measure of the number of the species present or it can represent a function of the number of species and their relative abundance. Goodman (1975) used it to refer to the number of trophic levels and the number of interconnections between species within and between trophic levels. If a species diversity index is to be used then according to Bunce (1980) the index must meet the statistical requirements of an unbiased sample of known variance. Accordingly he advocates the use of Simpson's Index.

$$D = 1-\sum_{i=1}^{s} (Pi)^2 \quad \text{(Simpson 1949)}$$

D = Simpson's Index of Diversity, Pi = proportion of individuals of species i in the community

The frequent use of diversity has led many (e.g. Bunce 1980) to comment that it is over used. Hill (1975) after reviewing the literature concluded that the existing data and evidence is contradictory and that the axiom that equates stability with diversity is still in reality a hypothesis. It should not be assumed that diversity is necessarily indicative of high value and as communities become increasingly studied

precise judgements can be made; there may for example be a case for arguing that low diversity is of high value in heathland. One further problem associated with species diversity is that it is partly related to area and environmental or topographical diversity. Therefore species diversity is not an absolute criterion. It is possible to over estimate it and especially so if community and habitat diversity are evaluated separately and included in the same final index. Species diversity estimates should not be used uncritically to compare sites of different sizes because as sample size increases so does the number of species encountered. Taylor et al. (1976) have presented evidence for random fluctuation in diversity from site to site.

Diversity is a complex ecological concept that reflects many properties of an ecosystem's structure and function. Most workers have only estimated the diversity of flowering plants in the form of the number of vascular species per unit area.

It is argued (see Tans 1974) that it is desirable to have a range of community types conserved which particularly represent the communities associated with different physical features. This may then facilitate the conservation of species not confined to a single community. The assessment of habitat and community diversity requires an accepted classification scheme of which there are several readily available, e.g. Elton and Miller (1954).

The use of a measure of species diversity in the evaluation of a habitat or community is not uncommon and is thought to be crucial by Peterken (1974) who commented that "unless some definite and limited objective governs the choices and overrides all other criteria the most important site will probably be the site with the most species in or the most rare species." Dearden (1976) concluded that diversity is a valid concept to be included in ecological evaluations and he continues his argument to justify the inclusion of rarity. However he is cautious about combining these values in inflexible formulae.

4.2.1.2 Examples of evaluation schemes using diversity estimates

Wright's (1977) scheme requires a subjective estimate of both species, community and habitat diversity, a score of one being awarded to habitats or communities with the lowest diversity and a score of three

to those with highest diversity. An assessment of floral diversity is implicit within Ward and Evans' (1976) method for evaluating British limestone pavements. The approach of Tubbs and Blackwood (1971) has been widely used in the South of England and requires a subjective estimate of floral richness to distinguish between the two categories of unsown vegetation depending on the rarity of the habitat type and the presence of outstanding features. Ranwell (1969) required a subjective assessment of the faunal and floral diversity within one figure on a scale from one to three. Tans (1974) evaluated species diversity within the criteria of "Quality" and Helliwell (1969) evaluated a feature called "Natural History Interest" which includes species rarity and species diversity. Goldsmith (1975) used 20 m x 20 m sample plots to assess floral richness, he assumes animal species richness to be correlated with the number of vertical layers on the vegetation and he has indicated that grassland would score one whilst well developed woodland would score four. These vertical layers must be rigidly defined for each major habitat type since some workers will e.g. identify more than one vertical layer within the grassland habitat. What is really being estimated here is habitat structure.

Tans (1974) evaluates community diversity by awarding a score of five to areas with four or more communities present whilst areas with a single community score one. Helliwell (1969) evaluates a feature called Ecological Balance which is related to the diversity and ubiquity of the community.

4.2.1.3 Concluding comments

It is apparent from the above that most workers' estimates of diversity have been incomplete and particularly faunal diversity rarely features in any scheme. Furthermore too many schemes require a subjective estimate thus adversely influencing the ability to consistently reproduce results. There appears to be a consensus amongst workers that the criterion diversity should be included within evaluation schemes. Where it is used it is important that there should be no confusion between species, community or habitat diversity and one should be alert to the problem of unwittingly overestimating them if all three are included within a single index.

4.2.2 Extent

4.2.2.1 Discussion

The importance of a site is usually considered to increase with area, and other considerations being equal a large site will usually have a greater "carrying capacity" than a smaller site. This greater carrying capacity being reflected in a higher species diversity and/or a greater abundance of the different species. The relationship between the number of species encountered and area usually follows the pattern shown in Fig. 4.1 Hopkins (1955) and Kerney (1976) found that after a rapid initial rise in the number of species with area the rate of rise decreases with increases in area. The number of species encountered increases as the size of the area examined increases because of the greater opportunity of finding the less abundant species.

Connor and McCoy (1979) claimed that the parameters of the species-area relationship have little ecological meaning but may be useful for the comparison of different geological areas. The geographic similarity between islands and nature reserves has led a number of people to suggest implications for the selection and design of nature reserves from studies of island biogeography (see Terborgh 1974, Diamond 1975, Fleming 1975, Diamond and May 1976 and MacArthur and Wilson 1963, 1967). These theories have led conservationists to argue for a few large reserves rather than a large number of small reserves. Higgs and Usher (1980) have argued that this is by no means always the case and there may be circumstances where smaller reserves are preferable, e.g. on quarry nature reserves, to maximise the number of higher plant species there is a benefit to having a number of smaller areas.

Size as a criteria is not an absolute guide of ecological value and in very rare and highly fragmented habitat types other factors may be more important. Tans (1974) suggested that the importance of size is relative to different community types and he commented that the minimum size for woodlands is near 40 acres whilst for a remnant prairie five acres is sufficient to maintain its community integrity. Our knowledge of the area requirements of species and communities is still scant.

Figure 4.1 Hypothetical relationship between area of site and number of possible species present.

No. of species = no. of species per unit area x area$^{0.26}$.

From Helliwell, D.R. (1973)

4.2.2.2 Examples of evaluation schemes including an estimate of area

Goldsmith's (1975) scheme requires the extent of each habitat type in a kilometre square to be recorded in hectares. Wrights (1977) evaluation scheme for the assessment of potential nature reserves does not include size although this feature is recorded on the site survey card. Wright does however evaluate a feature called "Sensitivity to Disturbance" and the presence of a buffer zone, size is therefore inherent in his scheme. The results of Tubbs and Blackwood's (1971) method were presented in the form of a Relative Ecological Evaluation Map (see chapter seven) thus conveying information on size. A similar technique was used by Helliwell (1969) in "Surveying Severnside" where the survey data was collected on 1:2500 scale map. Ranwell (1969) has produced an evaluation scheme for coastal sites and size was recorded in acres as one of the nine criteria evaluated. Gehlbach (1975) evaluated extent subjectively recognising that the educational value of an area is related to its size in that if an area is too small it will be damaged by repetitive use and he commented upon the educational value of large tracts of habitat types. Tans (1974) also regarded the presence or absence of a buffer zone as a protective area of importance and he evaluated extent and the nature of a buffer zone on an eight point scale.

4.2.2.3 Concluding comments

There appears to be a considerable unanimity of view that extent or area is a valuable criterion and most workers have included an estimate in their scheme. As our knowledge of the relationship between area and the populations it supports becomes increasingly sophisticated we should be able to use the criteria in a more meaningful way when ranking habitats in the order of their ecological value.

4.2.3 Naturalness

4.2.3.1 Discussion

This term applies to vegetation which appears to be unmodified by man. Moir (1972) has included minimum disturbance by man as an essential feature of natural areas and Jenkins and Bedford (1973) characterised natural areas by the absence of what they called "artificial

human disruption". Margules and Usher (1981) have proposed the definition of a natural ecosystem as one in which man may be present but if he is, then he is totally dependent upon, and limited by their environment. This is an arbitrary feature in that many areas of outstanding ecological value are man-made e.g. the Norfolk Broads, Chalk Downland. Equally due to a lack of reliable historical data it is not always possible to judge to what extent a habitat has been affected by man.

4.2.3.2 Examples of schemes incorporating naturalness

Peterken (1974) has produced a system for identifying primary woodland using indicator species. Ranwell (1969) evaluates a quality he called "purity" assessed on the evidence of human usage and disturbance of the site. Wright (1977) requires the landscape to be evaluated in terms of, human interference continuing (score 1), seminatural landscape (score 2) and near natural landscape (score 3). The nearest Tubbs and Blackwood (1971) came to evaluating naturalness is in the category of vegetation described as "unsown". This latter category is subjectively divided into two depending upon an estimate of rarity of the habitat type and the presence of features of outstanding scientific importance. Clearly habitats which have only been marginally influenced by man's activities will fall into the upper of these categories but so will many other habitat types possibly man made. Gehlbach (1975) evaluates a feature called "Heritage Value" which appears to be synonymous with naturalness although it is given the lowest weighting of the five features he evaluates. Tans (1974) scheme applies only to natural areas but he did assess the quality of naturalness on a ten point scale according to the extent of disturbance.

4.2.3.3 Concluding discussion

In the U.K. the identification of naturalness presents considerable difficulties because of the extent of mans' influence on biotic communities. Pennington (1969) has shown that all but the high montane grasslands were originally man induced and even these are subject to grazing. Tans (1974) and Gehlbach's (1975) schemes specifically referred to the ranking of natural areas in the United States. This is an

exceptional occurrence in Britain where it is more usual to find semi-natural communities (Tansley 1953). There are considerable difficulties in empirically assessing a criterion like naturalness and including it within a ranking scheme.

4.2.4 Species rarity and habitat rarity

4.2.4.1 Discussion

The use of "species rarity" as a criterion is a prerequisite for the conservation of rare species. This reflects the value society accords to a rare species although this is not a protection afforded equally to all rare species and aesthetic considerations appear to be a determinant in selecting those species which society wishes to conserve. The definition of a rare species is arbitrary, but a useful guideline for plants in the U.K. is that a species is rare if it is known to occur now in not more than fifteen 10 km squares of the Atlas of the British Flora (Perring and Walters 1976). Nevertheless a species recognised by such a definition to be rare in the UK may have a different status elsewhere.

Adams and Rose (1978) criticised the preoccupation with rarity since in ecological terms it is an elusive concept. In an attempt to examine the notion of rarity, Mayr (1963) recognised two types of rare species, highly specialised and very localised. Drury (1974) developed this into three types of distribution of rare species.

a) Individuals adapted to stress sites e.g. *Ribes spicatum*, a plant of limestone pavements.

b) Widespread but locally infrequent species, being widely dispersed in the communities in which they occur but nowhere common e.g. peregrine falcon (*Falco peregrinis*).

c) Species occurring in large numbers but a few localities e.g. *Agrostis setacea*.

to which may be added a fourth category

d) Species occupying changing environments.

There is frequently a correlation between habitat rarity and species rarity and it is often the case that the reason why a species is declining or is rare is because its habitat is being reduced or it is being so adversely modified that a species can no longer adapt to its changed

environment. A convenient example of this is the Dartford Warbler (Sylvia undata) which is a bird of lowland dry heathland. The Royal Society for the Protection of Birds has found it necessary to set up a bird sanctuary in Dorset on the Arne Peninsula to protect this species. This is in effect protecting the habitat of the Dartford Warbler and a habitat which is becoming increasingly rare.

4.2.4.2 Examples of evaluation schemes including an estimate of rarity

Peterken (1974) has spoken in terms of species quantity and species quality, the former term referring to species diversity and the latter to species rarity. This may not be acceptable since it is arguable from a moral standpoint that all species are equal in a qualitative sense. However Peterken (1974) does include these features in his scheme for assessing woodland flora. Equally, species rarity is evaluated by Ward and Evans (1976), Helliwell (1969), Gehlbach (1975), Tans (1974) and Wright (1977) and it is implicit within Tubbs and Blackwood's (1971) paper. The identification of rare species is central to Ward and Evans (1976) technique for assessing British Limestone Pavements. The approaches of Adams and Clough (1978) and Van der Maarel (1978) include an element recognising that rarity as a concept varies with scale.

Several workers have required a direct estimate of Habitat or Community Rarity arrived at by either objective or subjective means, (Wright (1977), Goldsmith (1975), Tans (1974), Gehlbach (1975)) it is implicit within Helliwell (1969) and Tubbs and Blackwood's (1971) schemes. The methods developed by Moore (1962), Peterken (1974) and Ward and Evans (1976) are to a large extent concerned with identifying rare habitats. This feature is also considered by the Maine Planning Board U.S.A. in selecting conservation areas.

4.2.4.3 Concluding comments

Dearden (1969) concluded that the rarity of land use systems does appear to be a worthwhile component in ecological evaluation. As argued above it is the protection of rare habitats which should be a priority since in most instances this will lead to the protection of rare species. Because of the high value conservationists attach to some species and not to others which may be equally rare; rare in the

conservation sense is an ambiguous term. When used in the ecological sense where it refers to the abundance of a habitat or species rarity and has a useful role to play within a scheme of ecological evaluation.

4.2.5 Fragility and threat

4.2.5.1 Discussion

This criterion reflects the degree of sensitivity of habitats, communities and species to man induced change and their ability to adapt to change. Human interference is not a criterion based on any ecological principle; there may be a case for evaluating threat and fragility separately since fragility suggests an intrinsic predisposition to threat. Ratcliffe (1977) quoted the example of the relatively safe blanket bogs of East Sutherland and Caithness which are fragile communities and could easily be damaged if forestry increased.

4.2.5.2 Examples of evaluation schemes including an estimate of fragility or threat

For some habitats and communities the presence of a buffer zone affords some protection from external pressure. Wright (1977) requires the presence of a buffer zone to be recorded within the category of Sensitivity to Disturbance. Tans (1974) evaluates threat over a ten point scale subdivided into five categories, those sites where threat is imminent score ten and where there is little threat and destruction is unlikely the site scores 2. Gehlbach (1975) evaluates a feature called Human Impact which approximates to threat. Areas where human impact is possible but not imminent scores five, where human impact is imminent scores ten and where human impact is in progress but the features are salvageable through management score fifteen. Thus Gehlbach (1975) gives the highest score to those natural areas which have suffered human impact. Furthermore he gives this criterion the highest weighting judging the least important feature to be whether the site is in or near climax condition. Ranwell (1969) has evaluated a quality called 'purity' which is based upon evidence of human usage and disturbance of the site. Sites with little disturbance score 3, sites which are moderately disturbed score 2 and highly disturbed or polluted sites score 1.

4.2.5.3 Concluding comments

One of the aims of any technique of ecological evaluation is to present evidence which may be used to minimize damage to a site when a development is proposed. All forms of development can be argued to constitute a threat to habitats; an ecological evaluation should help identify prime sites and help in the process which might result in the threat being removed. Fragile sites generally tend to be well documented, widely recognised and already enjoying some form of protection. Whilst if one is developing a scheme for evaluating potential sites for nature reserves it might be wise to assess fragility, within the objective of this study which is to broadly evaluate all communities, it is a less appropriate criterion to include.

4.2.6 Typicalness and Representation

The Nature Conservancy Council accepted that there is a case for conserving typical examples of particular ecosystems which may not be rare or even contain rare species. However the point is made that there is likely to be a wide choice of such sites and the actual selection may have to be arbitrary or influenced by non-scientific factors. Representation in nature reserves of the range of biota present is a fundamental goal in conservation and as a concept subsumes typicalness (Specht *et al.* 1974).

The extent to which an ecological area is already represented by existing conservation areas is a criterion used by the Maine State Planning Office. That is to say if such habitat or community types are not already conserved then they will be given priority.

This would appear to be a valuable criterion for evaluating potential nature reserves, but of less use on a broader scale. As a criterion it is difficult to quantify and is not likely to assume a high priority even within the Nature Conservancy.

4.2.7 Recorded history

The amount of recorded data on a site can be a factor of some importance in accounting for changes in habitat structure and community composition. Ratcliffe (1977) quotes the example of Wicken Fen, Cambridgeshire where a large body of data has been collected over several

decades upon which it is possible to describe the changes that occurred. This is not however a criterion of absolute importance and is less important than other features for with time all sites if they are of such key importance will attract scientific study. However Wright (1977) gives the factor equal weighting with other criteria scoring one if information is unavailable, scoring two if a limited amount of information is available and three if the site is well documented. The higher the score the greater the contribution to its final value. This criterion is considered by the Maine State Planning Office (Adamus and Clough 1978) in selecting conservation areas.

4.2.8 Position in an ecological/geographical unit

The Nature Conservancy Council has given preference, where it does not lower the standard of selection, to the desirability of having several sites within one geographical area thus representing a series of communities within one area. The New Forest is a case in hand. The opportunities provided by the New Forest are unique in the South of England and whilst this criterion is never likely to assume a great importance it is of even less importance in Lowland England. This is not an independent criterion and is closely related to extent and habitat, community and species diversity.

4.2.9 Potential value

It is possible particularly in the case of woodlands that if a site is managed in such a way as to compensate for any deterioration in that site it may eventually have considerable ecological value. Whilst at the point of initial survey an area may be of limited ecological value under the current management it may assume considerable ecological importance. A reasonably accurate prediction of the course of ecological succession is needed to assess potential value.

4.2.10 Physico-chemical features

Ranwell (1969) has evaluated subjectively a physico-chemical criterion based on the range of knowledge available about each habitat group. It includes both physiographical features and physico-chemical soil features.

4.2.11 Optimum population

Ranwell (1969) also includes a subjective evaluation ranging from a score of four to one of the population features of higher plants and animals. If a habitat is found to have the best population of a local species it scores four, whilst if the habitat only contains representative populations it scores one.

4.2.12 Geographical limits

A site may assume ecological importance if it contains one or more species at the limits of their geographical distribution. Ranwell (1969) evaluates this feature subjectively, the highest score of three being given to habitats containing many such species and a score of one being given to habitats containing one or none such species.

4.2.13 Educational and research use

This criterion has been used to include formal teaching, research use and informal nature use. This criterion is implicit with the Nature Conservancy Council evaluation and is assessed by Tans (1974), Wright (1977), Ranwell (1969), Helliwell (1969) and Gehlbach (1975). However of the five major criteria Gehlbach evaluates, Educational Utility is given the second lowest weighting. This feature is also considered to be important by the Maine State Planners (Adamus and Clough 1978). There is a concern that heavy use of conservation sites for field studies might prejudice their conservation value.

4.2.14 Combinatory value

Ranwell (1969) has also evaluated a feature he calls combinatory value. This reflects the value of the position of a habitat and the adjacent land. So if a site of national ecological value was adjacent to the habitat under consideration the habitat would score 3. If the habitat was adjacent to a developed area it would only score zero.

4.2.15 Availability

This criterion has been used by workers evaluating sites of potential nature reserves and has been scored by Tans (1974) over a five point scale. This criterion has been evaluated in a similar way by Wright (1977).

4.2.16 Other management features

This is a collective term to describe a series of management features evaluated by Wright (1977). Availability has been excluded here as it is dealt with elsewhere but it includes the following, each of which has been assessed separately by Wright; access to site, security of boundaries, security of tenure, liabilities, necessary manpower, costs, special features and potential amenity use.

4.2.17 Indicator species

Several workers have produced schemes for evaluating specific habitat types using indicator species. Peterken (1974) has produced a method for assessing woodland flora using indicator species. Moore (1962) used a similar technique as a part of his classical study on the heaths of Dorset. Helliwell (1978) has produced a system for evaluating farmland using indicator species, to a large extent these indicator species are rare vascular plants and rare birds.

4.2.18 Direct returns

Helliwell (1969) has evaluated the income from certain types of wildlife due to shooting and the value of produce sold.

4.2.19 The approach of the Maine State Planning Board U.S.A.

The planners of the Maine State Planning Board have listed the criteria they will operate when selecting potential conservation sites. Some of these features have already been mentioned. In addition to these criteria mentioned above they also consider the following:

(a) Potential economic effects of conservation.
(b) Potential conservation effects - that is to say can be shown to benefit from being conserved.
(c) Management potential.
(d) Geographic distribution - in that areas will be favoured which are at a greater distance from similar areas.
(e) Quality - areas that are better representative of a particular key feature will receive greater consideration.
(f) Variety of values - area having the widest variety of features will receive the highest consideration.

4.3 Selection of criteria

Nineteen evaluation features have been reviewed and the approach developed by the Maine State Planning Board U.S.A. The task now is to extract from this list the features which are to be used for this study. The selection of criteria is based upon the following:

(i) The criterion must be relevant to the evaluation of ecological resources within the countryside.

(ii) The criterion must be capable of objective evaluation and must have a scientific basis.

(iii) The criterion must lend itself to an empirical quantification.

(iv) The criterion must have embodied within it a breadth of ecological information.

(v) The criterion must be a true ecological parameter and not confused with a parameter of conservation value.

It will be seen from Table 4.1 that relatively few criteria meet these three requirements. Only five features meet these five criteria namely size, species diversity, community and habitat diversity, species rarity and community and habitat rarity. Community and habitat diversity could be represented to a large extent within species diversity if the area being studied is clearly defined.

Margules (1960), in a more limited review of the criteria used by workers in this field proposed a hierarchy which may be useful in assessing potential conservation sites (see Fig. 4.2).

Table 1 indicates that the criteria diversity and area appear to be widely recognised as being indicative of ecological value. Margules (1960) in a survey of eight conservation sites found diversity to be a major criteria with high "importance values" at all but one site.

The use of selected ecological parameters for ecological evaluation has been criticised by those preferring to evaluate the functions of nature. Harms (1973) in reviewing nine Dutch evaluation studies carried out in the Netherlands concluded that the emphasis was generally on structural aspects, and that the data used generally derived from estimates. Harms preferred the following criteria, rarity of ecosystems, uniqueness and spacial variation for considering pattern and naturalness, optimality and maturity for considering processes. It

TABLE Summary of Evaluation Criteria Used in the Schemes Reviewed

OBJECTIVE	AUTHOR	Extent	Species Diversity	Community & Habitat Diversity	Naturalness	Species Rarity	Habitat & Community Rarity	Fragility & Threat	Typicalness	Recorded History	Ecological/ Geographical Unit	Potential Value	Physico-Chemical Features	Optimum Population	Geographical Limits	Educational & Research Use	Combinatory Value	Availability	Other Management Features	Indicator Species	Direct Returns	Representation	No. of Plant Structure Formation	Species or Habitats which contribute to the Character of an area	Species or Habitats which have contributed to past art work	Accessibility	Usage by Wildfowl	Replaceability
Evaluation of Key Sites	Ratcliffe 1977	*	*		*	*	*	*	*	*	*					*												
Ranking of Natural Areas	Tans 1974	*	+	*	*	*	*	*								*		*										
Ranking of Natural Areas	Gehlbach 1975	+		*	*	*	*	*								*												
Evaluation of Coastal Sites in G.B.	Ranwell 1969	*	*		*			*					*	*	*	*	*											
Evaluation of Potential Nature Reserves	Wright 1977		*	*	*	*	*	*		*						*		*	*									
Evaluation of Ecological Resources	Goldsmith 1975	*	*				*																					
Evaluation of Land for Planning	Tubbs & Blackwood 1971	*	+	+	+	+	+						+															
Valuation of Wildlife Resources	Helliwell 1969, 1970, 1973, 1974	*	+	*		*	+									*			+	*	*							
Assessment of Limestone Pavements	Ward & Evans 1976		+			*	*																					
Assessing Woodland Flora	Peterken 1974		*		*	*	*																					
The Heaths of Dorset	Moore 1962						*													*								
Potential Conservation Areas	M.S.P.O. (Adamus & Clough 1978)						*			*						*						*						
New South Wales (South Coast of)	Austen & Miller 1978	*	*		*	*	*														*							
Wildlife preference shown by countryside visitor on the North Yorkshire Moors	Everett 1978		*		*				*	*														*		*	*	
Holland	Van der Ploy & Vism 1972	*	*	*	*	*	*																				*	
Wildfowl Habitat	Williams 1980		*			*																						*
United States	Klopatek et al. 1981		*	*		*					*																	*

* Indicates that the criterion was evaluated directly within that particular scheme.

\+ Indicates that the criterion was evaluated within some other criteria.

M.S.P.O. Main State Planning Office, U.S.A.

Figure 4.2 An hierarchy of criteria for conservation evaluation. The levels refer to the stage of the evaluation process, at which the criteria are used (from Margules 1980).

has been argued by Braat et al. (1979) that since the resultant data does not represent any aspect of the ecological relationships of the area studied, they cannot justifiably be called ecological evaluations.

Van der Ploeg and Vlijm (1978) in a later review of Dutch evaluation studies concluded that the most frequently used criteria are species richness and rarity for botanical aspects and rarity and abundance for zoological aspects. The values attained are then most commonly summed. Braat et al. (1979) made the following conclusions:

(i) Few researchers have tried to evaluate complete ecosystems.

(ii) There is confusion between ecological value and conservation value, some authors believing the latter to be quantifiable.

(iii) The validity of some of the complex formulae is questionable and are often pseudo-objective, often justifying 'a priori' judgements.

(iv) Processes in ecosystems are rarely valued and large taxonomic groups are ignored with the possible result of undervaluing ecosystems.

(v) The time over which most studies are effected is brief and data is only collected on a single occasion and not repeated.

Whilst criticism has been levelled at the over-simplistic approach of measuring selected criteria, Caldwell (1970) has argued that more complex work is inapplicable to this field.

'A practical objection to the plausibility of an ecologically oriented public policy is the complexity of the ecosystems themselves. (.....) because ecologists insist that everything relating to an ecosystem must be taken into account, nothing can be taken into account. This (.....) is because ecology provides no method for assessing priorities among the properties of ecosystems in relation to human values. The conclusion follows that the findings of ecological science are largely inapplicable (although not necessarily irrelevant) to the economics and politics of land policy.'

Dearden (1978) suggested that research should concentrate on answering the question:

"Does ecological diversity and rarity constitute an approximation of ecological value?"

The distinction has already been drawn between conservation value which may not have a scientific basis and ecological value which does

have a scientific basis. An examination of Table 4.2 demonstrates that few criteria meet the requirements of this study, in all probability therefore one should only evaluate size (or area or extent), diversity and rarity as long as one is concerned with evaluating biological resources generally. Such a scheme would not meet the requirements of for example identifying potential nature reserves.

The dangers of a subjective scheme are illustrated by data contained in Margules (1980) paper where a panel of assessors were asked to score a range of sites on a scale of 0 for no conservation value and 20 for highest value. The extreme ranges of the scale were rarely used and the total values for all eight sites ranged from 83 to 132 out of a possible total of 160. Margules accounts for this difference in that the panel members differ from one another in attitudes and values. An empirical and objective scheme would not have had such a large degree of variance. Robinson et al (1976) in a landscape evaluation study found that personality differences may mean some people consistently ignore or consistently use extreme categories. Robinson also identified a reluctance to use the highest and lowest values of a numeric, equal interval scale for fear that one would encounter a better or worse example later. Margules (1980) found that some members of his panel used a greater range than others, possibly attributable to a reluctance on the part of some to deviate far from what they see as the average or the norm.

Most existing schemes have concentrated on examining the flora and have neglected the fauna of natural communities, although a few workers have looked at selected groups particularly the avian taxon. Refseth (1980) has suggested that because insects have an important role in ecosystems, they should be included in any classification regarding the conservation of natural diversity.

4.4 The use of ecological indices

There does not appear to be an explicit way of combining criteria to give an overall index. However many workers have attempted to produce such an index (e.g. see Williams 1980 and Goldsmith 1975 and Klopatek et al. 1981). Ott (1978) discussed some of the problems resulting from the condensation of a large amount of data into a single number.

Not only is a certain amount of information rendered unavailable by the index number but it may be used in a manner for which it was not designed and may seriously distort the intention of the research used to calculate the value. To alleviate some of these problems and to increase objectivity Klopatek et al (1981) used index values only to compare similar phenomena within a given geographical area. They also drew attention to areas of singular merit in order to highlight tracts which may have characteristics which require additional attention before deciding on their future fate. The essential requirement is that any index should be capable of objective derivation from the field data (capable of manipulation without loss of primary data).

There are obvious advantages in combining data within a single index; this appears to be the requirement of the planners. Some authors have introduced weighting into the formulae by which the ecological indices are derived. However Goldsmith (1975) has advocated no scientific evidence at present which might lead us to weight one factor heavier than another and clearly those authors who have introduced weighting can only have done so on a very subjective basis.

Margules (1980) states that if it were possible to formulate an index of conservation value it might be expressed as some function of each criterion thus:

$$V = f\ (C_1,\ C_2,\ C_3\ ----\ C_n)$$

where C_1 ---- C_n are the criteria to be employed in the index (Usher in press). Since correlation may exist between criteria they can neither be independently assessed nor can they be consumed in a simple way by addition or multiplication.

Some examples of formulae:

Goldsmith (1975).

An index of ecological value (I.E.V.) for each kilometre square was determined as follows:

$$IEV = \sum_{N}^{i=1} (Ei \times Ri \times Si \times Vi)$$

E = Area.

R = Rarity (R = 100 - % area per land system).

S = Plant spcies richness.

V = Animal species richness (presumed to be correlated with number of vertical layers e.g. 1 for grassland, 4 for woodland).

Pickering's formula (see Marsh 1978)

$$EV = \log \sum_{1}^{n} (V^3 \times e \times r \times s)$$

The rationale behind the decision to cube the value obtained for 'v' is not readily apparent. Other workers might argue that there is no justification for this weighting and indeed if weighting is to be applied rarity is a more deserving criterion.

Williams (1980)

An index for the ranking of wildfowl habitats:

$$SV = \sum \frac{(\bar{d}i \times wi) \times D^2}{s}$$

SV = Site value.

$\bar{d}$ = Average number of days usage by the ith species for x seasons.

wi = Rarity value weight for the ith species.

D^2 = Average number of species present for x season squares.

s = Scale value.

Whilst the difficulties in using ecological indices cannot be ignored their attractiveness within the framework of planning cannot be ignored. This thesis proposes the use of a simple Ecological Index but in a later chapter 'multivariate' statistical techniques are recommended as well as or instead of the proposed Ecological index.

4.5 A new ecological index

The advantages and disadvantages of combining data within a formula have been previously discussed. Any such index must be used

cautiously and interpreted by a qualified ecologist.

Resulting from the arguments presented elsewhere in this chapter it was decided to measure the criteria: extent, species richness of flora, faunal diversity of the ground fauna as sampled by D. Vac (being indicative of faunal diversity) and rarity.

These four criteria either have or can be adjusted to have a maximum value of one. If it is found to be useful then they can be summed to give a maximum value of four for the communities of highest value. The sum of these four figures can be called the Community Aggregate Score (C.A.S.)

C.A.S. =	Extent (in km^2)	+	Floral Species Richness	+	Faunal Diversity of Ground Fauna (α)	+	Rarity

CHAPTER 5

5. METHOD

5.1 Introduction

There are two main stages in an ecological evaluation, firstly a biological survey of the area under investigation mapping the communities present and recording the variables to be measured. This is followed by a ranking of the communities applying the evaluated criteria.

5.2 Site survey

The communities present in the study area were mapped on a scale of 1:10,560 or 6 inches to 1 mile. The 1:25,000 scale was found to be too small to allow the inclusion of sufficient detail. The availability of 1:25,000 maps in part precluded their use. However field mapping on this scale would have been very demanding on time and more importantly was not necessary to meet the objectives of this study.

The Nature Conservancy Council had already mapped the major communities in this area. This work was done under contract for the NCC and was part of a much larger survey. The classification system adopted for the NCC study was also used in this study. This avoided some unnecessary duplication. Whilst the NCC survey was completed largely from aerial photographs the mapping was checked in the field and found to have a high degree of accuracy.

The following ten broad community types were identified and formed the basis of the survey.

1. Dry heathland
2. Wet heathland
3. Bog
4. Deciduous woodland
5. Conifer plantation
6. Scrub
7. Rough grassland
8. "The Moors" - an estuarine area basically grassland with a mixture of rough grazing and improved grassland.
9. 'Mixed' woodland (meaning deciduous/coniferous)
10. *Phragmites* marsh.

Holdgate (1975) criticised this approach involving as it does "a simplification of the variety of nature." It is recognised that the ten community types used in this study ignore much within type variation and the intergradation between the components of community mosaics.

An approach involving objective sampling without any preconceived ideas would have been preferable. The intensity of sampling required and the consequent time involved precluded the use of this more satisfactory approach. A further weakness of the adopted classification system is that it makes comparisons difficult in so far as e.g. an oak woodland in Wales or Cumbria is very different from oak woodland in East Anglia.

More disciplined but very time consuming "phytosociological" techniques were also considered and rejected. It would appear that the main information loss arising out of the adapted survey categories are that of data on ecotones and on community diversity. The approach used would be quite inadequate for measuring the variation in ecological systems.

5.3 Sample unit

The Ordnance Survey one kilometre grid square was used as a sample unit. This has the advantage over using communities as one's sample unit in that it removes obvious bias when mapping. Difficulties arise in the field from locating the position of kilometre squares and whilst they are good for stimulating coverage they cut across natural boundaries. Also other schemes of both ecological, landscape and agricultural evaluation have used kilometre grid squares.

5.4 The estimation of the area of the communities

The extent or area of each recorded community was derived from the survey data by transferring it to tracing paper and then by cutting out and weighing the communities, an obviously time consuming task with a higher margin of error for the very small communities. The small size of many communities similarly precluded the use of planimeters and Computer Digitizers (see Webb and Haskins 1980). The use of electronic machines designed to measure leaf area for example on the basis of the proportion of light emitted to the amount of reflected

again appear to have a high margin of error.

5.5 The estimation of floral species richness

The identification of the number of species in a habitat is very much a matter for individual specialists. The greater one's knowledge of a given community, the fewer species might be overlooked. It was decided to concentrate on flowering plants so as to facilitate identification and to reduce the task to manageable and accurate proportions.

In planning decisions and when comparisons are being made between communities it is likely that two types of information will be required. Firstly, how does a given community compare with other similar communities in the region. In terms of species richness, is it richer or poorer? Usually within any one region there are examples of communities which are generally acknowledged by local experts to be the 'best' by whatever criterion is being used.

Secondly a planner may also however be required to compare two quite different communities with intrinsically arithmetically different species richnesses.

One method of meeting these two requirements is to compare each mapped community with the locally acknowledged best example, using the same ecological criterion. One could arbitrarily divide the species list for the richest community into three and apply this criterion to other communities, therefore if a site contained two-thirds or more of the number of species in our best example it would be awarded a species richness grade of one, between ⅔ and ⅓ a grade of 0.66 and less than ⅓ 0.33.

Treating the data in this way will allow comparisons to be made between different botanical communities when compared with those acknowledged to be the best in the region. This scale could be refined as required.

5.6 Faunal diversity

Few workers have included an evaluation of faunal diversity (but see Ogle 1981) and for reasons already mentioned it was decided to sample the invertebrate ground fauna. The Dietrick vacuum sampler

(Dietrick 1961), generally known as the 'D-vac' was used because it is easy to use and allows many samples to be taken in a short time. Henderson and Whittaker (1977) found that catch size did not vary with time of day but the method was unsatisfactory for wet grass. They established that the longer the sampling period the more representative the sample was by increasing the proportion of the more elusive types captured. However the technique is selective towards Diptera, Hymenoptera, Hemiptera, Thysanoptera and Acarina respectively. Duffey (undated) showed that the extraction efficiency was poor in May and relatively good in August. It appears then that comparable results will be achieved with the 'D-vac' if sampling is carried out on a dry day in August. The principle merit of the 'D-vac' is that information becomes readily available but at the expense of some information loss, and that the information is comparable for the communities studied. One further drawback of the 'D-vac' is that samples are heavily contaminated with litter. Hopkins (1983) has compared the efficiency of pitfall trapping with the use of the 'D-vac'. He found that few of the species taken were exclusive to the 'D-vac'. The 'D-vac' was used in the mode proposed by Hopkins (1983). The cone of the 'D-vac' was placed over the vegetation and agitated for 30 seconds to dislodge the animals. This was done eleven times to give a 'D-vac' 'sample' approximately the equivalent of one square metre.

In the analysis of the flora the information was presented in the form of a species richness grade, it would have been logical to do the same for the fauna. However an analysis of the 'D-vac' samples produced an irregular pattern, on the one hand there were many samples containing few species many of which were well represented, on the other hand a large number of samples contained a large number of species but were less well represented. So as not to lose this information the data was represented in the form of a species diversity grade. Elsewhere in this report a strong argument has been made for using Simpson's Index of Diversity but this was found to be mathematically inconsistent and therefore William's Index of Diversity was used which has the principle merit of being independent of sample size.

5.7 Sampling

A modificiation of Bunce and Shaw's (1973) method for a standardised

ecological survey was used, in this technique the role of individual choice and judgement is eliminated where possible and systematised where not. In any exercise such as this where comparisons are to be made, comparability is essential.

Each mapped community was sampled at 4 randomly located points within that delineated area. These points were fixed by superimposing an acetate sheet with a regular grid of dots over the map. The number of dots falling on that community was counted and four points selected using random numbers. These points were used to sample the flora and ground invertebrate fauna in 100 sq m plots. The fauna were sampled from the centre of this 100 metre square. The mean of the four results was subsequently calculated for each community.

5.8 Rarity

As has already been argued rarity as a concept is open to various interpretations and it is possible to discriminate between different forms of rarity. Several workers have conveniently expressed the rarity of communities using the following formula:

$$R = 1 - P$$

R = Rarity of community.

P = Proportion of that community within the area under study.

This is a simple and convenient formula but it does have the drawback that the Rarity Index derived from the formula is not directly inversely proportional to the abundance of the community. This is illustrated by the following figures applying to an area covering ten square units.

	Area of community	P	R
Community type 1	5 units	0.5	0.5
Community type 2	3 units	0.3	0.7
Community type 3	1 unit	0.1	0.9
Community type 4	1 unit	0.1	0.9

Whilst community types 3 and 4 are five times as rare as community one the Rarity Index of 3 and 4 are not even double that of community type one. It must therefore be remembered that an index which derives rarity in this manner favours the more abundant communities.

TABLE 5.1 Totals of Community Types in Study Area

	Area km^2	Proportion	Rarity Index*
Dry Heathland	2.534	0.166	0.834
Wet Heathland	0.314	0.021	0.957
Bog	0.695	0.0455	0.955
Marsh	3.933	0.257	0.743
Deciduous Woodland (Includes Mixed)	0.944	0.0618	0.938
Coniferous Plantation	2.058	0.135	0.865
Rough Grassland	3.959	0.251	0.741
Meadow	0.403	0.026	0.974
Scrub	0.442	0.0289	0.9711
	15.280		
Long Island (- Dry Heathland)	0.0394		
Round Island (- Dry Heathland)	0.0443		

* Rarity Index

= 1 - Proportion

Another weakness of this approach is that the Rarity values may become distorted within small study areas. The values derived for this study area are to be found on the preceding page, where it will be noted that pine plantations have a higher value than dry heathlands. It is therefore important that such values are derived from as large an area as is possible although the absence of a national inventory of communities often makes this difficult, if not impossible. The area to which the Rarity Values refer must be clearly stated. As the results of the National Vegetation Classification (J. Rodwell pers. comm.) become increasingly available it should be straightforward to determine rarity values for community types relative to their distribution throughout the nation.

5.9 Time of sampling

The mapping of the communities was carried out in 1979 and 1980. The estimates of floral species richness are derived from fieldwork carried out in June and July of 1981. The 'D-vac' sampling was carried out on dry sunny days at around midday in August 1982. At the very best the data collected represents a snapshot of the system. More comprehensive sampling would have been desirable but was limited by the amount of effort involved.

5.10 The study area

The site surveyed was the area covered by Sheet SY 98 NE of the Ordnance Survey (Scale 1:10,560 or 6 inches to 1 mile). Those marine habitats constituting part of Poole Harbour were not included. Maps 1, 2 and 3 locate the study area within the context of Great Britain, the Poole Basin and Poole Harbour respectively.

At the start of this study the size of the study area was judged to be manageable for the time available. In retrospect the area proved to be too large for a one person survey and a substantial amount of time was spent surveying and sampling.

The area was selected as being suitable for a variety of reasons. The Biology Department at Southampton University has had a tradition of pursuing joint research projects in this area with either the Institute of Terrestrial Ecology at Wareham or the local Nature Conservancy Office at Slepe Farm, Wareham. The presence of these two organisations rendered

Maps 1 and 2. The boxed area in Map 1 is shown enlarged. The study area is shown dotted on Map 2.

Map 3. The Study Area.

a great deal of local specialist knowledge and expertise. The Dorset Naturalists' Trust has been very active in this part of the Isle of Purbeck and of particular interest to this study was the ecological evaluation carried out in 1977 (Dorset Naturalists' Trust 1977).

The eight square kilometres of the study area are isolated and there are few inhabitants. A variety of habitat types and designations are present including a recent coniferous forest, a large S.S.S.I known as the "Moors" and the Hartland Moor National Nature Reserve.

This part of south west Dorset is susceptible to a wide range of environmental pressures. The area is becoming increasingly popular in the holiday season for tourism. The discovery of significant oil deposits has served to focus the attention of environmentalists. Substantial deposits of ball clay and the ever increasing need to justify the needs of nature conservation within the many other competing demands on land use increase the potential number of environmental conflicts in this area. Within this context any evaluation may serve to be of some future use.

The area is generally flat being at or near sea level. It is dominated by patches of heath, birch scrub and bog. The latter arising from substantial clay pockets of considerable commercial value. The heath and birch is generally associated with acid podsols with a humus-packed top horizon and often an iron pan. The pockets of clay are marked by patches of bog vegetation of moor grass, sphagnum and cotton grass. In the more fertile areas where a deep top soil of alluvium has developed grazing pastures are found. Kerr (1968) gives an account of the past land uses of this area.

The presence of many rare plants and animals within the area has served to heighten its ecological significance. Some of the rare species known to be present are:

Erica ciliaris (Dorset heath), Gentiana pneumonathe (marsh gentian), Lacerta agilis (sand lizard), Ischnura pumilio (scarce ischnura) and Sylvia undata (Dartford Warbler).

CHAPTER 6

6. ECOLOGICAL EVALUATION OF THE STUDY AREA

6.1 Introduction

The aim of this Chapter is to provide a detailed analysis of the results. To test the application of techniques of ordination and to present a detailed ecological evaluation of the study area.

6.2 Summary of results

In total 367 communities were evaluated under the proposed scheme. The maximum possible Community Aggregate Score is four. The largest score obtained was 3.16 and this was for a large area of deciduous woodland which has the status of a National Nature Reserve. The lowest score obtained was 1.07 and this was for a small area of *Phragmites* marsh on the edge of Poole Harbour.

Twenty-eight communities achieved a score greater than 2.6. All of these with the exception of two were parts of designated National Nature Reserves or Sites of Special Scientific Interest. The two exceptions were a large area of rough grassland and an area of deciduous woodland.

When the Dorset Naturalists Trust surveyed this area as part of their survey of the whole of the Isle of Purbeck their results show a high degree of similarity (Dorset Naturalist's Trust, 1977). Whilst their survey was largely subjective and based on the approach of Tubbs and Blackwood (1971) and carried out on a much smaller scale, it gave highest values to the areas around The Moors, Hartland Moor, Arne Heath and Froxen Copse. The results of this study agree with the results of the D.N.T. survey.

The table on the following page gives a summary of the results. Table 6.1 includes the mean Community Aggregate Score for each community evaluated. In order of decreasing magnitude they were, deciduous woodland, bog, dry heathland, wet heathland, meadow, rough grassland, marsh and coniferous plantation. The detailed results are found in Appendix D on a grid square basis along with the community distribution maps and the Community Aggregate Scores.

TABLE 6.1 Summary of Results

Community	Number of Communities Evaluated	Total Area km^2	Community Aggregate Score -with S.D.
Deciduous woodland	29	0.9437	2.2779 ± 0.4926
Bog	34	0.6953	2.3180 ± 0.2834
Dry heathland	52	2.5338	2.2778 ± 0.3745
Wet heathland	22	0.3137	2.1709 ± 0.2870
Meadow	1	0.4034	2.1145
Rough grassland	41	3.9591	1.9289 ± 0.3982
Scrub	65	0.4412	1.5716 ± 0.1782
Marsh	106	3.9325	1.5350 ± 0.3751
Conifer plantation	23	2.0578	1.4617 ± 0.1376

6.3 Multivariate analysis of the data

The summary of results given above does not significantly depart from the expectations of experienced fieldworkers and agrees with a previous more subjective evaluation (Dorset Naturalists Trust (1977)). Nevertheless to test the validity of the proposed ecological index an alternative approach is required. The elusive notion of "ecological value" makes the rigorous testing of the community aggregate score difficult because there is no base line against which to compare it as long as ecologists differ in their interpretation of ecological value. A further difficulty of indices like the community aggregate score is that they are very crude and are poor at reliably discriminating between sites of similar value.

Techniques of multivariate analysis may have a role to play in both of these contexts. There are techniques which using the variables measured cluster sites which have some features in common but segregate sites which are distinct from one another. The advantage of a suitable technique of multivariate analysis is that one need not rely upon a crude ranking of sites but can work towards the clustering of sites. The analysis of the data may present a cluster of sites which could be interpreted to be of high value and another cluster of intermediate value and so on.

This approach has several advantages; firstly it can be used to check the validity of the C.A.S. It also goes some way to help resolving the issue of which variables should be measured. Generally the reliability of multivariate techniques is enhanced by increasing the number of variables measured.

Initially three techniques were inspected, multiple regression analysis, principal components analysis and canonical discriminant function analysis. In Chapter 8 where future work is discussed some other possible techniques are identified.

6.4 Multiple regression analysis

Multiple regression analysis requires that the variables be independent and not be correlated with one another. This is a robust technique and the latter requirement is usually ignored unless there are strong correlations of about 0.8 or more. Ecological theory suggests that the variables measured are not independent of one another and Table 6.2 which lists the various correlation coefficients contains

several which are as strong or stronger than 0.8. Multiple regression analysis is therefore inappropriate to this set of data.

6.5 Principal Components Analysis

An investigation of this type is principally concerned with identifying one of the two extremes of the variance that occurs within a sample. It is concerned with identifying the site or sites which have the highest ecological value and it has been suggested that this is a function of floral and faunal species richness, area and rarity. For this reason a clustering technique of P.C.A. may group together on one extreme the sites of high value, on another extreme the sites of low value and there may be in between one or more groups of intermediate value.

P.C.A. is capable of displaying the major compositional relationships of the samples (sites) under consideration. The detection of the variables that principally account for these relationships is the main objective of ordination techniques such as P.C.A.

The principal merit of P.C.A. is that distortion of the data is minimal. Whilst the technique was developed in 1933 its use for ecological purposes has grown since it was introduced by Goodall (1954). It is now one of the most widely used ordination techniques in ecological work. Blacklith (1971 Ch. 12) has listed a series of case studies illustrating the uses of P.C.A.

In P.C.A. each object (in this case a community) is envisaged as a point in hyperspace. The axes of each of these points represent a variable. The coordinates of these axes are the values of the variates. P.C.A. creates new axes which are linear transformations of the original ones. Each is orthogonal to the preceding axis and is parallel to the line of greatest residual variation in the system. A small number of axes may account for a large proportion of the total variation. These are extracted as the principal components (Bolger 1980).

P.C.A. is sensitive to non-normality and non-linearity of data (Lambert and Dale 1964, Anderson 1973). Greig-Smith (1964) predicted and it was subsequently demonstrated (Gauch and Whittaker 1977) that the value of P.C.A. decreases as the range of the data increases. P.C.A. is mainly a technique of efficient summarisation and any ideas as to the meaning of axes are purely hypothetical (Lambert and Dale 1964).

TABLE 6.2 Correlation between parameters evaluated for each community types. (Standard Error of estimate of 'r' in brackets).

Community type	'r' for floral species richness on Area.	'r' for faunal diversity on Area.	'r' for faunal diversity on F.S.R.
1. Dry heath	0.1147 (5.0710)	0.3355 (0.1635)	0.4064 (0.1586)
2. Conifer plantation	0.2979 (2.1393)	0.2810 (0.1008)	0.6345 (0.0812)
3. Wet heath	0.3284 (5.9751)	0.1338 (0.1711)	0.0452 (0.1725)
4. Bog	0.0149 (6.03628)	0.2859 (0.16105)	0.1068 (0.1671)
5. Rough grassland	0.1176 (15.839)	0.2305 00.1260)	0.3637 (0.1205)
6. Deciduous woodland	0.0638 (44.1746)	0.6435 (0.1852)	0.01732 (0.2420)
7. Marsh	0.038008 (9.2234)	0.3571 (0.1285)	0.5708 (0.1129)
8. Meadows	0.9948 (2.0743)	0.7179 (0.04376)	0.6431 (0.0481)
9. Scrub	0.0377 (6.8703)	0.3243 (0.0892)	0.1870 (0.0926)
10. Mixed woodland	0.4259 (7.9070)	0.8227 (0.1963)	0.8486 (0.1827)

Bolger (1980) and Orloci (1966) have reviewed and tested a range of ordination techniques. Whilst P.C.A. requires a great deal of computation Bolger concluded that it was mathematically the most efficient technique to use, accounting in most cases for more than 75% of the variance.

A form of P.C.A. known as 'DIVISIVE' developed here at Southampton University was used. Its function is to separate data into 'natural' groupings. Whilst P.C.A. does not give statistical values it can be used to check the validity of groups and to show the presence of new groups. If distinct groups exist they probably lead to the maximum variance being along the line running through them, thus the groups will tend to be separated by one of the first principal axes.

The programme used recommends the optimal number of groups or clusters into which the sample can be divided. The "between sub groups" coefficient is a measure of the reliability of the split, the higher the value the more distant the groups and the "within group" coefficient gives an indication of the heterogeneity of the group.

6.6 Canonical Discriminant Function Analysis. (C.D.F.A.)

The C.D.F.A. (as found in the Statistical Package for Social Scientists (S.P.S.S.) (Nie *et al.*, 1975)) appears to be a particularly useful and appropriate technique. It can be used to check the validity of predetermined groupings.

C.D.F.A. in some ways is not unlike P.C.A., it calculates multivariate axes which separate the suspected groups by maximising the between groups differences relative to the within group variation. These axes are a function of all of the variables evaluated. The programme used presents data in the form of a scatter-gram or histogram, the position of the points along the axes is given by the canonical discriminant function coefficients. The new canonical variates or axes are defined similarly to principal components but with respect only to variability between groups. Thus the first canonical axis is oriented in the direction of maximum between-group difference. The new axes may then be used to represent the position of the group centroids. It is a requirement of the technique that distribution of individuals within each group is approximately similar.

The canonical discriminant function coefficients, if unstandardised, are the values by which each variable measured within a community is

multiplied before the products are summed to give its position on a given axis. However, additional information can be gained from the standardised coefficients. These take into account the possibility that the different variables measured may well be of different mathematical orders.

If there is a range in the values of the standardised coefficients (especially if of different signs) this suggests a reliable split. A large value for a standardised coefficient indicates that the measured variable is making a large contribution to the axis and is important in separating the groups. The program used also performs a Wilks Lambda Test (converted to an F test) which measures the degree of group discrimination; it is a multivariate version of the one-way analysis of variance. A small lambda value gives a large 'F' ratio and this indicates that there is a significant difference between the groups when all the variables are taken into account. Each variable is also adjusted statistically by a Wilks Lambda (converted to 'F') to see if individually it is significantly different between the groups. Sometimes variables are highly significant, but do not have high standardised coefficients. This is a result of their being differences between the groups but not adding much to the discrimination when combined with the other variables.

The program also gives the percentage of specimens which are "correctly classified". A value of 100%, therefore, means that all that group are in the "correct" group, thus it is a measure of the degree of overlap of the original groupings.

6.7 The use of P.C.A. and C.D.F.A. in this study

In Chapter 4 a formula was proposed by which the variables measured could be combined to give a community aggregate score which it is suggested reflects the ecological value of the site(s) being studied.

The use of these various indices has been criticised and the issues raised have been discussed elsewhere.

Whilst the P.C.A. and C.D.F.A. are useful, in the final analysis they may not be a substitute for the proposed formula. At best only a two dimensional representation is given and the small number of variables used undermines their value. Furthermore since the basis of these two techniques lies in a calculation of correlation coefficients, one can detect a circularity of argument in using these techniques to test the proposed formula.

2.0 to the last group. Those sites with a value of less than 2.5 but greater than 2.0 were allocated to the intermediate group. The C.D.F.A. program can then check the validity of these groups using the variables measured. The proportion of sites correctly classified will give a strong indication of the correctness of the formula.

The data was analysed in two different directions, firstly it was analysed on an O.S. kilometre grid square basis attempting to identify by multivariate analysis those communities which had the highest ecological value. Secondly the data was analysed on a community basis, for example all the wet heathland sites were analysed to identify the best sites in

From a statistical point of view, the omission of the rarity values for the analysis of the community types may undermine the significance of the analysis.

6.8 The broad applicability of C.D.F.A. to ecological evaluation

C.D.F.A. has considerable potential for use in assessing ecological value. There is no reason why the proposed formula should not be extended to include additional parameters subject to them meeting the stated criteria. It is not a prerequisite of the program that the data used be standardised and this is of particular value. In this study the C.D.F.A.

aring in mind the comments on the previous page, C.D.F.A. y have some advantages over P.C.A.; nevertheless those servations still hold.

6.9 Summary of Principal Components Analysis

A meaningful P.C.A. could not be effected for grid squares 9587 and 9588. Neither was a P.C.A. carried out for the large number of small sites of marshland. The time taken to modify the programme and process the data was out of proportion to the useful information it would have generated.

Tables 6.3, 6.4 and 6.5 provide a summary of the P.C.A. The first two vectors accounted for at least 80% of the variance in every grid square and every community. The first principal component was highly correlated with flood species richness for each community type and in every grid square except 9687 and 9987. These two grid squares were relatively floral species poor. Here ground invertebrate diversity was the main contributor to the first vector.

TABLE 6.3 Parameter Attribute Loadings Derived from PCA of Grid Squares

GRID SQUARE	PCA AXIS ONE				PCA AXIS TWO				PCA AXIS THREE			
	AREA	FAUNAL DIVERSITY	FSR	RV	AREA	FAUNAL DIVERSITY	FSR	RV	AREA	FAUNAL DIVERSITY	FSR	RV
9585	-0.002	0.061	0.992	-0.109	-0.115	0.990	-0.054	0.062	0.939	0.090	0.032	0.329
9586	0.016	0.592	0.803	-0.063	0.014	0.135	0.135	0.990	0.050	0.793	-0.595	-0.122
9587	-	-	-	-	-	-	-	-	-	-	-	-
9588	-	-	-	-	-	-	-	-	-	-	-	-
9685	0.013	0.493	0.870	-0.028	0.033	0.845	-0.472	0.248	-0.413	-0.170	0.131	0.885
9686	0.070	0.459	0.885	-0.034	0.154	0.830	-0.454	-0.287	-0.294	0.310	-0.103	0.898
9687	0.049	0.842	0.528	0.098	0.197	-0.454	0.777	-0.388	0.971	0.085	-0.218	-0.043
9688	0.027	0.527	0.849	-0.018	-0.060	-0.789	0.479	-0.380	0.920	0.152	0.131	-0.336
9689	-0.006	-0.439	-0.898	0.006	-0.008	0.004	-0.008	-1.000	-0.001	-0.899	0.438	-0.008
9785	0.005	0.037	0.998	-0.056	0.801	0.357	-0.044	-0.478	0.513	0.003	0.046	0.857
9786	-0.089	0.034	0.989	-0.113	0.840	0.326	0.014	-0.433	0.366	0.236	0.126	0.891
9787	0.073	0.461	0.884	-0.035	0.137	0.873	-0.467	-0.002	-0.054	0.027	0.984	0.998
9788	0.063	0.503	0.853	-0.127	0.167	0.846	-0.497	0.096	-0.264	0.029	0.144	0.953
9789	0.066	0.428	0.898	-0.079	0.112	0.896	-0.415	0.173	-0.090	-0.111	0.146	0.979
9885	-0.079	0.352	0.920	0.155	0.346	0.859	-0.330	0.182	-0.574	-0.008	-0.181	0.799
9886	0.014	0.328	0.945	0.017	0.351	0.877	-0.311	0.108	0.735	-0.190	0.067	-0.648
9887	0.138	0.251	0.929	-0.233	-0.029	0.758	-0.037	0.651	-0.603	-0.470	0.352	0.540
9888	0.115	0.080	0.875	-0.175	0.337	0.801	-0.017	0.495	0.905	-0.162	-0.158	-0.360
9889	0.101	0.336	0.900	-0.260	0.271	0.821	-0.205	0.458	-0.572	0.140	0.330	0.738
9985	-0.027	0.258	0.959	0.115	0.145	0.956	-0.255	0.016	-0.359	0.006	-0.123	0.925
9986	0.153	0.497	0.854	-0.007	0.238	0.819	-0.520	-0.040	-0.218	0.103	-0.012	0.971
9987	0.00	0.00	0.00	1.00	0.00	0.00	1.000	0.000	0.806	0.591	0.000	0.000

FSR - Floral Species Richness RV - Rarity Value

TABLE 6.4 Parameter Attribute Loadings Derived from PCA of Community Sites

COMMUNITY TYPE	PCA AXIS ONE			PCA AXIS TWO			PCA AXIS THREE		
	AREA	α	FSR	AREA	α	FSR	AREA	α	FSR
ROUGH GRASSLAND	0.068	0.309	0.949	0.756	0.604	-0.251	0.756	0.604	0.251
CONIFER PLANTATION	0.196	0.851	0.487	0.933	-0.009	-0.361	0.303	-0.525	0.795
BOG	0.056	0.348	0.935	0.059	0.934	-0.352	0.997	-0.075	-0.031
DECIDUOUS WOODLAND	0.054	0.493	0.868	0.116	0.860	-0.496	0.992	-0.127	0.011
WET HEATHLAND	0.005	-0.180	0.984	0.013	0.984	0.186	1.000	-0.012	-0.007
DRY HEATHALAND	0.090	0.640	0.763	0.195	0.740	-0.643	0.977	-0.207	0.058

α = estimate of ground invertebrate diversity

TABLE 6.5 P.C.A. summary - % of total variance accounted for by each axis, vector or principal component

GRID SQUARE OR COMMUNITY	PCA 1	PCA 2	PCA 3
9585	64.34	27.4	6.01
9586	68.39	20.42	9.84
9587	-	-	-
9588	-	-	-
9685	65.38	28.00	5.39
9686	72.75	18.30	7.15
9687	79.92	11.59	5.40
9688	80.08	12.67	4.91
9689	88.23	78.03	3.74
9785	91.39	5.90	2.17
9786	62.05	25.65	9.41
9787	61.08	30.06	7.78
9788	81.14	12.69	5.18
9789	74.88	18.12	6.37
9885	73.51	12.32	7.55
9886	63.57	30.44	5.13
9887	82.59	14.69	1.61
9888	73.05	17.67	6.69
9889	86.41	9.15	3.83
9985	61.35	27.57	8.68
9986	65.80	27.96	4.28
9987	66.34	29.48	3.92
ROUGH GRASSLAND	61.82	23.34	14.84
CONIFER PLANTATION	67.78	27.53	4.69
BOG	57.78	39.65	2.58
DECIDUOUS WOODLAND	76.23	23.07	0.70
WET HEATHLAND	71.53	28.31	0.17
DRY HEATHLAND	72.08	21.44	6.48

The second principal component was highly correlated with ground invertebrate species diversity. Squares 9785 and 9786 were exceptions where P.C.A.2 was highly correlated with area. These two squares contain some large communities ranging from 0.4 km^2 downwards. Other exceptions were 9987 and 9687 referred to above where floral species richness made the largest contribution to P.C.A.2 and 9586 and 9689 where the rarity value made the largest contribution.

With the exceptions mentioned above area and rarity had little influence on the clustering. From the P.C.A. of the grid squares it does appear that the most important parameters needed to obtain a good clustering of the sites in the divisive P.C.A. used are floral species richness and ground faunal diversity. A similar conclusion can be drawn from the P.C.A. of the communities, where with the exception of the conifer plantation P.C.A.2 was correlated with area and P.C.A.1 with ground faunal diversity. This arises from the consistently low floral species richness measurements for the conifer sites.

6.10 Summary of C.D.F.A.

Paragraph 6.10 should be read bearing in mind the comments added to paragraph 6.7 on page 67.

these groupings using the variables measured in their original crude form without reference to the formula by which the C.A.S. was derived. Tables 6.6, 6.7 and 6.8 summarise the results. Inspection of these tables show a wide range of values for the standardised canonical discriminant function coefficients suggesting a reliable split of the sites into their allocated groupings. The values for Wilk's Lambda for both functions indicates that there are significant differences between these proposed groupings. These differences are attributed to differences in the measured parameters between the sites evaluated but it is suggested that these differences reflect different ecological values.

There is a high degree of similarity between the artificial groupings adopted using the C.A.S.s and the groups arrived at from the C.D.F.A. Nowhere does the % of correctly classified groups drop below 88%. It may well be that the proposed formula can be used with some degree of confidence or alternatively a C.D.F.A. can be used instead of the formula. If the latter were to be the case the sites to be evaluated would have to

TABLE 6.6 Summary of CDFA for communities

COMMUNITY	ACTUAL GROUP	NO. IN CASE	% PREDICTED GROUP MEMBERSHIP 1	2	3	% CORRECTLY CLASSIFIED
Bog	Good 1	12	100	0	0	88.24
	Medium 2	16	6	75	19	
	Poor 3	6	0	0	100	
Rough grassland	Good 1	0	0	0	0	93
	Medium 2	13	0	92.3	7.7	
	Poor 3	27	0	3.7	96.3	
Conifer plantation	Good 1	0	0	0	0	100
	Medium 2	1	0	100	0	
	Poor 3	22	0	0	100	
Deciduous woodland	Good 1	11	90.9	9.1	0	93.33
	Medium 2	8	0	87.5	12.5	
	Poor 3	11	0	0	100	
Wet heathland	Good 1	5	100	0	0	90.91
	Medium 2	11	9	82	9	
	Poor 3	6	0	0	100	
Dry heathland	Good 1	19	95	5	0	98
	Medium 2	20	0	100	0	
	Poor 3	11	0	0	100	

TABLE 6.7 Summary of CDFA for grid squares

GRID SQUARE	ACTUAL GROUP	NO. IN CASE	% PREDICTED GROUP MEMBERSHIP			% CORRECTLY CLASSIFIED
			1	2	3	
9585	Good 1	8	100	0	0	100
	Medium 2	4	0	100	0	
	Poor 3	1	0	0	100	
9586	Good 1	6	100	0	0	100
	Medium 2	7	0	100	0	
	Poor 3	11	0	0	100	
9685	Good 1	5	100	0	0	95.83
	Medium 2	7	0	100	0	
	Poor 3	12	0	8.3	91.7	
9686	Good 1	1	100	0	0	100
	Medium 2	2	0	100	0	
	Poor 3	10	0	0	100	
9687	Good 1	3	100	0	0	100
	Medium 2	3	0	100	0	
	Poor 3	15	0	0	100	
9688	Good 1	5	100	0	0	100
	Medium 2	5	0	100	0	
	Poor 3	8	0	0	100	
9689	Good 1	1	100	0	0	100
	Medium 2	2	0	100	0	
	Poor 3	2	0	0	100	
9785	Good 1	0	0	0	0	92.86
	Medium 2	5	0	80	20	
	Poor 3	9	0	0	100	
9786	Good 1	0	0	0	0	100
	Medium 2	1	0	100	0	
	Poor 3	9	0	0	100	
9787	Good 1	3	100	0	0	93.33
	Medium 2	10	0	100	0	
	Poor 3	17	0	11.8	88.2	
9788	Good 1	4	100	0	0	100
	Medium 2	8	0	100	0	
	Poor 3	25	0	0	100	
9789	Good 1	4	100	0	0	100
	Medium 2	4	0	100	0	
	Poor 3	16	0	0	100	
9885	Good 1	2	100	0	0	93.33
	Medium 2	4	25	75	0	
	Poor 3	9	0	0	100	
9886	Good 1	0	0	0	0	100
	Medium 2	2	0	100	0	
	Poor 3	13	0	0	100	
9887	Good 1	0	0	0	0	100
	Medium 2	2	0	100	0	
	Poor 3	9	0	0	100	
9888	Good 1	1	100	0	0	100
	Medium 2	3	0	100	0	
	Poor 3	22	0	0	100	
9889	Good 1	1	100	0	0	100
	Medium 2	2	0	100	0	
	Poor 3	6	0	0	100	
9985	Good 1	1	100	0	0	88.89
	Medium 2	5	20	80	0	
	Poor 3	21	0	9.5	90.5	
9986	Good 1	0	0	0	0	95.24
	Medium 2	3	0	100	0	
	Poor 3	18	0	5.6	94.4	
9987	Good 1	0	0	0	0	100
	Medium 2	0	0	0	0	
	Poor 3	12	0	0	100	

TABLE 6.8 Summary of CDFA statistics

GRID SQUARE OR COMMUNITY	STANDARDISED CDF COEFFICIENTS FUNCTION 1				FUNCTION 2				WILKS LAMBDA FUNC. 1	FUNC. 2
	F	A	X	C	F	A	X	C		
9585	0.45	0.72	0.36	-0.02	-0.54	-0.60	0.98	0.42	0.29	0.74
9586	0.26	0.91	0.83	-0.13	-0.61	-0.51	0.81	0.52	0.31	0.81
9685	-0.30	0.99	1.13	0.67	-0.05	-0.49	0.69	-0.05	0.11	0.90
9686	0.25	1.03	0.74	0.69	-0.52	0.51	-0.47	0.63	0.10	0.76
9687	0.31	-0.49	1.11	-0.21	-0.41	0.10	0.71	0.11	0.11	0.82
9688	0.28	0.74	0.78	0.41	0.68	-0.64	0.82	0.68	0.08	0.78
9689	0.30	0.90	0.66	0.61	0.51	-0.41	0.71	0.61	0.38	0.78
9785	0.29	0.78	1.06	0.76	-	-	-	-	0.28	-
9786	0.33	-0.51	1.05	-0.19	-	-	-	-	0.45	-
9787	0.14	0.91	0.87	0.51	0.54	-0.75	0.56	0.34	0.20	0.92
9788	0.25	0.77	0.81	0.61	0.53	-0.61	0.61	0.41	0.11	0.66
9789	0.34	1.22	1.49	1.58	0.76	0.06	-0.62	-0.011	0.04	0.88
9885	0.56	0.47	0.95	0.81	0.87	-0.04	0.33	-0.45	0.14	0.93
9886	0.28	0.83	0.62	-0.02	-	-	-	-	0.29	-
9887	-1.78	-1.35	2.26	0.92	-	-	-	-	0.01	-
9888	0.61	0.60	0.83	0.45	0.71	0.46	0.62	-0.03	0.12	0.81
9889	-0.47	-2.2	2.30	0.70	1.10	-1.18	3.16	2.32	0.02	0.46
9985	0.28	0.61	1.01	0.37	1.08	-0.24	0.06	0.05	0.24	0.99
9986	0.79	0.11	0.82	-1.0	-	-	-	-	0.28	-
9987	0.31	0.81	0.92	-0.11	-	-	-	-	0.26	-
Wet heathland	1.41	0.14	1.28	-	-0.32	0.87	0.20	-	0.17	0.88
Deciduous woodland	1.07	-0.21	1.05	-	-0.47	0.29	0.53	-	0.05	0.69
Conifer planation	-	-0.67	1.18	-	-	-	-	-	0.31	-
Dry heathland	0.84	0.31	0.87	-	0.68	-0.06	0.53	-	0.93	0.36
Bog	1.18	0.30	1.18	-	-0.46	0.81	0.08	-	0.15	0.96
Rough grassland	0.67	0.47	0.64	-	-	-	-	-	0.46	-

N.B. Where no value appears for the coefficient or Wilk's Lambda either the missing variable was a constant for each site or the calculation of the second function was not necessary to separate the sites into clusters.

F = Floral species richness A = Extent or area of community X = Ground faunal diversity C = Rarity value

be placed in some form of groupings, the validity of which could then be tested by the programme. These groupings could be arrived at after a field inspection by an experienced ecologist and the groupings tested by feeding the data gathered into the programme which is widely available.

Table 6.8 can be used to identify those parameters which were most significant in effecting the C.D F.A. If a large value is recorded for the standardised coefficients then that variable is making a large contribution to the axis and is important in separating the sites. The rarity values make little contribution to either axes. Ground faunal diversity makes the greatest contribution to axis one for most grid squares and also features significantly in axis two but in many grid squares containing a range of sizes of sites area becomes important.

6.11 Discussion of the multivariate analysis of the grid squares

6.11.1 Introduction

The following discussion is based on the grid square by grid square basis. The results of the P.C.A. and C.D.F.A. for the square are presented in graphical form adjacent to that discussion. The graph for the P.C.A. shows the groupings of sites recommended by the analysis. Each point on the graph refers to a site and the number next to it allows the site to be located on the community distribution map for that square to be found in Appendix D.

The results of the C.D.F.A. have in most cases been presented in the form of a scattergram. Again the points on the scattergram refer to specific sites. If the site is indicated by a diamond then that site achieved a C.A.S. greater than 2.5; if indicated by a circle then the site achieved a C.A.S. between 2.5 and 2.0 and if indicated by a triangle and a value less than two. Here the number adjacent to each site refers to the position occupied by the community when all the sites in that grid square are ranked in the descending order of their C.A.S.

In some instances it was only necessary when carrying out the C.D.F.A. to plot the first axis in order to achieve a good separation. In these cases the results of the C.D.F.A. are presented as a histogram; where this has been done the rank positioning of each site has been

omitted to avoid obscuring the sites. Nevertheless it is possible to identify each site by referring to the P.C.A.

6.11.2.1 Grid square 9585

This square is dominated by 2 features, a coniferous plantation and the Hartland Moor N.N.R. The P.C.A. recommended the division of the 13 sites into 3 groups. The eight sites of group one constitute the bulk of the N.N.R. With the exception of site 4, an area of bog they are all dry heathland sites scoring highly in the parameters measured. Sites 1 and 4 which represent a sub-division of this group have a lower faunal diversity. The area of bog is recognised to be a very rare habitat type supporting a specialized flora and fauna including the Large Marsh Grasshopper (Stethophyma grossum) which is rare and decreasing in Britain (Dorset Naturalists Trust 1977).

Sites 3 and 12 were allocated by the P.C.A. to a separate group being wet heathland and rough grassland communities respectively.

Sites 6, 10 and 2 constituted the 3rd group. Six and ten are wet heathland sites within the N.N.R. and site 2 which is well distanced on the P.C.A. is the coniferous plantation.

When the three wet heathland sites are positioned in an ordination of all the wet heathland sites they do not fall within that group which is recognised to be the best in the study area (see P.C.A. of wet heathland sites). It may be the presence of rare species such as Erica ciliaris which has justified their inclusion within the N.N.R. According to the Nature Conservancy the Hartland Moor N.N.R. contains the finest stands of E. ciliaris in the country.

This analysis does therefore suggest that within the study area there are wet heathland sites of greater ecological value than those within the N.N.R.

The positioning of the sites by the P.C.A. is confirmed by the C.D.F.A. These in turn agree with the ranking derived from the C.A.S. suggesting that sites 1, 4, 5, 13, 7, 9, 8 and 11 are of the highest ecological value and worthy of particular consideration.

6.11.2.2 Grid square 9586

The P.C.A. recommended the subdivision of these 24 communities into 4 groups. Group one contains four communities, three of them (4, 6

Fig. 6.1 P.C.A. of Grid Square 9585

Fig. 6.2 C.D.F.A. of Grid Square 9585

and 11) being areas of deciduous woodland. Sites 10 and 15 narrowly excluded from this group are also deciduous woodland. Deciduous woodland is very rare in the study area as it is in the whole of the Isle of Purbeck, (occupying something less than 5% of the Isle of Purbeck (Dorset Naturalists Trust 1977)), this along with its high floral and invertebrate diversity accountsfor its segregation from the other sites. Site 14 known as the 'Moors' has S.S.S.I. status, being a very rare and diverse habitat constituting a large area of rough grassland intersected by ditches and dykes (Dorset Naturalists Trust 1977). Sites 14, 6 and 4 were given the highest C.A.S. in this grid square.

The twelve communities in group 2 range from deciduous woodland through to wet heath and dry heath and marsh and bog. The P.C.A. did not easily split groups I and II and they are best regarded as one group all of which are of high ecological value and deserve special consideration.

The eight communities of groups three and four are characterised by low invertebrate and floral species richness and relative commonness. It is dominated by an extensive coniferous plantation (site 21) and areas of scrub and marsh.

The C.D.F.A. failed to produce any significant clusters although there was a clear axis of segregation. In this context C.D.F.A. supported the P.C.A. in isolating the same sites at the extremities. The positioning of sites by the C.D.F.A. agreed absolutely with the groupings derived from the C.A.S.

6.11.2.3 Grid squares 9587 and 9588

These two grid squares contained very few communities; and neither program would run on the data available. Site 1 in square 9587 known as the 'Moors' is an S.S.S.I.

6.11.2.4 Grid square 9685

The P.C.A. recommended subdividing the 24 communities into four groups. Hartland Moor N.N.R. occupies the western fringe of this square.

The members of group one are sites characterised by a high ground invertebrate diversity and generally high floral species richness. Sites 9, 8, 11, 17, 4, 5 and 15 are part of the N.N R., site 18 is

Fig. 6.3 P.C.A. of Grid Square 9586

Fig. 6.4 C.D.F.A. of Grid Square 9586

Fig. 6.5. P.C.A. of Grid Square 9685

♦ Sites with a C.A.S. greater than 2.5

● Sites with a C.A.S. between 2.5 and 2.0

▲ Sites with a C.A.S. less than 2.0

x Indicates group centroid

Fig. 6.6 C.D.F.A. of Grid Square 9685

hinting at the inappropriateness of the boundary of the N.N.R. Site 2 an area of rough grassland also falls within this group of high value sites but is just outside the N.N.R. boundary. The two sites which form the remainder of the N.N R. (24 and 19) fall within the third group separated because of their high ground invertebrate diversity but low floral species richness.

The sites of group one were significantly separated from the remainder of the grid square. The P.C.A. enables the further subdivision of this group distancing site 9 which was a species poor area of wet heathland.

The members of the third sub group characterised by a high ground invertebrate diversity are worthy of special attention despite their floral species paucity. Site 6 is a meadow on the banks of the Corfe River, although not a particularly good example it is a rare habitat type in this area.

The sites in group four are either marshland or scrub all containing few flowering species.

Whilst agreeing in all other aspects with the ranking derived from the C.A.S. and the C.D.F.A. suggests that site 1 (ranked thirteenth) has been misclassified by the formula. In the C.D.F.A. it is positioned very close to the site of twelfth value but considerably distanced from the site of fourteenth value. Therefore the C.D.F.A. may lead one to suggest that this site is of higher value than its C.A.S. might lead one to conclude.

6.11.2.5 Grid square 9686

The P.C.A. recommended dividing the fifteen sites of this grid square into two groups. Site 6, ranked first in this grid square occupies the most extreme position on this ordination; it is an area of deciduous woodland scoring highly in all the parameters measured. Site 3 also contained within this group is a large area of marshland with a high floral species richness. Site five an area of rough grassland is distanced from the other sites because it contains few flowering species.

Group 2 is generally characterised by sites with a low floral species richness. Nevertheless there is a considerable range here in ground faunal diversity from site eleven (very low) to site 4 (high).

Fig. 6.7 P.C.A. of Grid Square 9686

Fig. 6.8 C.D.F.A. of Grid Square 9686

The C.D.F.A. confirmed the rankings derived from the C.A.S. As did the P.C.A. the C.D.F.A. isolated site 6 as being of particular ecological interest.

6.11.2.6 Grid square 9687

This square contains a rich mosaic of community types; the 21 sites were divided into three groups by the P.C.A.

The five sites of group one all have high ground invertebrate diversities. Site four an area of deciduous woodland was ranked first and because of its high floral species richness and high rarity value, it is isolated from all sites. Site 3 ranked fourth is an area of dry heathland and was once considered as a possible N.N R. because of the isolation of the site and the absence of any recreational pressures. Sites 5 and 13 occupying adjacent positions being wet heathland sites are ordinated more or less in the same position, indicating the considerable ecological potential of the S.E. corner of this grid square. A large coniferous plantation (site 2) dominates much of the grid square, it occupied the eleventh position in the ranked order, it is isolated in the ordination scoring poorly in most of the assessed parameters. The C.D.F.A. confirmed the classification derived from the C.A.S. and also segregated sites 4, 5 and 13 from the remainder.

6.11.2.7 Grid square 9688

This site has many similarities with the previous grid square. It contains a rich variety of habitats many of which were considered as a potential site for a N.N.R. This area is composed largely of sites 1, 4, 5, 6, 7, 9 all closely ordinated and separated into one group along with site 11. All of these sites have a high floral species richness and with the exception of site 11 a high ground invertebrate diversity. The members of this group occupied the highest position in the ranking and indicate that the area of wet and dry heathland and bog in northwest corner of this grid square bordering the shores of Poole Harbour are of special merit.

The southwest corner is occupied by a bog site (9) and a large coniferous plantation (site 2) planted on what was previously dry heathland. The plantation is located in the third group of the P.C.A. and lies fourteenth in the ranked order out of eighteen for this square.

Fig. 6.9 P.C.A. of Grid Square 9687

◆ Sites with a C.A.S. greater than 2.5

● Sites with a C.A.S. between 2.5 and 2.0

▲ Sites with a C.A.S. less than 2.0

x Indicates group centroid

Fig. 6.10 C.D.F.A. of Grid Square 9687

Fig. 6.11 P.C.A. of Grid Square 9688

◆ Sites with a C.A.S. greater than 2.5

● Sites with a C.A.S. between 2.5 and 2.0

▲ Sites with a C.A.S. less than 2.0

x Indicates group centroid

Fig. 6.12 C.D.F.A. of Grid Square 9688

It is appropriate to mention that the adjacent grid square (9788) contains an R.S.P.B. Nature Reserve and a N.N.R. This must serve to heighten the importance of the large tracts of dry heathland (site 1, square 9688) which is continuous with these designated sites.

The C.D.F.A. produced no major discrepancies with either the P.C.A. or C.A.S.

6.11.2.8 Grid square 9689

This grid square is dominated by the Wareham Channel of Poole Harbour. The small area of land permanently above the high tide level is located in the far south east corner of the grid square. The P.C.A. of this grid square is unusual in that the rarity values of the communities contribute significantly to the second vector (see Table 6.3.1).

The ordination dramatically separates the five sites into 2 groups. The first group of sites 1, 4, 3 occupied the 3 highest positions in the ranking and are wet heathland, dry heathland and bog respectively. They are characterised by a high floral species richness. Sites 2 and 5 being scrub and marsh are considerably distanced scoring poorly in most of the parameters around.

The C.D.F.A. emphasised the importance of site one segregating it from the other two sites worthy of special merit.

6.11.2.9 Grid square 9785

The influence of man's activities is particularly profound in this grid square; the southern region is extensively covered by a coniferous plantation. The remainder of the square is dominated by rough grassland under agricultural use.

In the P.C.A. of this grid square area replaced ground invertebrate diversity as the main contributor to the second axis. The P.C.A. recommended dividing the 14 sites into three groups. Sites 5, 8, 10 and 12 constituted the first group ranked 4, 5, 2 and 3 respectively. These sites are characterised by a high floral species richness.

Site one ranked first was allocated to the second group, being a large area of rough grassland with a high ground invertebrate diversity. The apparent mislocation of this site hints at one of the weaknesses of identifying sites of high ecological value by a P.C.A. This is

Fig. 6.13 P.C.A. of Grid Square 9689

Fig. 6.14 C.D.F.A. of Grid Square 9689

Fig. 6.15 P.C.A of Grid Square 9785

♦ Sites with a C.A.S. greater than 2.5

● Sites with a C.A.S. between 2.5 and 2.0

▲ Sites with a C.A.S. less than 2.0

x Indicates group centroid

Fig. 6.16 C.D.F.A. of Grid Square 9785

because one of the characteristics of this grid square is that it is composed of a few large communities; correspondingly as mentioned above P.C.A.2 was highly correlated with area instead of ground faunal diversity as is the case in most other grid squares. Plotting the third vector which might be considered to be helpful is not so in this case since it is correlated with the rarity values.

It is precisely in cases like this where one site appears to be mislocated that it is essential to have alternative techniques available such as the proposed formula.

The C.D.F.A. also produced an anomaly suggesting that the site ranked fifth, (site 8 an area of marsh) has been overvalued by the formula. It is located adjacent to site 4 a conifer plantation and distanced from the site ranked fourth (site 5). The site on the extreme right of the C.D.F.A. is site one the highest ranking site with a C.D.F.A. of 2.24.

The conclusion from the P.C.A. of this grid square is that whilst the 'Divisive' program is sound the recommended groupings need to be interpreted cautiously. A similar statement applies to the next grid square.

6.11.2.10 Grid square 9786

As in the previous grid square P.C.A.2 is correlated with area. This arises from the fact that there are few communities present but each is fairly extensive. The values for the C.A.S. are not high and only one of the ten communities (site 4) an area of marshland has a value exceeding two. This site is appropriately isolated on the P.C.A.2 and distanced from the remaining sites.

Site 2 ranked second is an area of dry heathland. This is one of the heaths on the Arne Peninsula all of which are generally regarded to be of high value.

Site 1 in the third group is an extensive area of rough grassland but relatively low in flowering and invertebrate species. It is the size of this site approaching as it does nearly half a square kilometre which accounts for its position in this ordination.

The C.D.F.A. confirms the results of the P.C.A. The site on the extreme right is the area of marshland ranked first. The groupings derived from the C.A.S. were confirmed by the C.D.F.A.

Fig. 6.17 P.C.A. of Grid Square 9786

♦ Sites with a C.A.S. greater than 2.5

● Sites with a C.A.S. between 2.5 and 2.0

▲ Sites with a C.A.S. less than 2.0

x Indicates group centroid

Fig. 6.18 C.D.F.A. of Grid Square 9786

6.11.2.11 Grid square 9787

The P.C.A. of the thirty sites in this grid square isolated a group of eight sites whose members generally had a high floral species richness and a high ground invertebrate diversity.

Site one and thirteen an extensive area of dry heathland and bog respectively were ranked first and second and occupy the most extreme position on the first vector.

Site three (ranked sixth) was not amongst this group but was positioned in the third group and occupied the most extreme position on the second vector. This is an extensive area of mixed woodland with a high invertebrate diversity.

The nine sites constituting the fourth group are small in area and achieve low scores in the parameters assessed.

With one exception the C.D F.A. agreed with the groupings derived from the C.A.S. Site 26 ranked fourteenth, an area of marshland is possibly undervalued by the formula. The ordination for the C.D.F.A. places it adjacent to site 21, an area of bog ranked thirteenth. The C.A.S.s' for these two sites were 2.03 and 1.98 respectively. This emphasises the crudeness of the formula and its doubtful ability to successfully discriminate between sites where ecological value may not significantly differ.

6.11.2.12 Grid square 9788

The western edge of this grid square is occupied by the "Big Wood" National Nature Reserve and the R.S.P.B. Nature Reserve (site one).

Groups one and two identified by the P.C.A. included the first ten ranked sites. The high Community Aggregate Scores indicating that they may be of some ecological significance.

Site one corresponding with the N.N.R. occupies the most extreme position on both vectors scoring highly in the parameters assessed. Site nine, an area of bog ranked second lies on the boundary of the N.N.R. but both its positioning and C.A.S. indicate it to be significantly less important than the N.N.R.

Sites 6, 11, 12, 15, 17, 22 and 23 are areas of dry heathland and wet heathland belonging to the same group as the above sites. Their high C.A.S.s' and isolation within the ordination lend support to previous discussions by the N.C.C. that all of the areas of heathland

Fig. 6.19 P.C.A. of Grid Square 9787

Fig. 6.20 C.D.F.A. of Grid Square 9787

Fig. 6.21 P.C.A. of Grid Square 9788

◆ Sites with a C.A.S. greater than 2.5

● Sites with a C.A.S. between 2.5 and 2.0

▲ Sites with a C.A.S. less than 2.0

x Indicates group centroid

Fig. 6.22 C.D.F.A. of Grid Square 9788

on the Arne Peninsual should enjoy the status of an N.N.R.

The C.D.F.A. emphasised the importance of sites 1, 9, 10 and six ranked one to four and in no way disagreed with the P.C.A.

6.11.2.13 Grid square 9789

The P.C.A. of this grid square did not wholly agree with the ranking derived from the C.A.S. The first and second vectors were correlated with floral species richness and ground invertebrate diversity.

Sites 3, 5 and 1 ranked first second and third were isolated within one group. For no apparent reason sites 23, ranked 18 and 13 ranked 22 are also included here. Neither site scored highly in the two parameters listed above. Computational errors have been eliminated and the reason for their inclusion cannot be identified. Since the C.D.F.A. agreed entirely with the classification derived from the C.A.S. the fault may lie within the P.C.A. technique. Site 3, is a wooded area of mature oak and birch known as Froxen Copse. Appendix A contains some additional information on this grid square. This information was presented at a Public Inquiry. The C.A.S. of 2.87 for Froxen Copse (c.f. Big Wood N.N.R. with a C.A.S. of 3.16 in square 9788) suggest that the Inspectors' concluding remarks in the final paragraph of this Appendix underestimate the ecological value of Froxen Copse.

Sites 1, 2, and 5 are areas of dry and wet heathland belonging to the series of heaths found on the Arne Peninsula. Site 3 is an area of deciduous woodland not too distant from the deciduous woodland in the previous grid square to prevent intermixing of the population of birds present.

Accordingly these sites are thought to be worthy of special consideration in the management of this area.

6.11.2.14 Grid square 9885

The grid square is dominated by several areas of marshland and a large coniferous plantation. The plantation (site 1) was ranked twelfth and fourteenth and located by the P.C.A. in a group whose members are characterised by their low scores in the parameters measured.

Fig. 6.23 P.C.A. of Grid Square 9789

◆ Sites with a C.A.S. greater than 2.5

● Sites with a C.A.S. between 2.5 and 2.0

▲ Sites with a C.A.S. less than 2.0

x Indicates group centroid

Fig. 6.24 C.D.F.A. of Grid Square 9789

Fig. 6.25 P.C.A. of Grid Square 9885

Fig. 6.26 C.D.F.A. of Grid Square 9885

The most potentially interesting group identified by the P.C.A was made up of sites 9 (ranked 1st), 8 (ranked 2nd) 6 (ranked 3rd) and 4 (ranked 6th).

Sites 15 and 12 ranked 4th and 5th respectively were allocated to the second group because of their low floral species richness but their ground invertebrate diversities were only exceeded by site one.

Here the P.C.A. appear not to dramatically disagree with the ranking derived from the P.C.A. Neither did the C.D.F.A. produce any major discrepancies.

6.11.2.15 Grid square 9886

The fifteen sites in this grid square were allocated to one of three groups by the P.C.A. on the basis of their floral species richness. The first group was composed of sites 3 and 12 ranked second and third. Site one, an area of rough grassland ranked first, was placed in the second group because of its lower floral species richness. Nevertheless it is significantly distanced in the ordination on account of its high ground invertebrate diversity. Site four, a large area of marshland ranked fourth, was also isolated from the other eleven sites.

The C.D.F.A. produced no discrepancies and sites three and twelve occupy the most extreme positions on the first canonical discriminant function.

6.11.2.16 Grid square 9887

This grid square borders Poole Harbour and is largely composed of marshland. The restricted access on Long Island and Round Island made their inclusion within this survey impossible.

Eleven sites only were processed for the P.C.A. and sites 1, 2 and 4 ranked 1st, 2nd and 4th were located within one group whose characteristic was that of a high floral species richness.

Sites 11 and 14 are also worthy of special consideration. These are bogland sites ranked third and fifth with a low floral species richness but for this grid square a high ground invertebrate diversity.

The C.D.F.A. confirmed the groupings derived from the C.A.S. and isolated with the lowest Canonical Discriminant function sites 13 and 8

Fig. 6.27 P.C.A. of Grid Square 9886

♦ Sites with a C.A.S. greater than 2.5

● Sites with a C.A.S. between 2.5 and 2.0

▲ Sites with a C.A.S. less than 2.0

x Indicates group centroid

Fig. 6.28 C.D.F.A. of Grid Square 9886

Fig. 6.29 P.C.A. of Grid Square 9887

◆ Sites with a C.A.S. greater than 2.5

● Sites with a C.A.S. between 2.5 and 2.0

▲ Sites with a C.A.S. less than 2.0

x Indicates group centroid

Fig. 6.30 C.D.F.A. of Grid Square 9887

occupying the last two ranked positions. The implication being that in any planning consideration from the ecological view there is little merit in conserving either of these two sites.

6.11.2.17 Grid square 9888

The twenty five communities of this grid square were allocated to three groups by the P.C.A. The group numbered 3 contained most of the dry heathland and wet heathland sites. Once again the members of the group are characterised by a high floral species richness.

One of the patterns which is emerging in this grid square by grid square analysis is the need to be circumspect in interpreting the recommended groupings. For example site 6 is not included in the group above. It is an area of wet heathland ranked third with a high ground invertebrate diversity only equalled by sites one and ten. Caution must be exercised in making unwarranted assumptions about the ecological value of one particular grouping as recommended by the P.C.A. P.C.A. is a mathematical technique which at best allows the interpreter to generate hypotheses from the ordination.

Nevertheless attention has been drawn to site one, one of the dry heaths of the Arne peninsula complex. This site along with the sites ranked second, third and fourth were distanced from the remainder in the C.D.F.A.

6.11.2.18 Grid square 9889

This grid square contains the most extreme tip of the Arne Peninsula which is dominated by a large area of marshland and Gold Point heath. The latter was ranked first with a C.A.S. of 2.52. Ranked second was a small area of deciduous woodland (site 10) with a C.A.S. of 2.27.

Gold Point Heath is characterised by a high ground invertebrate diversity and high floral species richness.

Sites 3, 5, 7 and 8 occupying the four lowest rank positions for this grid square are area of scrub and were placed in one group together by the P.C.A.

The C.D.F.A. significantly distances site one from the other nine sites once again suggesting that it is of particular ecological merit. These findings would concur with the present status of this area as a Grade I S.S.S.I.

Fig. 6.31 P.C.A. of Grid Square 9888

♦ Sites with a C.A.S. greater than 2.5

● Sites with a C.A.S. between 2.5 and 2.0

▲ Sites with a C.A.S. less than 2.0

x Indicates group centroid

Fig. 6.32 C.D.F.A. of Grid Square 9888

Fig. 6.33 P.C.A. of Grid Square 9889

♦ Sites with a C.A.S. greater than 2.5

● Sites with a C.A.S. between 2.5 and 2.0

▲ Sites with a C.A.S. less than 2.0

x Indicates group centroid

Fig. 6.34 C.D.F.A. of Grid Square 9889

6.11.2.19 Grid square 9985

Three community types cover the bulk of this square. The southern and south western portions are covered by coniferous plantation whilst the areas to the north are occupied by rough grassland. Running north into Poole Harbour through the centre of this square is a small stream passing over poorly drained clay dominated by several bog communities.

The P.C.A. of this grid square does reflect how valuable ordination techniques may be in ecological evaluation. The P.C.A. recommended allocating the twenty seven communities to five groups. Groups one and two contained the communities occupying the first six ranked positions using the community aggregate scores.

Sites 6, 25 and 23 ranked 1st, 2nd and 4th are bog communities in group one of high floral species richness. Sites 8, 5 and 24 ranked 3rd, 5th and 6th generally have a lower floral species richness but site 8 does have a high ground invertebrate diversity.

The coniferous plantation were located in the fifth group all of whose members achieved low scores in the parameters assessed.

6.11.2.20 Grid square 9986

The western and south eastern corner of this grid square is occupied by rough grassland. Site one is a particularly extensive area of rough grassland approaching a third of a square kilometre and was ranked first with a C.A.S. of 2.35. The remainder of the grid square is covered by Phragmites marsh.

Marshland sites 2 and 4 ranked 2nd and 3rd had a high floral species richness and were placed in one group together by the P.C.A. Site one mentioned above had a lower floral species richness and was placed in a second group but is distinguished by its high ground invertebrate diversity.

Many of the sites in this grid square achieved very low values for the parameters measured and the P.C.A. failed to discriminate between these sites and they all occupy the same position on the ordination.

6.11.2.21 Grid Square 9987

This grid square is composed of twelve marshland communities on the borders of Poole Harbour.

Fig. 6.35 P.C.A. of Grid Square 9985

Fig. 6.36 C.D.F.A. of Grid Square 9985

Fig. 6.37 P.C.A. of Grid Square 9986

Fig. 6.38 C.D.F.A. of Grid Square 9986

Fig. 6.39 P.C.A. of Grid Square 9987

♦ Sites with a C.A.S. greater than 2.5

● Sites with a C.A.S. between 2.5 and 2.0

▲ Sites with a C.A.S. less than 2.0

x Indicates group centroid

Fig. 6.40 C.D.F.A. of Grid Square 9987

The P.C.A. confirmed the ranking derived from the community aggregate scores. Site one ranked first was significantly distanced from the remaining eleven communities on account of its higher ground invertebrate diversity. The C.D.F.A. similarly segregated this site since it had the highest canonical discriminant function.

6.12 Discussion of the multivariate analysis of the communities

6.12.1 Introduction

In this analysis each community was analysed in turn; the advantages of this approach is that it does for example enable one to identify those sites of a particular community type which are of the highest value in the study area. The summaries of the P.C.A. and C.D.F.A. have been presented earlier in the chapter.

In the following pages some examples have been selected to illustrate this point.

6.12.2.1 Wet heathland

In this study dry heathland communities were characterised by the dominance of *Calluna vulgaris*, although *Erica cinerea* is often prominent especially after heath fires. In poorly drained areas *Erica tetralix* and in some areas *Erica ciliaris* and its hybrids characterise wet heath.

The P.C.A. recommended the division of the 22 sites into 4 subgroups. The first axis is highly correlated with floral species richness (attribute loading 0.984) and accounts for 71.53% of the variance. The second axis is highly correlated with invertebrate diversity (attribute loading 0.984) and accounted for 28.31% of the residual variance. The third axis accounting for 0.17% of the residual variance and is highly correlated with area (attribute loading 1.00). The plots of these sites can be seen on the following page. The sites have been numbered in decreasing order of the value of the community aggregate score. A cross reference is included in the final appendix to allow these sites to be located within their appropriate grid square.

Subgroup one contains the five sites which are part of the Arne Heath complex and are part of a grade one S.S.S.I.

Fig. 6.41 P.C.A. of Wet Heathland Sites

The three communities in subgroup two have a high ground invertebrate diversity especially site 4. Site 7 falls within the Hartland Moor N.N.R.

The six communities of subgroup three are generally of low invertebrate diversity but compared to the rest of the wet heathland sites of medium floral species richness.

Subgroup four contained the remaining eight sites generally of low floral species richness but sharing a wide range of invertebrate diversity. Sites 15, 16 and 18 fall within the Hartland Moor N.N.R.

Twenty two wet heathland sites were evaluated for the C.D.F.A., five of these had a C.A.S. greater than 2.5 and accordingly were identified as of good ecological value, eleven had a C.A.S. greater than 2.0 and were identified as being of medium value and the remaining six were placed in the 'poor' value group. 90.91% of the grouped cases were correctly classified by the formula, the errors occurring in the group of medium ecological value where the C.D.F.A. suggested that one of its members should be promoted and one demoted. The scattergram for these sites is on the following page. The value of Wilks Lambda was only significant for the floral species richness variable (0.0013), the other two variables having little influence on the groupings. The range of values of the standardised canonical discriminant function coefficient (1.41 to 0.149 for Function One and -0.324 to 0.8727 for Function Two) strongly suggested a reliable split between the three groups. The first C.D.F.A. is highly significant (0.08) and therefore one does not necessarily need the 2nd function, however if this had not been plotted then on the site of medium quality which is distanced from the rest of that centroid would not have been identified. This site is according to the program misgrouped, whilst it has a low floral species richness it is by far the largest site (0.05 km^2) and has a high invertebrate diversity.

The two analyses effected separate the wet heathland sites 1, 2, 3, 5 and 6 suggesting that these are of higher ecological value than the others and should receive special consideration in a planning decision. Site 4 as mentioned above is also worthy of inclusion within this group as are sites 7 and 8. The findings of the analysis support the proposed formula, those sites identified above having the highest community aggregate scores.

Fig. 6.42 C.D.F.A. of Wet Heathland Sites

Within the study area there appear to be more important wet heathland sites than those located within the N.N.R.s. Three of the sites within the Hartland Moor N.N.R. are allocated in this analysis to the least important group. This in part reflects the importance allocated to the presence of rare species in selecting such areas for statutory protection.

6.12.2.2 Dry heathland sites

Several workers have commented upon the decline in the area of heathland and associated fragmentation (Hopkins 1983; Webb & Haskins 1980). The use of the O.S. kilometre grid square has artificially heightened this pattern where small sites are located across two or more adjacent grid squares.

According to the C.D.F.A. 98% of the sites were correctly classified, site 19 being misplaced. Site 19 was allocated by the C.D.F.A. to the group of sites of medium ecological value because although its floral species richness was high, both its area and invertebrate diversity were significantly less than the other members of the group. Invertebrate diversity and floral species richness made the most significant contribution to both functions and were therefore most important in splitting the groups. The first function was 100% significant accounting for 97.95% of the variance which is strongly correlated with floral species richness.

The P.C.A. recommended the division of the fifty sites into four groups. Subgroup I contained the first eighteen sites and corresponds with the sites judged to be of high ecological value when using the formula as confirmed by the C.D.F.A. The best four sites are part of the Arne Heath 'system' adjacent to the R.S.P.B. nature reserve. Site five is to the north of the Hartland Moor N.N.R. but just outside its Northern boundary. Sites 6, 7, 8, 10, 11, 13 and 14 are part of the N.N.R. As was the case in Wet Heathland this study suggests that there are better dry heathland sites than those located within the N.N.R. The criteria used by the Nature Conservancy are quite different from the criteria measured in this study (see Ratcliffe (1977)). However, heathland is of characteristically low plant diversity and thus the diversity of invertebrates might be expected to be lower than that in more complex habitats. Diversity may be a questionable criterion when used in heathland surveys.

Fig. 6.43 P.C.A. of Dry Heathland Sites

Fig. 6.44 C.D.F.A. of Dry Heathland Sites

Floral species richness and invertebrate diversity made a more or less equal contribution to both axes.

The 16 sites in subgroup 2 were separated from the previous group on the basis of their lower invertebrate diversity. In other aspects they were equal to the subgroup I. Site 32 is the area of dry heathland contained within the Arne R.S.P.B. nature reserve. The seven sites of subgroup 3 were of significantly lower floral species richness and invertebrate diversity. These were also relatively small sites. Subgroup 4 contained the eight sites of least ecological value, all being very small with a low faunal diversity and low floral species richness.

The values ascribed to the dry heathland sites by the formula are supported by the P.C.A. and C.D.F.A. Area was relatively unimportant in grouping the sites on the basis of their ecological value.

6.12.2.3 Deciduous woodland sites

The distribution of the 30 sites on both the P.C.A. and C.D.F.A. shows a remarkable similarity. This suggests that the allocation of the sites to the three broad categories of groups on the basis of their C.A.S. was sound.

The C.D.F.A. indicated that 93.3% of the groups were correctly classified; only site 19 was incorrectly placed in the category of medium ecological value; it should have been placed in the low value group principally because of its low floral species richness. It is the latter variable and faunal diversity which make the largest and equal contribution to the splitting of the groups along the first function. This function has a 100% significance and it is not necessary to plot the second function; however, if this had not been done the particular excellence of site one would not have been highlighted.

The P.C.A. recommended the division of the 30 sites into 4 subgroups. The first axis accounting for 76.23% of the variance was most strongly correlated with the floral species richness (attribute loading 0.868), the second axis accounting for 23.07% of the residual variance was most strongly correlated with invertebrate diversity (attribute loading 0.860).

Fig. 6.45 P.C.A. of Deciduous Woodland

Fig. 6.46 C.D.F.A. of Deciduous Woodland

Subgroup one included the seven sites with the highest C.A.S. characterised by high floral and invertebrate diversity and large sites Site No. 1 is the Arne "Big Wood" N.N.R. established in 1954 as an example of an extremely unusual type of oak/birch woodland with a juxtaposition of heathland and Spartina grassland. Site No. 5 is known as Froxen Copse in grid square 9789. Earlier in this chapter the point has been made that the significance of this area of deciduous woodland was under estimated in a Public Inquiry (see Appendix B). Within the Isle of Purbeck deciduous woodland is a rare habitat.

Subgroup 2 was characterised by sites of high floral species richness and lower invertebrate diversity than the members of subgroup I. The two sites of subgroup three were of intermediate value being somewhat poorer than the members of subgroups I and II but richer than the members of subgroup IV, occupying the middle of the range of invertebrate diversity and floral species richness. The ten sites in subgroup four are characterised by having a low floral species richness but a wide range of invertebrate diversity.

The variable area did not play a significant contribution to the P.C.A. for deciduous woodland until the third P.C.A. axis which it dominates. These analyses have produced nothing to contradict the values arrived at using the proposed formula.

6.13 Concluding comments

This chapter has sought to demonstrate the potential application of techniques of multivariate analysis to this field of work placing the emphasis on clustering sites of more or less equal ecological value rather than relying on a crude ranking. C.D.F.A. is particularly useful because the data does not have to be standardised. Neither of the techniques used in this Chapter has been designed for ecological evaluation and the facility of the P.C.A. to cluster does rely on the presence of packages of "discrete variance" in the sample. If this is not present then clustering will not occur.

In chapter eight where future work is discussed other techniques of multivariate analysis are discussed some of which may be more appropriate in achieving clustering.

CHAPTER 7

7. REVIEW OF ALTERNATIVE TECHNIQUES OF ECOLOGICAL EVALUATION WITH SIMILAR OBJECTIVES

7.1 Introduction

The aim of this section is to apply to a part of the study area other schemes of ecological evaluation with a view to critically testing their broad applicability. As has already been noted there are few existing schemes where the main objective is that of a broad evaluation of ecological resources. The schemes of Tans (1974) and Gehlback (1975) were rejected because they were developed to identify natural areas, few of which exist in the U.K. The methodology developed in this thesis represents an extension of Goldsmith's (1975) technique and this was selected for a comparative study. Tubbs and Blackwood's scheme was also used because it is the only technique which has been widely used in this country. West Sussex County Council (1973) carried out an ecological appraisal of the county using a method developed by the S.E. region of the Nature Conservancy Council.

These three techniques were applied to an area of four square kilometres selected from the centre of the study area to avoid the influence of edge effects.

7.2 Tubbs and Blackwood (1970)

The outstanding advantage of their method was that it proved to be very simple to use; the evaluation could be quickly and cheaply effected since it requires little ecological data to be gathered. Most of the work can be done from existing land use maps and aerial photographs with a confirmatory field visit.

The method argues that ecological zones will be characterised by the dominance of one of three broad categories of vegetation related directly to land use:-

(a) the complex of habitats comprising a particular type of agricultural land;

(b) commercial woodland;

(c) 'unsown' vegetation (which is taken here to include woodlands not in commercial production).

Areas of more than one half kilometre square of (b) and (c) are distinguished as zones. Areas of (a) less than half a kilometre square are absorbed within (b) or (c). It is suggested that the size criteria is adequate to indicate a general distribution of ecological values but is small enough to draw attention to areas of woodland and unsown vegetation occurring as islands within agricultural areas. There then remains the possibility of failing to identify a very small but possibly very significant site.

The evaluation of the zones is explicitly subjective as follows:

Ecological zone type	Relative value
Unsown vegetation (including non-commercial woodland)	Categories I or II, depending on a subjective estimate of rarity of habitat type and presence of features of outstanding scientific importance.
Commercial woodland	II or III depending on a subjective estimate of value as wildlife reservoirs.
Agricultural land	It is assumed that the relative value of an agricultural zone will depend on the extent of habitat diversity and that this will be reflected in the presence and amount of a number of definable features. These are grouped and evaluated according to a system of subjective scoring as follows:-

Grouping of features

1. permanent pasture and long term leys
2. hedgerows and hedgerow timber
3. boundary banks, roadside cuttings and banks, roadside verges
4. park timber and orchards other than those in commercial production
5. ponds, ditches, streams and other watercourses
6. fragments of other unsown vegetation (including woodland) smaller than the one half kilometre square size criteria

Subjective scoring for each group of features

0 = none or virtually none present in zone

1 = present (not conspicuous feature of zone)

2 = numerous (conspicuous feature of zone)

3 = abundant

Evaluation of zone

scoring	category
15-18	II
11-14	III
6-10	IV
0-5	V

The final product is presented on a Relative Ecological Evaluation Map. (See the following page)

Some of the other advantages of this technique include the fact that it is not based on the O.S. kilometre grid square and despite its subjectiveness the results can be repeated fairly consistently. The size criteria will inevitably underestimate the significance of linear habitats. The data generated will be of use in the development of broad planning strategies such as structure plans. The loss of detail inevitable within the three wide ranging categories limits its use for detailed local planning decisions particularly in the area studied which is characterised by a rich mosaic of habitat types.

The emphasis on the wildlife value of agricultural land is a pleasing aspect of this scheme. The suggested scheme of assessing the components of the agricultural landscape is less satisfactory whereby all examples of one feature are given equal value. For example the presence of all hedgerows is recognised by the same subjective value irrespective of the ecological differences that may exist between different hedgerows. The same argument applies to all the features evaluated within this category.

In summary the method of evaluation devised by Tubbs and Blackwood is a rapid and useful technique but its subjectivity and the broad generalisations inherent in its method severely limit the scope of its use to anything other than broad ecological evaluations at for example the county level. A modification of this technique was used by the Dorset Naturalists' Trust to evaluate the Isle of Purbeck (D.N.T. 1977). Their results have been confirmed by the method developed in this thesis. The value of Tubbs and Blackwood's method outside Southern Lowland England remains to be tested.

7.3 Goldsmith (1972)

The partial objectivity is one of the attractive features of this scheme. An attempt is made to solve the obvious conceptual and practical difficulties in scoring and combining disparate criteria within a formula by multiplication. Whilst weighting is explicitly excluded the criteria assessed are of different mathematical ranges and therefore cannot contribute equally to the final Index of Ecological Value (I.E.V.).

Map 4. Relative Ecological Evaluation Map.
(Reduced by approximately one third
from SY 98 NE 1:10,560).

$$\text{I.E.V.} = E \times R \times S \times V$$
$$= (e_1 \times r_1 \times s_1 \times v_1) + (e_2 \times r_2 \times s_2 \times v_2) \ldots\ldots (e_n \times r_n \times s_n \times v_n)$$

where: e_n = the extent of the nth. habitat type, recorded as area (ha) or length (km) when related to linear habitats.

r_n = scarcity value of the nth, habitat type, defined in relation to the land system basis adopted.

as $r = (100 - A)$

where A = % area of that habitat within the land system in which the site (km.sq.) falls

$$= \frac{\text{total area of habitat in land system}}{\text{total area of land system}}$$

$$A = \frac{\text{total length of habitat in land system}}{\text{total area of land system}}$$

Total

s_n = species diversity of the nth. habitat type, measured in terms of average number of species recorded in the nth. habitat. If this number varies significantly between the land systems, this should be allowed for in the calculations.

v_n = the number of vertical layers represented in the nth. habitat type, assessed on the basis of the height restrictions used by Elton (1966).

Thus the I.E.V. refers to a kilometre square, the Index being a sum of the values obtained for each habitat within that square. It is not explained why the parameters are multiplied to obtain a value for each habitat and then summed to obtain a total value for each grid square.

The authors concluded that the Index does give an indication of the overall status of the area studied but this is based on unsatisfactory data and no multivariate analysis was carried out to confirm the positioning of the sites in a rank order. The attention given to linear habitats e.g. hedges, hedgerows and streams is in direct contrast to that found in Tubbs and Blackwood's scheme. However is it realistic to expect the presence of a species rich hedgerow to dramatically influence the outcome of a planning decision? Another difference was that this scheme was developed in the Welsh Border country across a range of land types from rough moorland grazing to fertile arable land.

An admitted weakness of the scheme was the establishment of an average value for the floral species diversity of each habitat type. In my application of Goldsmith's method the floral species diversity for each separate site was included since this information has already been derived. Faunal diversity is argued by Goldsmith to be related to plant structural diversity and this was reflected in the number of vertical layers in the habitat.

The results of applying Goldsmith's method to the four selected grid squares are shown on the following page. The Community Aggregate Scores derived from the method developed in this thesis are included for comparison with the i.e.v.'s. The figures in brackets refer to the rank orders of the indices for that grid square.

The increased objectivity is a pleasing aspect of this technique, nevertheless the formula has a disadvantage of containing elements of different mathematical ranges and thus introducing weighting. Furthermore the recording of the number of vertical layers greatly favoured the values derived for mixed and deciduous woodland against all the other communities in the study area which scored two compared with five for woodland. The final figures for each kilometre square are very large and Goldsmith found it necessary to divide by 10,000 to reduce them to manageable units.

7.4 West Sussex County Council (1973)

Habitat types were identified from aerial photographs at a scale of 1:12,000, habitats were subjectively scored on a range of 0 to 10. The method of sampling involved placing an overlay containing 16 equally spaced dots (each dot representing 6.25% of a sq.km.) on the base map. The vegetation type covered by a particular dot was recorded and scored as follows:

High Grade Habitats		Other Habitats	
Woodland	10 points	Parkland	8 points
Scrub	"	Orchard	6 "
Heath	"	Plantation	6 "
Rough Grassland	"	Improved Grass	3 "
Tidal Mudflats	"	Arable	2 "
Sand Dunes, Sand	"	Developed Areas	no "
Saltings	"		
Freshwater Marsh	"		
Freshwater	"		

TABLE 7.1 Indices of Ecological Value for Grid Square 9687

Cartographic Area	e	r	s	v	i.e.v.	C.A.S.
1	1.350	0.960	9	2	23.328 (11)	1.9177 (7)
2	31.600	0.870	4	2	219.936 (3)	1.6909 (11)
3	25.950	0.830	11	2	473.847 (2)	2.4204 (4)
4	8.610	0.940	28	5	1133.076 (1)	2.9217 (1)
5	6.400	0.960	17	2	208.896 (4)	2.5504 (2)
6	7.010	0.970	13	2	176.792 (5)	1.6533 (12)
7	4.059	0.870	7	2	49.439 (8)	1.3641 (17)
8	3.321	0.830	8	2	44.103 (9)	2.1428 (5)
9	1.480	0.940	13	5	90.428 (6)	1.7702 (9)
10	2.340	0.740	24	2	83.117 (7)	1.7082 (10)
11	1.480	0.970	8	2	22.969 (12)	1.4954 (13)
12	1.230	0.741	21	2	42.911 (10)	1.3140 (18)
13	1.722	0.960	11	2	18.184 (14)	2.5334 (3)
14	0.861	0.960	6	2	9.919 (16)	1.8615 (8)
15	0.738	0.960	14	2	19.837 (13)	2.1347 (6)
16	0.861	0.743	13	2	16.633 (15)	1.2095 (21)
17	0.369	0.870	4	2	2.568 (17)	1.3016 (19)
18	0.110	0.970	9	2	1.9206 (18)	1.4817 (14)
19	0.100	0.830	7	2	1.162 (19)	1.3373 (15)
20	0.085	0.830	7	2	0.988 (20)	1.4215 (16)
21	0.100	0.870	4	2	0.696 (21)	1.2989 (20)

$$\text{I.E.V.} = \sum \text{i.e.v.} = 5166.681$$

for grid square 9687

(figures in brackets refer to the rank order)

TABLE 7.2 Indices of Ecological Value for Grid Square 9688

Cartographic Area	e	r	s	v	i.e.v.	C.A.S.
1	30.63	0.834	15	2	766.363 (1)	2.7559 (1)
2	21.40	0.865	11	2	407.242 (2)	1.6401 (14)
3	4.43	0.834	11	2	81.282 (3)	2.1026 (9)
4	1.353	0.959	18	2	46.711 (4)	2.5877 (3)
5	0.984	0.955	18	2	33.830 (7)	2.6566 (2)
6	0.984	0.834	15	2	24.620 (8)	2.3825 (7)
7	1.107	0.959	16	2	33.972 (6)	2.5596 (4)
8	0.984	0.971	12	2	22.930 (9)	1.6442 (13)
9	1.600	0.834	13	2	34.694 (5)	2.5425 (5)
10	0.250	0.955	16	2	7.640 (11)	2.4119 (6)
11	0.012	0.743	38	2	0.677 (17)	1.9736 (11)
12	0.492	0.955	16	2	15.036 (10)	2.1835 (8)
13	0.004	0.971	9	2	0.070 (18)	1.4886 (16)
14	0.246	0.955	14	2	6.578 (12)	2.0273 (10)
15	0.123	0.959	9	2	2.123 (15)	1.6494 (12)
16	0.123	0.971	8	2	1.911 (16)	1.4818 (15)
17	0.301	0.865	7	2	3.645 (13)	1.3265 (7)
18	0.100	0.741	20	2	2.964 (14)	1.2514 (18)

I.E.V. = $\sum$ i.e.v. = 1429.29

for grid square 9688

(for figures in brackets refer to the rank order)

TABLE 7.3 Indices of Ecological Value for Grid Square 9787

Cartographic Area	e	r	s	v	i.e.v.	C.A.S.
1	21.000	0.830	13	2	453.18 (2)	2.865 (1)
2	15.250	0.830	8	2	202.52 (5)	2.339 (5)
3	12.670	0.940	20	5	1190.98 (1)	2.318 (6)
4	7.380	0.741	38	2	416.18 (3)	2.1157 (9)
5	3.080	0.959	11	2	64.98 (11)	2.0855 (11)
6	3.320	0.741	36	2	117.13 (8)	2.1008 (10)
7	2.950	0.938	12	5	166.03 (6)	2.0413 (12)
8	5.170	0.743	16	2	122.92 (7)	1.4834 (25)
9	1.350	0.971	21	2	55.06 (13)	1.9267 (16)
10	1.107	0.960	21	2	44.63 (15)	2.5297 (3)
11	2.706	0.940	25	5	317.96 (4)	2.3689 (4)
12	1.230	0.970	22	2	52.50 (14)	1.9255 (17)
13	1.845	0.960	27	2	95.64 (9)	2.7166 (2)
14	1.353	0.740	37	2	74.09 (10)	2.2434 (8)
15	7.380	0.970	19	2	27.20 (19)	1.8726 (19)
16	1.230	0.740	31	2	56.43 (12)	1.8491 (20)
17	1.230	0.830	12	2	24.50 (21)	1.9168 (18)
18	0.984	0.970	17	2	32.45 (16)	1.5673 (23)
19	0.492	0.970	6	2	5.73 (25)	1.3284 (29)
20	0.615	0.740	21	2	19.11 (24)	1.4361 (28)
21	0.123	0.960	17	2	4.01 (27)	2.0260 (13)
22	0.738	0.740	21	2	22.94 (23)	1.5655 (24)
23	1.353	0.830	11	2	24.71 (20)	1.9692 (15)
24	0.615	0.970	20	2	23.86 (22)	1.6406 (22)
25	0.123	0.830	9	2	1.84 (30)	1.7775 (21)
26	0.723	0.740	28	2	29.96 (18)	1.9807 (14)
27	0.511	0.940	13	5	31.22 (17)	1.4784 (27)
28	0.098	0.960	26	2	4.89 (26)	2.3145 (7)
30	0.091	0.970	19	2	3.35 (29)	1.4815 (26)
31	0.190	0.740	13	2	3.66 (28)	1.3054 (30)

I.E.V. = $\sum$ i.e.v. = 3689.66

for grid square 9787

(figures in brackets refer to rank order)

TABLE 7.4 Indices of Ecological Value for Grid Square 9788

Cartographic Area	e	r	s	v	i.e.v.	C.A.S.
1	21.890	0.94	20	5	2057.66 (1)	3.1571 (1)
2	17.590	0.74	37	2	545.41 (3)	1.9614 (14)
3	9.960	0.74	24	2	340.99 (4)	1.8613 (19)
4	11.310	0.74	33	2	552.38 (2)	2.0269 (12)
5	5.530	0.74	32	2	261.90 (6)	1.8666 (18)
6	3.075	0.83	14	2	71.46 (12)	2.6086 (4)
7	4.305	0.74	32	2	203.88 (7)	1.8799 (16)
8	3.570	0.97	16	2	110.81 (10)	1.7471 (24)
9	2.340	0.96	29	2	130.29 (8)	2.7728 (2)
10	3.200	0.94	20	5	300.80 (5)	2.6112 (3)
11	2.830	0.83	18	2	84.56 (11)	2.3753 (6)
12	1.850	0.83	15	2	46.07 (13)	2.3399 (7)
13	1.970	0.94	14	5	129.63 (9)	1.8520 (21)
14	1.600	0.96	11	2	33.79 (16)	2.0963 (11)
15	1.230	0.83	13	2	26.54 (20)	2.2824 (9)
16	0.984	0.94	9	5	41.62 (15)	1.5601 (26)
17	1.107	0.83	16	2	29.40 (17)	2.3068 (8)
18	0.738	0.97	17	2	24.34 (22)	1.4880 (31)
19	0.738	0.97	14	2	20.04 (23)	1.5393 (28)
20	0.492	0.94	11	5	25.44 (21)	1.7090 (25)
21	0.738	0.97	19	2	27.20 (18)	1.5136 (30)
22	0.615	0.83	15	2	15.31 (27)	2.1993 (10)
23	0.615	0.96	16	2	18.89 (24)	2.4009 (5)
24	0.615	0.94	15	5	43.36 (14)	1.5565 (27)
25	0.615	0.94	16	5	46.25 (12)	1.8865 (15)
26	0.615	0.96	14	2	17.81 (26)	1.9840 (13)
27	0.50	0.74	25	2	18.50 (25)	1.8418 (22)
28	0.66	0.97	21	2	26.89 (19)	1.8685 (17)
29	0.16	0.97	16	2	4.97 (28)	1.4822 (32)
30	0.07	0.97	22	2	2.16 (30)	1.8369 (23)
31	0.06	0.97	12	2	2.56 (29)	1.4555 (36)
32	0.08	0.97	11	2	1.71 (32)	1.5327 (29)
33	0.05	0.97	13	2	1.26 (34)	1.2867 (37)
34	0.08	0.97	11	2	1.71 (32)	1.4557 (35)
35	0.05	0.83	12	2	1.00 (36)	1.8537 (20)
36	0.06	0.97	15	2	1.75 (31)	1.4812 (33)
37	0.05	0.97	11	2	1.07 (35)	1.4811 (34)

I.E.V. = $\sum$ i.e.v. = 5269.41

for grid square 9788

(figures in brackets refer to rank order)

A score for each habitat was obtained by multiplying the number of dots falling on it by its weighting. The scores were summed to give a total for the square. A continuous area of half a sq. km. or more, of one of the high grade habitats was awarded ten additional points. The value of arable land or improved grassland is increased by hedges, ditches, etc. and this is represented by scoring additional points for the number of fields per sq. km. as follows:-

0 - 5 fields	-	0 points
6 - 10 "	-	5 "
11 - 20 "	-	10 "
21 - 30 "	-	20 "
31+ "	-	30 "

Additional points were assigned to each square in which the following occurred:-

N.N.R.s	-	20 points
Local Nature Reserves	-	20 "
S.S.S.I.s	-	10 "
Other Nature Reserves	-	10 "

The scores obtained for West Sussex ranged from 26 to 190. The scores were rounded off to the nearest 10, divided by a factor of 10 and grouped as follows:-

3 to 6	-	low
7 and 8	-	medium
9 to 11	-	high
12 plus	-	very high

The scores for the four grid squares are given in the following table.

The principal value of this system was its simplicity but its extreme subjectivity and implicit assumption in giving equal weighting to the high grade habitats undermines the theoretical basis of this approach.

7.5 Concluding discussion

It is illuminating to compare the results of the techniques reviewed above with the technique presented in the earlier part of this thesis. Since all four techniques set out to assess ecological value then the results should be similar. There are however discrepancies, in part reflecting lack of concensus as to what

TABLE 7.5 Evaluation Scores Using the 'West Sussex' method

Grid Square 9787

Category	No. of Dots	No. of Points
Dry heathland	2	20
Rough grassland	9	90
Deciduous woodland	6	60
Marsh	3	30
Scrub	2	20
Bog	1	10
N.N.R.	-	10
Fields	-	10
	Total	250

Score = 25 points - very high ecological value.

Grid Square 9788

Category	No. of Dots	No. of Points
Dry heathland	9	90
Mixed woodland	3	30
Rough grassland	3	30
Wet heathland	1	10
Deciduous woodland	2	20
Marsh	2	20
Scrub	1	10
Bog	1	10
	Total	220

Score = 22 points - very high ecological value.

Grid Square 9688

Category	No. of Dots	No. of Points
Dry heathland	10	100
Pine plantation	5	30
Wet heathland	1	10
Bog	2	20
Scrub	1	10
	Total	170

Score = 17 points - very high ecological value.

Grid Square 9687

Category	No. of Dots	No. of Points
Dry heathland	6	60
Pine plantation	8	48
Wet heathland	1	10
Bog	1	10
Scrub	2	20
	Total	168

Score = 17 points - very high ecological value.

constitutes ecological value. Nevertheless Goldsmith's method and the method proposed in this study are based on similar principles, despite this the correlation between the C.A.S and the i.e.v. are inconsistent. The correlation coefficients are given in Table 6. There is a good correlation for the very best sites, both methods readily identify such sites but below this there is far less agreement.

A P.C.A. analysis was carried out using the data required to derive the i.e.v. The results partially explain the poor correlation mentioned above. Table 7.8 gives the attribute loadings highlighting the strong influence of species diversity (as defined for use in the formula) and extent have on the first two principal components. The second axis was highly correlated with extent and in three out of four grid squares the first axis was highly correlated with species diversity. Grid square 9688 was an exception, P.C.A. 1 being highly correlated with scarcity. It is not possible to identify a clear reason for this, there are no very rare communities in this grid square. It may be explained by the large number of very small sites within this kilometre square. The scarcity value is therefore much higher than the extent in the majority of cases and therefore features more significantly in the divisive run of the P.C.A.

The high attribute loadings for the variable extent emphasise the weighting given to it in Goldsmith's formula e.g. in grid square 9688 the site occupying the second position in the rank order is a large and extensive pine plantation. It is placed well above several dry heathland and wet heathland sites which have a higher species diversity and the same number of vertical layers. This accounts for the negative value of 'r' obtained for this grid square between the I.E.V and the C.A.S. The formula for deriving the I.E.V. might well be improved by expressing extent in square kilometres rather than hectares.

Whilst the P.C.A. confirmed the ability of the I.E.V. to identify the various best sites in each grid square, the groupings recommended did not always coincide with the rank orders. Clear clusters were not always identified but this is a comment upon the appropriateness of

TABLE 7.6 Correlation coefficients between the C.A.S. and i.e.v.

Grid Square	'r'	Equation
9687	0.66	Y = 347x - 497
9688	-0.025	Y = 96.6 - 7x
9787	0.43	Y = 247x - 360
9788	0.54	Y = 440x - 704

TABLE 7.7 Evaluation scores for the four grid squares obtained using Goldsmith's method and the 'West Sussex' scheme

Grid Square	I.E.V.	West Sussex Scheme
9687	5166.68	17 points
9688	1429.29	17 "
9787	3689.66	25 "
9788	5269.41	22 "

TABLE 7.8 P.C.A. of data derived from Goldsmith's method applied to grid squares 9687, 9688, 9787 and 9788

	ATTRIBUTE LOADINGS														
	AXIS ONE					AXIS TWO					AXIS THREE				
GRID SQUARE	e	r	s	v	% variance	e	r	s	v	% variance	e	r	s	v	% variance
9687	-0.109	-0.004	0.994	-0.013	74.5	0.994	-0.003	0.109	0.022	24.2	-0.024	0.025	0.011	0.999	1.07
9688	-0.004	1.000	-0.010	0.000	99.73	0.970	0.002	-0.244	0.000	0.17	0.244	0.010	0.970	0.000	0.10
9787	-0.109	-0.004	0.994	-0.013	74.5	0.994	-0.003	0.109	0.022	24.42	-0.024	0.025	0.011	0.999	1.07
9788	0.477	-0.007	0.879	-0.017	81.17	0.872	0.002	-0.471	0.134	17.23	-0.110	0.011	0.079	0.991	1.6

Fig.7.1 P.C.A. of data for grid square 9687 required for Goldsmith's formula. Numbers by the squares refer to cartographic area within the grid square. The numbers inside the boxes refer to the rank order of that site within the grid square using the i.e.v. Hatched lines indicate the clustering of sites as recommended by the P.C.A.

Fig.7.2 P.C.A. of data for grid square 9688 required for Goldsmith's formula. Numbers by the squares refer to cartographic area within the grid square. The numbers inside the boxes refer to the rank order of that site within the grid square using the i.e.v. Hatched lines indicate the clustering of sites as recommended by the P.C.A.

Fig. 7.3 P.C.A. of data for grid square 9787 required for Goldsmith's formula. Numbers by the squares refer to cartographic area within the grid square. The numbers inside the boxes refer to the rank order of that site within the grid square using the i.e.v. Hatched lines indicate the clustering of sites as recommended by the P.C.A.

Fig.7.4 P.C.A. of data for grid square 9788 required for Goldsmith's formula. The numbers inside the boxes refer to the rank order of that site within the grid square using the i.e.v. Hatched lines indicate the clustering of sites as recommended by the P.C.A. (Numbers indicating cartographic areas have been omitted for clarity).

P.C.A. to this type of work rather than the validity of Goldsmith's formula. The form of P.C.A. used will only identify clusters if discrete 'packages of variance' exist within the data.

The summed i.e.v.s for the four grid squares and the values obtained using the 'West Sussex' method show discrepancies (see Table 7.7). These values convey a different impression to that given by the relative ecological evaluation map for example squares 9688 and 9787 are dominated by grade 1 zones and yet have the two lowest I.E.V. Conversely squares 9788 and 9687 with the least amount of grade 1 zones receive the highest I.E.V. The 'West Sussex' method appears to be too broad and subjective to discriminate between sites of high ecological value.

7.6 Conclusion

All four techniques readily identify the superior sites; however anomalous results can be produced using Goldsmith's method due to extent being recorded in hectares rather than square kilometres. Tubbs and Blackwood's and the 'West Sussex' schemes will not discriminate between sites of high ecological value. Finally it should be remembered that these conclusions have been arrived at from a study of four square kilometres. If a more extensive area had been studied different results might have been obtained.

CHAPTER 8

8. CONCLUDING DISCUSSION

8.1 Future work

Chapter 6 sought to demonstrate the potential contribution that techniques of multivariate analysis could make to the field of ecological evaluation. In the longer term specific techniques and programmes might be forthcoming. Two other existing techniques are also mentioned here. 'Clustan' analysis specifically aims to identify clusters within sets of data. Ward's (1963) method was applied to grid square 9687 (see Chapter 6 for a detailed analysis of grid square 9687). The results are presented in the form of a dendrogram and are shown in Fig. 8.1. Sites 3, 5, 12 and 4 are well separated from the rest (these were ranked 4th, 2nd, 18th and 1st respectively by the C.A.S.) Sites 9 and 14 are also distinct ranked 9th and 8th by the C.A.S. Of the remaining sites 1, 13 and 8 form one series whilst 11, 15, 18, 19, 7, 16, 20, 2, 6, 10 and 17 form another major group. The appropriateness of this technique to ecological evaluation merits further consideration.

Similarly Hill's (1973) technique of Reciprocal Averaging may be appropriate to this field of work. A version developed by Kent (1977) was applied to grid square 9687 and the dry heathland sites. The results of this ordination are shown in figures 8.2, 8.3, 8.4 and 8.5.

Whittaker (1967) has indicated that one of the advantages of reciprocal averaging is that the axes are easy to interpret whereas the axes derived from principal components analysis may be difficult to interpret or sometimes uninterpretable. Whittaker (1967) in his comprehensive review of ordination methods maintain that the mathematically simpler method of ordination such as reciprocal averaging give better results. Hill (1973) concluded that in most practical application reciprocal averaging gives ordination which are simpler to those derived by principal components analysis of standardised data.

Kent's (1977) version computates three axes and any combination of these axes can be plotted for the ordination. For grid square 9687 the plot of the first two axes (Fig. 8.2) produces results which do not wholly concur with previous findings. Site 2 ranked 11th and site 3 ranked 4th are clearly distanced from the other sites. Sites 4, 5 and 12 ranked 1st, 2nd and 18th also form a distinct group. The majority

Fig.8.1 Dendrogram showing the results of a 'Clustan' analysis for grid square 9687. The figures refer to the sites within the grid square.

Fig.8.2 The results of applying Hill's Reciprocal Averaging Technique to grid square 9687. The ordination plots axis 1 (X) against axis 2 (Y). The numbers refer to the sites within the grid square.

Fig.8.3 The results of applying Hill's Reciprocal Averaging Technique to grid square 9687. The ordination plots axis 1 (X) against axis 3 (Y). The numbers refer to the sites within the grid square.

Fig.8.4 The results of applying Hill's Reciprocal Averaging Technique to grid square 9687. The ordination plots axis 2 (X) against axis 3 (Y). The numbers refer to the sites within the grid square.

Fig.8.5 The results of applying Hill's Reciprocal Averaging Technique to the dry heathland sites. The ordination plots axis 1 (X) against axis 2 (Y). Numbers refer to the ranked order of the sites using the C.A.S. The sites can be located within the study area by using appendix E.

of the sites are positioned along a gradient running in the direction of the Y axis. The plot of the first and third axes (Fig. 8.4) produces a less satisfactory arrangement but site three is distanced from the remaining sites. The plot of the second and third axes (Fig. 8.4) does produce some interesting clusters e.g. sites 5, 12 and 4 and sites 8, 13 and 1.

When this technique of reciprocal averaging was applied to the dry heathland sites (Fig. 8.5) the results only partially agreed with the ranking derived from the C.A.S.

These examples quoted above have not been discussed in detail but are intended to be illustrative of the direction in which future work might proceed.

It also has to be recognised that the methodology developed in this thesis has been tested on a limited range of habitats. The ever increasing importance of urban conservation places a premium upon the use of urban ecological evaluation. Aquatic habitats both freshwater and marine were also omitted from this study.

The long term looksto a range of methods of ecological evaluation each designed to evaluate a specific community or habitat. It has been mentioned elsewhere in this thesis that a high floral diversity may not be a desirable feature of dry heathland communities. Ward and Evans' (1976) method for evaluating limestone pavements illustrates this point.

8.2 Representativeness of the data

The data was collected over a short period of time during the summer months and because of the large area studied and the quantity of sampling necessitated by this study repeat visits were not feasible. Inevitably the data represents a very small snapshot of a dynamic system. Also a limited range of parameters was measured in this study. This range could be extended to include other appropriate factors as long as they meet the stated criteria. An extended range of parameterswould improve the efficiency of multivariate techniques.

8.3 The communication gap - a personal view

Conversations with many planners indicate a strong desire on their part to include the results of ecological evaluations within planning

decisions. Few planners appear to be aware of the range of methods available because most have been published in scientific journals.

Most planners through their local authorities have access to large computers thus facilitating the use of the sort of program proposed in this study. Many local authorities now employ an ecologist but too often their work is involved with recreational aspects. Perhaps there is a need for redefining the role of ecologists working for local authorities involving them more intimately in the planning procedure. This redefinition of role coupled with the availability and awareness of computer programs effecting ecological evaluations might lead to the ecological argument being presented with greater clarity in planning discussions.

Hampshire County Council's (1968) assessment of the East Hants Area of Outstanding Natural Beauty whilst now dated is a novel approach in that an evaluation of different factors was effected and produced in map form. Amongst other evaluations there was a landscape evaluation, an agricultural evaluation, a recreational evaluation and an ecological evaluation. If the results of these evaluations were placed on transparent acetate sheets and the maps superimposed upon one another then this would help in identifying those sites where development would do least environmental harm. There would appear to be a role for multivariate analysis in this broad approach to planning where the variables assessed could include non-ecological parameters.

The study of the E. Hants A.O.N.B. was a large scale study but it would seem desirable to adapt this approach to studies on a smaller scale. The technique developed by Tubbs and Blackwood (1971) was used in the E. Hants Study. In Chapter 7 it was indicated that this technique whilst having many strengths is not entirely appropriate for small scale studies. The technique proposed in this thesis may be more appropriate within this context.

Priorities for the future might rest along the following lines.

(a) An intensive dialogue between ecologists and planners. Whereby ecologists become aware of the needs of planners and the format in which information is required. Conversely acquainting planners with the techniques of ecological evaluation presently available along with their limitations and scope.

(b) A critical review of the role of ecologists employed by local authorities.

(c) An investigation of the use of existing programs presently commercially available (e.g. Nie et al. 1975) with a view to their use by ecologists employed by local authorities, in many cases using data already available in data banks.

These three points if coupled with a continuing research programme into the field of ecological evaluation would lead to a heightening of the significance of ecological issues in planning discussion onto a level equal with other considerations.

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APPENDIX A

Extract from The Public Inquiry into the appeal by E.C.C. Ball Clays against the refusal of the Dorset County Council to permit the winning and working of clay at Russel Quay, Arne, near Wareham in Dorset.

As far as the ecological argument is concerned, one of the grounds for refusing the planning application was that the present exceptional value of the Arne Peninsula from a national conservation point of view would be greatly reduced if such activities took place. The appeal site is forty-four acres at the Northern end of the peninsula and includes a shallow pond (about nine acres) which is separated from Wareham Channel by a low sandbank. On the East side of the pond, within the site and extending South and slightly East beyond it, there is a wooded area of mature trees (mostly oak and birch) with small clearings of bracken, gorse and bramble. This area is known as Froxen Copse. There are two areas of pasture on the site, totalling about 11½ acres, one adjoining the shoreline immediately West of the pond, the other lying South of the pond. The rest of the site is thickly wooded with mainly birch and oak, the trees extending continuously along the South West boundary of the site and along the South side of the pond. Most of the site is very low lying, the greatest height being about fifteen feet above sea level. On the West, the site is bounded by heathland which extends to Russel Quay at the North West corner of the Peninsula, and which rises in a generally Southerly direction to a height of more than seventy feet a.o.d. To the East of the site is Gold Point Heath (rising to about forty feet a.o.d.), part of the Eastern spur of the Peninsula which ends at the saltings at Patchings Point and which encloses the North side of Arne Bay. The Southern boundary of the site is about 150 yards from the high water mark of Arne Bay.

One unusual aspect about this Public Enquiry was that the Nature Conservancy Council was not present to give evidence. This situation arose because of the terms of the lease under which the Hartland Moor National Nature Reserve was leased, one of the conditions of this lease is that the N.C.C. have undertaken not to object to any such enquiry like this. The appellants sought expert ecological advice from three experts on the flora and vegetation, the zoology and the marine biology. One of the astonishing matters to come out of this enquiry was that the N.C.C. had very little factual information on the appeal site and therefore all of the ecological information came from bodies other than the N.C.C. and such was the dispute that it led to the Inspector to record that the disagreement between the appellants and the objectors on conservation issues seemed to be entirely subjective, there being very little conflict

on objective matters. The appellants conservation witnesses demonstrated the effects of the proposed workings on the ecology of the Arne Peninsula were exaggerated by the objectors, so much so that the ecological importance of this very small part of the Peninsula was not worth putting the ceramic industry at risk. The following is the evidence presented by the three ecological experts for the appellants.

'The working party had noted the Nature Conservancy's view that further detailed conservation research would be required in order to make a proper evaluation of the area proposed for clay winning. The appellants had therefore sought the advice of three expert ecologists.

The flora and vegetation of the Arne Peninsula had been examined during a number of visits between June and September 1975. Most of the ground was covered by dry and wet heaths. The dry heath, on the more elevated land was dominated by ling and was relatively species poor; it was being invaded by bracken. The more interesting wet heaths could be recognised by an abundance of cross-leaved heath and the occurrence of cotton grass and sundews, with much less ling. The continued presence of the chalk on the access track was detrimental to heathland and should be removed, as proposed by the appellants.

A different range of communities has been found in the vicinity of the appeal site. The vegetation of the pond was poor with a fringe of sea rush, common reed and cord grass (Spartina anglica). The weedy or scrubby vegetation around the pond included characteristic species such as birch, holly, elder, hawthorn, with willow scrub in the wetter parts; the birch appeared to be invading the wet heaths. Froxen Copse included some substantial trees of the pendunculate oak which, judged from sample tree borings, had an average age of about 250 years, with some perhaps twice as old. There was also elms (suffering from Dutch Elm disease), mature birch, ash and pines. The two areas of pasture within the appeal site had formerly been woodland and were now overgrown with thistle and ragwort. More than 200 species of flowering plants were recorded on the area investigated, but about a quarter of these were transitory plants in the reclaimed fields; among the naturally occurring species, there were relatively very few of special interest.

The lower levels of the extensive saltings of Arne Bay contained

mostly cord grass, and the higher parts a saltmarsh vegetation which was poor in species and much invaded by Spartina. The northern shore of the peninsula showed the vestiges of a strand-line but did not have a good strand-line flora. A small shingle ridge, east of Gold Point, appeared to be encroaching south-westwards on to the saltings and the adjacent heathland.

The natural vegetation of the peninsula was being interfered with by several anthropogenic factors, particularly trampling and grazing by cows. Trampling not only damaged or destroyed plants, but also introduced micro-habitats in the form of hoof-marks which could alter details of the surface drainage. There was also damage by human trespassers and the obvious risk to the heathland in the form of fire.

Chalk rubble had been used in the construction of the Arne-Ridge Road and, as a consequence, a typical flora had become established on the verges. This calcicole vegetation was of interest, one particular feature being the number of orchids, including the rare marsh helleborine.

In the expert's view, the area which would be eliminated by the appeal development (the lake, most of the surrounding woodland and scrub and the two pasture fields did not include any species of real consequence, nor were the plant communities of great interest. The only loss of species in the area would be the transitory plants in the reclaimed fields. Although the site was included in a S.S.S.I., the amount of human interference and lack of communities of great ecological interest had greatly minimised its biological importance. The wet heath to the South West of the appeal site was too distant for its drainage to be affected by the excavations. The transport of clay along the access track to Arne village was unlikely to disrupt seriously dry heathland communities provided the hardcore for the road surface was compatible with heathland vegetation and would adversely affect neither the acidity nor the mineral composition of the soil. Most of the wet heaths were some distance from the route and would not be affected so long as the road did not alter the present drainage pattern. The County Council were aware of the considerable ecological interest of the roadside verges between Arne and Ridge and, as they had agreed the location of the proposed passing bays, the flora should not be seriously harmed.

It was the expert's considered opinion that there was no good ecological reason why the proposed clay extraction should not be permitted. Arne heathland was not at risk. He agreed however that any future working on the heathland East or West of the appeal site would seriously affect the ecological importance of the area.

The zoology expert had confined his observations to the aerial, terrestrial and fresh water fauna of the appeal site. He had visited the site on fourteen or fifteen occasions between March and August 1975, had studied the relevant literature, and had had meetings with the interested conservation bodies.

The lake, which was of recent origin, was brackish for most of the time and its faunal diversity was very low. None of the specimens found were rare or of particular biological interest; he had found no dragonfly larvae in the lake. The birds of the lake were transient and few attempted to breed there. It appeared to be a temporary roost for small numbers of the many species which at other times inhabited the saltings or mud flats around the harbour. In its present form, the lake could not be considered a stable habitat; if left alone, it would change to a freshwater or brackish swamp. Management and human interference of some sort would be needed to maintain it as open water.

The invertebrate fauna of the appeal site was rich and diverse. The glades were particularly attractive to butterflies and up to eighteen species were known to occur there, including less common species such as the Ringlet and Silver Studded Blue. The small mammal population of mice and voles was typical of the type of habitat. Sika deer occurred in the glades. No trace had been found of otter; any which did occur on the peninsula would only be transient males as there were no suitable breeding sites for otters on Arne. The only reptiles seen on the appeal site had been adders. No colonies of sand lizards or smooth snakes (both endangered and protected species), had been found or were known to be present in the area and no individuals of either species had been seen by the expert; no part of the appeal site was a suitable habitat for these reptiles. The brackish nature of the lake would almost certainly prevent any amphibians breeding in the area and none had been seen.

The bird fauna of the appeal site was typical of deciduous woodlands

with open areas of grassland and water. A few species (e.g. the Reed Warbler), were clearly associated with the lake margin whereas others, (e.g. The Spotted Flycatcher), were particularly associated with Froxen Copse. All species had been recorded from other localities on the peninsula. None of Arne's rare birds (Dartford Warblers, Hobbies, Nightjars or Nightingales) had been observed by the expert, or were recorded as being present, in the appeal site area.

The mudflats around Arne and the harbour formed a continuous ecological unit. The wild fowl and Waders moved about within this unit and into and out of the area adjacent to the appeal site. Their status and location, compiled from various sources, were given. Certain areas were preferred by particular species for instance, Patchins Point attracted Brent geese and Spotted Redshank while on the other hand, Blacktailed Godwits were seldom found in the vicinity of the peninsula. Most of the wild fowl of special interest wintered in the open waters of the harbour or Arne Bay. Thus, although the mudflats and the harbour attracted a bird fauna of national interest and importance, the area adjacent to the appeal site was not one of the most attractive areas, nor was it preferred by the most important species. This view was based on the expert's own observations and on information available to him. He accepts that more recent information, such as from the Birds of the Estuaries Inquiry which he had not consulted, might necessitate a revision of his opinion.

The major biological interest of the peninsula, as opposed to the harbour, centred around the freshwater habitats and the heathland and its associated fauna. All the truly freshwater habitats were man-made and located outside the appeal site; their primary interest was as dragonfly sites. The heathland fauna included rare species of birds of national interest and both the sand lizard and smooth snake, but for none of these uncommon species was Arne the only location; they all occurred elsewhere in Purbeck and in reserves under the management of the R.S.P.B. or N.C.C.

The proposed clay extraction would progressively destroy the habitat of the appeal site and much of the fauna, especially the slow-moving invertebrates. Many species, particularly the birds, would

however be able to move to alternative sites on the peninsula, while a significant part of the fauna should persist in the remaining sections of Froxen Copse and adjacent woodland. In the expert's opinion, the proposed operations would have minimal consequences to the fauna of Arne as a whole.

The birds of the harbour and adjacent mudflats were used to the noise and disturbance from the many existing activities in the harbour and the added effect of clay extraction during working hours would be minimal. This view was maintained even on the basis of the bird population figures put forward by the R.S.P.B.

The heathland could be affected only by the proposed means of access to the appeal site. The road itself would take up very little land and, provided it was constructed of natural but inert materials, it should not fragment or isolate parts of the heath nor act as a barrier, preventing the passage of reptiles. In view of the low volume of traffic involved, the noise and passage of vehicles to and from the site would cause only slight disturbance to heathland animals and the effect would spread out over only a very small area. None of the species of particular biological importance would be adversely affected.

Increased human activity resulting from the proposed clay extraction could be destructive in terms of trampling, risk of fire, and litter, but could be minimised by ensuring that vehicles and people kept to the road, by the strict control of litter and oil spillage, and by other relevant precautions. There was unlikely to be any increase in unauthorised public access to the area.

In the expert's opinion, the appellants' plans for restoration were not only compatible with conservation interests, but would also constitute a biological improvement, especially the enlarged lake which if freshwater, would become a better ornithological habitat than the existing pond.

The marine biologist had been invited by the appellants to consider any problems which might arise from the discharge of water into the harbour from the proposed workings, and he had carried out his investigations during the periods of suitable tidal conditions between July and early September 1975.

On the North side of the Arne peninsula, the upper shore comprised areas of coarse sand, shell gravel, pebbles and stones and was

littered with refuse. In several places the under-layer of clay was extensively exposed. The lower shore was an unbroken area of fine soft mud in places up to one metre deep and often sloppy in texture. Near the headlands, particularly at Gold Point, there were large accumulations of thrown-up material - dead mollusc shells and some living invertebrates. There was a small population of the larger seaweeds in the stony areas, but the greatest concentration of plant material was the extensive diatom cover on the surface of the muddy lower shores. The fauna of the soft mud was typified by a dense surface population of Hydrobia ulva grazing the diatom film, while within the mud was an equally typical population of Scrobicularia plana. The upper sandy areas were characterised by setts of Balanus crenatus on the larger stones and by Nereis diversicolor in the pockets of muddy shell gravel. Among the cast-up molluscs, the large numbers of Sedentary tunicates indicated the presence of populations of these species in deeper waters.

On the East side of the peninsula, at Shipstal Point, there was a more extensive rocky area; its flora was generally similar to that of the stonier parts of the Northern shore. The upper shore here had a very heavy deposit of cast-up dead materials. The most significant feature of the fauna was a widespread dense population of anenomes (Cereus pedunculatus).

The entire area of Arne Bay consisted of salt marsh with a system of channels bordered by very deep sloppy mud. It had typical salt marsh flora and fauna. The surface of the mud was grazed by a very dense population of Hydrobia ulva, many with very eroded shells.

Further details of the flora and fauna of the shores of the peninsula were given. In general, they were in no way biologically unusual or important and as far as the expert could tell, they contained no important species.

The tidal and current system of Poole Harbour was extremely complex. Although the range of the quarter-diurnal tides was small, the tidal streams were very strong because of the harbour's narrow entrance channel. Investigations by F.H.W. Green in 1940 had suggested that a general tendency for material to be swept out of the basin, either seaward by the strong ebb in the lower harbour, or riverward by the strong flood near the mouth of the Frome. Sea water tended to stay in

the lower layers, with river water sliding over the top. Arne Bay probably had its own circulatory system which could account for the retention of its very soft mud. It seemed likely that any material put in the harbour off the Arne peninsula would tend to be flushed either seaward or riverward depending on its position relative to the two tidal forces and on the state of the tidal cycle.

The harbour water contained a great deal of suspended matter. Observations of the surface water, taken with a Secchi disc about 150 metres offshore near the appeal site, had indicated a very low opacity, largely due to bottom soft mud churned up by water movements and partly by suspended matter brought down by the rivers Frome and Piddle. There were biological indications that the suspended inorganic matter might be confined to the upper layers: the cast-up specimens of Sedentary Tunicates were conspicuously healthy and, since their filter mechanisms were easily choked by foreign solid matter, they had presumably not had to contend with the opaque conditions observed near the surface. Further evidence might be adduced by the widespread presence in the harbour of extensive colonies of the native British oyster. Samples of suspended matter collected by two-netting had contained a very high proportion of dead and decaying plant material. Samples taken with a standard plankton net had not indicated an abundance of macro-phytoplankton but the zooplankton was rich and typical of an estuarine habitat. Further details of the hydrography and suspended matter were given.

Poole Harbour had a well-established oyster fishery. The native British oyster (Ostraea edulis) was fished in all but one area where an important species (Crassostraea gigas) was cultured The former, which occurred as natural communities, was particularly sensitive to suspended inorganic material. While the expert accepted that ball clay effluent could be disastrous to oysters if discharged in their vicinity, the amount of settlement from the proposed discharge would be very small and quite insignificant compared with the suspended matter which now settled in the oyster areas. In any case, the salinity of the surface water near the appeal site was too low for oysters. In the expert's opinion, the effluent from the proposed workings would not in the least affect the oysters. Nor, in his view, would it affect the food chain for the wild fowl and Waders which were at present obviously not harmed

by the 2 tons of material brought down each day by the rivers.

Despite the fact that so much solid matter was suspended in the upper water layers of the harbour, the expert recommended that the quantity of solids in the proposed discharge should be restricted if at all possible. The actual limit, in terms of parts per million, was not significant. It was however, important that effluent entering the harbour should not be piped to the more saline deeper waters where it would tend to flocculate. If allowed to diffuse with the less saline upper layers, it would probably be flushed over and away from the oyster beds which were in or near the deep channels. The outlets should be fairly close to the surface and to the shore. The expert agreed that some form of monitoring would be advisable. The introduction into the harbour of dissolved chemicals (such as would result from a chemical treatment of the effluent) could be more serious than the introduction of suspended solids; bivalves, like the native oyster, were capable of building up heavy concentrations of dissolved chemicals in their tissues, rendering them economically worthless.

Ecological Evidence Presented by Dorset County Council

'The County Council had accepted the recommendation of the Poole Harbour Conservation Study (1967) that there should be a strictly protected zone to cover the remoter shores on the Purbeck side of the harbour, including Arne peninsula, to maintain wildlife sanctuaries and feeding grounds. Several applications for development had been rejected on appeal as being inconsistent with this policy, for instance on Round Island to the South-East of Arne Bay and on Giggers Island in the Wareham Channel.

The distribution of a number of factors were shown which were indicative of the landscape and ecological significance of the whole consultation area. These included S.S.S.I.s, land owned by the National Trust, reserves managed by the N.C.C., D.N.T. and R.S.P.B. existing heathlands and the area of Poole Harbour defined by the project M.A.R. conference in 1961 as a Grade B site of international importance for wild fowl (there were only 8 Grade A and 8 Grade B sites in the whole of Great Britain). A visual inspection of this plan strongly supported the claim that the Arne peninsula was probably the most sensitive area in landscape and ecological terms in the consultation area.

Arne's premier nature conservation importance in Dorset was based on the following factors:

a) It was one of the few large blocks of varied semi-natural vegetation in the county with substantial areas of heath, woodland, bog, marsh and transition to coastal habitats.

b) It had a long coastline in proportion to total area and such a variety of habitat graduations that there was a maximal amount of edge effect which was ecologically attractive.

c) It contained habitats of growing rarity in the county, particularly heathland, undrained bog and over-mature woodland.

d) Its sympathetic surroundings without major building development or intensive agricultural or recreational areas.

e) It had sufficient isolation and freedom from disturbance to permit successful experimental management and scientific study.

f) Aesthetic appeal and wildness'.

Ecological Evidence Presented by the Dorset Naturalists Trust

'The paid-up membership of the D.N.T. now stood at 3,185. Their primary objective was to protect wildlife habitats, both by means of their reserves (now totally about 1,300 acres) and by trying to influence public opinion. They were often consulted by the planning authority and had recently produced three conservation studies for areas under threat from development, one of these related to Poole Harbour and district. The Trust employed a conservation officer and a resident warden and a seasonal assistant for their Brownsea Island reserve.

The D.N.T. had done all in their power to conserve the three most threatened wildlife habitats in the county, the coastline, the downland and the heaths. They had been consistent in their attitude to the Arne peninsula, i.e. the whole area designated as a S.S.S.I. and had assisted the R.S.P.B. to acquire their reserve. Because of severe fragmentation of heathland elsewhere, the Purbeck heaths - particularly the Studland to Arne heaths - were especially valued. The extreme pressures likely to arise from the exploits of oil and clay had been foreseen in the early 1960's by the D.N.T. and the N.C.C. and they had collaborated in a survey which had highlighted Arne and Studland as being of the highest value in terms of ecology, amenity and educational value.

The N.C.C. had been forced to withdraw from the inquiry because of the unfortunate agreement made nearly 25 years ago, an agreement which the N.C.C. would not have made a few years later when they had known more about the area. By 1960, when the D.N.T. had been formed, the N.C.C. had become well-established with an expert scientific staff at Furzebrook and there had never been any reason to doubt their rigorous scientific approach in the selection of sites for conservation. The imminent publication of the N.C.C. reserves review would demonstrate the sophisticated nature of their criteria, they would put into perspective the value judgements of the apellants' three biologists which were based on their personal criteria of the particular interest of species or communities.

The Arne peninsula was made a unique and valuable ecological complex by a number of factors:-

a) Geographically, it was in an area where, for climatic reasons, there was an overlap in the ranges of species which were separated in other parts of Britain and Europe by gradients of environmental conditions in both East-West and North-South directions.

b) Species distribution maps showed that the area had an excellent record for the occurrence of species which were generally typical of South-West Britain.

c) Poole Harbour had been designated by project M.A.R. as a grade B site.

d) Proximity to the sea had resulted in a paramaritime Southern heathland which was very rare.

e) Habitats within the Arne S.S.S.I., including the heathland, salt marshes and fenland, had been assessed by the N.C.C. as of the highest status, giving it the designation of a grade 1 side.

f) Transitions between these and other habitat types presented scientifically interesting ecological gradients.

g) Its relative freedom from disturbance was beneficial to wildlife.

The natural history of Arne had been well studied. Over the last 10 years, the Arne R.S.P.B. warden had collected a lot of data on the fauna of Arne, both from his own observations and from the records of visiting experts:-

a) Reptiles: all 6 British species were to be found on the peninsula. The Sand Lizard and Smooth Snake, which were now legally protected, were rare and their distribution was very restricted, but unfortunately

there were still viable populations of both at Arne.

b) Mammals: 26 species had so far been recorded, including Roe Deer and Badger. This was a wide variety for a relatively small area indicating the diversity of habitats present.

c) Orthoptera (grasshoppers, bush-crickets, cockroaches): 13 species had been recorded, almost half the native British species. Of these, the Heath Grasshopper and Lesser Cockroach were of particular note, being very restricted in distribution in Britain. During the late summer and autumn, 7 species of orthoptera, including the Lesser Cockroach, had been recorded at the appeal site.

d) Dragonflies: the peninsula was possibly one of the top five sites in Britain for dragonflies; 18 species were known to breed and 4 others had been recorded, including the uncommon and important scarce Ischnura and small Red-Damselfly. The pond at the appeal site was not very suitable for breeding dragonflies because of its salinity and in the late summer only 3 species, had been recorded there.

e) Butterflies: at least 24 species were known to breed regularly on the peninsula, almost half the British breeding species. At the appeal site 18 species had been recorded on 4 summer visits, to which could be added the Silver-Studded Blue and Ringlet observed by the zoology expert. This was very good for such a small area and the list was certainly incomplete.

f) Macrolepidoptera (the larger moths): since 1969, nearly 325 species had been recorded on the peninsula, including the nationally rare Speckled Footman, Ringed Carpet, Rosy Wave, Festoon and Scarce Prominent. Most of the records had come from a Rothamsted trap and computerisation of similar data throughout Britain indicated that Arne was within the area of highest diversity. At the appeal site, 67 species had been recorded by light trapping on 33 nights during August-October 1975. If the site had been trapped for the whole year, it would undoubtedly have proved a rich area for macrolepidoptera.

g) Microlepidoptera (the small moths): over 300 species had been identified by Mr. E. Bradford, an eminent amateur naturalist, many being very local or rare.

h) Craneflies: the peninsula had not yet been extensively studied but so far 68 species had been identified, including 3 national rarities.

i) Caddisflies: only 25 species had been identified which was not surprising as there was little fresh water on the peninsula.
j) Beetles: little work had yet been done but the presence of the Wood Tiger, Tanner Beetle and Glow Worm suggested detailed recording would be rewarding. The value of the appeal site in this connection was illustrated by a report by Mr. D. Appleton which had been based on two short visits in September 1975.
k) Spiders: trapping on Arne had been in progress since 1969 and 209 species had been taken. This was a high total as there were only about 620 British species all told, 7 of those recorded on Arne were notably rare.

Thus, taking also into account the ornithological aspects (dealt with by the R.S.P.B. and Dr. D. Godfrey, an amateur ornithologist), the wildlife of the peninsula including the appeal site was both rich and diverse. The value of the appeal site was principally as an integral component of the large complex of habitats. Indeed, the peninsula itself was seen to be of greater significance if considered as part of the Arne to Studland conservation zone, of agreed D.N.T. and N.C.C. strategy. This strategy had been supported by the county planners.

The 3 main parts of the appeal site which would be affected by the apellants' proposals were as follows:-
a) Rough pasture which was reverting in places to heath, scrubland and woodland. These transitional habitats added diversity and, by acting as sheltered glades, contributed to the high value of the site for lepidoptera.
b) Froxen Copse, with its overmature trees and some natural regeneration, provided a unique habitat within the Arne S.S.S.I., for instance, it contained Enchanter's Nightshade and Wild Primrose which were not found elsewhere on the peninsula and its Lichens were of greater antiquity than those of Big Wood nature reserve. Old oak woodland was rare in Dorset and was seldom afforded any protective status.
c) The pond, though modified by man, was believed to be a natural lagoon cut off from the sea by the lateral movement of beach material. Management could readily improve its range and numbers of species without any of the dangers which could arise from the proposed larger and deeper pond.

The following features of the wildlife would be put at grave risk or destroyed by the appellants' proposal:-

a) Increased traffic on the narrow road, from Ridge to Arne could destroy roadside verges of outstanding interest for their floral communities, including several rare species; there was no way of repairing a single track road without re-routing traffic over the verges. For a long time, the D.N.T. had had a management agreement with the county surveyor to ensure the conservation of these verges.

b) The proposed road from Arne village to the appeal site would encourage public access, even if it was illegal. This could disturb the fauna, especially the birds and could even jeopardise complete communities since old heath was particularly susceptible to trampling. It was accepted that the suggested provision of a gate would make the road appear more private. The D.N.T. had not yet decided whether to oppose the claim for a public footpath along this route.

c) Increased access could increase the risk of fire. In the last 5 years Arne S.S.S.I. had only had 4 fires, whereas Hartland Moor which was surrounded by public roads, had had 15 fires.

d) The viability of the wet heath immediately adjacent to the appeal site could be threatened by alterations to the drainage system.

e) The discharge of water containing suspended clay into Poole Harbour could effect the entire ecology of the area and be especially damaging to wildfowl and Waders. Though the discharge would be subject to conditions imposed by the water authority and the county council, it would involve a different scheme from the appellants' previous practice in the area. The possibility of accidents, or of insufficient maintenance of the filtration and discharge system was a very real hazard.

f) The loss of old oak trees and associated fauna in Froxen Copse was likely to be irreplaceable. The proposal to leave some of the trees would hardly be adequate to ensure the survival of the habitats' conservation interest.

The restoration of ball clay workings to create a complex and complete ecological community of plants and animals was an ambitious project requiring a full scale trial in addition to pilot studies. The success of the landscape proposals would depend on overcoming severe edaphic and climatic hazards. The Arne peninsula, with its outstanding

scientific and conservation interest was an entirely inappropriate place for such an experiment.

If the policy of ball clay mining in Dorset was to be reviewed, the D.N.T. would willingly co-operate with all parties to find a strategy acceptable both to the industry and to the conservation interest. They would also be pleased to help in advising on the rehabilitation of old workings. Positive action was required to safeguard the scientific and conservation interests of a much larger area than the present appeal site. A management plan embracing both Arne and Hartland Moor should be agreed with the land owners, as only management of the area as one unit could ensure the long term status.

The D.N.T. strongly supported the county council's case for the dismissal of the appeal and for the revocation of the 1957 permission. They did not however advocate conservation at any price and would follow the same view as the County Council if the Secretary of State were to decide, without any doubt, that a dismissal of the appeal site would lead to unemployment and put the ceramic industry at risk.

Ecological Evidence Presented by the Royal Society for the Protection of Birds

'The R.S.P.B. employed a full-time warden on the Arne reserve, with an assistant and 2 voluntary wardens in the summer. It was open to a limited number of visitors 4 days a week in summer, and 4-5 days a month in winter. In 1975, permits had been issued to 1,700 visitors. The public bridleway to Shipstal Point crossed the reserve and the society had created a nature trail near its Eastern end. This had been very successful and had caused no significant damage to the area. In 1975, 2,700 copies of the booklet had been issued and an estimate 9,000 persons had used the trail.

In 1974, the R.S.P.B. had appointed a research biologist to make a 3 year study of the Dartford Warbler and at present a film unit was making a major film on Southern heathland. In 1975 the society had spent some £14,000 on Southern heathland conservation.

In recent years, there had been a great increase in public interest in wildlife and concern for its conservation and this had been paralleled in the statutory sphere by growth in the Nature Conservancy.

Wildlife was a natural resource necessary to human needs as had been admirably expressed in the report "Sinews for Survival".

The R.S.P.B. very much regretted the absence of the N.C.C. at the enquiry. They could have added to the weight of scientific evidence and could have explained the practical reasons which had led to their agreement with the Encombe Estate in 1953. The appellants could have been magnanimous and asked the Encombe Estate to let the N.C.C. appear. It must be concluded from the appellants' attitude that they were happy not to have the N.C.C. at the enquiry because of the strength of the case they would have brought against the appeal.

The reduction of heathland was probably the single most severe threat to birds and other animals in Dorset. It had decreased from about 56,000 acres in 1896 to 45,000 acres in 1934, 25,000 acres in 1960 and then to 15,000 acres in the present day. The Hobby, Nightjar, Woodlark and Dartford Warbler were nationally rare birds which had important parts of their British populations on the heaths. The Dartford Warbler was almost confined to Dorset and New Forest heaths. It suffered great losses in severe weather and in 1963, only 11 pairs had been known in the country after 2 successive bad winters; at least 2 or 3 of these pairs had survived on the heaths adjoining Poole Harbour, probably because of their better climate. The slow recolonisation of the Dartford Warblers in their previous haunts had been hindered by the continuing fragmentation of the heaths and it had been found that they occurred in greater numbers per unit area on large heaths than small ones.

A survey of Dartford Warblers in 1974 had shown that of the British total of 560 pairs, 286 had been in Dorset, 134 in Purbeck and 30 at Arne. Arne had about 12% of the Purbeck heaths but 22% of its Dartford Warblers. Of the 9 pairs of breeding Dartford Warblers found on the peninsula North of the R.S.P.B. reserve, 4 were adjacent to the proposed access road and one adjoined the East side of the appeal site. The appeal development would therefore impinge on about 15% of the population of the peninsula.

Besides the Dartford Warbler, there were many other natural history interests in the heaths, as reported by other parties in the inquiry and by the N.C.C. in the working party report. The appeal development would be marginal encroachment on the heath but would be particularly

undesirable because of the special value of the peninsula and the previous remoteness of the site. Furthermore, the destruction of rough pasture on the appeal site, now used for cattle grazing, was likely to increase the demand for agricultural reclamation of heathland in the area.

From the records of the reserve warden and his assistants and from other incidental observations, an annotated check list had been prepared of the species of birds seen on the reserve and on the appeal site and of the species that bred in both places. During the last 10 years, 185 species had been recorded on the reserve, compared with 330 in Dorset in the whole of recorded history. The appeal site had a rich breeding population, 41 species compared with about 50 on the reserve. It included the Spotted Flycatcher, Canada Goose and Kestrel which did not breed elsewhere on the peninsula. Nightingales and Wood Warblers had been heard singing on the appeal site, although neither had been proved to breed there. Teal, which bred on the pond, were only known from one other area of the peninsula. The complete species list for the appeal site numbered 107. Only one bird, the Curlew Sandpiper, had been seen on the appeal site and never on the reserve. An important feature of the site was the pond which attracted a number of non-breeding wildfowl and Waders, particularly Greenshanks, Spotted Redshanks and Common Sandpipers.

If the appeal site was excavated, the ornithological loss could be 2 or 3 birds not otherwise breeding on the peninsula and a further 3 or 4 that were uncommon elsewhere in the area (Moorhen, Shelduck, Teal and Short-Toed Treecreeper). It would also involve the loss of the shallow brackish pond used by a variety of wildfowl and Waders. Though comparatively small losses, these represented the kind of gradual diminution of quality of a very valuable area which the society wished strongly to resist. Moreover, there would be no guarantee, if the development took place, that reinstatement would provide a significant area of shallow lake water or that the after-use of the site would be in the interests of nature conservation.

Counts of Waders and wildfowl in Poole Harbour during the last 6 years had indicated that it was of international importance for Shelduck and Black-Tailed Godwit and of national importance for Red-Breasted Merganser, Curlew, Redshank and probably Slavonian Grebe, in the sense

of the definition adopted in 1974 at the Heiligenhafen conference. The R.S.P.B. were concerned for the welfare of these birds on two counts - disturbance and possible pollution of the harbour waters. Waders were very prone to disturbance because their feeding times on the mud were limited by tidal and light conditions. At high tides, they rested in secure places on land; Patchin's Point (East of the appeal site) was the roosting place adjacent to Arne Bay's important Waders. While these birds could well get used to the disturbance of the actual clay extraction, it was anticipated that overburden removal would be more disturbing and more conspicuous and might have undesirable effects. Any discharge into the harbour from the appeal site would be added to a situation which was complicated, under-studied and changing. At present, the turbidity of the harbour varied rapidly with the state of the tide indicating that material stirred up from the bottom was soon precipitated again in stiller waters. The very fine clay particles in the effluent would however probably remain in suspension for a long time, increasing the turbidity and lengthening the period each day when turbidity was high. Eventually the clay wastes would be precipitated by the ionic effect of contact with salt water and it was likely that the material would be deposited in the muddy areas surrounding the Arne peninsula or elsewhere in the harbour.

By defracting light the suspended materials in the water could reduce the primary production especially by planktonic flora. They could interfere with the filter feeding organisms and could also affect fish. Though large quantities of suspended material were brought into the harbour by the rivers, it did not necessarily follow that the additional turbidity caused by the clay wastes would be trivial by comparison. Many of the mud-dwelling invertebrates had planktonic immature phases and the breeding seasons were mainly in the summer when the quantity of suspended solids in the rivers was negligible compared with winter and the harbour's waters might naturally be at their clearest. Extra suspended material from a clay quarry could thus influence the settling patterns and ultimately the distribution of many of the inter-tidal invertebrates.

Once settled, the clay wastes could have detrimental effects on the bottom fauna and consequently on the birds that fed on the mud flats. Sample collections of the common invertebrates, taken on inter-

tidal mudflats off the peninsula had shown remarkably low species densities compared with findings elsewhere. This could well be due to the extensive siltation that had taken place over the last century and, if so, this did not seem an appropriate time to add to the problem. The probable foods taken by a selection of Waders in the area included species potentially susceptible to clay wastes, particularly the filter-feeding cockle and polychaete worms which lived in burrows and required stability in the substrate.

There was not adequate information to assess the extent of the damage likely to be done to the fauna of the harbour by the proposed discharge of clay wastes but, in view of the considerable importance of the area, any damage could have serious repercussions. Without detailed research, it would be impossible to be sure that a maximum of 30 p.p.m. of suspended solids, referred to by the W.W.A., would protect the harbour fauna. If clay working was permitted, the appellants should take the responsibility of financing or executing quantified surveys to assess the present ecology of the area and to monitor any changes.

Overall, the aesthetic quality of the solitude and natural beauty of the Arne peninsula would be seriously affected by the proposed ball clay working. The noise of earth moving equipment and the frequent lorry traffic on the road bisecting the R.S.P.B. reserve, would introduce an industrial element into a wild and remote scene and would be evident from the viewpoint at Shipstall Point.

The R.S.P.B. had not been consulted on the proposed route of the Arne bypass which, at its Southern end, involved cutting a swathe through an area of mature timber in the reserve. This destruction was quite unnecessary and, if the development was permitted, the road should be re-routed farther North. A screen of trees could be planted to hide the road from the Arne houses and this would constitute a slight biological gain rather than a loss.

If the appeal was allowed and ball clay working became established on the peninsula, it would be well-nigh impossible to prevent its extension, initially into the wider workable area identified by the working party and subsequently to any other deposit that might be proved. The intrusion of noise and heavy traffic would already be an accepted fact and each successive development - though plausibly

represented as affecting a small part of the whole - would make the remainder less valuable and accordingly less defensible.

There might be occasions when it was necessary to sacrifice a part of the total wildlife resource in order to achieve another, even more important objective. However, before sacrificing a site of international or national biological importance, every effort should be made to find an alternative solution but this effort had not been made in the present case. Although the Council of the R.S.P.B. had not specifically stated that the present appeal should be opposed in all circumstances, the Society's officers considered they had the tacit approval of the Council to object fully, even if the dismissal of the appeal were to cause unemployment and put the ceramic industry at risk. It was the Society's duty under their Royal Charter to protect birds in the national interest and they should not withdraw from this duty if there was some other conflicting national interest.

Ecological Evidence Presented by an Amateur Ornithologist

For the last 6 years this witness, with a team of 12 assistants, had studied the water-fowl of Poole Harbour and had taken monthly censuses of all estuaring species. The harbour was noted for its wintering water-fowl, especially in severe weather conditions. Despite the mild winters since 1969, large numbers of many species had been recorded, including in some cases a considerable proportion of the Southern English population. The following species had been specially selected for mention in the British Trust for Ornithology's Birds of the Estuaries Enquiry:

a) Shelduck: Poole Harbour was rated ninth out of the 19 estuaries listed as of international importance.

b) Teal: the harbour had the fifth largest population of all sites monitored.

d) Red-Breasted Merganser: a count of 481 in the harbour in November 1975 indicated that it might support the third largest British population of this rather scarce duck.

d) Dark-Bellied Brent Geese: the harbour population of over 200 represented about 0.5% of the world population.

e) Black-Tailed Godwit: in winter and spring, the harbour supported a

very significant population of this uncommon species which was the subject of special conservation efforts.

f) Small Grebes: though not numerous, the Slavonian and Black-Necked Grebes were very important members of the harbour's bird population.

In very cold winters, Poole Harbour was of crucial importance. For instance, in the severe winter of early 1963, the waters immediately North-West of the appeal site had been packed with birds including 1,400 Tufted Ducks, 1,800 Pochards, 350 Scaup and 13 Smew. Hydrological factors apparently kept this part of the harbour slightly warmer than the rest and it remained ice-free longer. Freedom from disturbance in this area was therefore highly desirable to maintain the potential of the harbour as a cold weather refuge.

The Western part of the harbour was, in effect, a large nature reserve and it was feared that the appeal development would split the present unified wildlife habitat into two portions. The species diversity and numbers of a wildlife area were known to have a strong dependence on its size.

The Northern shores of the Arne peninsula were used for feeding, resting and roosting and data from the Birds of the Estuaries Enquiry indicated the presence of large numbers of water-fowl including some of the most important species. The pond on the appeal site was the best autumn area for Greenshank in the harbour with up to 21 birds there in 1969/70, about 3.2% of the total British migrant population at that time. The loss of habitat, disturbance and pollution caused by the proposed clay-working would have an extremely bad effect on birds frequenting the Arne shores. Furthermore, the ultimate settlement in adjacent areas of the harbour of the fine particulate clay discharged from the proposed workings might produce detrimental effects, such as the choking of marine organisms on which many water birds fed and smothering of the mudflats in which many of these organisms lived.

A central feature of any conservation plan for the harbour's important water-fowl populations was that the Southern and Western sectors must remain free from deleterious development. Permission for one form of undesirable activity would weaken the case against other subsequent proposals. There must be no exceptions, if such a conservation policy was to be maintained with justice and fairness.'

Concluding Comments on the Ecological Evidence by the Inspector

The appeal site is a constituent part of a S.S.S.I. and as such the destruction of its habitat by clayworking must be regarded as reprehensible from the point of view of nature conservation and must have some adverse effects on adjacent inter-related habitats. The site however comprises only a relatively very small part of the S.S.S.I. it is not itself the haunt of any of the rare species for which Arne is famous and it does not encroach on any of the existing nature reserves. Although the evidence at the enquiry establishes that the peninsula as a whole is undoubtedly of great national conservation value, I do not think that the site itself has been proved to be of outstanding ecological importance except for the old oak woodland habitat of Froxen Copse which would only be partly destroyed by the appeal development. It seems to me most unlikely that the disturbance caused by the proposed clay working would have more than a marginal effect on the nationally and internationally important populations of wildfowl, and waders in the harbour in view of the existing activities now tolerated by these birds. The access track to the appeal site from Arne Village crosses the much more important heathland habitat, but I believe its use by the appellants' traffic would only marginally harm the ecosystem provided vehicles and people kept strictly to the defined route.

APPENDIX B

Extract from report of the working party on the environmental implications of an exploration well site at Wytch Farm Oil Field on the Goathorn Peninsula.

Goathorn Peninsula is one of several jutting out into the harbour which overlooks a number of small islands with the largest, Brownsea, forming the backcloth. The peninsula is about 1¼ miles long with a base about 1000 yards across tapering to a flat headed end some 170 yards wide. All the land adjacent to the shores is low lying so that the bays at low tide become saltings and mud flats. The central ridge of the peninsula is generally about 25 ft above sea level and slopes down irregularly on either side to the shore. Most of the surrounding peninsulas and islands are of similar height so that they are intervisible.

Most of the peninsula is now covered by Scots Pine which is the dominant vegetation and which is regenerating itself from mother trees. As a general rule, the tree cover is very dense and grows up to 40 ft except at the Northernmost tip where heights are less. On the Southern and Western part of the peninsula particularly, there are old field boundary banks and small oak woods and trees up to 50 ft in height. Some of the pine areas are so dense as to have no understorey, otherwise it is bracken or heather.

There are clearings on the peninsula where heather and bracken grow between the Scots Pine and one of the largest has been selected as the proposed well site. To the West of this large clearing, trees are less dense than elsewhere.

Much of the peninsula is the subject of a Dedication Agreement under the Forestry Acts 1919 to 1947 between the owners, Rempstone Estate and the Forestry Commission for the management of the area and which was drawn up in 1953. The present phase of the agreement relates to the period from October 1975 to September 1980 and a Plan of Operations which entails selective thinning of 325 acres (132 ha.) of conifers, mainly Scots Pine throughout the area, with clear felling and restocking with hardwoods of a small plantation of 5 acres (2 ha.) of chestnut on the Eastern side of the peninsula near Water Point.

Along the Eastern side of the peninsula is a track about 9 ft wide, which follows the route of a former tramway leading to a pier at Goathorn Point. This tramway and pier were used many years ago for the transport and loading of ball clay from near Newton and Corfe Castle. An overhead 11 Kv electricity line to Furzey Island follows the line of

the track to the pier, near to which is a holiday cottage owned by Rempstone Estate.

There is no public right of way along the track from Newton to Goathorn Point, which is only used occasionally by holidaymakers using the cottage, fishermen who moor their boats near the pier and horseriders, by agreement with the Estate.

POOLE HARBOUR

The waters of Poole Harbour at high tide cover over 10,000 acres. The inundated area is reduced by up to 75% at low water of the lowest Spring Tides. Poole Harbour Commissioners are the statutory authority responsible for the management of the harbour and the Southern Sea Fisheries District Committee for commercial fishing. Apart from commercial port activities, the harbour supports a thriving commercial fishing industry, a considerable part of which is devoted to shell fishing.

The waters between Poole and Chichester are now the prime breeding area in Europe for oysters. The harbour is subject to a Regulating Order in respect of shellfish and is claimed by Southern Sea Fisheries to be the best location in Britain for intensive farming of oysters. The main oyster breeding and growing beds are in the Southern part of the harbour near South Deep, and this activity provides 40% of the commercial fishing income.

Recreational activity, including sailing and sea angling is controlled by harbour byelaws. Many people moor their boats at points along the sandy Southern shores and often trespass by picknicking on private land, especially on Goathorn Peninsula.

The marshes and extensive mud flats which appear at low water provide a haven for waders and wildfowl; in addition, the mud flats also support commercial activities in the form of eel fishing and bait digging.

ECOLOGICAL INTERESTS OF POOLE HARBOUR AND THE PURBECK HINTERLAND

INTRODUCTION

From an ecological point of view, Goathorn Peninsula cannot be considered in isolation from the rest of the Southern shores of Poole

Harbour and its hinterlands. Poole Harbour is one of the largest natural harbours in Europe and with its mud flats, marshes and islands it attracts both large numbers and a great diversity of wildfowl and waders. The peninsula of Studland, Goathorn, Ower and Arne are an integral part of the system providing a much indented and 'natural' shoreline with a variety of very marked transitional zones from inter-tidal areas to heathland and woodland. The heaths of the hinterland include the large, unfragmented expanses of Studland and Arne Peninsulas and a number of remnants of heathland serving as stepping stones between the two.

The whole of the area from Studland to Arne is biologically unique (Cmd 7122 NR 28) since it is the one area in Britain in which there occurs an extraordinary overlap of distributions of many species of plants and animals, some of which are found only Eastwards from their occurrence in Dorset and are mainly Continental in origin while others extend only Westwards through the country and are Oceanic or Western in their distribution. A good example of this is seen in the distribution of species of Dwarf Gorse in the Poole Basin. The Eastern Dwarf Gorse (Ulex minor), is found only on lowland heathlands in Southern and Eastern Britain and in Northern Europe. The Western Dwarf Gorse (Ulex gallii), is restricted to Western Britain and the Atlantic coast of Europe. In the Poole Basin the distribution of these two species overlaps. It is the kind of overlap within a relatively restricted zone of the Dorset heathlands associated with the hinterlands of Poole Harbour that provides an unequalled opportunity for the study of, and research into ecological relationships of both rare and common species in this part of Britain.

RANGE OF HABITATS

The range of habitats present in the area from Studland to Arne is very diverse reflecting not only the underlying soils and geological diversity but also the climate and maritime influences. This range of habitats can be identified from map 8 and the main characteristics of each type together with selected associated species is shown in Table 1. An indication of the specific habitats and special interests represented in the vicinity of Goathorn Peninsula is included within this Table.

The two most important vulnerable habitats present in the vicinity of the oil field are heathland and marshland.

Heathland

In the last 200 years the area of heathland in Dorset has declined from 40,000 ha to 5,600 ha (Webb and Haskins 1978) and in the past five years it has still been disappearing at a rate of over 100 ha per annum in the county. Furthermore, the remaining heaths have become much fragmented and now there are only fourteen blocks remaining of over 100 ha, of which Studland/Godlingston is the second largest. Purbeck District contains 53% of the total heathland remnant and this includes the three major National Nature Reserves in the county and the extensive RSPB reserve.

Marshland and Wetlands

Poole Harbour is given a national rating as a coastal site of outstanding importance in Britain (Nature Conservation Review 1977). It is particularly noted for its diversity of wintering wildfowl and wader species; the marshlands with minimal tidal range and some of the oldest and most extensive *Spartina anglica* marshes in Britain, and the mudflats, provide important food reserves for the birds. The shoreline and intertidal areas around the Southern shores are virtually undisturbed but over the past 10 years in the Harbour as a whole 1.8 km of natural shoreline has been lost and 43 ha of intertidal land reclaimed by infilling - with a further 63 ha by possible future reclamation (May VJ 1968 and pers. comm. 1978).

Brands Bay

This is of special note as it is the area of the harbour with the second highest overall percentage total figure for range of special wildfowl and waders. Peak figures for total numbers of birds seen in Brands Bay during the winter can be as high as 4,500. The sheltered waters, mudflats and marshes along the Western shore of the bay are a favoured area. Wintering species of note include the Brent Geese, here found at the Westerly edge of their distribution in Southern Britain, and the Shelduck for which Poole Harbour is high in the national league

TABLE 1: MAIN HABITAT TYPES STUDLAND - GOATHORN - ARNE

HABITAT	SPECIAL FEATURES	FLORA AND FAUNA OF NOTE	NATURE CONSERVATION MANAGEMENT REQUIREMENTS	LOCATION WITHIN GOATHORN AREA
HEATHLAND	Habitat type of national importance which has diminished greatly in extent in recent years, and is still being lost, at a rate of over 100 ha per annum from the total of 5,600 ha remaining in Dorset Highly vulnerable to fire erosion and reclamation. Used extensively for field study and research.	Many species found only in association with this type of habitat.	Maintenance of a good range of age stands of the major component vegetation types. Heather may be grazed or mown in parts. No further reclaimation. Control of nutrients entering the system - no added chemicals or sewage on heathland or land adjacent to heath.	6 ha grazed heath alongside old Tramway cutting.
(i) Dry Heath	Open heath on higher land dominated by Ling Heather and Bell Heather, often invaded by pine, birch, gorse or rhododendron.	Sand Lizard and Smooth Snake breed in mature, open heath. Dartford Warbler nests in 'closed' gorse clumps. Heath grasshopper. Silver Studded Blue Butterfly. Nightjar nesting on open heath.	Maintain reptile habitat in prime condition - removal of some pine/bracken. Cut gorse on rotation to maintain dense gorse growth. Fire protective measures.	7 ha on Goathorn Peninsula itself. Also on the embankments of the old Tramway.
(ii) Damp/Wet	Open heath dominated by Cross-leaves Heather and Dorset Heath; Purple Moor Grass in wetter areas giving rise to 'tussock' heath.	Dorset Heath and other restricted plant species e.g. Marsh Gentian, Fir Club Moss, Brown Beak Sedge. Boy Bush Cricket. Rarer species of Dragonfly and Damselfly.	No drainage or interference with water regime. No eutrophication from nutrients entering the system. Occasional late summer grazing.	4.5 ha on Goathorn Peninsula.
(iii) Bog	Very wet Sphagnum bog over peat often with open water.	Dragonfly and Damselfly breeding areas. Bog Orchid and other rare plants.	Maintenance of water regime and freedom from chemical fertiliser run-off etc.	1 ha south of Site D.

TABLE 1 contd.

(iv) Saltmarsh	Spartina (Cord Grass) marsh has invaded the harbour this century and dominates much of the intertidal area around the Southern shores; subject of much research; sediment binder.	Spartina spp. and hybrids.	Natural build up and break down. Can be grazed by cattle or cut for silage.	Extensive areas in Brands May and Newton Bay.
	'True' saltmarsh occurs over a vertical tidal range of approximately 1 m.	Glasswort, Samphire, Sea Aster, Sea Lavender, Short Winged Conehead Cricket.		Around the Goathor Peninsula shores especially on the East shore.
(v) Freshwater	Creeks leading back into non-tidal areas and freshwater streams provide important salinity gradients and transitional salt and freshwater marshland zones often grading rapidly into wet heathland or woodland.	Saltmarsh and fresh-water marsh including reed beds and breeding birds. Wet heathland plant species, Marsh Orchids etc.	Grazing in summer. Cutting reed beds on approx. four year rotation to maintain good growth and form.	
	Often flooded at spring tides and in winter; important for grazing geeze and duck and as holding grounds at high tide and in storm conditions.	Aquatic and semi-aquatic species of plants. Breeding insects in ditches and dykes.	Grazing of meadows. Maintenance of ditches and dykes on approx. five year rotation.	At the 'back' of Brands Bay and Newton Bay.
WOODLAND				
(i) Broadleaved (Dry)	Oak is commonly found with associated Sweet Chestnut and Silver Birch, with Holly as understorey on more acid ground and Hazel on less acid ground. Occurs as fringe wood land around many parts of the harbour shore-line, overhanging the shore in places.	Birds of Prey. White Admiral Butterfly. Royal Fern. Copses important for breeding birds and often good ground and shrub layer flora, e.g. Bluebells, primroses etc. Good fungi.	Management on 100 yr plus cycle for natural regenera-tion of oak. Coppicing of hazel understorey. Main-tenance of trees as 'screen' around shoreline.	Game Copse, Newton Copse and edge of Newton Bay and Brands Bay, especially along West and East shorelines of Goathorn Peninsula.

TABLE 1 contd.

(ii) Broadleaved	Alder-Sallow 'carr' type woodland with permanently high water table. Often develops in areas of impeded drainage alongside tracks.	Associated insect fauna of particular importance. Royal Fern.	Maintenance of high water table.	Beside the cattle grid at Ower Farm road. Beside track running from Site D.
(iii) Coniferous	The Purbeck Forest planted during the period 1940-50 covers what was formerly Rempstone Heath. (Pine is the natural climax vegetation on some heathalnd).	Deer.	Some managed by the Forestry Commission and some Dedicated Woodland.	Purbeck (Rempstone) Forest covers 594 ha. Dedicated Woodland on Goathorn of 55 ha. of naturally regenerating Scots Pine.
	Forest rides and unplanted areas often carry remnants of heath and provide good 'open' areas for butterflies etc.	Heathland spp.		
HEDGES, ROADSIDE VERGES	Thick hedges carrying shrubs and trees occur generally in the area and often are 'double hedges with intervening ditch. Shrub species and oak and hazel important, especially berry-bearing species as winter food for birds. Many interesting plant communities established on road-side verges.	Wild Plum, Hawthorn/ Blackthorn, Butchers Broom. Many orchid spp. Nettle leaved Bellflower, Cowslips, heathland species, rare Horsetail spp. etc.	Hedge trimming to A-shape and maintenance of hedge banks in natural state. No removal of trees.	Many areas.

TABLE 1 contd.

WETLANDS	Habitats including a range of vegetational types of particular value as bird holding grounds.	Poole Harbour has a great diversity of waders, duck and geese.	Maintenance of quality and variety of feeding and roosting grounds, and freedom from disturbance and intrusion.	Brands Bay a highly preferred area for birds within the Harbour
	Marshland has come under threat from reclamation by infilling or drainage in recent years, including losses of natural shoreline.		No further reclamation and no further loss of natural shoreline.	
(i) Mudflats	Very important bird feeding grounds at low tide - mud dwelling fauna includes worms, shellfish and molluscs. Surface algae such as Entermorpha & Ulva and Zostera (Eel Grass) important food resource for duck and geese.	Duck, geese and waders including rarer Brent Geese and Black Tailed Godwit.	Untreated sewage or industrial or sewage effluent must be controlled throughout the harbour to protect this very vulnerable ecosystem as a whole.	Extensively exposed in Brands Bay and Newton Bay at low tides.
(ii) Sandy Shore	Mud dwelling fauna provide food resource for wader birds. 'Loafing' areas for duck and geese.	Duck, geese and waders.	Maintain free from pollutants and disturbance.	Around in N shore of Goathorn Pen.

table of important Shelduck sites in Britain and Ireland (British Trust for Ornithology, Birds of the Estuaries Report). A special study of Birds in Brands Bay (NCC internal report 1978-79) on the pattern of movements indicates a clear inter-relationship between the harbour and its immediate hinterland and the significance of tidal changes, and the weather. There is little human disturbance to prohibit such movements and in many places the woodland which runs adjacent to the shore provides very effective screening and flooded fields provide important holding grounds.

Management

Successful wildlife conservation does not depend solely on the protection of a few isolated nature reserves but is dependent on maintaining a suitable matrix of habitat types which nature reserves can fit as reservoirs of species for dispersal outwards into the surrounding landscape. It is important to recognise the need for management of habitats in order to optimise breeding conditions for some species of wildlife, e.g. the rare Dartford Warbler requires thick, bushy gorse strands in which to nest and shelter from adverse weather conditions and, therefore, gorse is cut to rejuvenate it on an 8-10 year rotation. The habitat Table (1) also includes some examples of specific habitat management requirements.

RARE AND IMPORTANT SPECIES

Many such species are known to occur in this area and, although Goathorn Peninsula has not been subjected to the same intensity of biological surveys as the Arne and Studland Peninsulas it can be reasonably assumed that where the right habitat conditions are present, there is every expectation of finding some of these species of special interest in the vicinity of the proposed well site.

Reptiles - Sand Lizard and Smooth Snake. Protected under the Conservation of Wild Creatures and Wild Plants Act 1975. The reptiles require a good cover of mature Ling Heather interspersed with open sandy patches and a warm temperature. Colonies of Sand Lizards are known to occur on Goathorn Peninsula and on the banks along the access route.

Dartford Warbler - a rare species frequenting heathland. The Dartford Warbler nests on thick gorse clumps on heathland and is restricted to the heathlands of Dorset with the greatest concentration of breeding territory in Purbeck. After the severe winter of 1962/63 the species suffered a severe setback and reached dangerously low numbers and it took over ten years for the population to build up again. It seems that the severe winters of 1977-79 have had a similar effect to 1962-63 and this situation is further exacerbated by the loss of some 400 ha of heathland in Purbeck in the intervening period with subsequent reductions in potential breeding habitat.

TABLE 2. Nos of breeding pairs of Dartford Warbler in Purbeck 1963-79 (pers. comm. B. Pickess) and Dorset Nat. Hist. Arch. Proc. 1976)

1963	64	65	66	67	68	69	70	71	72	73	74	75	76
2	3	7	10	16	29	38	38	54	62	101	127	c130	c130

77	77	78	79
c80	c55	c35	c5

(NB Figures in the second line are derived from extrapolation of numbers recorded at Arne but are reliable within 1 to 5 pairs).

Other nationally important breeding birds here recorded include the Nightjar, a ground nesting species declining generally in Britain and known to breed on Goathorn Peninsula and certain birds of prey frequenting the woodland and marshes. Other species with over 20% of the Purbeck breeding population represented between Arne and Studland include the Redshank, Teal, Water Rail, Reed Warbler, Shelduck, Stonechat and Little Owl. (RSPB pers. comm.).

The importance of wintering wildfowl and waders has already been mentioned. It should be noted that monthly records of these birds have been kept for over 20 years (Bull 1962) and D. Godfrey pers. comm.) and the Brent Goose, Shelduck and Blacktailed Godwit of Brands Bay have been the subject of a special study over the winter of 1978-79.

Brent Goose - a rare species frequenting the harbour. The Brent Goose, a wintering species in Southern Britain whose numbers have increased in Poole Harbour in recent years, probably due to loss of preferred habitat to the East. Brands Bay on average holds approximately 50% of the total harbour population of the Goose and a maximum number of birds recorded per day during the period November-January 1978-79 was 185. The birds concentrate in flocks and move back into the bay with the advancing tide showing a preference for the Goathorn side where they feed on the green algae present amongst the *Spartina* marsh. On occasions the Geese move back onto adjoining fields and graze the pasture.

Insects - Many noteworthy and nationally rare species which have a very restricted distribution occur locally. These include a number of Damselflies and Dragonflies restricted to wet heath such as the Small Red and the Southern Damselflies, the Downy Emerald Dragonfly. The Heath Grasshopper, Short-winged Conehead Bush Cricket and silver Studded Blue Butterfly and found on the drier heath.

Invertebrates - The fauna of the harbour waters and mudflats provide the major food resources for the waders and wildfowl visiting the harbour; density and distribution of the main mud dwelling groups vis: worms, molluscs and crustaceans have been well documented (Stubbings and Arnold 1971-74). The length of time over which bird feeding grounds are exposed in the harbour largely governs the movement of birds. The mud fauna is particularly sensitive to pollutants since the mudflats act as a sump.

Plants - Many species are of special note, in particular those associated with the wetter and more vulnerable heathland. Dorset Heath and its hybrid forms with Crossleaved Heath, Marsh Gentian, Marsh Club Moss, Sundew (all 3 species) and Royal Fern are of particular note. Many of these have been the subject of special long term study and research more particularly in Dorset Heath and Marsh Gentian in the context of discontinuous distributions in this area.

ECOLOGICAL RESEARCH AND NATURE CONSERVATION INVESTMENT

Scientific investment in the Purbeck area over the past half century has been exceptional and reflects the value placed on the area by both professional and amateur workers and field study groups. Furzebrook Research Station, near Wareham, which opened in 1953 was chosen largely for its situation in relation to the major lowland heathland complex in Britain: it now forms part of the Institute of Terrestrial Ecology. In addition, Purbeck is much used for field studies by educational groups staying in Swanage and Bournemouth and is the haunt of a very large number of visiting naturalists.

Ecologists consider that it is essential that this area maintain its potential for research and baseline survey and that there is continuing security of tenure for long term investigation into both fundamental and applied ecological problems.

The Nature Conservancy Council, a government agency, together with voluntary bodies such as the Dorset Naturalists' Trust and the Royal Society for the Protection of Birds, have concentrated much of their effort in Dorset within the Purbeck area in seeking nature reserve or other management agreements over land of high nature conservation value. In particular, the National Nature Reserve at Studland has been greatly extended recently to include Godlingston Heath and the RSPB has negotiated the freehold of their major reserve at Arne with extensions and additional leasehold areas. Other areas with potential for agreement are under discussion around the Southern shores of Poole Harbour and there has long been a special arrangement with the Divisional Road Surveyor over the management of certain roadside verges of special note in the Purbeck area. In order to take into account the full range of ecological interests in the area as now known, the Sites of Special Scientific Interest coverage is to be extended at the next Schedule Revision (See Map 2).

ECOLOGY

Having regard to the open nature of the well site area, the felling of trees in the immediate vicinity is not likely to have any significant effect. Similarly the limited removal of trees along the access route will have little effect.

The stripping of ground vegetation at the well site will cause some loss of heathland habitat.

Although the site works will destroy the existing habitat at the well site, the construction of ditches and earth banks, with the provision of new vegetation will offer the chance of creating some new heathland habitat by way of compensation.

Similarly, site works and construction of passing places on the access route will cause a direct loss of sites for reptiles and for Dorset heaths, but there will be opportunities for recreating this habitat on an experimental basis.

The choice of material for use as hardcore is important. We have evidence from the Divisional Surveyor on the engineering qualities of limestone, against which must be set the effect of leaking into acid soils. At the well site however, the proposal to surface the area with tarmacadam would reduce the amount of penetration following rainfall. Outside the site we have insufficient information to comment on the likely effect of surface water drainage.

One of the impacts on the ecology of the area will be caused by noise generated by the construction works and drilling. This is discussed more fully in paragraph 22, which deals with the ambient noise.

The effect of noise on bird life is dependent on the time when it occurs. It can be very important especially during the breeding season, and in a coastal region when it can interfere with feeding habits during tidal change.

There will be construction noise at the well site for approximately four weeks followed by drilling operations for three months with continuous traffic movement along the access. There will be periods of fairly high levels of both impact and continuous noise.

A significant source of disturbance to bird life is the presence of human beings.

APPENDIX C

Extract from Scientific and Historic Interest of the Purbeck Coast.

Geology

The wealth of geological forms and variations in observable strata attracts much attention from students and scientists. Not only are these 'type sections' but they are together with the corallian series (from Radcliff to Ringstead Bay) the best exposures of rocks in the United Kingdom and therefore are of great interest in terms of petrological (study of rocks) and palaeontological (study of past life e.g. fossils) studies. It is a highly important area for the teaching of the principles of tectonics (earth movements) in a series of rocks of different properties. Emphasising all these geological values is the fact that, in a very small distance a continuous succession from the Oxford Clay to the upper chalk is present.

The most interesting stretches of the coastline are Redcliff Point to White Nothe (corallian outcrop) Bats Head to Worbarrow Tout (tectonics and Portland to Upper Chalk Exposures) Worbarrow Tout to Winspit (Kimmeridge Clay and Portlandian).

A wide variety of rock types also makes the area an important location for the teaching of geomorphological processes (study of land form). Examples of this are to be found at Old Harry Rocks, Worbarrow Bay, Lulworth Cove and Durdle Door.

Ecology

The changing landform, soil and micro-climate have given rise to a wide variety of different habitats within which many varied species of animal and plant life have been able to survive. This is especially so in areas where access has been restricted, either naturally, as with certain inaccessible cliffs and shore lines, and artificially, as in the army ranges and nature reserves. Virtually the whole of the coastline which is the subject of this study has been designated as nationally worthy of recognition as a Site of Special Scientific Interest (SSSI).

Ecologically important areas are:-

(a) The 'near' shore - up to 2 km from high water mark all along the coast are sheltered habitats, protected by bays, for a large number of species.

The Dorset Naturalists Trust publication 'Marine Wildlife Conservation in Dorset 1974' points out that the diversity of physical features in the area has led to a great variety of marine habitats and species being represented. Marine organisms and wildlife provide food for local sea bird populations. These marine organisms also make an important contribution to the productivity of fish populations.

(b) The Purbeck Cliffs. These habitats are considered highly important for nesting seabirds. In Purbeck the following birds are virtually restricted to the area between Swanage and St. Alban's Head: - Guillemots, Razorbills, Puffins and Kittiwakes.
This is the Eastern-most breeding site for the Auks on the English Channel and a serious decline in number, or their extinction in Purbeck, could be interpreted as the beginning of their extinction on the coast of South West England as a whole. The number of Puffins and Razorbills have declined very rapidly over the last ten years and to prevent this decline further conservation measures should be considered.
Fulmars, Shags, Black-backed Gulls and Herring Gulls nest throughout the area and are either holding their own or are on the increase. A much wider range of species use the area for wintering e.g. Slavonian Grebes, Oyster Catchers and a still greater selection use the area as a resting place during migration. In the latter context the unploughed and unsprayed areas of undercliff are extremely important as strategic points on major migratory routes.

(c) Heathland. The extensive tracts of heathland around Bovington which are of special interest for their reptile and bird life and certain rare plant communities have been the subject of a Nature Conservancy publication (Wildlife on the Ranges); which analyses some of the wildlife in detail. The Institute of Terrestrial Ecology and Heathland Research Station is based at Furzebrook, Wareham, giving some further indication of the importance of heathland generally in this area.

(d) Sand Dunes. These are found around Studland and although not an uncommon formation in this country they form a National Nature

Reserve but are currently under threat of destruction from an uncontrolled informal recreation where the foreshore dunal area is not covered by the Reserve Status.

(e) Downland. The chalk downland provides a distinctive habitat for flora and fauna. A wide variety of butterflies, insects and large species such as hares and roe deer are to be found. The ecological interest of these areas is such that specific conservation measures, if adopted, could preserve and enhance the wildlife character of the chalk downland that remains.

(f) Disused Mine Shafts. These are located around Worth and Langton Matravers and are inhabited by bat populations. The greater Horseshoe Bat is found here and is one of only three colonies left in the British Isles.

It should be stressed that though these habitats have distinct features they are part of a wider ecological system and that damage to surrounding areas, whether from pollution out at sea, from fire on scrubland, or from disturbance by visitors are likely to have adverse related effects on these very sensitive areas.

The Sites of Special Scientific Interest and Nature Reserves are indicated on Map 6 in the appendix and show the extent of the SSSI on the length of coast between Bowleaze Cove and Peveril Point. This is designated as a site of special Scientific Interest in relation to its geological formations. There is a very strong ling between this geological significance and the wealth and variety of wild life.

Archaeology

The coastal area has a large number of ancient field monuments. Their importance is demonstrated by the fact that many have been scheduled as Ancient Monuments of national importance under the Ancient Monuments and are, therefore, to some measure, protected from destruction. Outstanding among these are the Iron Age fortifications on Bindon Hill and Flower's Barrow, the extensive field systems of Chaldon Herring and Worth Matravers, as well as the deserted medieval

village at Ringstead and many prehistoric barrows. There are, however, many more ancient monuments still clearly visible on the ground which have not yet had their importance recognised. In addition to thse, many sites have left no obvious signs on the ground but have been discovered by archaeological field work.

For the visitor the monuments to be seen along the coastal path offer a fairly comprehensive selection of Dorset's history. Prehistoric barrows situated on the tops of hills are numerous, but are only a fraction of their original number which has been decimated by natural erosion and ploughing. Occupation during the Iron Age is amply demonstrated by the fortification works and many small occupation sites. It is clear that many of these settlements were engaged in the working of Kimmeridge shale to produce bracelets and other decorative pieces, which were to find their way to all parts of the country. Roman occupation demonstrates a similar use of local resources. Settlements are indicated in and near Studland, Nine Barrow Down, around Swanage, Worth Matravers, Kimmeridge and Tyneham many burials have been found.

APPENDIX D

Results

9585

2
1
3
Stone
Drain
Stone
Hartland Moor
6
5
7
8
11
Stone
9
10
13
12

9586

Drain
Drain
Drain
Drain
Drain
Drain
20
24
21
15
14
Bank Gate Cottages
17
10
23
22
16
13
A R N E
11
9
8
12
7
3
6
Slepe Copse
4
Tumulus
1
5
2
Broad Marsh
Slepe Heath

Grid Square 9585

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade	Area km^2	Ground Invert. Diversity (α)	α (Standardised)	Rarity Value	Community Aggregate Score
1	Dry heathland	15	1.00	0.210	24	0.6154	0.8342	2.6596 (2)
2	Pine plantation	7	0.33	0.199	14	0.3590	0.8653	1.7533 (13)
3	Wet heathland	10	0.66	0.027	28	0.7179	0.8588	2.3637 (9)
4	Bog	19	1.00	0.249	24	0.6154	0.9545	2.8189 (1)
5	Dry heathland	14	1.00	0.0037	30	0.7692	0.8342	2.6071 (4)
6	Wet heathland	9	0.33	0.0492	27	0.6923	0.9588	2.0303 (11)
7	Dry heathland	15	1.00	0.0295	30	0.7692	0.8342	2.6329 (3)
8	Dry heathland	17	1.00	0.0504	28	0.7179	0.8342	2.6025 (5)
9	Dry heathland	19	1.00	0.0394	28	0.7179	0.8342	2.5915 (6)
10	Wet heathland	8	0.33	0.0012	28	0.7179	0.9588	2.0079 (12)
11	Dry heathland	19	1.00	0.0098	29	0.7436	0.8342	2.5876 (7)
12	Rough grassland	32	0.66	0.0074	25	0.6410	0.7409	2.0493 (10)
13	Dry heathland	11	1.00	0.00062	29	0.7436	0.8342	2.5784 (8)
TOTALS	Dry heathland			0.3336				
	Pine plantation			0.199				
	Wet heathland			0.0774				
	Bog			0.249				
	Rough grassland			0.0074				

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

Grid Square 9586

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade	Area km^2	Ground Invert. Diversity (α)	α (Standardised)	Rarity Value	Community Aggregate Score
1	Dry Heathland	14	1.00	0.1365	24	0.6154	0.8342	2.5861 (7)
2	Pine Plantation	8	0.33	0.1402	10	0.2564	0.8653	1.5919 (21)
3	Wet Heathland	11	0.66	0.0086	28	0.7179	0.9588	2.3453 (16)
4	Deciduous Woodland	22	1.00	0.0185	39	1.00	0.9382	2.9567 (1)
5	Rough Grassland	71	1.00	0.0567	20	0.5128	0.7409	2.3104 (7)
6	Deciduous Woodland	25	1.00	0.0221	36	0.9231	0.9382	2.8834 (3)
7	Marsh	26	1.00	0.0615	24	0.6154	0.7427	2.4196 (11)
8	Bog	19	1.00	0.0086	26	0.6667	0.9545	2.6298 5
9	Dry Heathland	11	0.66	0.01722	18	0.4615	0.8342	1.9729 (18)
10	Deciduous Woodland	28	1.00	0.05658	28	0.7179	0.9382	2.7127 (4)
11	Deciduous Woodland	26	1.00	0.00037	25	0.6410	0.9382	2.5796 (8)
12	Dry Heathland	19	1.00	0.0504	26	0.6667	0.8342	2.5513 (9)
13	Marsh	24	0.66	0.0554	14	0.3590	0.7427	1.8171 (19)
14	Moors	45	1.00	0.1599	31	0.7949	0.9736	2.9284 (2)
15	Deciduous Woodland	21	1.00	0.0006	18	0.4615	0.9382	2.4003 (14)
16	Deciduous Woodland	24	1.00	0.0012	19	0.4873	0.9382	2.4266 (10)
17	Deciduous Woodland	25	1.00	0.0111	25	0.6410	0.9382	2.5903 6
18	Deciduous Woodland	21	1.00	0.0004	16	0.4103	0.9382	2.3489 (1)
19	Scrub	19	0.33	0.0004	11	0.2821	0.9711	1.5836 (22)
20	Pine Plantation	8	0.33	0.0160	8	0.2051	0.8653	1.4164 (23)
21	Scrub	20	0.33	0.00062	9	0.2308	0.9711	1.5325 (24)
22	Marsh	19	0.33	0.0135	13	0.3333	0.7427	1.4195 (12)
23	Scrub	25	0.66	0.0037	7	0.1795	0.9711	1.8143 (20)
24	Dry Heathland	14	1.00	0.0062	22	0.5641	0.8342	2.4045 (13)
TOTALS	Dry heathland			0.2103				
	Pine Plantation			0.1562				
	Wet Heathland			0.0086				
	Deciduous Woodland			0.11084				
	Rough Grassland			0.0567				
	Marsh			0.1304				
	Bog			0.0086				
	Meadow			0.1599				
	Scrub			0.00468				

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

9587

HWMMT
Hyde's Quay
3
2
5
HWMMT
Drain
T
Drain
Drain
Drain
Drain
Drain
Drain
Drain
Drain
Drain
Drain

9588

HWMMT
Mud
High
2
1

Grid Square 9587

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade	Area km^2	Ground Invert. Diversity (α)	α (Standardised)	Rarity Value	Community Aggregate Score
1	Moors	50	1.00	0.2165	34	0.8719	0.9736	3.0620 (1)
2	Pine Plantation	8	0.33	0.1230	7	0.1795	0.8653	1.4978 (5)
3	Dry Heathland	39	1.00	0.1107	30	0.7692	0.8342	2.7141 (2)
4	Bog	42	1.00	0.0025	14	0.3590	0.9545	2.3160 (3)
5	Marsh	19	0.33	0.0344	16	0.4103	0.7427	1.5174 (4)
TOTALS	Meadows			0.2165				
	Pine Plantation			0.123				
	Dry Heathland			0.1107				
	Bog			0.0025				
	Marsh			0.0344				

Grid Square 9588

1	Dry Heathland	11	0.66	0.0012	22	0.5641	0.8342	2.0595 (1)
2	Bog	16	0.66	0.0086	14	0.3590	0.9545	1.9821 (2)
TOTALS	Dry Heathland			0.0012				
	Bog			0.0086				

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

9685

Slepe Farm
Slepe
Old Tramway
Drain
HP to MTs
Carle R
Tk
FP
Spr
FB

9686

Slepe Moor
Middlebere Farm
HWMMT
Mud
Drain
Tk
HP to which MTs flow

Grid Square 9685

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade	Area km^2	Ground Invert. Diversity (α)	α (Standardised)	Rarity Value	Community Aggregate Score
1	Rough Grassland	29	0.33	0.2608	25	0.6410	0.7409	1.9727 (13)
2	Rough Grassland	91	1.00	0.1267	23	0.5897	0.7409	2.4573 (6)
3	Rough Grassland	37	0.66	0.0603	19	0.4872	0.7409	1.9484 (5)
4	Bog	23	1.00	0.0517	25	0.6410	0.9545	2.6472 (2)
5	Dry Heathland	19	1.00	0.0332	22	0.5641	0.8342	2.4315 (7)
6	Meadow	23	0.33	0.0160	31	0.7949	0.9736	2.1145 (10)
7	Bog	14	0.66	0.0111	25	0.6410	0.9545	2.2666 (9)
8	Dry Heathland	18	1.00	0.0148	31	0.7949	0.8342	2.6439 (3)
9	Wet Heathland	8	0.33	0.0086	28	0.7179	0.9588	2.0153 (12)
10	Wet Rough Grass-land	31	0.66	0.0111	11	0.2821	0.7409	1.6941 (18)
11	Dry Heathland	17	1.00	0.0037	31	0.7949	0.8342	2.6328 (4)
12	Marsh	21	0.66	0.0246	11	0.2821	0.7427	1.7094 (17)
13	Marsh	20	0.66	0.0062	9	0.2308	0.7427	1.6397 (19)
14	Scrub	14	0.33	0.0185	7	0.1795	0.9711	1.4991 (20)
15	Dry Heathland	19	1.00	0.0283	20	0.5128	0.8342	2.3753 (8)
16	Marsh	17	0.33	0.0197	10	0.2564	0.7427	1.3488 23
17	Bog	22	1.00	0.0185	27	0.6923	0.9545	2.6653 (1)
18	Dry Heathland	15	1.00	0.0182	29	0.7436	0.8342	2.5960 (5)
19	Wet Heathland	8	0.33	0.0073	31	0.7949	0.9588	2.0910 (11)
20	Scrub	13	0.33	0.0035	7	0.1795	0.9711	1.4841 21
21	Scrub	17	0.33	0.0032	7	0.1795	0.9711	1.438 22
22	Marsh	19	0.33	0.0077	6	0.1538	0.7427	1.2342 24
23	Dry Heathland	11	0.66	0.0041	11	0.2821	0.8342	1.7804 (16)
24	Wet Heathland	8	0.33	0.0051	26	0.6667	0.9588	1.9606 (14)
TOTALS	Rough Grassland			0.4477				
	Bog			0.0812				
	Dry Heathland			0.1029				
	Meadow			0.0160				
	Wet Heathland			0.0210				
	Wet Rough Grassland			0.0111				
	Marsh			0.0581				
	Scrub			0.0252				

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

Grid Square 9686

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade	Area km^2	Ground Invert. Diversity (α)	α (Standardised)	Rarity Value	Community Aggregate Score
1	Marsh	19	0.33	0.1931	14	0.3590	0.7427	1.6248 (9)
2	Rough Grassland	85	1.00	0.1058	25	0.6410	0.7409	2.4877 (2)
3	Marsh	26	1.00	0.2030	17	0.4359	0.7427	2.3816 (4)
4	Rough Grassland	29	0.33	0.0800	22	0.5641	0.7409	1.7150 (8)
5	Rough Grassland	30	0.66	0.0886	26	0.6667	0.7409	2.1562 (5)
6	Deciduous Woodland	28	1.00	0.0467	32	0.8205	0.9382	2.8054 (1)
7	Marsh	25	1.00	0.0098	9	0.2308	0.7427	1.9833 (6)
8	Rough Grassland	18	0.33	0.0012	17	0.4359	0.7409	1.5080 (10)
9	Scrub	7	0.33	0.0062	7	0.1795	0.9711	1.4868 (11)
10	Deciduous Woodland	22	1.00	0.0062	19	0.4872	0.9382	2.4316 (3)
11	Scrub	23	0.66	0.0013	9	0.2308	0.9711	1.8632 (7)
12	Marsh	18	0.33	0.0013	8	0.2051	0.7427	1.2791 (14)
13	Marsh	19	0.33	0.0062	7	0.1795	0.7427	1.2584 (15)
14	Scrub	8	0.33	0.0013	6	0.1538	0.9711	1.4562 (12)
15	Scrub	12	0.33	0.0012	6	0.1538	0.9711	1.4561 (13)
TOTALS	Marsh			0.4133				
	Rough Grassland			0.2755				
	Deciduous Woodland			0.0529				
	Scrub			0.0100				

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

9687

Arne Road
Salterns Copse
Drain
Drain

9688

Turford
Water Mark of Medium Tides
Arne Heath
Tumulus

Grid Square 9687

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade	Area km^2	Ground Invert. Diversity (x)	α (Standardised)	Rarity Value	Community Aggregate Score
1	Wet Heathland	9	0.33	0.0135	24	0.6154	0.9588	1.9177 (7)
2	Pine Plantation	4	0.33	0.3161	7	0.1795	0.8653	1.6909 (11)
3	Dry Heathland	11	0.66	0.2595	26	0.6667	0.8342	2.4204 (4)
4	Deciduous Woodland	28	1.00	0.0861	35	0.8974	0.9382	2.9217 (1)
5	Bog	17	0.66	0.0640	34	0.8719	0.9545	2.5504 (2)
6	Scrub	13	0.33	0.0701	11	0.2821	0.9711	1.6533 (12)
7	Pine Plantation	7	0.33	0.0406	5	0.1282	0.8653	1.3641 (17)
8	Dry Heathland	8	0.66	0.0332	24	0.6154	0.8342	2.1428 (5)
9	Mixed Woodland	13	0.33	0.0148	19	0.4872	0.9382	1.7702 (9)
10	Marsh	24	0.66	0.02337	11	0.2821	0.7427	1.7082 (10)
11	Scrub	8	0.33	0.0148	7	0.1795	0.9711	1.4954 (13)
12	Rough Grassland	21	0.33	0.0123	9	0.2308	0.7409	1.3140 (18)
13	Wet Heathland	11	0.66	0.0172	35	0.8974	0.9588	2.5334 (3)
14	Wet Heathland	6	0.33	0.0086	22	0.5641	0.9588	1.8615 (8)
15	Bog	14	0.66	0.0074	20	0.5128	0.9545	2.1347 (6)
16	Marsh	13	0.33	0.0086	5	0.1282	0.7427	1.2095 21
17	Pine Plantation	4	0.33	0.0037	4	0.1026	0.8653	1.3016 (19)
18	Scrub	9	0.33	0.0011	7	0.1795	0.9711	1.4817 (14)
19	Dry Heathland	7	0.33	0.001	11	0.2821	0.8342	1.4473 (15)
20	Dry Heathland	7	0.33	0.0009	10	0.2564	0.8342	1.4215 (16)
21	Pine Plantation	4	0.33	0.001	4	0.1026	0.8653	1.2989 (28)

TOTALS		
	Wet Heathland	0.0394
	Pine Plantation	0.3614
	Dry Heathland	0.2946
	Deciduous Woodland	0.0861
	Mixed Woodland	0.0148
	Bog	0.0713
	Scrub	0.0860
	Marsh	0.0319
	Rough Grassland	0.0123

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

Grid Square 9688

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade	Area km^2	Ground Invert. Diversity (α)	α (Standardised)	Rarity Value	Community Aggregate Score
1	Dry Heathland	15	1.00	0.3063	24	0.6154	0.8342	2.7559 (1)
2	Pine Plantation	11	0.33	0.2140	9	0.2308	0.8653	1.6401 (14)
3	Dry Heathland	11	0.66	0.0443	22	0.5641	0.8342	2.1026 (9)
4	Wet Heathland	18	1.00	0.0135	24	0.6154	0.9588	2.5877 (3)
5	Bog	18	1.00	0.0098	27	0.6923	0.9545	2.6566 (2)
6	Dry Heathland	15	1.00	0.0098	21	0.5383	0.8342	2.3825 (7)
7	Wet Heathland	16	1.00	0.0111	23	0.5897	0.9588	2.5596 (3)
8	Scrub	12	0.33	0.0098	13	0.3333	0.9711	1.6442 (13)
9	Dry Heathland	13	1.00	0.0160	27	0.6923	0.8342	2.5425 (5)
10	Bog	16	0.66	0.0025	31	0.7949	0.9545	2.4119 (6)
11	Marsh	38	0.66	0.0001	9	0.2308	0.7427	1.9736 (11)
12	Bog	16	0.66	0.0049	22	0.5641	0.9545	2.1835 (8)
13	Scrub	9	0.33	0.0001	7	0.1795	0.9711	1.4806 (16)
14	Bog	14	0.66	0.0025	16	0.4103	0.9545	2.0273 (10)
15	Wet Heathland	9	0.33	0.0012	14	0.3590	0.9588	1.6490 (12)
16	Scrub	8	0.33	0.0012	7	0.1795	0.9711	1.4818 (15)
17	Pine Plantation	7	0.33	0.0030	5	0.1282	0.8653	1.3265 (17)
18	Rough Grassland	20	0.33	0.0010	7	0.1795	0.7409	1.2514 (18)
TOTALS	Dry Heathland			0.3321				
	Pine Plantation			0.2170				
	Wet Heathland			0.0258				
	Bog			0.0148				
	Scrub			0.0111				
	Marsh			0.0001				
	Rough Grassland			0.0010				

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

9689

Wareham Channel
Mud

9785

Mud
Mud
which flow
Drain
Drain
Drains
Cuckoo Pen
Wytch Farm
Spr
Tk
Wytch Fir Pound

Grid Square 9689

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade	Area km^2	Ground Invert. Diversity (α)	α (Standardised)	Rarity Value	Community Aggregate Score
1	Wet Heathland	16	1.00	0.0049	21	0.5385	0.9588	2.5022 (1)
2	Scrub	9	0.33	0.0012	7	0.1795	0.9711	1.4818 (5)
3	Bog	18	1.00	0.0049	14	0.3590	0.9545	2.3184 (3)
4	Dry Heathland	14	1.00	0.0049	21	0.5385	0.8342	2.3776 (2)
5	Marsh	20	0.66	0.0010	11	0.2821	0.7427	1.6858 (4)

TOTALS		
	Wet Heathland	0.0049
	Scrub	0.0012
	Bog	0.0049
	Dry Heathland	0.0049
	Marsh	0.0010

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

Grid Square 9689

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade	Area km^2	Ground Invert. Diversity (α)	α (Standardised)	Rarity Value	Community Aggregate Score
1	Rough Grassland	37	0.66	0.4539	15	0.3846	0.7409	2.2394 (2)
2	Rough Grassland	33	0.66	0.996	13	0.3333	0.7409	1.8338 (6)
3	Pine Plantation	9	0.33	0.0590	10	0.2564	0.8653	1.5107 (9)
4	Pine Plantation	14	0.33	0.1415	12	0.3077	0.8653	1.6445 (7)
5	Marsh	29	1.00	0.0664	11	0.2821	0.7427	2.0912 (4)
6	Marsh	19	0.33	0.0148	9	0.2308	0.7427	1.3183 14
7	Marsh	19	0.33	0.0271	12	0.3077	0.7427	1.4075 13
8	Marsh	22	1.00	0.0160	11	0.2821	0.7427	2.0408 (5)
9	Scrub	9	0.33	0.001	7	0.1795	0.9711	1.4816 10=
10	Deciduous Woodland	20	1.00	0.005	13	0.3333	0.9382	2.2765 (1)
11	Marsh	23	0.66	0.0020	9	0.2308	0.7427	1.6355 (8)
12	Deciduous Woodland	36	1.00	0.001	11	0.2821	0.9382	2.2213 (3)
13	Scrub	8	0.33	0.0020	6	0.1538	0.9711	1.4569 12
14	Scrub	9	0.33	0.0010	7	0.1795	0.9711	1.4816 (10)
TOTALS	Rough Grassland			0.5535				
	Pine Plantation			0.3419				
	Marsh			0.1262				
	Scrub			0.0040				
	Deciduous Woodland			0.006				

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

9786

Mud
High Water Mark of Medium Tides
Middlebere Lake
Mud
Mud
High Water Mark of Medium Tides
Jetty
Middlebere Quay
(Disused)
Drain

9787

Grip Heath
Coombe

Grid Square 9786

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade	Area km^2	Ground Invert. Diversity (α)	α (Standardised)	Rarity Value	Community Aggregate Score
1	Rough Grassland	29	0.33	0.4440	15	0.3846	0.7409	1.8995 (4)
2	Dry Heathland	8	0.66	0.0996	14	0.3590	0.8342	1.9528 (2)
3	Marsh	22	0.66	0.0947	14	0.0947	0.7427	1.8564 (5)
4	Marsh	37	1.00	0.0541	11	0.2821	0.7427	2.0789 (1)
5	Marsh	21	0.66	0.0295	9	0.2308	0.7427	1.6630 (6)
6	Scrub	17	0.33	0.0123	13	0.3333	0.9711	1.6467 (7)
7	Scrub	29	0.66	0.0111	11	0.2821	0.9711	1.9243 (3)
8	Marsh	17	0.33	0.0086	9	0.2308	0.7427	1.3121 (10)
9	Rough Grassland	28	0.33	0.0025	11	0.2821	0.7409	1.3555 (9)
10	Scrub	18	0.33	0.0012	6	0.1538	0.9711	1.4561 (8)
TOTALS	Rough Grassland			0.4465				
	Dry Heathland			0.996				
	Marsh			0.1870				
	Scrub			0.0135				

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade	Area km^2	Ground Invert. Diversity (α)	α (Standardised)	Grid Square 9787 Rarity Value	Grid Square 9787 Community Aggregate Score
1	Dry Heathland	13	1.00	0.2103	32	0.8205	0.8342	2.8650 (1)
2	Dry Heathland	8	0.66	0.1525	27	0.6923	0.8342	2.3390 (6)
3	Mixed Woodland	20	0.33	0.1267	36	0.9231	0.9382	2.3180 (7)
4	Rough Grassland	38	0.66	0.0738	25	0.6410	0.7409	2.1157 (9)
5	Wet Heathland	11	0.66	0.0308	17	0.4359	0.9588	2.0855 (11)
6	Rough Grassland	36	0.66	0.0332	26	0.6667	0.7409	2.1008 (10)
7	Deciduous Woodland	12	0.33	0.0295	29	0.7436	0.9382	2.0413 (12)
8	Marsh	16	0.33	0.0517	14	0.3590	0.7427	1.4834 (25)
9	Scrub	21	0.66	0.0135	11	0.2821	0.9711	1.9267 (16)
10	Bog	21	1.00	0.0111	22	0.5641	0.9545	2.5297 (3)
11	Mixed Woodland	25	0.66	0.0271	29	0.7436	0.9382	2.3689 (5)
12	Scrub	22	0.66	0.0123	11	0.2821	0.9711	1.9255 (17)
13	Bog	27	1.00	0.0185	29	0.7436	0.9545	2.7166 (2)
14	Marsh	37	1.00	0.0135	19	0.4872	0.7427	2.2434 (4)
15	Scrub	19	0.33	0.0074	22	0.5641	0.9711	1.8726 (19)
16	Rough Grassland	31	0.66	0.0123	17	0.4359	0.7409	1.8491 (20)
17	Dry Heathland	12	0.66	0.0123	16	0.4103	0.8342	1.9168 (18)
18	Scrub	17	0.33	0.0098	10	0.2564	0.9711	1.5673 (23)
19	Pine Plantation	6	0.33	0.0049	5	0.1282	0.9653	1.3284 (29)
20	Rough Grassland	21	0.33	0.0062	14	0.3590	0.7409	1.4361 (28)
21	Bog	17	0.66	0.0012	16	0.4103	0.9545	2.0260 (13)
22	Rough Grassland	21	0.33	0.0074	19	0.4872	0.7409	1.5655 (24)
23	Dry Heathland	11	0.66	0.0135	18	0.4615	0.8342	1.9692 (15)
24	Scrub	20	0.33	0.0062	13	0.3333	0.9711	1.6406 (22)
25	Dry Heathland	9	0.66	0.0012	11	0.2821	0.8342	1.7775 (21)
26	Marsh	28	1.00	0.0072	9	0.2308	0.7427	1.9807 (14)
27	Deciduous Woodland	13	0.33	0.0051	8	0.2051	0.9382	1.4784 (27)
28	Bog	26	1.00	0.0010	14	0.3590	0.9545	2.3145 (8)
29	Scrub	19	0.33	0.0009	7	0.1795	0.9711	1.4815 (26)
30	Marsh	13	0.33	0.0019	9	0.2308	0.7427	1.3054 (30)

TOTALS	Dry Heathland	0.3899
	Deciduous Woodland	0.0346
	Rough Grassland	0.1339
	Wet Heathland	0.0308
	Mixed Woodland	0.1543
	Marsh	0.0743
	Scrub	0.0501
	Bog	0.0317
	Pine Plantation	0.0049

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

9788

Big Wood
Arne Dairy House
Arne Farm
Arne
Tumulus (site of)

9789

Russel Quay
Wind Pump
Froxen Copse

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade	Area km^2	Ground Invert. Diversity	(α)	α (Standardised)	Grid Square 9788 Rarity Value	Grid Square 9788 Community Aggregate Score
1	Deciduous Woodland	20	1.00	0.2189	39		1.00	0.9382	3.1571 (1)
2	Rough Grassland	37	0.66	0.1759	15		0.3846	0.7409	1.9614 13
3	Marsh	24	0.66	0.0996	14		0.3590	0.7427	1.8613 19
4	Rough Grassland	33	0.66	0.1132	20		0.5128	0.7409	2.0269 12
5	Rough Grassland	32	0.66	0.0554	16		0.4103	0.7409	1.8666 18
6	Dry Heathland	14	1.00	0.0307	29		0.7436	0.8342	2.6086 (4)
7	Rough Grassland	32	0.66	0.0431	17		0.4359	0.7409	1.8799 16
8	Scrub	16	0.33	0.0357	16		0.4103	0.9711	1.7411 24
9	Bog	29	1.00	0.0234	31		0.7949	0.9545	2.7728 (2)
10	Deciduous Woodland	20	1.00	0.0320	25		0.6410	0.9382	2.6112 (3)
11	Dry Heathland	18	1.00	0.0283	20		0.5128	0.8342	2.3753 (6)
12	Dry Heathland	15	1.00	0.0185	19		0.4872	0.8342	2.3399 7
13	Deciduous Woodland	14	0.33	0.0197	22		0.5641	0.9382	1.8520 21
14	Wet Heathland	11	0.66	0.0161	18		0.4615	0.9588	2.0963 11
15	Dry Heathland	13	1.00	0.0123	17		0.4359	0.8342	2.2824 9
16	Mixed Woodland	9	0.33	0.0098	11		0.2821	0.9382	1.5601 26
17	Dry Heathland	16	1.00	0.0111	18		0.4615	0.8342	2.3068 8
18	Scrub	17	0.33	0.0074	7		0.1795	0.9711	1.4880 31
19	Scrub	14	0.33	0.0074	9		0.2308	0.9711	1.5393 28
20	Deciduous Woodland	11	0.33	0.0049	17		0.4359	0.9382	1.7090 25
21	Scrub	19	0.33	0.0074	8		0.2051	0.9711	1.5136 30
22	Dry Heathland	15	1.00	0.0062	14		0.3590	0.8342	2.1993 10
23	Wet Heathland	16	1.00	0.0062	17		0.4359	0.9588	2.4009 (5)
24	Deciduous Woodland	15	0.33	0.0062	11		0.2821	0.9382	1.5565 27
25	Deciduous Woodland	16	0.66	0.0062	11		0.2821	0.9382	1.8865 15
26	Wet Heathland	14	0.66	0.0062	14		0.3590	0.9588	1.9840 14
27	Rough Grassland	25	0.66	0.0050	17		0.4359	0.7409	1.8418 22
28	Scrub	21	0.66	0.0066	9		0.2308	0.9711	1.8685 17
29	Scrub	16	0.33	0.0016	7		0.1795	0.9711	1.4822 32
30	Scrub	22	0.66	0.0007	8		0.2051	0.9711	1.8369 23
31	Scrub	12	0.33	0.0006	6		0.1538	0.9711	1.4555 36
32	Scrub	11	0.33	0.0008	9		0.2308	0.9711	1.5327 29
33	Scrub	13	0.33	0.0005	11		0.2821	0.9711	1.2867 37
34	Scrub	11	0.33	0.1538	6		0.1538	0.9711	1.4557 35
35	Dry Heathland	12	0.66	0.0005	14		0.3590	0.8342	1.8537 20
36	Scrub	15	0.33	0.0006	7		0.1795	0.9711	1.4812 33
37	Scrub	11	0.33	0.0005	7		0.1795	0.9711	1.4811 34

TOTALS	Deciduous Woodland	0.28782
	Rough Grassland	0.3925
	Marsh	0.0996
	Dry Heathland	0.1174
	Scrub	0.0705
	Bog	0.0234
	Wet Heathland	0.0283

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

Grid Square 9789

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade	Area km^2	Ground Invert. Diversity (α)	α (Standardised)	Rarity Value	Community Aggregate Score
1	Dry Heathland	15	1.00	0.1845	27	0.6923	0.8342	2.7110 (3)
2	Dry Heathland	15	1.00	0.0589	22	0.5641	0.8342	2.4672 (5)
3	Deciduous Woodland	43	1.00	0.1021	32	0.8205	0.9382	2.8608 (1)
4	Rough Grassland	26	0.33	0.0517	21	0.5385	0.7409	1.6611 (14)
5	Wet Heathland	36	0.33	0.0381	29	0.7436	0.9588	2.7405 (2)
6	Pond			0.0258				
7	Rough Grassland	25	0.33	0.0185	21	0.5385	0.7409	1.6279 (16)
8	Wet Heathland	13	0.66	0.0344	19	0.4872	0.9588	2.1404 (8)
9	Marsh	24	0.66	0.0640	10	0.2504	0.7427	1.7231 (12)
10	Marsh	25	1.00	0.0160	7	0.1795	0.7427	1.9382 (9)
11	Bog	29	1.00	0.0148	22	0.5641	0.9545	2.5334 (4)
12	Scrub	15	0.33	0.0148	11	0.2821	0.9711	1.5980 (17)
13	Scrub	17	0.33	0.0160	7	0.1795	0.9711	1.4966 22
14	Dry Heathland	21	1.00	0.0135	16	0.4103	0.8342	2.2580 (7)
15	Marsh	27	1.00	0.0135	7	0.1795	0.7427	1.9357 (10)
16	Scrub	19	0.33	0.0148	8	0.2051	0.9711	1.5210 (20)
17	Scrub	20	0.33	0.0123	6	0.1538	0.9711	1.4672 24
18	Marsh	21	0.66	0.0025	9	0.2308	0.7427	1.6360 (15)
19	Scrub	11	0.33	0.0005	9	0.2308	0.9711	1.5324 19
20	Marsh	20	0.66	0.0009	11	0.2821	0.7427	1.6857 (13)
21	Scrub	11	0.33	0.0008	7	0.1795	0.9711	1.4814 23
22	Scrub	9	0.33	0.002	8	0.2051	0.9711	1.5082 (21)
23	Scrub	9	0.33	0.0018	9	0.2308	0.9711	1.5337 18
24	Bog	18	1.00	0.0014	16	0.4103	0.9545	2.3662 (6)
25	Bog	15	0.66	0.0018	11	0.2821	0.9545	1.8984 (11)
TOTALS	Dry Heathland			0.2694				
	Deciduous Woodland			0.1021				
	Rough Grassland			0.0775				
	Wet Heathland			0.0566				
	Marsh			0.1247				
	Bog			0.0192				
	Scrub			0.0640				

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

9885

Mud
Mud
Fitzworth
Copse
Drain
Drains
Drains
Spr
7
5
13
4
2
3
10
12
14
6
15
9
32
42
39
50
8

9886

HWMMT
HWMMT
HWMMT
Mud
Mud
Mud
Nath
Point
Drain
12
14
11
5
8
9
6
7
15
3
10
FP

Grid Square 9885

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade	Area km^2	Ground Invert. Diversity (α)	α (Standardised)	Rarity Value	Community Aggregate Score
1	Pine Plantation	8	0.33	0.2891	7	0.1795	0.8653	1.6639 (12)
2	Marsh	10	0.33	0.0824	14	0.3590	0.7427	1.5141 (13)
3	Rough Grassland	32	0.66	0.0554	19	0.4872	0.7409	1.9435 (7)
4	Marsh	25	1.00	0.0710	11	0.2821	0.7427	2.1048 (6)
5	Marsh	24	0.66	0.0590	12	0.3077	0.7427	1.7694 (9)
6	Bog	24	1.00	0.0111	17	0.4359	0.9545	2.4015 (3)
7	Marsh	24	0.66	0.0320	11	0.2821	0.7427	1.7168 (10)
8	Bog	18	1.00	0.0627	19	0.4872	0.9545	2.5044 (2)
9	Deciduous Woodland	21	1.00	0.0246	23	0.5897	0.9382	2.5525 (1)
10	Rough Grassland	35	0.66	0.0160	17	0.4359	0.7409	1.8528 (8)
11	Pine Plantation	7	0.33	0.0209	7	0.1795	0.8653	1.3957 (14)
12	Bog	15	0.66	0.0344	21	0.5385	0.9545	2.1874 (5)
13	Rough Grassland	14	0.33	0.0123	9	0.2308	0.7409	1.3140 (15)
14	Marsh	20	0.66	0.0246	11	0.2821	0.7427	1.7094 (11)
15	Rough Grassland	34	0.66	0.2829	22	0.5641	0.7409	2.2479 (4)
TOTALS	Pine Plantation			0.3010				
	Marsh			0.2780				
	Rough Grassland			0.3665				
	Bog			0.1082				
	Deciduous Woodland			0.0246				

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

Grid Square 9886

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade	Area km^2	Ground Invert. Diversity (α)	α (Standardised)	Rarity Value	Community Aggregate Score
1	Rough Grassland	34	0.66	0.2792	25	0.6410	0.7409	2.3211 (1)
2	Marsh	19	0.33	0.1562	13	0.3333	0.7427	1.5622 (6)
3	Dry Heathland	13	1.00	0.0221	17	0.4359	0.8342	2.2922 (2)
4	Marsh	22	0.66	0.0677	11	0.2821	0.7427	1.7525 4
5	Marsh	14	0.33	0.0197	7	0.1795	0.7427	1.2719 (12)
6	Marsh	16	0.33	0.0246	5	0.1282	0.7427	1.2255 (13)
7	Marsh	18	0.33	0.1599	2	0.0513	0.7427	1.2839 (11)
8	Marsh	24	0.66	0.0172	3	0.0769	0.7427	1.4968 (9)
9	Marsh	12	0.33	0.0037	2	0.0513	0.7427	1.1277 (15)
10	Deciduous Woodland	14	0.33	0.0062	14	0.3590	0.9382	1.6334 (5)
11	Marsh	22	0.66	0.0135	4	0.1026	0.7427	1.5188 8
12	Marsh	30	1.00	0.0074	7	0.1795	0.7427	1.9296 (3)
13	Marsh	20	0.66	0.00001	2	0.0513	0.7427	1.4540 (10)
14	Marsh	24	0.66	0.00001	5	0.1282	0.7427	1.5309 (7)
15	Marsh	14	0.33	0.0111	3	0.0769	0.7427	1.1607 (14)
TOTALS	Rough Grassland			0.2792				
	Marsh			0.4809				
	Dry Heathland			0.0221				
	Deciduous Woodland			0.0062				

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

9887

Long Island
Mark of Medium Tides
Wych Channel
Mud
Mud
Landing Stage
Round Island
Mud

9888

Mud
Arne Bay
HWMMT
Shipstal Point
ROMANO-BRITISH POTTERY KILN (site of)
High Water

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade		Ground Invert. Diversity (α)	α (standardised)	Rarity Value	Community Aggregate Score
1	Marsh	30	1.00	0.1365	12	0.3077	0.7427	2.1869 (1)
2	Marsh	37	1.00	0.1476	11	0.2821	0.7427	2.1724 (2)
3	Round Island			0.0443				
4	Marsh	35	1.00	0.0271	7	0.1795	0.7427	1.9492 (4)
5	Long Island			0.0098				
6	Long Island			0.0049				
7	Marsh	21	0.66	0.0062	1	0.0256	0.7427	1.4345 (8)
8	Marsh	19	0.33	0.0037	0	0.00	0.7427	1.0764 (11)
9	Long Island			0.0185				
10	Long Island			0.0001				
11	Bog	17	0.66	0.0078	14	0.3590	0.9545	1.9813 (3)
12	Scrub	11	0.33	0.0002	6	0.1538	0.9711	1.4551 (7)
13	Scrub	13	0.33	0.0003	4	0.1026	0.9711	1.4040 (10)
14	Bog	16	0.66	0.0057	12	0.3077	0.9545	1.9279 (5)
15	Scrub	20	0.33	0.0060	4	0.1026	0.9711	1.4097 (9)
16	Dry Heathland	12	0.66	0.0002	11	0.2821	0.8342	1.7765 (6)
TOTALS	Marsh			0.3210				
	Round Island			0.0443				
	Dry Heathland			0.0151				
	Long Island			0.0185				
	Bog			0.0135				
	Scrub			0.0065				

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

Grid Square 9888

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade	Area km^2	Ground Invert. Diversity (α)	α (Standardised)	Rarity Value	Community Aggregate Score
1	Dry Heathland	16	1.00	0.0529	15	0.3846	0.8342	2.2717 (1)
2	Marsh	26	1.00	0.0160	10	0.2564	0.7427	2.0151 (4)
3	Marsh	20	0.66	0.0504	4	0.1026	0.7427	1.5557 (16)
4	Scrub	14	0.33	0.0295	10	0.2564	0.9711	1.5870 (15)
5	Marsh	38	1.00	0.0246	6	0.1538	0.7427	1.9211 (5)
6	Wet Heathland	11	0.66	0.0209	15	0.3846	0.9588	2.0243 (3)
7	Long Island		1.00	0.2821	11	0.2821	0.8342	2.1360 (2)
8	Dry Heathland	14	1.00	0.0197	2	0.0513	0.7427	1.8125 (11)
9	Marsh	25	0.33	0.0185	15	0.3846	0.9382	1.6713 (13)
10	Deciduous Woodland	14	1.00	0.0185	4	0.1026	0.7427	1.8613 (8)
11	Marsh	28	1.00	0.0160	5	0.1282	0.7427	1.8869 (6)
12	Marsh	30	0.33	0.0160	7	0.1795	0.9711	1.4954 (17)
13	Scrub	11	0.33	0.0148	14	0.3590	0.9382	1.6444 (14)
14	Deciduous Woodland	13	1.00	0.0178	4	0.1026	0.7427	1.8601 (9)
15	Marsh	35	0.66	0.0148	9	0.2308	0.9588	1.8619 (7)
16	Wet Heathland	11	0.66	0.0123	2	0.0513	0.7427	1.4664 (19)
17	Marsh	24	0.66	0.0124	3	0.0769	0.7427	1.4931 (18)
18	Marsh	21	0.33	0.0135	1	0.0256	0.7427	1.1094 (24)
18a	Marsh	19	0.33	0.0111	0	0.00	0.7427	1.0862 (25)
19	Marsh	12	0.33	0.0135	3	0.0769	0.9711	1.3786 (20=)
20	Scrub	11	0.33	0.0006	3	0.0769	0.9711	1.3786 (20=)
21	Scrub	7	0.66	0.0006	9	0.2308	0.9545	1.8460 (10)
22	Bog	14	0.33	0.0007	2	0.0513	0.9711	1.3527 (22)
23	Scrub	18	0.66	0.0003	8	0.2051	0.8342	1.7000 (12)
24	Dry Heathland	8	0.33	0.0007	2	0.0513	0.7427	1.1247 (23)
25	Marsh	18	0.33	0.0007	0	0.00	0.7427	1.0732 (26)
26	Marsh	14		0.0005				
TOTALS	Dry Heathland			0.0855				
	Marsh			0.2079				
	Scrub			0.0458				
	Wet Heathland			0.0209				
	Long Island			0.0209				
	Deciduous Woodland			0.0357				
	Bog			0.0006				

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

9889

Mud
8
Gold Point
Gold Point Heath
10
7
HWMMT
Patchins Point
9

9985

5
16
19
Ower Heath
2
20
15
HP to which MTs flow
6
Shotover Moor
Ower Farm
10
Drain
26
13
17
Drains
8
9

Grid Square 9889

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade	Area km^2	Ground Invert. Diversity (χ)	α (Standardised)	Rarity Value	Community Aggregate Score
1	Marsh	28	1.00	0.1415	11	0.2821	0.7427	2.1663 (4)
2	Dry Heathland	21	1.00	0.14515	21	0.5385	0.8342	2.5178 (1)
3	Scrub	28	0.66	0.00738	9	0.2308	0.9711	1.8693 (7)
4	Scrub	46	1.00	0.0148	8	0.2051	0.9711	2.1910 (3)
5	Scrub	21	0.66	0.0074	6	0.1538	0.9711	1.7923 (8)
6	Marsh	25	1.00	0.0049	9	0.2308	0.7427	1.9784 (5)
7	Scrub	16	0.33	0.0009	4	0.1026	0.9711	1.4046 (9)
8	Scrub	8	0.33	0.0008	3	0.0769	0.9711	1.3788 (10)
9	Marsh	27	1.00	0.0041	8	0.2051	0.7427	1.9519 (6)
10	Deciduous Woodland	53	1.00	0.0020	13	0.3333	0.9382	2.2735 (2)
TOTALS	Marsh			0.1505				
	Dry Heathland			0.1451				
	Scrub			0.0312				
	Deciduous Woodland			0.002				

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

Grid Square 9985

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade	Area km^2	Ground Invert. Diversity (α)	α (Standardised)	Rarity Value	Community Aggregate Score
1	Scrub	21	0.66	0.0098	10	0.2564	0.9711	1.8973 (7)
2	Rough Grassland	18	0.33	0.2780	20	0.5128	0.7409	1.8617 (8)
3	Pine Plantation	8	0.33	0.1156	6	0.1538	0.8653	1.4647 (19)
4	Pine Plantation	9	0.33	0.0713	8	0.2051	0.8653	1.4717 (17)
5	Rough Grassland	34	0.66	0.1587	19	0.4872	0.7409	2.0468 (5)
6	Bog	24	1.00	0.0332	20	0.5128	0.9545	2.5005 (1)
7	Rough Grassland	20	0.33	0.0381	19	0.4872	0.7409	1.5962 (15)
8	Bog	14	0.66	0.0431	22	0.5641	0.9545	2.2217 (3)
9	Pine Plantation	7	0.33	0.0221	7	0.1795	0.8653	1.3969 (22)
10	Marsh	22	0.66	0.0160	2	0.0513	0.7427	1.4700 (18)
11	Bog	13	0.33	0.0197	21	0.5385	0.9545	1.8427 (9)
12	Deciduous Woodland	16	0.66	0.0111	9	0.2308	0.9382	1.8401 (10)
13	Rough Grassland	27	0.33	0.0209	20	0.5128	0.7409	1.6046 (14)
14	Pine Plantation	7	0.33	0.0185	6	0.1538	0.8653	1.3676 (24)
15	Marsh	14	0.33	0.0160	5	0.1282	0.7427	1.2169 (27)
16	Marsh	20	0.66	0.0230	3	0.0769	0.7427	1.5091 (16)
17	Pine Plantation	7	0.33	0.0664	4	0.1026	0.8653	1.3643 (25)
18	Pine Plantation	8	0.33	0.0140	8	0.2051	0.8653	1.4139 (21)
19	Marsh	22	0.66	0.0074	8	0.2051	0.7427	1.6152 (13)
20	Scrub	11	0.33	0.0123	5	0.1282	0.9711	1.4416 (20)
21	Pine Plantation	6	0.33	0.0086	7	0.1795	0.8653	1.3834 (23)
22	Pine Plantation	6	0.33	0.0086	5	0.1282	0.8653	1.3321 (26)
23	Bog	18	1.00	0.0086	10	0.2564	0.9545	2.2195 (4)
24	Bog	17	0.66	0.0160	15	0.3846	0.9545	2.0151 (6)
25	Bog	20	1.00	0.00861	17	0.4359	0.9545	2.3990 (2)
26	Deciduous Woodland	12	0.33	0.00615	15	0.3846	0.9382	1.6590 (11)
27	Deciduous Woodland	14	0.33	0.00615	14	0.3590	0.9382	1.6334 (12)
TOTALS	Scrub			0.01722				
	Rough Grassland			0.4957				
	Pine Plantation			0.3444				
	Bog			0.1292				
	Marsh			0.0455				
	Deciduous Woodland			0.0258				

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

9986

Fitzworth Point
HWMMT
Mud
Drain
Fitzworth Heath
Ower Bay
Ower Lake
Landing-Stage
Countess Point

9987

HWMMT
Mud

Grid Square 9986

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade	Area km^2	Ground Invert. Diversity (α)	α (Standardised)	Rarity Value	Community Aggregate Score
1	Rough Grassland	30	0.66	0.3010	25	0.6410	0.7409	2.3519 (1)
2	Marsh	26	1.00	0.1599	14	0.3590	0.7427	2.2616 (2)
3	Rough Grassland	20	0.33	0.0824	20	0.5128	0.7409	1.6661 (7)
4	Marsh	26	1.00	0.0283	10	0.2564	0.7427	2.0274 (3)
5	Marsh	19	0.33	0.0283	9	0.2308	0.7427	1.3318 (10)
6	Rough Grassland	31	0.66	0.0209	17	0.4359	0.7409	1.8577 (4)
7	Marsh	21	0.66	0.0135	0	0.00	0.7427	1.4162 (9)
8	Marsh	30	1.00	0.0098	0	0.00	0.7427	1.7525 (5)
9	Marsh	2	0.33	0.0049	0	0.00	0.7427	1.0776 (14)
10	Marsh	4	0.33	0.0062	0	0.00	0.7427	1.0789 (13)
11	Marsh	8	0.33	0.0074	0	0.00	0.7427	1.0801 (12)
12	Marsh	11	0.33	0.0049	0	0.00	0.7427	1.0776 (15)
13	Marsh	4	0.33	0.00369	0	0.00	0.7427	1.0764 (16=)
14	Marsh	7	0.33	0.00369	0	0.00	0.7427	1.0764 (16=)
15	Marsh	4	0.33	0.00369	0	0.00	0.7427	1.0764 (16=)
16	Marsh	4	0.33	0.00369	0	0.00	0.7427	1.0764 (16=)
17	Marsh	6	0.33	0.00369	0	0.00	0.7427	1.0764 (16=)
18	Marsh	4	0.33	0.00246	0	0.00	0.7427	1.0752 (21)
19	Marsh	5	0.33	0.1230	2	0.0513	0.7427	1.2470 (11)
20	Scrub	10	0.33	0.0003	5	0.1282	0.9711	1.4296 (8)
21	Scrub	32	0.66	0.0002	2	0.0513	0.9711	1.6826 (6)
TOTALS	Rough Grassland			0.4132				
	Marsh			0.2964				
	Scrub			0.0005				

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

Grid Square 9987

Cartographic Area	Community	Floral Species Richness	Floral Species Richness Grade	Area km^2	Ground Invert. Diversity (α)	α (Standardised)	Rarity Value	Community Aggregate Score
1	Marsh	7	0.33	0.1845	5	0.1282	0.7427	1.3854 (1)
2	Marsh	6	0.33	0.0443	0	0.00	0.7427	1.1170 (4)
3	Marsh	4	0.33	0.0172	0	0.00	0.7427	1.0899 (5)
4	Marsh	4	0.33	0.0172	2	0.0513	0.7427	1.1412 (2)
5	Marsh	3	0.33	0.0098	0	0.00	0.7427	1.0825 (6)
6	Marsh	4	0.33	0.00861	0	0.00	0.7427	1.0813 (7)
7	Marsh	8	0.33	0.0135	2	0.0513	0.7427	1.1375 (3)
8	Marsh	5	0.33	0.0009	0	0.00	0.7427	1.0736 (8)
9	Marsh	4	0.33	0.0008	0	0.00	0.7427	1.0725 (9)
10	Marsh	5	0.33	0.00058	0	0.00	0.7427	1.0733 (10)
11	Marsh	4	0.33	0.00041	0	0.00	0.7427	1.0731 (11=)
12	Marsh	3	0.33	0.00043	0	0.00	0.7427	1.0731 (11=)
TOTALS	Marsh			0.2983				

(The figures in brackets after the Community Aggregate Score indicate the rank positioning for the community within the grid square)

APPENDIX E

Cross reference for deciduous woodland sites

Grid square	Cartographic Area	Community Aggregate Score	Ranking
9788	1	3.16	1
9586	4	2.96	2
9687	4	2.92	3
9586	6	2.88	4
9789	3	2.86	5
9686	6	2.81	6
9586	10	2.71	7
9788	10	2.61	8
9586	17	2.59	9
9586	11	2.58	10
9885	9	2.55	11
9686	10	2.43	12
9586	16	2.43	13
9586	15	2.40	14
9586	18	2.35	15
9785	10	2.28	16
9889	10	2.27	17
9785	12	2.22	18
9787	7	2.04	19
9788	25	1.89	20
9788	13	1.85	21
9985	12	1.84	22
9788	20	1.71	23
9888	10	1.67	24
9985	26	1.66	25
9888	14	1.64	26
9886	10	1.63	27
9985	27	1.63	28
9788	24	1.56	29
9787	27	1.48	30

Cross reference of wet heathland sites

Grid square	Cartographic Area	Community Aggregate Score	Ranking
9789	5	2.74	1
9688	4	2.59	2
9688	7	2.56	3
9687	13	2.53	4
9689	1	2.50	5
9788	23	2.40	6
9585	3	2.36	7
9586	3	2.35	8
9789	8	2.14	9
9788	14	2.10	10
9685	19	2.09	11
9787	5	2.09	12
9585	6	2.03	13
9888	6	2.02	14
9685	9	2.02	15
9585	10	2.01	16
9788	26	1.98	17
9685	24	1.96	18
9687	1	1.92	19
9888	16	1.86	20
9687	14	1.86	4
9688	15	1.65	22

Cross reference for dry heathland sites

Grid square	Cartographic Area	Community Aggregate Score	Ranking
9787	1	2.87	1
9688	1	2.76	2
9587	3	2.71	3
9789	1	2.71	4
9585	1	2.66	5
9685	8	2.64	6
9585	7	2.63	7
9685	11	2.63	8
9788	6	2.61	9
9585	5	2.60	10
9585	8	2.60	11
9685	18	2.60	12
9585	9	2.59	13
9585	11	2.59	14
9586	1	2.59	15
9585	13	2.58	16
9586	12	2.55	17
9688	9	2.54	18
9889	2	2.52	19
9789	2	2.47	20
9685	5	2.43	21
9687	3	2.42	22
9586	24	2.41	23
9688	6	2.38	24
9689	4	2.38	25
9685	15	2.38	26
9788	11	2.38	27
9788	12	2.34	28
9787	2	2.34	29
9788	17	2.31	30
9886	3	2.29	31
9788	15	2.28	32
9888	1	2.27	33
9789	14	2.26	34
9788	22	2.20	35
9687	8	2.14	36
9888	8	2.14	37
9688	3	2.10	38
9588	1	2.06	39
9586	9	1.97	40
9787	23	1.97	41
9786	2	1.95	42
9787	17	1.92	43
9788	35	1.85	44
9685	23	1.78	45
9787	25	1.78	46
9887	16	1.78	47
9888	24	1.70	48
9687	19	1.45	49
9687	20	1.42	50