A method for identifying Prime Biodiversity Areas in a Natural Area in West Sussex

English Nature Research Reports

Number 180

A method for identifying Prime Biodiversity Areas in a Natural Area in West Sussex

Matt R. Phillips
Sussex Wildlife Trust

ISSN 0967-876X

ENGLISH NATURE

PREFACE

A method for identifying Prime Biodiversity Areas in West Sussex, ENRR 180

This work was commissioned to explore some of the practical issues of using Natural Areas as a basis for identifying Prime Biodiversity Areas (PBAs) within the administrative boundaries of a Local Authority. The report is presented here as received, apart from the replacement of the original maps with a smaller scale county map (see below). It does not, therefore, necessarily represent the views of English Nature.

Role of Natural Areas

The role of Natural Areas in identifying PBAs is fundamental. Natural Areas are reflections of the natural distribution of wildlife and natural features, and as such **English Nature strongly advocates their use as a basis for determining the location of PBAs**. .

This report found that Natural Areas, *'provided that they genuinely represent ecological distinctiveness... were much more suitable as areas of search than administrative boundaries, at least in biological terms.'* It does draw attention to the problems of integrating linear features, such as rivers, and the dangers of overlooking transitions between Natural Areas. In practice some PBAs will span two adjacent Natural Areas (this work looked at PBA selection within a single Natural Area), allowing the full integration of linear features and incorporating transitions. For example, the western Downs PBA probably extends into Hampshire. Using a Natural Areas approach will lead to many 'cross county' PBAs, which simply reflects the natural distribution of wildlife and natural features. Therefore, the coordinated action by Local Authorities will become essential, both in the process of identifying the location of the PBAs, and also in the implementation of policies and action plans.

Maps

The main objective of this report was to examine the methods suitable for the selection, rather than the actual identification, of PBAs. Therefore, it is not appropriate to include large scale maps with precise boundaries, as the PBAs identified can only be regarded as draft at this stage. The maps referred to on pages 31 and 57 were not suitable for reproduction and are not included in this report. However, the PBAs identified are shown on a county base-map (p58), and cross referenced to the appropriate maps referred to in the text. The original maps are available (A3, black and white photocopies). If required please contact Rob Cooke at EN, Peterborough.

Size

The PBA identified on the western Downs (PBA 2) appears very large. In practice this is a very diverse part of West Sussex, rich in semi-natural habitats and there are good reasons for its size. However, it is, perhaps, larger than many PBAs would be elsewhere.

Rob Cooke, Peterborough
Claire Burwood, Lewes

Contents

List of tables and figures

Acknowledgements

The present project was fully funded by English Nature. It was accompanied by the digitisation of ESD boundaries at West Sussex County Council, County Planning Department, conducted by Paul Rippingham.

Phase One habitat maps were provided by the County Planning Department based on maps from a project part funded by English Nature. Species data were provided by the Sussex Wildlife Trust and Sussex Ornithological Society. Thanks are due to Harry Montgomery at the Trust and Dr John Newnham at SOS and to the Scientific Committee at SOS for further input.

Thanks to Dr Tony Whitbread, Rob Cooke, Claire Burwood, Ann Griffiths and Alison Bish for comments on various drafts.

Thanks also to R. and I. Kearey and M. and G. Bish for accommodation.

Summary

Prime Biodiversity Areas (PBAs) have been defined as the zones with the highest current biodiversity and the greatest potential for conservation enhancement. However, no single method or definition has been applied in order to identify such areas. Many approaches have been developed for identifying current biodiversity hot-spots and many measures and surrogates suggested for characterising biodiversity have been used to set conservation priorities. In addition since the Rio Earth Summit of 1992, conservation organisations have suggested targets for enhancement and rehabilitation of priority habitats in the UK.

It has been suggested that PBAs should form the focus of this enhancement as they would be the most efficient, flexible and viable areas for habitat rehabilitation compared to equally large, but less biodiverse areas; the aim being to reverse habitat isolation and fragmentation. It has also been suggested that PBAs should be identified within English Nature's ecologically distinctive areas (Natural Areas) and/or within administrative units.

The present project examines the background to PBAs in terms of the different elements that are considered to comprise biodiversity and in terms of existing criteria for their identification. It develops a method for identification of PBAs within the South Downs Natural Area in West Sussex.

The biodiversity measures most appropriate to use in a study at the scale of a Natural Area are assessed and the data sources available are identified. It is concluded that data are required at a tetrad scale and that the collector effect should be minimised by using only the most systematically assessed sources - flora and birds. A sub-sample of conservation priority species would fit most closely with other targets and a summation method is applied to identify clusters of richness for each taxon.

An approach to identifying the patches of habitat on the Downs that form networks is presented using Phase One habitat maps. Different habitat types offer variable potential for being linked together as some can be more easily rehabilitated or re-created than others. This variation is translated into a 'consolidation range' which is defined as the distance from high quality sites that could be rehabilitated with intermediate quality habitat over a given time period. Overlapping ranges indicate sites that form a network. The outside edges of the outermost habitats in a network form the boundary of the PBA.

These approaches are used to identify possible PBAs each of which is tested against a set of criteria. These are derived from IUCN criteria for the identification of Centres of Diversity and from the criteria for SSSI designation (considered in an area context rather than a site context). PBAs should:

1. contain large habitat extent
2. form an ecological unit.
3. have thematic consistency.
4. accommodate conservation targets.
5. contain high conservation priority species richness.
6. maximise habitat and community diversity.
7. contain all or most characteristic habitat types.
8. contain a habitat network with high potential.
9. contain a mosaic of habitats and ecotones.
10. contain habitats or species with special edaphic adaptations.
11. meet criteria within administrative boundaries.
12. meet criteria within Natural Areas.
13. be able to achieve significant enhancement within a given timescale (50 years).
14. contain habitats with targets.
15. contain conservation priority habitats.
16. contain habitats that would benefit from sustainable use.
17. contain habitats under threat.

The results identify three PBAs. The first is the Arun valley PBA which extends to the break of

slope, but includes part of the escarpment to the east of the valley. The second is the western Downs PBA which encloses the escarpment to the west of the Arun and large sections of the Natural Area to the south – notably excluding the river Lavant valley. The third is the Adur valley PBA, extending to the break of slope. It is suggested that the river valley PBAs should be considered both inside and outside the Natural Area.

A fourth possible PBA on the eastern escarpment is rejected for failing to fulfil criteria. Alternative PBAs which fail to provide thematic/ecological consistency are also rejected, even though they would contain high biodiversity within a smaller area.

The method is discussed and the constraints imposed by the area of search considered. It is concluded that the criteria chosen should form the goals for and definition of PBAs. The summation and Phase One mapping approaches are essential supporting tools for identifying possible areas (or alternatives), but the goals of PBAs are the most important element of the process. It is suggested that given equivalent quality of data, the approach is practical to use and is in line with biodiversity theory.

Recommendations are made for extending the study and refining the method:

1. The approach be extended to the whole of West Sussex and boundaries digitised.
2. More appropriate consolidation ranges be researched.
3. Agricultural use be considered as a criterion; in particular levels of set-aside.
4. The implications of PBAs for agri-environment support be assessed.
5. Identifying local sites of conservation importance (such as SNCIs) be progressed where a network has not been identified.
6. Completion of the Rare Species Inventory be brought forward.
7. Factors relevant to the management and planning phase of designation be identified including the exact PBA boundaries.
8. A complementary hot-spots analysis be attempted in West Sussex.
9. A minimum PBA size be investigated.
10. A similar analysis crossing county boundaries be attempted.

1 Introduction

1.1 This project

1.1.1 Since the Rio summit of 1992 biodiversity research and assessment has taken on a specific and functional role in conservation planning and management. Yet, although biodiversity is a technical term for the variety of nature, there exists no definitive measure for describing the pattern of this variety nor its constituent parts.

1.1.2 This project seeks to explore some of the issues in identifying Prime Biodiversity Areas (PBAs) in the context of English Nature's Natural Areas programme. It is intended to concentrate on one identified Natural Area: the South Downs. In addition the project will explore the process in the context of existing administrative boundaries; reducing the area of search to the part of the South Downs Natural Area within West Sussex.

It will discuss three main themes:

1. Biodiversity - which measures of biodiversity are most practical to use in a Sussex context? Which surrogates are most appropriate? What data are available?
2. Area - How big is a PBA? Where are its borders? What is its ecological function?
3. Prime biodiversity - what criteria should characterise 'prime' biodiversity and are most useful in identifying PBAs?

These themes will be explored through the development of a method for identifying PBAs using Phase One habitat maps and locally generated species distribution data.

1.1.3 The South Downs in Sussex are part of an Environmentally Sensitive Area (ESA) and form the bulk of the South Downs Area of Outstanding Natural Beauty (AONB). The area has a dedicated management authority, the Sussex Downs Conservation Board (SDCB).

1.2 Definition of PBAs

1.2.1 Butcher *et al* (1995, p45) described High Biodiversity Areas (HBAs) as:

> *"places within an administrative unit that support the greatest diversity of species and the greatest extent and highest quality of semi-natural habitat, and which offer the greatest potential for restoration of habitat characteristic of the administrative unit."*

Biodiversity: The UK Action Plan (DoE, 1994a) provides an introductory exploration of the value of PBAs (see appendix 1). Although this is not a method or a guideline, it nevertheless provides a context: indicating that PBAs can be large; they are associated with Natural Areas; they are related to current *and* potential conservation value; they are related to both species and habitat

diversity; boundaries are not precise because the PBAs are biologically rather than opportunistically derived; they have national significance; and they can contain many different habitat types. The examples provided are of PBAs with identifiable thematic characteristics such as the North Norfolk Coast and Dorset heaths.

A more explicit definition is given in *Biodiversity: The UK Steering Group Report* (Biodiversity Steering Group, 1995, Annex C, p90), which states:

> *"Areas where particular concentrations of high priority habitats occur are often referred to as prime biodiversity areas. These are not designations, but are areas where action is likely to be most cost effective. Such concentrations offer opportunities for pro-active programmes aimed not only at managing those sites, but also increasing the level of biodiversity of intervening land through habitat management and enhancement, or by means of habitat recreation aimed at restoring the natural character of the local area."*

It goes on to recommend PBAs be defined by a particular approach: "*Overlay species and habitat data to show local clusters of biodiversity. Identify pbas* [sic] *on map*" (p91).

In the present report, then, PBAs are considered to be zones of high conservation priority; areas with biodiversity that can be conserved over the long term; that will promote conservation of other biodiversity elements; and will be most efficient to enhance given limited resources. They contain the greatest present diversity and the greatest conservation potential; for example for habitat restoration and enhancement.

The definition remains open to interpretation. One key issue is that in a landscape such as the Downs, which is already of high conservation interest being an ESA and an AONB, is possibly one large PBA. A PBA analysis may be able to identify where the clusters of greatest interest are, but that will not in itself resolve this central issue of scale.

1.2.2 The present project considers PBAs in a strictly local context. This follows from the UK Government's biodiversity strategy which highlights the increasing role of local authorities in developing and delivering biodiversity targets (Biodiversity Steering Group, 1995; DoE, 1994a and 1995).

However, the backbone of conservation in the UK is the national statutory SSSI network. This network is not considered adequate for conservation of all the UK's biodiversity (DoE, 1994a) so at a national level protected areas are required to supplement the existing network. Methods have been considered for assessing this supplementary network by using complementary biodiversity hot-spots (Williams *et al*, in press).

Such a method would potentially produce radically different solutions to hot-spots identified in a local context. For example, the butterflies of the South Downs are considered nationally important. So an analysis might give the Downs a higher weighting at a national level than they

would have relative to other parts of Sussex at a local level (Prendergast and Eversham, 1995). Likewise, the lowland heathlands of Sussex may not meet national criteria for being a PBA, while they almost certainly would in a local context. One of the reasons for this difference between local and national perspectives is that at a local level, any method based on summation using restricted range or conservation priority species (see below) would adopt local rarity and priority (Butcher *et al*, 1995), not just national priority; and a species may be rare locally, but common nationally. The local patterns and relative values of biodiversity, of course, are useful in their own right (Hawksworth and Kalin-Arroyo, 1995).

This illustrates the need for explicit goals for identifying PBAs with consistent criteria relating to conservation evaluation designed to optimise conservation resources through efficiency, flexibility and viability (Pressey *et al*, 1993; Vane-Wright *et al*, 1994).

1.2.3 Such priority setting has provided useful approaches to the identification of hot-spots (Forey *et al*, 1994; Gaston and Blackburn, 1995; Kershaw *et al*, 1995; Prendergast *et al*, 1993; Turpie, 1995). However, the present approach to PBAs follows Butcher *et al* (1995) and DoE (1994a) by assessing potential values as well as current ones. This allows recently developed national and local biodiversity targets to be incorporated into PBAs.

PBAs offer the opportunity to reach targets in zones offering the greatest returns on invested energy. This would not be at the expense of existing priorities; SSSIs are likely to remain the core of the UK's biodiversity strategy. It is suggested SSSIs would be no less important whether they were inside or outside a PBA and would continue to require conservation *and* enhancement. PBAs are the wider areas where conservation investment will receive better returns than less biodiverse but equally wide areas.

In addition the methods for identification of hot-spots so far have not considered the state of semi-natural habitat networks, or the extent and quality of habitat. The extent of habitat has been assessed by Butcher *et al* (1995), but the potential to knit together habitat patches and to enhance at an area scale has been overlooked.

The present approach is closely related to priority setting as it progresses away from opportunistic reasons for site designation (Pressey *et al*, 1993). For example, fragments of calcareous grassland on the South Downs have been conserved because they happened to be uneconomic to improve or cultivate (Williams, 1993). The systematic approach seeks to target conservation energy at those areas with greatest biodiversity, on the basis of biological and ecological criteria. The attitudes of local landowners who may favour conservation to a greater or lesser degree (Gowing *et al*, 1994; Morris and Potter, 1995) and agricultural economics are essential matters to be progressed at the management and planning phase of an identified PBA.

1.3 Biodiversity measures

1.3.1 The kind of biodiversity measures used need to be related directly to the goals of a PBA. This places an emphasis on sources of species and habitat data and their reliability. The ITE's Biological Records Centre has records on species distribution in the UK at the 10km square scale. However, this is too course a scale to consider when identifying PBAs which require a more sophisticated understanding of the biodiversity present and the state of the habitat network (Magurran, 1988).

As a result data are required at a tetrad scale (preferably with six figure grid references). Butcher *et al* (1995) were able to draw on comprehensive records in Somerset, enough to provide a sample of over 800 'notable' species.

Some taxa have been more systematically surveyed than others and in Sussex the most widely and systematically surveyed have been higher plants and birds. For each of these data are available to tetrad scale. In the case of birds, the information has been computerised by the Sussex Ornithological Society (SOS) and can be accessed relatively easily. Butterfly data have also been computerised by Butterfly Conservation, though this data was unavailable in the time given to the present project. Few other data, however, are computerised and any other systematic assessment of species distribution in Sussex would have to work species by species through the *Sussex Plant Atlas* (Hall, 1980) the *Atlas of Sussex Mosses, Liverworts and Lichens* (Rose *et al*, 1991) or through site records and Environmental Survey Directory (ESD) surveys. Some of these data are being input to Recorder, but as yet this process is incomplete. Other taxa are less well recorded. The situation in Sussex is similar to the rest of the UK.

The question arises as to whether these taxa are sufficient surrogates for Sussex's biodiversity and if so whether a selection of these could be taken further refining the goal of the study and the PBA identification process.

An additional factor is variation in recorder effort, the 'collector effect' which has a significant influence on distribution data with information ultimately representing collector behaviour rather than species patterns (Goldsmith, 1994; Prendergast, *et al* 1993; Sharrock, 1977).

1.3.2 The extent of semi-natural habitat in West Sussex has been surveyed using information from flight and satellite photography. This information has been digitised by WSCC and maps can be produced indicating the habitats of Sussex at a Phase One level. The last census was conducted in 1991. However, the information has not been extensively 'ground truthed' and the remote data require some interpretation. The habitat classifications have been harmonised with EN's Phase One categories (Nature Conservancy Council, 1990).

In addition to indicating habitat types, boundaries of conservation sites such as SSSIs, SNCIs and Ancient Woodland Inventory (AWI) woodlands have been digitised. The digitisation of the ESD

will enable ground truthing of this remote identification and give a more detailed insight into the contents of PBAs. This latter digitisation has accompanied the present study, but was unavailable for analysis. The ability to link map boundaries with a database, surveys and ultimately species data will be a major step forward and should inform the PBA identification process.

1.3.3 Biodiversity has been described in many ways. It is most usual to express it in terms of ecosystem, species and genetic diversity. However, other approaches have been developed where biodiversity is expressed as compositional, structural and functional diversity. Bisby (1995) has suggested four main approaches to measuring biodiversity:

1. Species richness.
2. Species diversity (including measures of abundance and recorder effort).
3. Taxonomic diversity.
4. Functional diversity.

Given these approaches, a number of surrogates for measuring biodiversity and ways of using them have been proposed. These have relevance to the identification of PBAs:

Species richness

A count of the number of species (often known as alpha-diversity) in a grid square provides an insight into how these squares compare. However, some areas are naturally more diverse than others. Assessing priority areas on the basis of such an approach would, for example weigh in favour of Downland grassland over lowland heath if vascular plants were considered and *visa versa* if aculeate hymenoptera were studied. Yet in terms of conservation priority neither one may be more important than the other. Habitats of intermediate quality frequently have high species richness, which may be because they are dominated by cosmopolitan or invasive species, neither of which are in need of conservation energy (Rapoport, 1986).

Hot-spots based on species richness are also poorly nested with those for rarity, conservation priority or endemism (Kershaw *et al*, 1995; Prendergast *et al*, 1993; Williams *et al*, in press). Sites of high abundance, on the other hand, are significantly correlated (Turpie, 1995). Species richness, then, does not provide an insight into areas of conservation priority (Rebelo, 1994; Turpie, 1995). It is important to note, however, that most of these studies have been at a course scale (usually using 10km squares) and it may be that species richness at a tetrad scale is even more (or much less) nested with other measures as patterns of diversity are scale dependent (Norton, 1994).

Endemism

Birdlife International has identified global hot-spots for endemic birds (those with delimited

ranges) dubbed Endemic Bird Areas (EBAs) (Gaston and Blackburn, 1995; Thirgood and Heath, 1994).

A similar approach was adopted by Prendergast *et al* (1994) who used birds with limited UK distributions as a sample for identifying hot-spots. They used the 25 per cent of species with the smallest distributions in the UK (based on the number of 10km squares they breed in).

This approach to any kind of endemism does not take account of the relative threat to each of these species, nor of their viability or ease of conservation. In addition, limited distribution species could be on the edge of their European range and therefore of limited conservation value compared to locally abundant species rare in Europe as a whole.

In international terms the UK is of limited value for its levels of endemism, though the South Downs does feature one endemic plant - early gentian (*Gentianella anglica*).

Surrogate, indicator and keystone species and ecological redundancy

A number of different approaches have been used based on exploring the nature of species and using species as surrogates for biodiversity. Some species are 'drivers' in that they fundamentally alter the ecosystems they inhabit, while others are 'redundant' and appear to have no influence (Walker, 1992). These driver species, also known as keystone species, could be considered as the indicator species for habitats as they have a disproportionate influence. However, the background information to make judgements about redundancy is not available and in terms of conservation priority, driver species may be no more important than redundant species (Gitay *et al*, 1996).

Indicator or representative species could also be adopted as a sample (Vane-Wright *et al*, 1994). They would have to be carefully selected; for example on the South Downs such species would have to indicate good dip and scarp slope grassland, good scrub secondary and ancient woodland, good riverine floodplain habitat, good wetland habitat, good arable margins and so on. What is more, the sample of species would have to be comparable to indicator samples for heathland, Weald woodland, coastal habitats and every other habitat type in Sussex. The danger would remain that species are selected as indicators because they are known to be in high quality habitat already; consequently the sites would be self-selecting. However, it is possible to use indicators systematically (Peterken, 1974).

A number of surrogates have been identified as indicators of biodiversity (Vane-Wright *et al*, 1994), in particular birds have been utilised in global studies (Gaston and Blackburn, 1995; Lawton *et al*, 1994; Turpie, 1995). However, in the UK studies at the 10km square scale have shown that bird hot-spots are not correlated with hot-spots for other taxa (Lawton *et al*, 1994; Prendergast *et al*, 1993).

It is possible at a smaller scale, such as tetrads, that birds would be good surrogates for total

diversity, but the habitat specificity of different taxa may be even more distinctive at this level. Any surrogates, then, would have to be carefully selected. Being rich in butterflies, for example does not mean 10km squares are also rich in bryophytes, dragonflies or birds (Lawton *et al*, 1994). At a smaller scale, the same kind of differences would accompany diversity of habitat structure. A range of taxa might even out these differences and also expose varied patterns of biodiversity distribution.

Taxonomic diversity

In taxonomic terms all species are not equivalent: in terms of genetics, evolution or ecology, some are more closely related than others and some have fewer close relatives than others do. based on a classification hierarchy some can be seen to be more distinct than others and would therefore contribute more to total diversity than others. This measure of difference has been identified as an important element of biodiversity (Gaston and Williams, 1993). Indeed it has been weighted within programs such as WORLDMAP (Williams *et al*, 1991). However, most biodiversity in the UK is assessed in simple species and habitat terms (Biodiversity Steering Group, 1995; DoE, 1994a). Given the timescale of the present project, taxonomic diversity has not been considered, but this biodiversity measure could alter weighting for different species in a subsequent assessment

Habitat diversity and extent

The extent of habitat and extent of delta-diversity (see figure 1.3.1, p41) in an area are central to identifying PBAs. The pattern of this level of diversity has not been included as yet in hot-spot analyses, though the extent of semi-natural habitat present has. Butcher *et al* (1995) included the extent of conservation managed semi-natural habitat as part of the assessment of the biodiversity of each tetrad in Mendip District. This extent was summed with scores for notable species to produce a combined measure.

It is not clear whether these biodiversity measures are comparable in this way or represent different patterns of biodiversity important in their own right. Habitat networks are likely to be important considerations in a PBA; even if a tetrad has a high extent of habitat, it could be an isolated site and not part of a PBA. A network of patches even with a lower extent may have a greater potential as the habitats could form a distinctive pattern.

Richness of habitat types is also likely to be important within a PBA. With a thematic PBA such diversity would need to be complementary and this would require an assessment of the habitat and management types within a Natural Area. In the Downs, for example, key habitat types would be: dip and scarp grassland, some scrub, chalk heath, ancient woodland, the escarpment, river floodplain habitats and arable margins (Williams, 1993). A significant

proportion of secondary native woodland and scrub, though, would be targeted for clearance to rehabilitate grassland, which is of a higher priority. Both scrub and secondary woodland would be encouraged (and considered core habitat types) on land with little or no chance of being rehabilitated to calcareous grassland.

Conservation priority species

Priority species for conservation have been proposed as the most useful measure of biodiversity as they can be related to other conservation planning targets (Kershaw *et al*, 1995; Vane-Wright *et al*, 1994). These are the species that are internationally, nationally or locally endangered, threatened or vulnerable plus species that are suffering serious population declines or those that have limited distributions (endemic or not).

However, using threatened species as surrogates may inhibit any long term aim of having a representative network of PBAs (c.f. *Typicalness*, Ratcliffe, 1977), as the threat to species is short to medium term (Kershaw *et al*, 1995). In addition, the presence of conservation priority and rare species does not predict species richness (see above).

Summing conservation priority species does not take account of their viability, their population size, or of the reasons for their rarity. Rabinowitz *et al* (1986) identified seven reasons why species are rare. For example they may naturally occur in small numbers across a wide area; or they may be highly habitat specific. Rare species may be present by chance or struggling in unfavourable conditions and do not necessarily indicate high quality habitat.

Complementarity

Complementary areas for biodiversity conservation have been presented as most efficient for achieving goals; more so than just taking the high-scoring sites, since an iterative method takes account of the attributes of areas while scoring approaches can exclude species of importance (Pressey *et al*, 1993; Turpie, 1995; Vane-Wright *et al*, 1994; Williams *et al*, in press). PBAs are not an attempt to maximise alpha- or beta-diversity within an area. But it may be valid to ensure they contain a large degree of the components that make up the delta-diversity of a landscape. For example, if Downs PBAs were to contain viable areas of all the characteristic habitat types of the Downs, then an iterative approach to identification may be necessary. However PBAs can be large and it may be that these habitat types would be included anyway.

The systematic approach at a tetrad scale is heavily influenced by data which may exhibit a strong collector effect and therefore be presenting a spurious sense of statistical rigour. Turpie (1995) suggests that a subjective interpretation also be conducted on areas indicated as hot-spots in order to ensure they fit within a local conservation context. In addition the

complementary area approach concentrates on minimum area, which may disfavour thinly spread rare forms (Kershaw *et al*, 1995) while failing to provide security for species which may be in only one or two sites. The PBA approach provides the additional measure of potential, which is designed to reduce threats and knit sites into areas thus reducing fragmentation and isolation (Kirby, 1995). As a result there is no need to minimise areas.

1.4 Area issues

1.4.1 The process of identifying the areas of highest biodiversity introduces issues of management scale. Traditionally UK conservation has been based on site protection and management. Once consideration is given to knitting sites together, the next level of conservation processes needs to form part of our background understanding of the areas and of our management strategies. 'Sites' are here defined as pockets of diversity, no less important than areas in terms of their overall contribution to local, national and international biodiversity conservation, but not (or less) suitable for habitat expansion, habitat linking/in-filling or habitat rehabilitation.

1.4.2 In terms of hierarchy smaller habitat patches change more rapidly and larger units (or the whole ecosystem) more slowly (Norton, 1994). As a result the pattern and nature of diversity across the PBA has to be assessed to inform understanding of larger units (see figure 1.3.1, p41) (McNaughton, 1994). At the scale of a Natural Area, delta-diversity is arguably significant (as defined in the present paper) as this represents the difference between characteristic habitat types within a Natural Area. Gamma-diversity is usually given to represent regional (i.e. super-national) levels of diversity. In this study, however, it has been considerably scaled down to stand as 'landscape region diversity'; in effect to represent the differences between diversity in Natural Areas in the landscape region of Sussex. Thus it is the kind of diversity specifically excluded from biodiversity assessment if using Natural Areas because it is the next scale higher - a measure of the diversity of landscape types.

However, a PBA network for the Sussex region would seek to maximise inclusive gamma-diversity. This would include the most biodiverse areas which are on the 'borders' of Natural Areas (Prendergast, pers. comm.). This would need to be a consideration when using Natural Areas as a unit of search. In addition Natural Areas include features that pass through many other Natural Areas, particularly rivers and coastlines. These would therefore include a set of the components that constitute gamma-diversity. As *r*-selected landscapes, it should be noted, these offer a high potential for habitat rehabilitation (Warren, 1983 and 1993).

For PBAs in general there seems to be no reason to exclude gamma-diversity as they have a thematic basis (see appendix 1). For example, assuming it matches the criteria, there could be an 'Arun valley' PBA which crosses a number of Natural Areas as well as a 'Downland' PBA that is

restricted to the borders of the Natural Area. In terms of the pattern of biodiversity, then, Natural Areas act as constraints. This has to be balanced against the benefits they offer in terms of narrowing the search and helping define the thematic character of the PBA.

1.4.3 When looking at area based conservation, attention is shifted from looking at elements of the system to looking at the structures and processes that perpetuate that system (Costanza *et al*, 1992). Area scale conservation offers the potential to manage a number of sites more economically, for example by consolidating grazing units on the South Downs (Williams, 1993). It means natural processes such as patch dynamics, flooding regimes, windstorms, succession or species territories can be viewed in a wider context (Phillips, 1994). If river valleys were considered for example, the whole catchment and its hydrological dynamics might be re-interpreted in this area context.

Many of these themes are beyond the scope of the present study. But they remain an important background consideration as well as a substantial benefit of identifying PBAs.

However, considering larger areas also requires that an appropriate timescale is embraced (Norton and Ulanowicz, 1992). In Sussex a timescale for considering conservation has been proposed as 50 years which is approximate to two human generations and longer than a single working lifetime (SxWT, 1996). Given this timescale, for example, more could be achieved in enhancing *r*-landscapes than *k*-landscapes (Warren, 1993).

1.4.4 Adopting an area approach allows for the enhancement of biodiversity. For example edge effects can be reduced and a range of ecotones encouraged with fewer 'sharp' boundaries. This would effectively increase habitat contiguity maximise beta-diversity while reducing fragmentation and isolation. Additionally it would move closer to conservation goals such as 'ecological health', 'biological integrity' and "maximising the human capacity to adapt to changing ecological conditions" (Reid, 1994).

1.5 Prime biodiversity considerations

1.5.1 Some criteria for identifying Centres of Diversity and hot-spots have been adopted using endemism and species richness (see above). These measures, plus area considerations can influence the goals in identifying PBAs. Other considerations may also form criteria.

Davis *et al* (1994-5) adopted additional criteria in identifying the IUCN's Centres of Diversity for vascular plants. These criteria contain both anthropogenic and ecological considerations, and they can be applied in a Sussex context to a greater or lesser extent:

1. *Sites should contain an important gene pool of plants that are of value to humans or that are*

potentially useful. Although it may not be useful to consider the use-value of species in Sussex, it may be appropriate to consider existing or potential sustainable uses which would benefit biodiversity. For example: coppice woodlands or high forests, recreation, tourism potential and, above all, agricultural grazing. These are in line with SSSI ancillary criteria such as 'Intrinsic appeal' (Ratcliffe, 1977; Goldsmith, 1983). Grazing is an appropriate sustainable use that benefits calcareous grassland. High forest management could also benefit secondary woodland. However, coastal habitats such as cliffs or mud flats would not benefit from utilisation and would therefore constitute more of a preservation landscape than a publicly engaging sustainable-use landscape.

2. *Sites should contain a diverse range of habitat types.* A diverse range of habitats would seem a highly relevant criterion in Sussex. PBAs might be expected to contain all, or nearly all, of the characteristic habitats of a Natural Area in line with the principal 'Typicalness' criterion for SSSIs (Ratcliffe, 1977).

3. *Sites should contain a significant proportion of species adapted to special edaphic conditions.* Special edaphic conditions could also be relevant in Sussex. For example on the Downs calcareous grassland consists of species communities adapted to relatively uncommon conditions; even more unusual soil conditions produce chalk heath. Calcareous woodland, though of conservation interest, might be considered to be more general in terms of its communities and not specially adapted. As a result, calcareous grassland and chalk heath might be given extra weight in this criterion on the South Downs. This is in line with the 'Fragility' criterion for SSSIs (Ratcliffe, 1977).

4. *Sites should be threatened or under imminent threat of large-scale devastation.* The level of threat is an important consideration. In Sussex the area most under large-scale threat is arguably the coastline; by coastal squeeze. Although inland areas are not under large-scale imminent threat, it is conceivable that they could be. Such a criterion would be in line with frequently used evaluation criteria in the UK (Margules, 1980).

1.5.2 Further ecological considerations could form criteria. These might be drawn from the same sort of ecological criteria behind SSSI designation (Goldsmith, 1983; Ratcliffe, 1977), with area considerations made over site considerations:

- *Size and Position in an Ecological Unit.* It would be appropriate to specify a minimum size for a PBA which might be considered a functional or discrete ecological unit. For example one of the reasons for the designation of Blakeney Point as an SSSI is its position in a coastal unit. A PBA can be seen as the unit (the Norfolk coast) and Blakeney one of its components. An approximate size for such a unit would be 10,000ha (Van Wieren, 1989) which is in line with the 10km square implied in *Biodiversity: The UK Action Plan* (see appendix 1). In the absence of a definitive size statement, however, criteria might include the PBA forming an

ecological unit and being large enough to accommodate conservation targets. The characteristics of this ecological unit would form the thematic consistency behind the PBA.

- *Naturalness and Typicalness*. As well as containing characteristic habitats, a PBA should contain mosaics of habitats and ecotones typical of a natural landscape. If they do not now, they should at least have the potential to do so over the timescale of assessment.
- *Extent*. Areas with high habitat extent offer the most potential and the highest viability. Furthermore the more intimate the habitat network, the more practical it would be to enhance.
- *Diversity*. Aside from the biodiversity measures discussed above, maximising levels of diversity might be appropriate.

1.5.3 Other management and anthropogenic considerations might be included as criteria. These are not the only important criteria, factors such as land ownership patterns might also be important. However, those below might be considered the definitive elements that would influence the ecological criteria. For example administrative boundaries are important for defining an area of search, but they are clearly not decided on ecological criteria and therefore would act as a defining influence on the ecology of a potential PBA:

- *Administrative boundaries*. Any administrative boundaries would effectively define the scale of search of the PBA (Norton, 1994), having an impact on its goals. It would be possible to develop an approach at national, regional, county, district or even parish scale. However, in terms of conservation policy, the county scale is arguably most pertinent as county authorities have been identified as a central force for delivery of conservation targets (Biodiversity Steering Group, 1995; DoE, 1994a and 1995). Furthermore data are often held or assessed at a county scale and county authorities are sources of information to a Phase One level. The issue for the criterion to establish is whether the boundary, whichever it is, constrains designation as a PBA or not.
- *Natural Areas*. EN has identified Natural Areas as ecologically distinct divisions of the UK. Using these might establish PBAs across county boundaries, which has more ecological validity than using administrative boundaries. For example, Chichester harbour may not form part of a PBA in West Sussex, but if the Hampshire Basin Natural Area were assessed, it could form part of a PBA extending along the coast to the west. Natural Areas help define the characteristic habitats which might form part of a PBA, but the transition habitats and ecotones of Natural Areas are rich in species (see above) and so the level at which Natural Areas do not contribute to defining the PBA should be a criterion.
- *Timescale*. The extent to which the assessment timescale is appropriate for a potential PBA should form part of the criteria. Given the ecology of a potential PBA, would significant levels of enhancement be achieved in the given time?

- *Targets*. PBAs might be considered the areas where national and local conservation targets would be applied - over and above other areas outside PBAs. Targets appropriate to the South Downs are discussed below. As a result the criterion is the extent to which targets are developed - PBAs may only be needed where there are targets.

1.6 National and local targets

1.6.1 Identifying PBAs is indicated in *Biodiversity: The UK Action Plan* (DoE, 1994a, p74) to be a national target. It states: "*Utilise existing knowledge to identify prime biodiversity areas in the UK based on best available levels of data recorded and agree a strategy to protect and enhance them involving all interested parties*".

PBAs, then, might be considered the appropriate locations for directing conservation targets nationally. They could also be used locally: "[the] *Local Biodiversity Action Plan should also identify where it is appropriate to halt recent trends in habitat fragmentation and create new and attractive landscapes by habitat enhancement and restoration*" (Biodiversity Steering Group, 1995, p26). PPG 9 (DoE, 1994b, p6) also suggests networks of habitats should be considered in planning regardless of whether they are inside or outside statutory sites and that sites could be "*extended*".

PBAs may also fit within concepts such as Critical Natural Capital and Constant Natural Assets which are being developed by EN and the Countryside Commission (Environmental Resources Management, 1995).

Many national and local bodies have developed targets for achieving biodiversity enhancement and extension which would be directed through PBAs.

1.6.2 *Biodiversity: The UK Steering Group Report* (Biodiversity Steering Group, 1995a) included specific targets for habitat expansion concentrating on habitat types and species conservation. A number of these Costed Habitat Action Plans and Habitat Statements are relevant to the South Downs Natural Area:

Cereal field margins - maintain, improve and restore by management the biodiversity of some 15,000ha of cereal field margins on appropriate soil types in the UK by 2010.

Ancient and/or species rich hedgerows - achieve sympathetic management of 95,000km by 2005.

Coastal and floodplain grazing marsh - rehabilitate 10,000ha by 2000 (5,000ha within ESAs, 5,000ha outside. 2,500ha of this is to be rehabilitated from arable land).

Calcareous grassland - maintain calcareous grassland in all parts of the UK where it occurs, restore degraded calcareous grasslands, buffering and linking small, vulnerable or discontinuous sites. Measures to be considered further include how existing measures (such

as ESAs and Countryside Stewardship) might establish links between fragmented calcareous grasslands; to allow plant and animal dispersal and facilitate grazing management.

Broad-leaved and yew woodland - expand new native woodlands where linked to ancient and semi-natural woodlands.

Boundary features - extend to increase cover and connect isolated habitat fragments.

Improved grassland - turn into semi-natural habitats.

1.6.3 West Sussex County Council (WSCC) has developed and is reviewing nature conservation policies in co-operation with other conservation partners in the county. These are currently moving towards the production of a Biodiversity Action Plan. Working to the principles of sustainable development, general environmental policies guide the Structure Plan which is now in its third review. Nature conservation strategies thus contribute to the plan and form part of overall policy. In support of the Structure Plan review the County Planning Department has produced an environmental capacity study which suggests that one of the directions for conservation strategy is to identify PBAs (WSCC, in prep.).

1.6.4 District Councils are generating conservation enhancement strategies:

River Adur floodplain - Adur District Council has proposed re-creating a natural floodplain ecosystem and riverine forest on the section of the river Adur that passes through the South Downs between Steyning and the A27.

Arun Valley Countryside Management Project - a management plan is currently being developed to include targets for enhancement of the biodiversity of the valley.

Community forests - it is possible other authorities in West Sussex will follow Crawley District Council and develop community forests.

1.6.5 The Sussex Wildlife Trust (SxWT) has produced ambitious targets for Sussex's different habitats over the next 50 years in its *Vision for the Wildlife of Sussex* (SxWT, 1996). Many of these are relevant to the Downs:

Calcareous grassland - 30 per cent of the Downs should be under calcareous grassland by 2045 (the current level is about five per cent).

New wildlife reserves - 15,000ha of low-value agricultural land to transfer out of production to create new wildlife reserves in target areas.

Wetlands - grazing marsh to cover 25,000ha of lowland floodplain with a reedbed of over 100ha. Including two 5,000ha wetland reserves.

Woodlands - 24 per cent of Sussex should be under woodland and forest.

1.6.6 The Sussex Downs Conservation Board has indicated some directions for habitat enhancement (SDCB, 1995). For example two actions planned for the Downs are:

Wetlands - opportunities should be sought to restore wetland systems by raising water levels.

Calcareous grassland - promote further reversion of arable to grassland within the ESA scheme on the escarpment and dip slope ridges.

1.6.7 The National Rivers Authority (now part of the Environment Agency) is in the process of producing Catchment Management Plans for the Arun and the Adur, which do not include wide-ranging targets, but do have guiding principles for enhancement of riverine habitats.

1.6.8 Other organisations might have an input in Sussex: the Countryside Commission, Ministry of Agriculture Fisheries and Food (Maff) (in particular with regard to Coastal Zone planning), other AONB authorities, bordering counties and other conservation organisations such as the National Trust (NT), Council for the Protection of Rural England (CPRE), Royal Society for the Protection of Birds (RSPB), Butterfly Conservation and SOS.

1.7 Identifying habitat networks

1.7.1 Butcher *et al* (1995) networked constituent habitat patches within HBAs by adopting an arbitrary search routine away from the centres of the highest-scoring tetrads in order to locate the boundary of the HBA. From the boundary of the semi-natural habitat patch nearest the centre of the tetrad a 700m search was made in all directions for occurrences of notable species or habitats. If any were encountered they formed part of the HBA. From these sites a 600m search was made and repeated reducing the search distance by 100m each time.

In other words a model was recognised with a centre of conservation 'interest' tailing off to a state with no interest and a boundary was imposed where the interest ended. The model also supposes that most interest was in the middle and that the potential of the HBA tapered off towards the boundary. A boundary analysis using a summation approach would need to show that the distribution of interest within a boundary is significantly different to the distribution of interest outside the boundary.

The model also predicts a tail off of interest. However Sussex exhibits habitat patches with very strict boundaries at the edge of management units. For example woodland interest ends abruptly adjacent to a woodland edge. In Sussex semi-natural habitats are sometimes scattered evenly over the landscape and sometimes apparently in clusters. Any PBA in Sussex, then, would be likely to have many points of high diversity in it, these may even be on the fringes of the PBA, rather than in the centre and interest can suddenly change.

The model ignores the variable potential of habitats for enhancement. In Sussex it is clear that rehabilitating calcareous grassland would be a more difficult task than rehabilitating secondary woodland, or even heathland. Consequently, given a 50 year timescale (see above), the search distance would have to be less from grassland than from woodland.

By using Phase One habitat maps, there is no need to assume a centre to the PBA as any method for identifying a PBA would take into account the network and distribution of habitat patches. However the problem remains of how patches would be knitted together and where the PBA boundaries are located.

An appropriate model might be to assess the potential distance existing habitats could extend if consolidation through enhancement, rehabilitation, in-filling or habitat creation were to take place. In other words, given a 50 year timescale, habitat that passes a threshold of interest could be rehabilitated up to a certain number of metres away from existing habitat thereby linking habitats to reduce isolation and fragmentation; where consolidation ranges overlap, the sites might be considered to form a single networked unit (see figure 1.71, p42). Some habitat types would be easier to consolidate than others. For example *r*-landscapes are easier to restore to natural condition than *k*-landscapes (Warren, 1993) so river floodplain habitats of conservation interest could be in the whole floodplain, perhaps several hundred metres from present riverine habitat. In contrast, given natural conditions, species typical of ancient woodland might only extend a few tens of metres from an existing site (Francis *et al*, 1992; Peterken, 1993a; Peterken and Game, 1984; Usher *et al*, 1992). Therefore the 'consolidation range' for ancient woodland is considerably less.

Secondary woodland of appropriate quality would be easier to encourage. Woodland could in fact be created in isolation from existing sites. However, the target is to encourage native woodland planting adjacent to ancient sites (Biodiversity Steering Group, 1995) and it is likely such sites would have a greater potential to reach an intermediate quality quicker than isolated sites (Peterken, 1993b).

The assumption is that even though new habitats could be created on arable land or improved grassland, they will never be able to attain the conservation interest of existing sites, at least not within 50 years, and will thus always be 'second best'. Nevertheless they would have a benefit in reducing isolation and fragmentation and would at the very least enhance the biodiversity of a PBA.

Calcareous grassland is hard to re-create to high standards 'naturally'. But with a target, the energy put into enhancement of it (and any) habitat type would increase (Buckley, 1989) and so the consolidation range would increase. Thus the use of national and local targets in PBA identification can be important.

With calcareous grassland two patterns emerge. Consolidation would require re-seeding with non-aggressive native species then introduction of an appropriate grazing regime on the land between

sites. Up to perhaps 50-100m from existing high conservation interest grassland some natural colonisation of valued species may take place, raising the grassland to a state of intermediate conservation interest. Beyond that distance only low interest could be achieved under 'natural' management. The consequence of this pattern is that grassland patches more than 200m apart could not be consolidated, would remain isolated from one another and could not be realistically considered as part of the same network or PBA.

The second pattern would envisage a greater management input, in order to bring more grassland up to intermediate interest at greater distances from high interest sites. This might be because there is a target for rehabilitating grassland. Based on the SxWT target for Downland grassland (SxWT, 1996), on average each grassland site needs to extend a further 500-700m in all directions in 50 years (lower if East Sussex is included in accommodation of the target). Thus more isolated sites could be considered part of a network.

An alternative to a consolidation range would be to consider the management units such as fields as the steps of rehabilitation from high interest sites. This clearly has a validity in management planning. However, some Natural Areas would exhibit considerable differences in management unit size and it may be preferable to define a consolidation range by biological rather than pragmatic criteria, at least in terms of identification. Detailed management and planning issues would be assessed at a second stage of the programme.

Once this network is identified, the boundary of the PBA is the outside boundary of the outermost habitat patches. In the future the PBA could be extended outwards beyond this boundary to the extent of the consolidation range of these outermost patches. For the present project, though, the consolidation range was only being used to identify the networks, not the boundary.

The model used in this study is designed to be close to the approach identified in *Biodiversity: The UK Action Plan* (DoE, 1994a, p43) which states:

> "*The prospects for habitat re-creation are best when land of greatest potential is selected; this will generally be where some semi-natural vegetation remains, were the soil has not been enriched through use of fertilisers and where nearby sites (notably SSSIs) can act as colonisation sources to speed the establishment of characteristic native species. Duplicating habitats around SSSIs and linking isolated sites together through the maintenance of appropriate landscape features have much to recommend them as positive measures to sustain biodiversity*".

2 Method

2.1 General approach

Three approaches were developed to identify PBAs in the area of search. The first two were designed to identify provisional PBAs which could then be tested in the third stage.

1. Assess the distribution of biodiversity in the Natural Area by tetrad in order to identify clusters of conservation interest using a set of summed biodiversity measures: conservation priority flora and birds, bird species richness and semi-natural habitat extent.
2. Analyse the network of habitat patches using Phase One habitat maps and identify the sites that could be consolidated into larger units.
3. Assess the potential PBAs according to a set of criteria including the findings of stages one and two to identify the general structure of PBAs.

Based on these three approaches a subjective interpretation was made of the findings to assess which parts (if any) of the Natural Area might be practical and useful to consider as PBAs.

2.2 Summation of biodiversity measures

2.2.1 In order to identify clusters of high conservation value tetrads, a summation approach was adopted using different biodiversity measures. The present study used the most accessible and systematically surveyed taxa: higher and lower plants and birds. Recorder effort variation can be corrected using a statistical transformation (Prendergast *et al*, 1993). However, this may not be appropriate at a tetrad scale and time constraints made it impractical to investigate in the present project.

No attempts were made to smooth these scores to even out the patterns of diversity as the area of search contained large 'edges' which would have distorted the smoothing. Nor were the measures standardised or compiled as it was felt the different distributions described should be understood in their own right.

The data were presented in simple 3D graphs on Excel to offer interpretative comparisons of biodiversity measure distributions. These graphs indicated the sums in the tetrads on the South Downs area of search only.

2.2.2 Briggs (1990) updated the *Sussex Plant Atlas*, but on the whole many records were out of date. However a selection of plant species records have been brought up to date as part of the SxWT's Rare Species Inventory (RSI) (Montgomery, unpubl.). The RSI lists records of locally, nationally and internationally rare species present in Sussex (East and West). This includes Red Data Book (RDB) species, scarce plants (Stewart *et al*, 1994), and locally rare species. The RSI is not restricted to plants, but is not yet complete and is only due to be so in 1999. Data on flora have

been updated to 1992 (Montgomery, pers. comm.). The list is, in effect, an inventory of conservation priority species in Sussex. On the West Sussex section of the South Downs the sample constituted 132 species.

2.2.3 SOS records are from two sources. The General records are collated from recorders submitting observations and therefore feature a distorting collector effect (Newnham, pers. comm.). These records also include survey data for particular species.

The second source is the Sussex Tetrad Atlas data. These were gathered more systematically, but only look at breeding records using the same method employed in the British Trust for Ornithology (BTO) New Atlas. These data are augmented with some records of rarer species from the General records to produce an inventory by tetrad of confirmed (or otherwise) breeding birds.

A sub-set of conservation priority species was selected from this Atlas record. On the recommendation of the SOS Scientific Committee the 20 species forming the draft agricultural bird Red Data list were chosen: kestrel, grey partridge, quail, corncrake, stone curlew, lapwing, stock dove, turtle dove, barn owl, skylark, song thrush, grasshopper warbler, spotted flycatcher, tree sparrow, goldfinch, linnet, bullfinch, cirl bunting, reed bunting and corn bunting. The more common species on this list such as skylark and song thrush were less well recorded as they generated less recorder interest than rarer species such as stone curlew and quail which were comparatively over-recorded, indicating the nature of the collector effect (Newnham, pers. comm.).

The study summed the RDB bird selection by tetrad and did a further summation of total bird species richness from the General records.

2.2.4 The extent of semi-natural habitat in each tetrad was categorised on the basis of the maps described in section 2.3. An exact area of habitat could have been obtained from the digitised data. However, time constraints made such an analysis impractical. The categories are shown in table 2.2.1 (p43).

2.3 Phase One habitat maps

A 1:50,000 Phase One habitat map was produced covering the characteristic and conservation priority sites on the Downs. These included AWI sites, SSSIs, SNCIs, broad-leaved semi-natural woodland, scrub, acid neutral and calcareous grassland, marsh, heathland habitats, mire, swamp, riverine and coastal habitats. The non-Downland habitats were included so the map could be used in future analyses. Notable exclusions were all artificial habitats including parkland, coniferous plantations, improved grassland and arable. The result was a distribution of high conservation

interest sites across the South Downs in West Sussex.

A model was proposed above that assessed the potential to in-fill between conservation sites based on their consolidation range. This range was used to form the basis of PBA identification.

Figure 2.3.1 (p44) shows the consolidation ranges for of different habitat types used in the present analysis. The ranges given were arbitrary and more appropriate numbers could be researched given more time than available for the present project. It was accepted that rather than being fixed values, the potential is actually over a wide margin. For example, coastal habitats could re-create themselves relatively easily, but constraints such as elevation would have a significant impact.

For coastal habitats 1,000m was given to express the relative ease of spreading the coast landward (rather than linking coastal habitats together).

The whole river floodplain could be relatively easily rehabilitated up to the side slopes of the valley, making consolidation of floodplain habitats possible over a wide range. Grazing marsh too could be relatively easily 'networked' between sites as a ditch system, for example, could be created and less conservation energy would need to be directed towards the actual grassland.

Scrub and hedgerow are relatively easy to generate, but are hard to bring up to an intermediate level of conservation interest. On the Downs there are important scrub habitats - though it should be noted that one priority on the Downs is to rehabilitate grassland by clearing scrub (SxWT, 1996; SDCB, 1995). Scrub in-filling in a PBA, then, would be likely on old cultivated land and to provide ecotones between woodland and grassland rather than on potential grassland.

Ancient woodland would be relatively difficult to re-create, but adjacent to secondary woodland would be likely to act as a valuable source of species. Secondary woodland could be planted on the Downs (though as indicated above this would only be on land which could not be rehabilitated to calcareous grassland), but to achieve an intermediate conservation interest would have to be adjacent to ancient woodland.

Heathland and grassland rehabilitation are strongly influenced by the state of the seed bank as well as the energy put into enhancement. The calcareous grassland range given here was based on the distance from the site that would have to be rehabilitated to meet the SxWT's target for grassland rehabilitation on the Downs (SxWT, 1996).

A line was drawn approximately 500m from the boundary of every calcareous grassland or woodland site; a 600m line around scrub; a 900m line around habitats in the floodplain and 800m around any grazing marsh in the Natural Area.

The consolidation range was used to identify which patches of semi-natural habitat formed a 'network' and which were outside any kind of network. This was done by drawing the range round every habitat patch and linking sites together.

Small sites and larger, but clearly isolated sites, were ignored as part of the analysis. However,

small sites clustered into an obvious network could be considered, as these retained a potential for enhancement in the context of a PBA.

Once the ranges had been drawn, the results were compared with a 1:50,000 Ordnance Survey map. This enabled obvious anachronisms to be identified such as ranges extending into built up areas. At this stage an appraisal was made of the sites in the area. If they were known to be particularly isolated, or particularly important they could then be excluded or included.

Once the sites in the network had been identified by this process, the range on the outside of the area was contracted to the edge of the outermost patches (see figure 2.4.1, p45). This identified the final PBA boundary, or the boundaries of alternative PBAs. Boundaries could pragmatically be associated with physical features, or human features such as roads. However, it was felt that this next aspect was a management planning stage which should be attempted with a more full range of information than the identification process. For example, the ESD could be used to give more detailed information on areas to draw the most realistic conclusions. Consequently the maps produced in the study were drawn to allow for maximum flexibility in the management and planning phase, when more exact boundary details would be necessarily addressed.

2.4 PBA criteria

A set of criteria were drawn up to direct identification of PBAs. These criteria were prioritised following the hierarchy suggested by Goldsmith (1983) and the selection criteria for SSSIs. The extent to which the potential PBAs identified in the earlier stages complied was indicated with a simple scoring system: high compliance (***), intermediate (**), low (but significant) (*) and no significant compliance (X).

Area scale ecological criteria

1. contain large habitat extent.
2. be large enough to form an 'ecological unit'.
3. have a thematic structure based on landscape scale ecological distinctiveness.
4. be large enough to accommodate habitat targets.

Diversity criteria

5. contain high conservation priority species richness, but not necessarily all species in the region; even if the precise number is unknown.
6. maximise beta- and delta-diversity, but exclude gamma-diversity unless consideration is being given to river valleys or coastal habitats. In this instance the whole river valley or coast should be considered.
7. contain viable extents of all or nearly all the characteristic habitat types of the Natural Area (in the case of South Downs identified to be: dip and scarp slope grassland, the escarpment itself, ancient woodland, scrub, chalk heath, riverine habitats and arable weed margins).
8. contain an intimate habitat network with potential for in-filling with rehabilitated, re-created

or created habitat characteristic of the Natural Area.

9. contain a significant mosaic of habitats and ecotones.

Uniqueness ecological criteria

10. contain habitats and species with special edaphic adaptations if these are characteristic of the Natural Area (in the case of the South Downs this requires special weight being given to chalk heath and chalk grassland).

Anthropogenic and management criteria

11. meet the criteria within the West Sussex administrative area without regard to areas outside.
12. meet the criteria within the EN Natural Area unless consideration is being given to river valleys or coastal habitats. In this instance the whole river valley or coast should be considered.
13. be able to achieve significant enhancement within the assessment timescale.
14. contain a high and viable extent of habitat types with national or local conservation targets.
15. contain a high and viable extent of conservation priority habitats.
16. contain species and habitats that would benefit from sustainable use.
17. contain habitats under threat.

3 Results

3.1 Summation of biodiversity measures

3.1.1 Concentrations of tetrads with high conservation priority flora diversity were identified in the Arun valley, in the Adur valley, on the Downs escarpment and on the escarpment on the eastern part of the Downs (see figure 3.1.1, p46).

The western Downs, (west of the Arun valley) had a concentration of high-scoring tetrads on sites close to the Arun and along the escarpment. Otherwise in this area there was a patchy distribution of conservation priority flora, with some gaps such as the Lavant floodplain.

To the east of the Arun valley, aside from the Adur valley, there were peaks of species diversity, but with large gaps. The Adur valley featured one particularly high-scoring tetrad as a result of coastal species being recorded upstream.

3.1.2 The Arun valley featured a high degree of semi-natural habitat extent. To the west there were many high-scoring tetrads indicating large sites. To the east (including the Adur valley), the habitat extent was far lower - reflecting the small isolated sites of that part of the Downs (see figure 3.1.2, p47).

3.1.3 High-scoring tetrads for the sample of RDB confirmed breeding birds from the SOS Atlas data were distributed in different locations to high-scoring conservation priority flora and habitat extent tetrads (see figure 3.1.3, p48). Both the Arun and Adur valleys featured high-scoring tetrads, though the former also featured several low-scoring ones. Few of the top-scoring tetrads were west of the Arun or east of the Adur. In the case of the former area, however, the value of scrub and woodland is relatively greater for wintering species which were not assessed here. Between the Arun and the Adur where habitats were small and isolated, there were concentrations of high-scoring conservation priority bird species.

This pattern was slightly different to total breeding bird species richness from the SOS General records (see figure 3.1.4, p49). The Arun and Adur valleys retain concentrations of high-scoring tetrads. The whole area east of the Arun was relatively more important, including the area east of the Adur.

3.1.4 The extent to which different biodiversity measures were correlated was likely to indicate how far they described different patterns of diversity. It would not be surprising for different taxa to show different patterns, as the habitat requirements for each taxon at a scale such as that studied here are bound to be highly variable.

Over the whole of the Downs a spearman's rank order correlation indicated habitat extent tetrad

scores were not significantly correlated with conservation priority flora scores (r_s=0.174), though this borderline correlation might indicate a trend. This suggested the level of habitat did not predict the level of conservation priority species; those species could be in small isolated sites, for example, or outside semi-natural habitat altogether.

This reflected the different nature of these measures of biodiversity at this scale indicating they were complementary but not strictly comparable. A successful assessment of PBAs, then, should use both species and habitat extent as measures, but these should not be compiled into one measure. Just one of these measures could also not act as a surrogate for the other and would therefore not represent all biodiversity at this scale.

The pattern is complex in detail. In the Arun valley PBA there was a significant correlation between habitat extent and conservation priority flora by tetrad score (r_s=0.465, $p<0.05$). In other words, where there was a lot of habitat there were more conservation priority flora and where there was less habitat there were fewer species. In the western Downs there was no significant correlation, despite the large tracts of semi-natural habitat. This suggested the species were contained outside the large habitat areas either in smaller isolated sites or outside conservation managed sites altogether. Such conditions might be considered to contribute to a benefit of designating this area a PBA.

In the east the low habitat density contributed to a pattern of highly isolated patches of biodiversity. However, for breeding birds the eastern half of the Downs was relatively more important. Using a product-moment correlation, high (and low) scores in tetrads for RDB birds were significantly correlated with high (and low) scores in tetrads for all bird species richness (r_p=0.376, $p<0.001$).

There was also significant correlation between RDB breeding birds and flora tetrad scores (r_p=0.252, $p<0.01$). In this case, however, an analysis at a smaller scale by dividing the South Downs into discrete blocks (the Arun valley, the area to its west, the Adur valley and the rest) revealed no significant correlation for any block other than the Arun valley (r_p=0.484, $p<0.05$). This indicated that the scale of analysis influenced the extent of correlation, further supporting the use of a range of measures to indicate clusters of high-scoring tetrads.

3.1.5 The pattern of diversity revealed by the alternative measures was complex and sometimes contradictory. At the given scale the implication was that none of the measures would be an ideal surrogate for all, but they all contributed to a deeper understanding of biodiversity distribution. A subjective interpretation of these results suggested four potential PBAs on the Downs and an alternative solution:

1. *The Arun valley.* Extending to the break of slope, but including the escarpment on its eastern side overlooking Amberley Wildbrooks, to the north.

2. *The Adur valley.* Extending from the break of slope on either side of the valley. The PBA would be low in habitat extent, but high in species values.

3. *The western Downs.* Including the whole escarpment west of the Arun and the extensive habitats that gradually peter out to the south. However this PBA would include patches of limited conservation interest and would have a complicated shape to exclude low-scoring tetrads.

4. *The Downs escarpment east of the Adur.* Probably extending into East Sussex. However, this potential PBA was less easy to define than the others, though it was important for birds.

5. An alternative would be to identify a larger PBA taking in the Arun PBA suggested above and extending through the immediate area next to the valley plus the western and eastern escarpment.

   This PBA would be augmented by an Adur PBA which might also extend to the east to take in the escarpment up to the border with East Sussex and to the west to include sites important for birds. If the Downs were considered in isolation of other Natural Areas, this latter approach would be more appropriate in terms of summation values.

3.2 Phase One habitat maps

The mapping approach using consolidation ranges proved able to identify those Downs habitat patches that could be networked most efficiently into areas. The maps are enclosed at the end of the present document (also see p57). Four broad areas were identified as possible PBAs and these could be considered in two alternative combinations:

Alternative 1

1. *The Arun valley.* The consolidation range process merged virtually the whole valley into one area (see Map 1). However, there was no distinct boundary to the south. The break of slope was considered to enclose the valley, but in terms of consolidation, the PBA effectively continued along the escarpment to the west; through the woodlands to the south west; along the escarpment to the east; and through the woodlands to the south east.

   Given the contiguity with the network of habitats to the west, the potential PBA can be drawn more closely to the valley in the west and in the east excluding the area east of Patching. The PBA resulting from this analysis is shown on Map 2.

2. *The Western Downs.* This large area consisted of a consolidated area contiguous with the Arun valley area but featuring a large gap in the far west and excluding the river Lavant valley (see Map 3 for the western and Map 1 for the eastern part of this area). There was a further gap at Houghton forest (a coniferous woodland plantation).

This analysis in particular illustrated interpretative issues. For example the scattered sites around SU865120 could either be included or excluded in the range analysis. It was decided in this instance to take the line through the middle, leaving a final decision to the management planning stage. The present analysis indicates, however, that even at the management stage, there should be recognition of the 'gap' between habitats at SU900120 (Goodwood) and SU885135 (Levin Down). This gap follows the valley to the east and was identified using the analysis alone, before reference was made to the Ordnance Survey map.

It is notable that the boundary of the consolidation range approximates to the 50m contour line. This may be indicating an ecological change, as richer soils and gentler slopes may have made cultivation easier than on steeper slopes, influencing habitat quality.

The PBA resulting from this analysis is shown on Maps 4a and 4b.

3. *The Adur valley.* This area was able to demonstrate considerable potential by containing large floodplain habitats, despite the lack of habitat extent generally (see Map 5). It was contiguous with the escarpment to the east, but not to the west. The area between the Arun and Adur valleys did not form significant networks.

   The PBA resulting from this analysis is shown on Map 6.

4. *The eastern escarpment.* This area was the least easy to identify as a possible PBA (see Map 5). The main constraint was that although along the escarpment sites could be consolidated, most sites in the vicinity remained isolated. In addition the habitat was almost all calcareous grassland. Although this is probably the most important habitat type of any extent on the Downs, a PBA might be expected to have a greater range of types present and be able to extend beyond just the escarpment.

Alternative 2

An alternative result was to identify two networks centred on the Arun and Adur valleys. In this instance Downs habitats to the east and west were included in the networks. In the case of the Adur valley this meant including the escarpment to the east. In the case of the Arun it meant including a much larger area to the west. The PBA identified for the Arun from this analysis is shown on Map 7. The Adur alternative would be similar to that on Map 6 plus the grassland patch to the east on the escarpment.

3.3 PBA criteria

Each of the potential PBAs was tested against the criteria (see table 3.3.1, p50).

1. *The Arun valley.* The *r*-Landscape of the Arun valley had quite distinctive ecological characteristics which could be relatively easily enhanced. Diversity was high and there were a

range of intimately networked habitats. The area was distinct from the rest of the Downs by offering an exceptional potential for featuring ecotones from the riverine grazing marsh further north through the greensand ridge and up the side slopes of the valley onto the Downs. It was felt therefore to meet the criteria better if this gamma-diversity were considered and the PBA were not restricted to the Downs. This gave it a thematic distinction from the Downs to the west which might be considered to form a different ecological unit interrupted by the river valley. This supported the Alternative 1 results of the Phase One habitat map analysis.

The valley also has a dedicated management project and could be a key area for achieving conservation targets. The main drawback of the PBA was that it had low extent of calcareous grassland and no chalk heath. Consequently another PBA would be needed to supplement this one.

2. *The Western Downs.* This potential PBA had a range of all habitats from grassland to woodland, including the greatest extent of chalk heath in Sussex. Arguably, however, the PBA was rather stronger on woodland than grassland. The northern boundary of the PBA ended with the chalk, the western at the county boundary and the eastern boundary was considered to be the break of slope into the Arun valley. The southern boundary was defined by the boundaries of the outermost habitat patches.

   The main drawback of this potential PBA was that despite having a large, intimate habitat network, it was less important than other areas for conservation priority species.

3. *The Adur valley.* Similar considerations were given to the Adur valley as to the Arun in terms of potential and species richness. However, the extent and interest of sites in the valley was less than in the Arun. The area also only featured a limited extent of calcareous grassland and no chalk heath. However it does have high potential and a specific set of targets for large-scale habitat rehabilitation.

4. *The eastern escarpment.* The part of the Downs escarpment to the east of the Adur consisted mostly of calcareous grassland, which was greater in extent than any of the previous potential PBAs. Yet it was low in habitat diversity, did not form any discernible ecological unit (at least not within the confines of West Sussex) and did not contain high conservation priority species richness.

   It is certain the grassland sites would benefit from being linked together as they contributed to a diverse, high interest network worth enhancing. However, their character was more of a 'prime biodiversity site', as the potential to encourage ecotones was limited. Consequently it was not considered to meet the criteria for being a PBA.

   Alternative 2 (see above) linked this area (or part of it) to the Adur PBA. This would diminish the thematic consistency of the Adur valley PBA. The Arun PBA proposed above was

considered to include part of the escarpment. However, in this instance it was observed, the escarpment would consolidate with conservation interest habitat to the north at Amberley Wildbrooks. The same could not be said for the Adur where the Downs habitats could not network with habitats outside the Downs.

It is possible that if the area were considered in the context of the section of the Downs Natural Area in East Sussex, some of these reservations would be resolved.

3.4 Interpretation of results

The criteria analysis indicated some variability between the potential PBAs. A subjective interpretation of the results suggested that the Alternative 2 proposal was unsuitable on the basis of thematic consistency. Examining the Alternative 1 proposals, the Arun valley, the Adur valley and the western Downs all achieved PBA status as constituted. The eastern grasslands and the Alternative 2 proposals all failed to achieve significant compliance with at least three criteria - at least one of which was high priority. It is notable that the richest tetrads for birds were not included in any potential PBA.

4 Discussion

4.1 Use of PBAs

At the outset of the analysis consideration was given to the question of whether the whole of the South Downs Natural Area was one large PBA; as it is an ESA, part of an AONB, features areas of nationally important calcareous grassland, contains many conservation sites and is important for certain species of butterfly, vascular plant and some birds. This would be consistent with the suggestion that large sections of existing ESAs could be considered PBAs (DoE, 1994a, see appendix 1).

The results of the study showed that large sections of the Downs would comprise PBAs and that these were even contiguous. However, it remains true that, given limited resources, some areas would see a greater benefit from an input of conservation energy than others. The PBA identification process revealed the areas where enhancement would produce better returns than other areas; where the high and characteristic diversity was located; and where targets could be achieved easiest.

If the whole of the Natural Area were to be considered a PBA, the implication is that resources would be better directed anywhere on the Downs rather than, for example, in the Weald, on greensand heathland or on the coastal plain. If the PBA network were designed on a national basis, it is possible this would be the case. In a local context, however, there are advantages to being able to maximise the regional diversity (gamma-diversity as defined in this study) and that means identifying the prime areas within each Natural Area.

As it stands the three PBAs identified would probably accommodate all the specific local and national habitat targets.

4.2 Use of Natural Areas and administrative boundaries in identification

4.2.1 The process failed to resolve issues of cross-boundary identification. The western Downs PBA ended rather abruptly on the western administrative boundary. It is probable the 'real' area extended into the neighbouring counties. However, administrative realities mean that a PBA recognised to be such in West Sussex would maintain integrity easier than a cross-border area and will feature locally generated conservation targets.

As difficult as this was the issue of whether the eastern area was a large site or a PBA. As outlined above the eastern Downs featured a large extent of calcareous grassland, but, as far as the border with East Sussex, neither featured a significant mosaic of habitats, nor all the characteristic habitat types. Indeed, the nature of the habitat distribution suggested that, were the grassland sites consolidated, they would form one large grassland site. The correlation between species and habitat tetrad scores was not significant. One interpretation of this may be that many species are occurring in small isolated sites, or between sites, highlighting the isolation and fragmentation of

the landscape. As calcareous grassland is relatively hard to rehabilitate, the sites do not appear to add up to a PBA.

However, if equivalent data from East Sussex were available, it is possible that the opposite picture would emerge and that a mosaic is present, the network intimate and isolation minimal.

It should be recognised that if the present method were applied across county boundaries, it would face a number of problems. RSI and SOS data are consistent for West and East Sussex; but not for Hampshire, Surrey or Kent. The latter counties have different methods of identifying locally important conservation sites equivalent to SNCIs, while East Sussex's SNCI network is incomplete. Phase One maps outside West Sussex may have different habitat interpretations and be based on information from different times (as is the case with East Sussex). The number of management authorities for consultation would also increase and their targets may vary widely.

These problems (which could be alleviated by spending more time on the process) have to be balanced against the more realistic ecological patterns produced by crossing such non-ecological boundaries. It is not intended here to suggest that counties should always be considered as the area of search, but the present study does show the practical difficulties of using *any* administrative boundary as it is likely they would be encountered in any scale of study. Were a number of studies carried out in neighbouring counties following the same systematic method, it is probable such border issues could be resolved on a site-by-site basis.

Given the present criteria the danger remains that because the eastern area may not be a PBA, that no effort would be put into habitat enhancement there. The sites could still benefit from consolidation, even if they form one large contiguous site rather than a mosaic PBA.

4.2.2 A number of benefits were identified by using Natural Areas as a unit of search in the process:

1. Gamma-diversity was problematic to include within PBAs. In some instances it was an advantage to develop areas with many of the features that make up the entire landscape diversity of Sussex - associated with rivers, coastlines or areas where interesting ecotones are favoured. In other cases, however, involving this scale of diversity was a disadvantage as it removed a thematic or characteristic basis from individual PBAs. For example, instead of having a western Downs PBA with certain characteristic biodiversity, a section of Sussex could be chosen, containing even higher biodiversity with no thematic basis other than being a slice of Sussex. This would not aid the process of habitat enhancement as targets identified by conservation bodies have specific habitats in mind.
2. Using Natural Areas helped concentrate the PBA identification process as there were a limited number of habitat types and notable species to consider. However the scale of a Natural Area can make a sample of conservation priority species rather small, particularly as

such species have limited distributions.

3. Natural Areas formed the thematic and characteristic basis of PBAs.

Disbenefits of using Natural Areas were also identified:

1. Restricting PBAs to Natural Areas could exclude potentially highly diverse and biologically interesting ecotones in the transition zones between different Natural Areas, unless these are given special consideration.
2. Using Natural Areas led to the production of unrealistic boundaries between PBAs - such as that between the Arun valley and western Downs PBAs in the present study.
3. It remained difficult to integrate linear features, particularly rivers and coastlines.
4. Although it helped establish the scale of the identification process, it did not resolve the issue of how large a PBA should be.

On balance it was felt the advantages of Natural Areas outweighed the disadvantages. As long as the Natural Areas genuinely represented ecological distinctiveness, they were much more suitable as areas of search than administrative areas, at least in biological terms. Rivers and coastlines can be considered separately without serious difficulties. Given that natural Area borders are transitions or overlaps, key sites will be incorporated into the most appropriate area.

4.3 Use of measures

On the basis of the approaches taken to identifying the most useful biodiversity measures, the conclusion was that a range of measures were best for describing the different distributions of diversity at the tetrad scale. The high level of habitat specificity shown by different taxa can make interpretation of clusters problematic and so it would seem appropriate not to compile them into a single biodiversity score, but to assess the distribution taxon by taxon. However, few taxa have been systematically surveyed to a tetrad level and even those that have exhibit a strong collector effect.

It is recommended that the approach developed here be refined:

1. A more complete bird sample could be adopted. It should include wintering species and perhaps some indicator species (despite the qualifications to using indicators discussed above). This would make best use of the comprehensive data available.
2. Habitat extent could be assessed more accurately with exact areas rather than using categories. This process, however, would be time-consuming.
3. The RSI for flora proved useful. However, the sample was small and therefore reflected the collector effect quite strongly. Its main value, though, was that it was a systematic sample which could be applied equally to the whole of Sussex, East and West, containing the sorts of

species that form part of general conservation priorities. The elements of sampling bias it might contain were arguably no worse than any other sample would contain. It is possible that greater attention should be paid to local rarity in future analyses.

4. Fauna diversity should be assessed if possible. In Sussex few records were to a suitable scale and so the sample was too small to be practical. Other areas may have a more complete sample. This however, could lead to problems of habitat specificity distorting distribution patterns.

5. An assessment of taxonomic diversity may also prove instructive to the process. However, this would require academic research.

4.4 Use of method

It is notable that set against almost any measure or criterion the Arun valley proved to be highly biodiverse, with a high potential and would therefore always be considered a PBA. The other PBAs were less clear cut. This may in part be because the Downs retain a general high level of conservation interest and, to some extent at least, every part of the Downs offers some 'prime' elements of biodiversity even though one sector may not be as 'prime' as another. However it was considered that the analytical approach given in the present document helped present the nature of the diversity in the region and can form a useful platform from which to make judgements about PBAs.

The conclusions were not absolutely decisive and remain open to subjective interpretation. For that reason the goals and the criteria should be the variables that form the PBAs and their boundaries and therefore they should be explicit. A goal such as all characteristic habitats being contained, for example, can be highly influential. Using summation methods the clusters were hard to interpret definitively; the western side of the Downs had greater habitat extent, the eastern half was more important for birds while both the Arun and Adur had consistent high scores. This may be because the Downs retains a general high level of interest which means the whole ESA should be a PBA to include the bird and habitat interests.

One way through might be to set criteria for statistical levels of diversity (Whittaker, 1977) or statistical proportions of conservation priority or habitat to be included. Either way it is likely that it is not sufficient to identify PBAs at this scale simply by looking for species richness clusters. This approach, plus a mapping approach to identify the networks of habitats should be used to inform the PBA criteria appraisal by identifying possible PBAs to be tested for criteria compliance.

The boundaries presented for each PBA are designed to be flexible and to allow for considerable change when agricultural, land ownership, administrative or other practical issues are considered. The subsequent stage would be able to make full use of the computerised data and digitised ESD

information. The present method is intended to provide a systematic, practical method for suitable, and biologically justified PBAs, which would then be subject to pragmatic consideration and consultation before being adopted, but which are not solely opportunistically derived. It is likely, however, they would have an important role in Biodiversity Action Plans and in offering directions for conservation targeting.

As they stand, some of the PBAs presented are more ambitious than others. For example the Arun valley PBA boundary has potential for outward expansion. The western Downs PBA boundary, however, would encapsulate a more ambitious rehabilitation programme as it encloses a larger area and includes significant gaps between habitat patches. Such issues might be addressed during a consultation exercise and when deciding who will enact the enhancement necessary. In addition allowance in boundaries, which are inherently artificial, should be made for natural processes.

4.5 Recommendations

1. It is recommended that the approach be extended to the whole of West Sussex in order to assess the level of gamma-diversity and to compare all areas against comparable parameters. The present analysis is incomplete in that criteria need to be tested in more than one Natural Area and in areas with more or less obvious networks. It would also be valuable to examine the entire extent of the valley PBAs identified in the present project.

2. The consolidation ranges given in the present study were presented as a starting point for further evaluation. It is suggested that if the range idea is taken further, more readily justifiable ranges be investigated.

3. Agricultural use in potential PBAs could also be assessed. The extent of set-aside or redundant agricultural land in a Natural Area could have implications for its designation. Soil grades could also be important. If land has only recently been cultivated, it would have a better chance of containing a near-natural seed bank. If land is low grade, it would be more justifiable to encourage it out of production.

4. The implications of identifying PBAs also need to be assessed in terms of agri-environment support for landowners and the attitudes of landowners in potential PBAs need to be identified.

5. A useful background element for the project was the designated sites network. It would be more difficult to perform this analysis in counties without a SNCI network. Consequently the sites of local importance would need to be assessed in advance. It is recommended this be progressed in East Sussex.

6. The RSI proved a valuable data source. It is recommended that its completion be brought forward to inform the PBA identification process.

7. The next phase of assessment should be tested. It would be valuable to consider the consultation processes needed, the approaches to land ownership and to identify whether key species are inside or outside conservation sites. The exact management boundaries could be identified with such assessments and it would be useful to digitise the results .

8. A complementary hot-spots analysis, perhaps using WORLDMAP could be attempted in West Sussex to compare with the present approach.

9. Future discussion of PBAs could focus on the size issue; seeking a minimum size for a self-sustaining area scale ecological unit. 10,000ha is suggested as a possible size.

10. A similar analysis should be attempted that crosses county boundaries to find to what extent they act as a constraint.

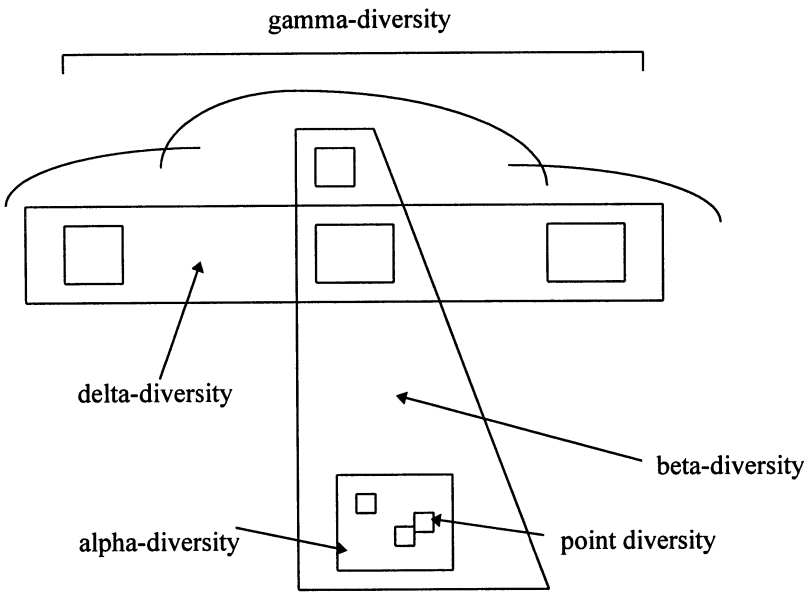

Figure 1.3.1: Adapted from McNaughton (1994). Alpha-diversity represents diversity in a local vegetation community, beta-diversity the differentiation of communities along a gradient, delta-diversity represents habitats in similar landscapes (in this study this is given at a scale of a Natural Area) and gamma-diversity is the inclusive diversity of a region (in this study this is defined as Sussex). Diversity is a measure of the difference of its elements, so gamma-diversity is identified as the difference between Natural Areas inclusive of Sussex as a regional unit.

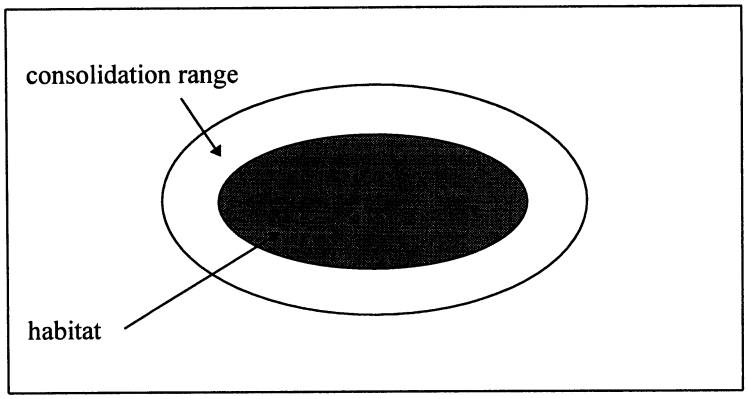

Figure 1.7.1a: A habitat patch with its consolidation range.

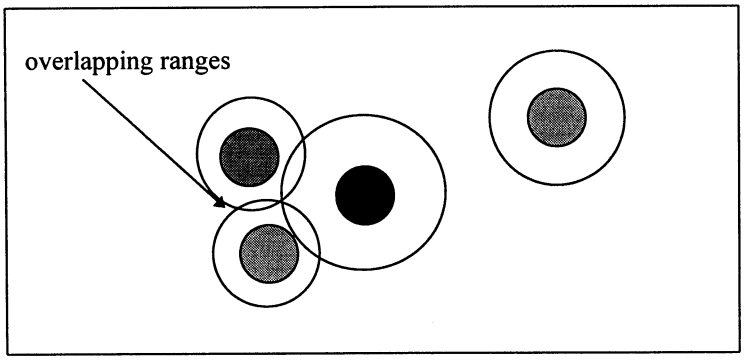

Figure 1.7.1b: Overlapping consolidation ranges resulting in three habitat patches consolidating into an area. The fourth patch is too distant to make in-filling practical and therefore falls outside the area and remains a site. Note the different ranges for different habitat types.

Table 2.2.1: Categories of cover of semi-natural habitat.

Category	% cover
1	0-20
2	21-40
3	41-60
4	61-80
5	81-100

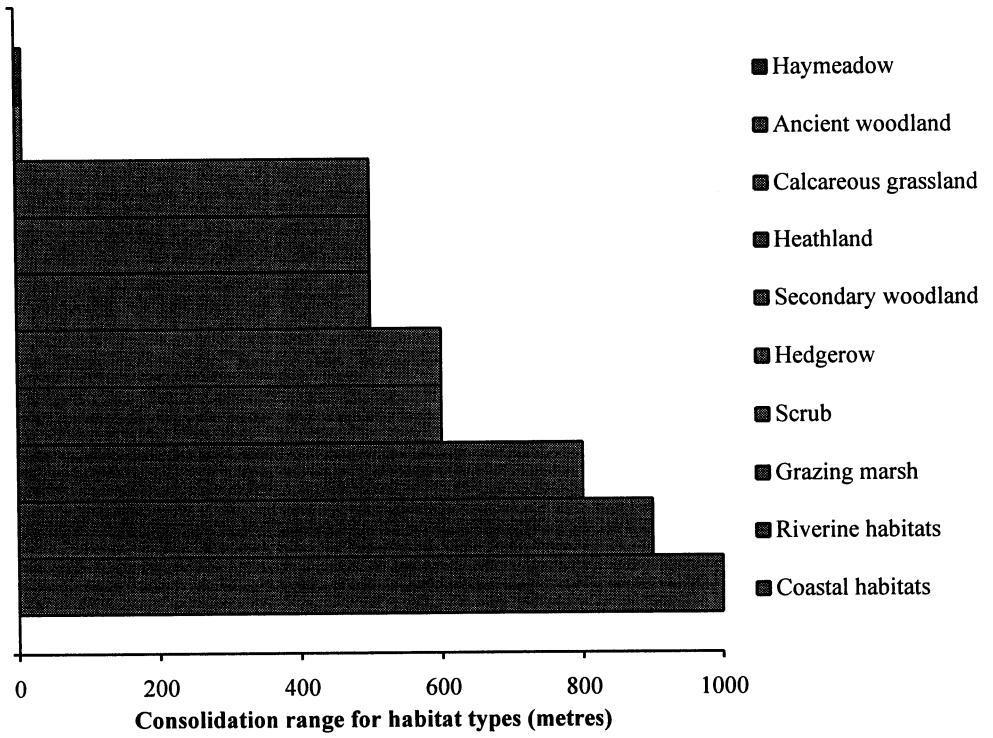

Figure 2.3.1: The consolidation range of different habitat types represents the distance from an existing high conservation interest site that could be enhanced, in-filled or rehabilitated with intermediate interest habitat. If two sites have an overlapping consolidation range, they could be considered part of the same network (see text for more details).

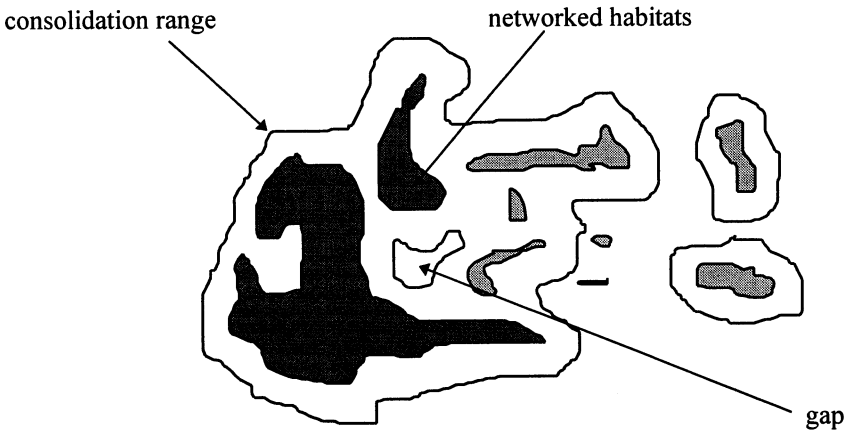

Fig 2.4.1a: A consolidation range analysis indicating the habitats that form part of a network. Note the two small sites excluded from the analysis and the two larger sites too distant to be included as part of the network of five sites. Also note the 'gap' in the middle which contains land ostensibly too distant to be part of the same network, even though it is at the centre of that network.

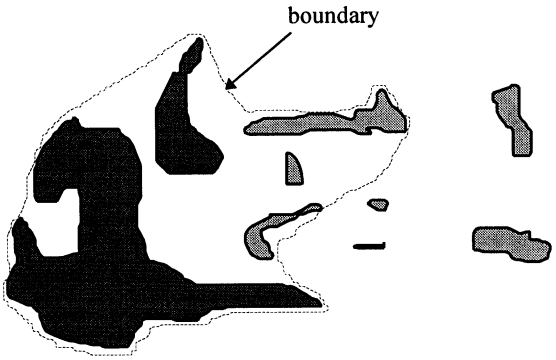

Fig 2.4.1b: The PBA consists of the patches identified to form part of the network, with the consolidation range of the 'outside' edge contracted to the outside edge of border sites. The boundary of the potential PBA is indicated here with a rough dashed-line. Note that now the whole area within the PBA is considered part of the PBA, even the section identified above which was considered a gap. Also note that the edge effect is minimised by rounding the patches to reduce site inclusive fragmentation.

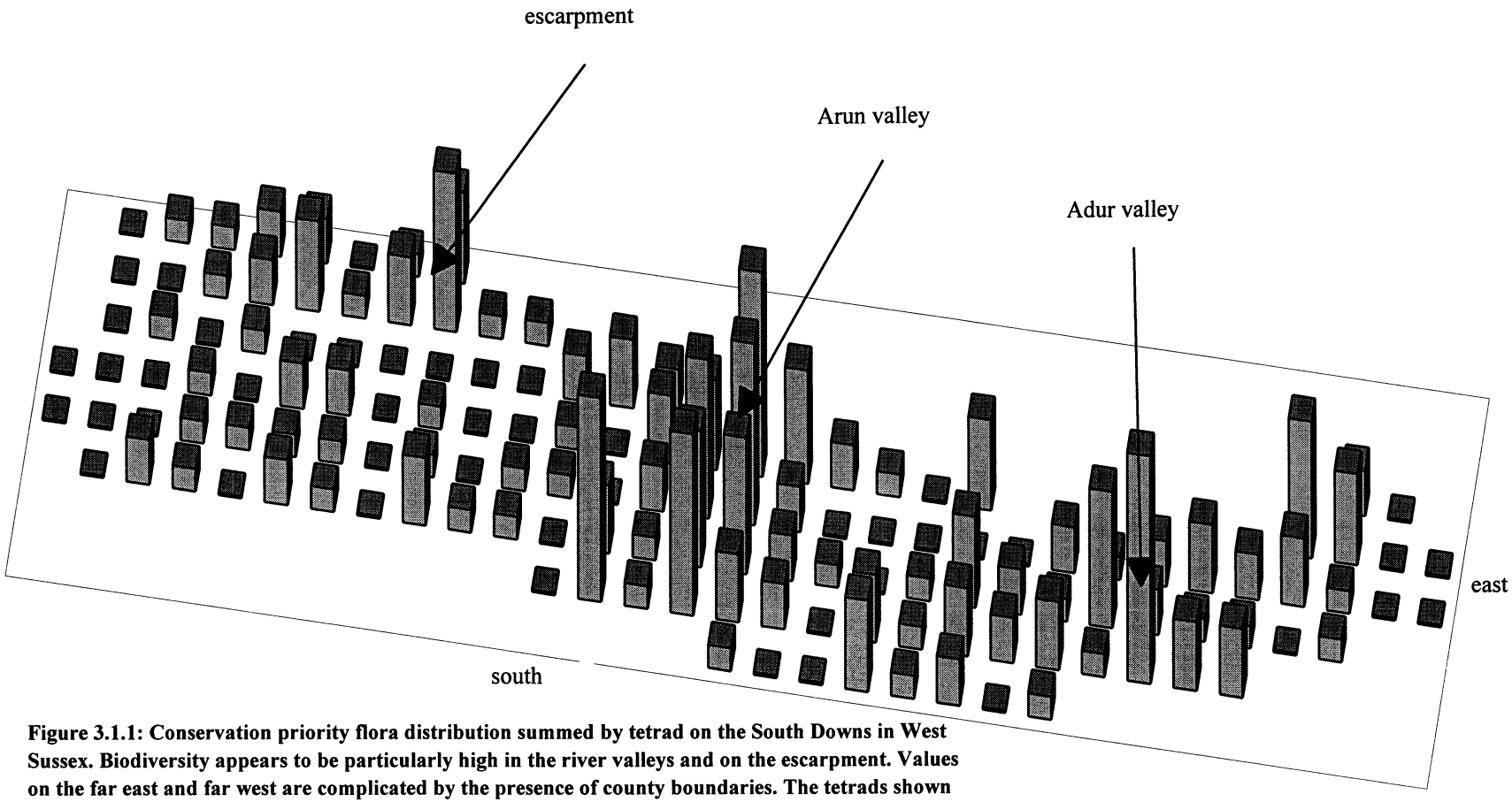

Figure 3.1.1: Conservation priority flora distribution summed by tetrad on the South Downs in West Sussex. Biodiversity appears to be particularly high in the river valleys and on the escarpment. Values on the far east and far west are complicated by the presence of county boundaries. The tetrads shown are those in the area of search only.

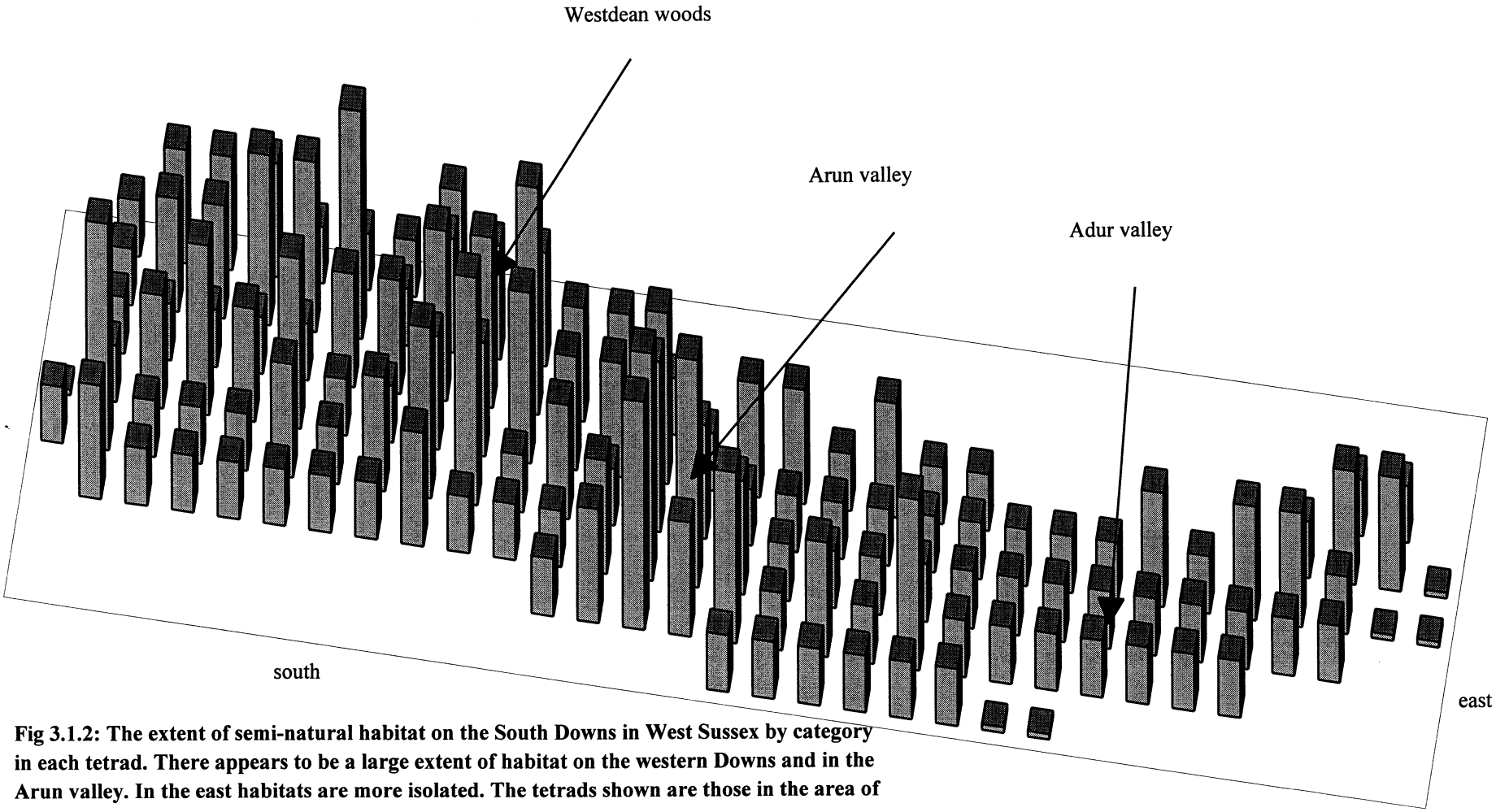

Fig 3.1.2: The extent of semi-natural habitat on the South Downs in West Sussex by category in each tetrad. There appears to be a large extent of habitat on the western Downs and in the Arun valley. In the east habitats are more isolated. The tetrads shown are those in the area of search only.

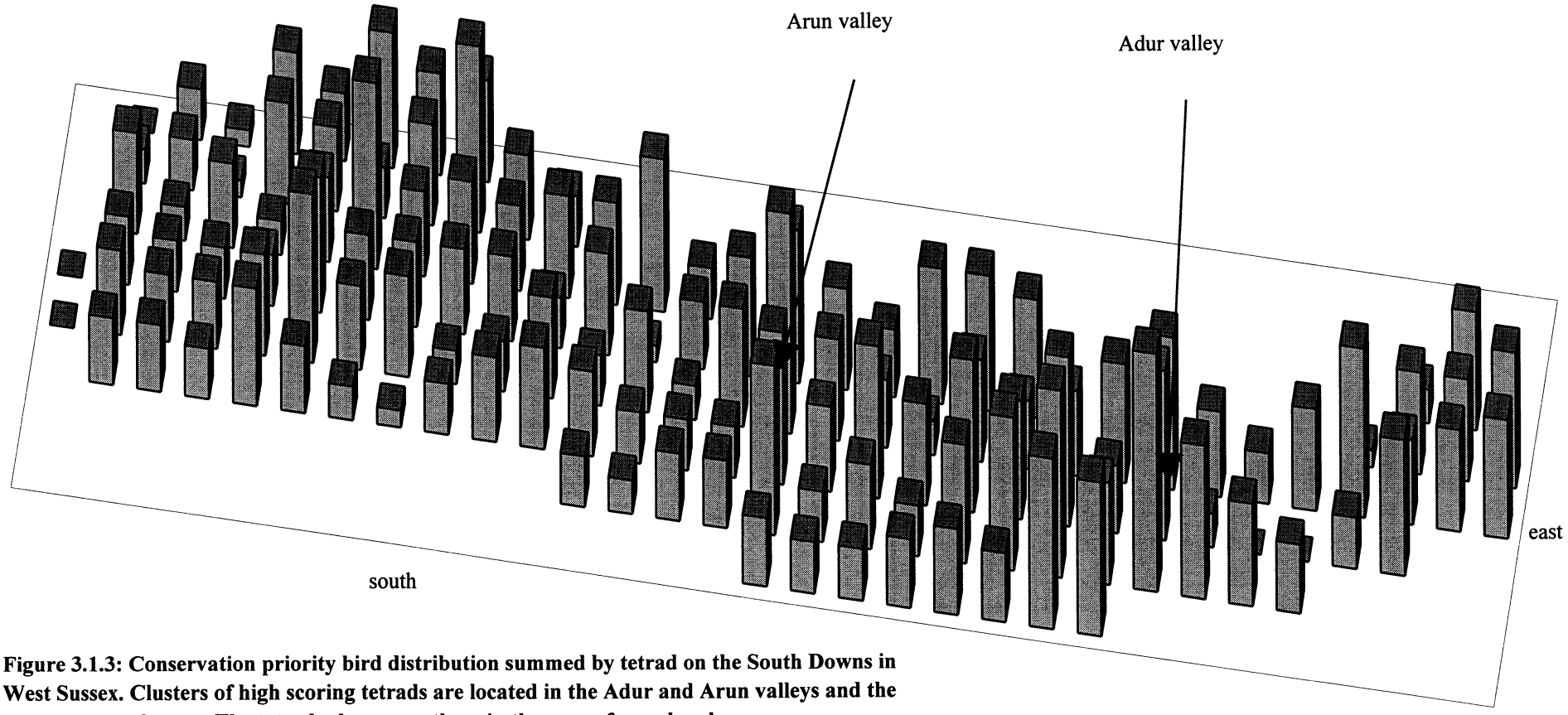

Figure 3.1.3: Conservation priority bird distribution summed by tetrad on the South Downs in West Sussex. Clusters of high scoring tetrads are located in the Adur and Arun valleys and the area between the two. The tetrads shown are those in the area of search only.

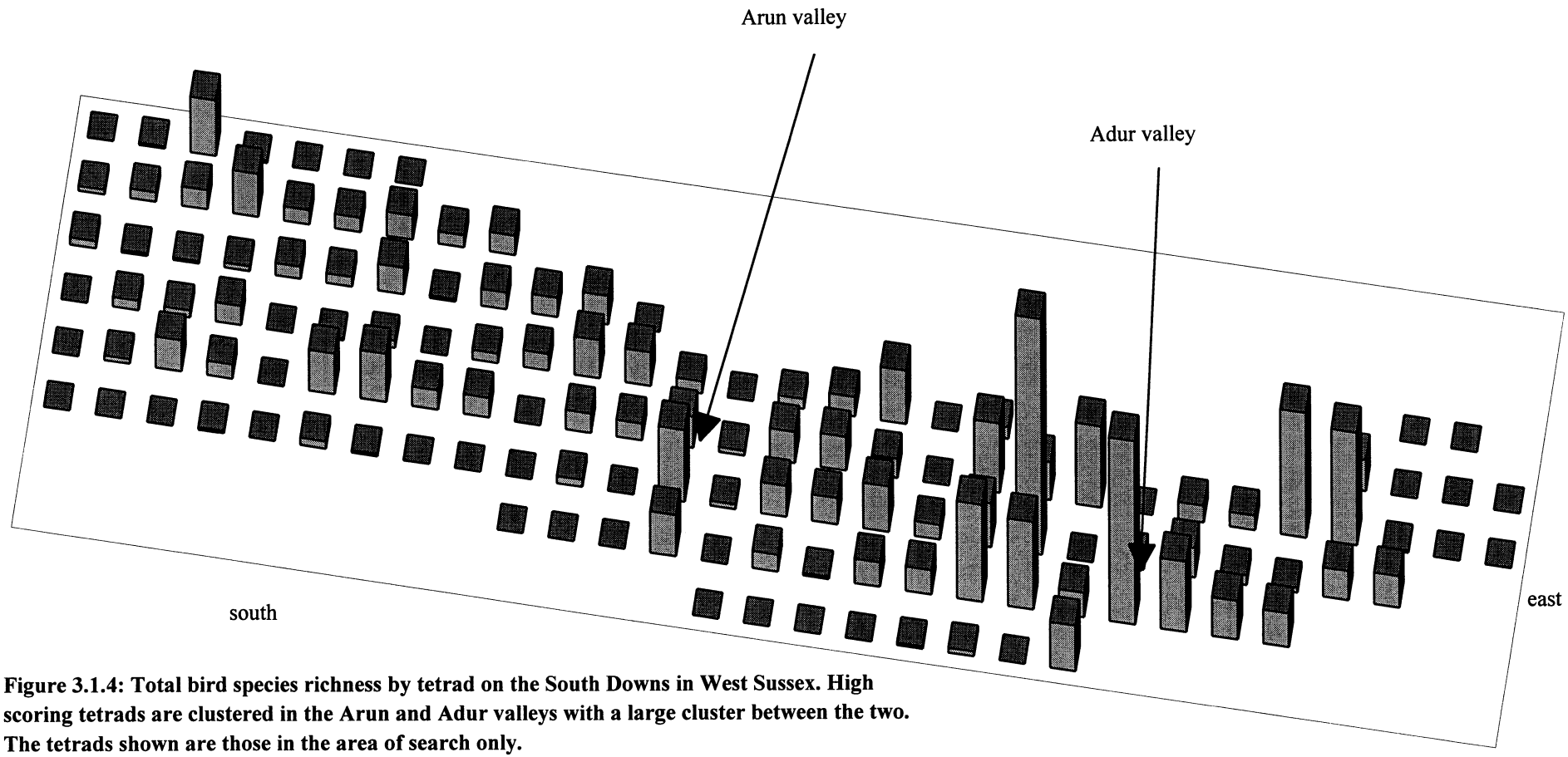

Figure 3.1.4: Total bird species richness by tetrad on the South Downs in West Sussex. High scoring tetrads are clustered in the Arun and Adur valleys with a large cluster between the two. The tetrads shown are those in the area of search only.

Table 3.3.1: Compliance of potential PBAs with criteria.

Criteria	Potential PBAs Alternative 1				Alternative 2	
	Arun valley	Western Downs	Adur valley	Eastern escarpment	Arun	Adur
Extent	***	***	X	*	***	*
Ecological unit	**	***	**	*	***	**
Thematic structure	***	**	***	**	X	X
Large enough for targets	**	***	**	X	**	*
Priority species richness	***	*	***	*	***	***
Diversity	***	**	**	*	***	**
Characteristic habitat types	*	**	*	X	*	*
Potential	***	***	***	X	***	*
Mosaic and ecotones	***	*	*	X	***	X
Specially adapted habitats	X	***	X	**	X	**
Validity within West Sussex	***	**	***	X	***	**
Validity within Natural Area	-	***	-	X	X	*
Achievement within timescale	***	**	***	*	***	**
Area has targets	***	**	***	*	***	***
Conservation priority habitats	*	**	*	**	*	*
Benefit from sustainable use	**	**	**	***	**	***
Under threat	X	*	X	*	X	X

Key: *** (high compliance)
** (intermediate)
* (low, but significant)
X (no significant compliance)

Glossary

Alpha-diversity - diversity in a local vegetation community and simple species richness.

AONB - Area of Outstanding Natural Beauty. National landscape designation for an area deserving protection from over-development.

AWI - Ancient Woodland Inventory.

Beta-diversity - differentiation of communities along a gradient.

Biodiversity - biological diversity; the variety of nature.

Biodiversity measures - the element of biodiversity that is being assessed. For example, a taxon such as birds, habitat extent, or taxonomic diversity.

BTO - British Trust for Ornithology.

Calcareous grassland - grassland on chalky, nutrient poor soils.

Centre of Diversity - WWF/IUCN version of PBA.

Delta-diversity - diversity of habitats in similar landscapes (given here as a Natural Area).

EBA - Endemic Bird Area. Based on delimited distributions for birds.

Edaphic - physical and biological soil conditions.

EN - English Nature.

ESA - Environmentally Sensitive Area. National agricultural designation. An area where farmers are rewarded for farming in an environmentally sensitive manner.

ESD - Environmental Survey Directory. A directory of all environmental surveys in Sussex with details of the location of information.

Gamma-diversity - regional diversity. Usually this represents very large scale diversity. However, it is used here in a scaled-down sense to represent the landscape diversity within a region, Sussex.

HBA - High Biodiversity Area. Administrative area based approach developed for Mendip District (Butcher *et al*, 1995).

Hot-spots - the map squares (typically at 10km scale) with the top five per cent of scores according to sums of various biodiversity measures.

ITE - Institute of Terrestrial Ecology.

***k*-Landscapes** - these are landscapes, typically spurs, which favour *k*-selected species and that would take a long time to 'recover' from disturbance as change is, generally, slow. Disturbance dynamics would be less regular and the sort of species encouraged that are long-lived and slow colonisers.

Natural Area - biogeographic zones which reflect the geological foundation, the natural systems and processes and the wildlife in different parts of England and provide a framework for setting objectives for nature conservation..

PBA - Prime Biodiversity Area.

Phase One - basic habitat assessment on maps, often using remote sensing techniques.

***r*-Landscapes** - typically landscapes that feature regular disturbance, such as flooding, and which favour short-lived species and quick colonisers. These landscapes would relax to equilibrium quickly and exhibit rapid change. As a result of the turnover of habitat structure, they can achieve a 'natural' structure more readily than a *k*-Landscape.

RDB - Red Data Book. IUCN list of endangered, threatened and vulnerable species.

SDCB - Sussex Downs Conservation Board. Dedicated management authority for the South Downs AONB, mandated by constituent county and district authorities.

SNCI - Site of Nature Conservation Interest. County scale non-statutory designation.

SOS - Sussex Ornithological Society.

Species richness - a count of the number of species present.

SSSI - Site of Special Scientific Interest. National statutory designation.

Taxonomic diversity - the differentness of species according to the topology of a hierarchical classification. Some species are more related to each other than to others. The more different those relationships, the more biodiverse. Furthermore, some species have few close relatives and therefore contribute more to biodiversity by being more distinct.

Tetrad - 2km by 2km map square. There are 25 in a 10km square.

WSCC - West Sussex County Council.

Appendix 1

DoE, 1994a, p76:

Prime biodivesity areas within natural areas

Much can be achieved by initially concentrating effort in a few locations where there are local concentrations of special sites and other areas of high biological interest. Where there is potential to manage clusters of the best areas and the land between them in away [sic] which sustains or enhances the contained biodiversity, large areas of good habitat can be created. Prime biodiversity areas are places within Natural Areas where the current state of the nature conservation resource reflects the overall character best and offers the greatest potential for full restoration of the character of the Natural Area. The characteristic wildlife of the natural area within which they fall will set the standard of biological diversity expected. Natural or semi-natural ecosystems with inherently low species richness still make an important contribution to the UK's total biodiversity as they may contain species not found elsewhere.

Such areas can be identified as part of the characterisation of the current state of the wildlife resource within Natural Areas. They are not a designation and precise boundaries are not necessary; in any case, opportunities for expansion may present themselves later.

There are a number of large areas which would qualify, for example the North Norfolk Coast, the Suffolk coast from Southwold to Felixtowe areas, the New Forest, Dorset heaths and significant parts of the various ESAs in existence, to mention just a few. Others are less obvious and may occupy as little as one 10km square or less. To locate these areas a variety of methods can be used and the results compared or superimposed.

References

Biodiversity Steering Group. (1995). *Biodiversity: The UK Steering Group Report.* HMSO, London.

Bisby, F. A. (1995). Characterization of biodiversity. In Heywood, V. H. and Watson, R. T. (eds). *Global Biodiversity Assessment.* Cambridge University Press, Cambridge, 20-106.

Briggs, M. (1990). *Sussex Plant Atlas Selected Supplement.* Sussex Botanical Recording Society and Brighton Borough Council, Booth Museum of Natural History, Brighton.

Buckley, G. (ed). (1989). *Biological Habitat Reconstruction.* Belhaven Press, London.

Butcher, W., Rowe, A. and Cloughley, P. (1995). *Mendip Biodiversity Action Plan.* Somerset Environmental Records Centre, Somerset.

Costanza, R., Norton, B. G. and Haskell, B. D. (eds). (1992). *Ecosystem Health: New Goals for Environmental Management.* Island Press, Washington DC.

Davis, S. D., Heywood, V. H. and Hamilton, A. C. (eds). (1994-5). *Centres of Plant Diversity: A Strategy for their Conservation. Vol 1. Europe, Africa, South West Asia and the Middle East; Vol 2. Asia, Australia and the Pacific; Vol 3. The Americas.* WWF and IUCN, IUCN Publications Unit, Cambridge.

Department of the Environment. (DoE). (1994a). *Biodiversity: The UK Action Plan.* HMSO, London.

Department of the Environment. (DoE). (1994b). *Planning Policy Guidance: Nature Conservation (PPG 9).* HMSO, London.

Department of the Environment. (1995). *The Rural White Paper.* HMSO, London.

Environmental Resources Management. (1995). Environmental Capital for the Countryside: Final Report. Countryside Commission, London.

Forey, P. L., Humphries, C. J. and Vane-Wright, R. I. (eds). (1994). *Systematics and Conservation Evaluation. The Systematics Association Special Volume No. 50.* Clarendon Press, Oxford.

Francis, J. *et al.* (1992). The establishment of ground flora species in recently planted woodland. *Aspects of Applied Biology*, **29**, 171-78.

Gaston, K. J. and Blackburn, T. M. (1995). Mapping biodiversity using surrogates for species richness: macro-scales and New World birds. *Proceedings of the Royal Society (London)*, **262**, 335-41.

Gaston, K. J. and Williams, P. H. (1993). Mapping the World's species - the higher taxon approach. *Biodiversity Letters*, **1**, 2-8.

Gitay, H., Wilson, J. B. and Lee, W. G. (1996). Species redundancy: a redundant concept? *Journal of Ecology*, **8**, 121-124.

Goldsmith, F. B. (1983). Evaluating nature. In Warren, A. and Goldsmith, F. B. (eds). *Conservation in Perspective.* John Wiley and Sons, Chichester, 233-246.

Goldsmith, F. B. (1991). *Monitoring for Conservation and Ecology.* Chapman & Hall, London.

Gowing, D. G. J., Morris, J., Spoor, G. and Dunderdale, J. A. L. (1994). Reconciling water regime requirements for environmental and agricultural management. In Kirby, C. and White, W. R. (eds). *Integrated River Basin Development.* John Wiley, Chichester, 475-83.

Hall, P. C. (1980). *Sussex Plant Atlas.* Sussex Botanical Recording Society and Brighton Borough Council, Booth Museum of Natural History, Brighton.

Hawksworth, D. L. and Kalin-Arroyo, M. T. (1995). Magnitude and distribution of biodiversity. In Heywood, V. H. and Watson, R. T. (eds). *Global Biodiversity Assessment.* Cambridge University Press, Cambridge, 107-191.

Heywood, V. H. (1994). The measurement of biodiversity and the politics of implementation. In Forey, P. L., Humphries, C. J. and Vane-Wright, R. I. (eds). (1994). *Systematics and Conservation Evaluation. The Systematics Association Special Volume No. 50.* Clarendon Press, Oxford, 15-22.

Kershaw, M., Mace, G. M. and Williams, P. H. (1995). Threatened states, rarity and diversity as alternative selection measures for protected areas: a test using Afrotropical antelopes. *Conservation Biology*, **9(2)**, 324-34.

Kirby, K. (1995). *Rebuilding the English Countryside: Habitat Fragmentation and Wildlife Corridors as Issues in Practical Conservation. English Nature Science No. 10.* English Nature, Peterborough.

Lawton, J. H., Prendergast, J. R. and Eversham, B. C. (1994). The numbers and spatial distributions of species: analysis of British data. In Forey, P. L., Humphries, C. J. and Vane-

Wright, R. I. (eds). (1994). *Systematics and Conservation Evaluation. The Systematics Association Special Volume No. 50.* Clarendon Press, Oxford, 177-95.

Magurran, A. E. (1988). *Ecological Diversity and its Measurement.* Croom Helm, London.

Margules, C. (1980). *A Study of the Assessment of Potential Conservation Sites.* Department of Biology, University of York.

McNaughton, S. J. (1994). Conservation goals and the configuration of biodiversity. In Forey, P. L., Humphries, C. J. and Vane-Wright, R. I. (eds). (1994). *Systematics and Conservation Evaluation. The Systematics Association Special Volume No. 50.* Clarendon Press, Oxford, 41-62.

Morris, C. and Potter, C. (1995). Recruiting the new conservationists: farmers' adoption of agri-environmental schemes in the UK. *Journal of Rural Studies*, **11(1),** 51-63.

Nature Conservancy Council (NCC). (1990). *Handbook for Phase 1 Habitat Survey - A Technique for Environmental Audit.* England Field Unit, JNCC, Peterborough.

Norton, B. G. (1994). On what we should save: the role of culture in determining conservation targets. In Forey, P. L., Humphries, C. J. and Vane-Wright, R. I. (eds). (1994). *Systematics and Conservation Evaluation. The Systematics Association Special Volume No. 50.* Clarendon Press, Oxford, 23-9.

Norton, B. G. and Ulanowicz, R. E. (1992). Scale and biodiversity policy: a hierarchical approach. *Ambio*, **21**, 244-49.

Noss, R. F. (1990). Can we maintain biological and ecological integrity? *Conservation Biology*, **4**, 241-4.

Peterken, G. F. (1974). A method for assessing woodland flora for conservation using indicator species. *Biological Conservation*, **6**, 239-45.

Peterken, G. (1993a). Long term floristic development of woodland on former agricultural land in Lincolnshire. In Watkins, C. (ed). *Ecological Effects of Afforestation.* C. A. B. International, Wallingford, 31-44.

Peterken, G. (1993b). *Woodland Conservation and Management, Second Edition.* Chapman and Hall, London.

Peterken, G., and Game, M. (1984). Historical factors affecting the number and distribution of vascular plant species in the woodlands of central Lincolnshire. *Journal of Ecology*, **72**, 155-82.

Phillips, M. R. (1994). *A Natural Area in Sussex: Structure and Value.* Ecology and Conservation Unit, University College London, London.

Prendergast, J. R. and Eversham, B. C. (1995). Butterfly diversity in southern Britain: hotspot losses since 1930. *Biological Conservation*, **72**, 109-114.

Prendergast, J. R., Quinn, R. M., Lawton, J. H., Eversham, B. C. and Gibbons, D. W. (1993). Rare species, the coincidence of diversity hotspots and conservation strategies. *Nature (London)*, **365**, 335-37.

Prendergast, J. R., Wood, S. N., Lawton, J. H. and Eversham, B. C. (1993). Correcting for variation in recording effort in analyses of diversity hotspots. *Biodiversity Letters*, **1**, 39-53.

Pressey, R. L., Humphries, C. J., Margules, C. R., Vane-Wright, R. I. and Williams, P. H. (1993). Beyond opportunism: key principles for systematic reserve selection. *Trends in Ecology and Evolution*, **8**, 124-28.

Rabinowitz, D., Cairns, S. V. and Dillon, T. (1986). Seven forms of rarity and their frequency in the flora of the British Isles. In Soulé, M. E. (ed). *Conservation Biology, the Science of Scarcity and Diversity.* Sinauer, Sunderland MA, 182-204.

Rapoport, E. H., Borioli, G., Moneau, J. A., Puntieri, J. E. and Oviedo, R. D. (1986). The design of nature reserves: a simulation trial for assessing specific conservation value. *Biological Conservation*, **37**, 269-90.

Ratcliffe, D. A. (ed). (1977). *A Nature Conservation Review.* NCC, Peterborough.

Rebelo, A. G. (1994). Using the Proteaceae to design a nature reserve network and determine conservation priorities for the Cape Floristic Region. In Forey, P. L., Humphries, C. J. and Vane-Wright, R. I. (eds). (1994). *Systematics and Conservation Evaluation. The Systematics Association Special Volume No. 50.* Clarendon Press, Oxford, 375-96.

Reid, W. V. (1994). Setting objectives for conservation evaluation. In Forey, P. L., Humphries, C. J. and Vane-Wright, R. I. (eds). (1994). *Systematics and Conservation Evaluation. The Systematics Association Special Volume No. 50.* Clarendon Press, Oxford, 1-13.

Rose, F., Stern, R. C., Matcham, H. W. and Coppins, B. J. (1991*). Atlas of Sussex Mosses,*

Liverworts and Lichens. Brighton Borough Council Booth Museum of Natural History, Brighton.

Sharrock, J. T. R. (1977). *The Atlas of Breeding Birds in Britain and Ireland.* Poyser, Berkhamstead.

Stewart, A., Pearman, D. A. and Preston, C. D. (1995). *Scarce Plants in Britain.* JNCC, Peterborough.

Sussex Downs Conservation Board. (1995). *A Management Strategy for the Sussex Downs Area of Outstanding Natural Beauty.* SDCB, Lewes.

Sussex Wildlife Trust. (1996). *A Vision for the Wildlife of Sussex*. Sussex Wildlife Trust, Henfield.

Thirgood, S. J. and Heath, M. F. (1994). Global patterns of endemism and the conservation of biodiversity. In Forey, P. L., Humphries, C. J. and Vane-Wright, R. I. (eds). (1994). *Systematics and Conservation Evaluation. The Systematics Association Special Volume No. 50*. Clarendon Press, Oxford, 207-27.

Turpie, J. K. (1995). Prioritizing South African estuaries for conservation: a practical example using waterbirds. *Biological Conservation*, **74**, 175-85.

Usher, M. *et al.* (1992). Plant species richness in farm woodlands. *Forestry*, **65**, 1-13.

Vane-Wright, R. I., Smith, C. R. and Kitching, I. J. (1994). Systematic assessment of taxic diversity by summation. In Forey, P. L., Humphries, C. J. and Vane-Wright, R. I. (Eds). (1994). *Systematics and Conservation Evaluation. The Systematics Association Special Volume No. 50*. Clarendon Press, Oxford, 309-26.

Van Wieren, S. (1989). The management of populations of large mammals. In Spellerberg, I., Goldsmith, F. B. and Morris, M. (eds). *The Scientific Management of Temperate Communities for Conservation. British Ecological Society Symposium 31*. Blackwell Scientific Publications, Oxford, 103-127.

Walker, B. H. (1992). Biodiversity and ecological redundancy. *Conservation Biology*, **6**, 18-23.

Warren, A. (1993). Naturalness: a geomorphological approach. In Goldsmith, F. B. and Warren, A. (eds). *Conservation in Progress*. John Wiley and Sons, Chichester.

Warren, A. (1983). Conservation and the land. In Goldsmith, F. B. and Warren, A. (eds). *Conservation in Perspective*. John Wiley and Sons, Chichester, 19-41.

West Sussex County Council. (In prep.). *West Sussex Environmental Capacity Study: Charting Environmental Change*. WSCC, Chichester.

Whittaker, R. H. (1977). Evolution of species diversity in land communities. *Evolutionary Biology*, **10**, 1-67.

Williams, P. H., Gibbons, D., Margules, C. R., Rebelo, A. G., Humphries, C. J. and Pressey, R. I. (in press). A comparison of richness hotspots, rarity hotspots, and complementary areas for conserving diversity using British birds. *Conservation Biology*.

Williams, P. H., Humphries, C. J. and Vane-Wright, R. I. (1991). Measuring biodiversity: taxonomic relatedness for conservation priorities. *Australian Systematic Botany*, **4**, 665-79.

Williams, R. (ed). (1993). *A Vision for the South Downs*. Sussex Wildlife Trust, Henfield.

Maps

The following maps are photocopies of full-colour Phase One habitat maps produced by WSCC. They are presented as guidance to the boundaries of the consolidation range and PBAs identified. They intentionally do not attempt to produce final detailed boundaries as maximum flexibility of interpretation would be desirable in the management and planning phase of PBA identification, It is suggested this phase would draw boundaries close to those presented here, but based on other practical considerations such as land ownership, field boundaries, built development and so on.

A key is not presented as some of the habitat types are identified by colour as well as pattern, and therefore appear the same in black and white. However, all the habitat types present are either in conservation priority sites such as SNCIs and SSSIs, or are characteristic of Downland. Artificial habitats (such as conifer plantations) arable land, amenity grassland and improved grassland) are excluded. Consequently all the habitat types shown can be taken to be of conservation priority.

Habitats included on the original map were: all ancient woodland; broad-leaved semi-natural woodland, scrub dense/continuous, scrub scattered, acid grassland unimproved, acid grassland semi-improved, neutral grassland unimproved, neutral grassland semi-improved, calcareous grassland unimproved, calcareous grassland semi-improved, marsh/marshy grassland, tall herb and fern - bracken, tall herb and fern - other, dry dwarf shrub heath (acid), dry dwarf shrub heath (basic), dry heath/acid grassland mosaic, mire or fen, swamp, swamp marginal, swamp inundation, open water - standing, open water - running, intertidal mud/sand, intertidal shingle/cobbles, intertidal green algal beds, saltmarsh dune/interface, saltmarsh scattered plants, saltmarsh dense/continuous, shingle above high tide mark, sand dune - dune slack, sand dune - dune grassland, sand dune - dune scrub and sand dune - open dune.

On all maps the consolidation range is represented by an unbroken black line and the border of a PBA by a dashed line. The straight lines are the borders of the area of search (judged by tetrad). Note that four grid squares on these maps constitute a tetrad.

The maps are:

Map 1: Consolidation range analysis for the Arun valley and part of the western Downs areas.

Map 2: Arun valley PBA.

Map 3: Consolidation range analysis for the western part of the western Downs. Note that the western edge is the county boundary and therefore not biologically derived.

Map 4a: Western part of the West Downs PBA.

Map 4b: Eastern part of West Downs PBA.

Map 5: Consolidation range analysis for the Adur valley area.

Map 6: Adur valley PBA

Map 7: Alternative 2 Arun valley PBA.

The location of PBAs identified in this report (ie within the South Downs Natural Area

scale - approx 1: 300,000