THE APPLICATION OF REMOTE SENSING TO THE MANAGEMENT OF URBAN WILDLIFE HABITATS

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SUMMARY

The project set out with two main aims. The first aim was to determine whether large scale multispectral aerial photography could be used to successfully survey and monitor urban wildlife habitats.

The second objective was to investigate whether this data source could be used to predict population numbers of selected species expected to be found in a particular habitat type.

Panchromatic, colour and colour infra-red, 1:2500 scale aerial photographs, taken in 1981 and 1984, were used.

For the orderly extraction of information from the imagery, an urban wildlife habitat classification was devised. This was based on classifications already in use in urban environments by the Nature Conservancy Council. Pilot tests identified that the colour infra-red imagery provided the most accurate results about urban wildlife habitats in the study area of the Blackbrook Valley, Dudley. Both the 1981 and 1984 colour infra-red photographs were analysed and information was obtained about the type, extent and distribution of habitats.

In order to investigate whether large scale aerial photographs could be used to predict likely animal population numbers in urban environments, it was decided to limit the investigation to the possible prediction of bird population numbers in Saltwells Local Nature Reserve. A good deal of research has already been completed into the development of models to predict breeding bird population numbers in woodland habitats. These models were analysed to determine whether they could be used successfully with data extracted from the aerial photographs.

The projects concluded that 1:2500 scale colour infra-red photographs can provide very useful and very detailed information about the wildlife habitats in an urban area. Such imagery can also provide habitat area data to be used with population predictive models of woodland breeding birds. Using the aerial photographs, further investigations into the relationship between area of habitat and the breeding of individual bird species were inconclusive and need further research.

Key Phrases: multispectral aerial photography
urban wildlife habitats
bird population prediction

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CHAPTER ONE

THE INTRODUCTION

1.1 Introduction

In the past, before the 1970's, urban green spaces had been disregarded by conservationists and ecologists. The plant species which survived in these environments were not believed to be of any great interest. In recent years there has been a change in attitudes and a number of studies have been conducted in urban areas to determine what plant and animal communities live in such environments (Sukopp and Werner, 1982). Research has identified two major types of urban habitat; areas of relict semi-natural habitat and habitats which have developed as a direct result of man's activities. Both are valued by urban conservationists.

The traditional emphasis of conservation; that is, to protect and manage rare habitats or species, is not as evident in urban conservation. As towns and cities are very dynamic environments, urban ecologists attempt to identify and protect areas of representative habitats as well as rare habitats. The aim is to increase the diversity of habitats found in urban areas. Urban habitat diversity is acheived and/or maintained by protecting valuable 'rare' wildlife sites, protecting areas of representative habitats and by creating new habitats in suitable locations such as areas devoid of green space.

Many of the wildlife habitats found in urban areas are the result of accident rather than design. On sites which have not been developed for some reason or another, complex plant communities have been allowed to evolve without much interference. There are however, increasing pressures on local authorities to convert unused land in urban areas to what is generally perceived as a more productive land use, such as for industry or housing. Therefore, the development and existence of isolated wildlife habitats in cities should not be left to chance any longer but should be actively encouraged and managed.

There is evidence to suggest that planning bodies are beginning to consider green areas in urban environments as being as important as other land uses which can be monetarily valued. The need for the creation and/or maintenance of urban wildlife habitats is increasingly being included in urban structure plans. The West Midlands County Council is only one example of an authority which has published a strategy for nature conservation (West Midlands County Council, 1984). In this report, the council stressed the need for a more positive approach to habitat maintenance and creation by all bodies working in the environment.

This change of attitude in favour of urban nature conservation is partly the result of the increasing amount of evidence available indicating that plant and animal species which were traditionally found in rural environments are now living in urban areas. The movement of such species to urban areas can be partially attributed to the changes in agricultural practices which have taken place in the rural areas. The Countryside Commission and the Department of the Environment have recently completed a study of landscape change, in which they considered farmland, woodland and semi-natural vegetation between 1947 and 1980, (Countryside Commission, 1986). Their results illustrated the extent of the destruction of animal habitats which has taken place in these environments. For example the percentage of cropped land has increased from 37 per cent of all farmed land in 1947 to 48 per cent in 1980. This expansion will go hand in hand with an increased use of artificial fertilizers, herbicides and pesticides. Almost 4000 miles of hedgerows are being destroyed every year and the area of semi-natural habitats (for example, heathland, moors, bogs, bracken, gorse, wetlands, bare rock and sand) has decreased by 25 per cent between 1947 and 1980. Many species which previously were most frequently found in rural areas are now living in urban environments. The pressures of the rural environment have encouraged species to take advantage of the relatively rich pickings which can be found in towns and cities. Some species have been very successful in their move towards urban habitats for example the Blackbird *Turdus merula* (Mulsow and Luniak, 1986) and the Fox *Vulpes vulpes* (MacDonald and Newdick, 1980).

Occasionally man's activities in urban areas have produced rare environmental conditions which have been exploited by rare plant communities or animal species. For example Gemmell et. al. (1983) identified uncommon plant communities on sites of toxic waste located in urban fringe areas around Manchester. A spider *Tegenaria agrestis* which was previously believed to be scarce, has been found living at Spaghetti Junction, Birmingham. Further investigations have shown this species to be abundant, surviving particularly on areas of scree.

Urban habitats are not only important for the continued existence of a diverse population of wildlife species but the presence of green areas have been shown to increase the general well-being of residents in urban areas (Deelstra, 1985). Emergy (1986) claimed urban conservation has personal, educational, environmental, economic and wildlife benefits. Harrison et. al. (1986) discussed the obvious appreciation felt by working class communities for wild areas in their neighbourhood. The people interviewed for this study had very little knowledge of natural history yet they were keen to acknowledge the pleasure they gained from wild green areas in childhood and as adults.

Some conservationists, for example Ratcliffe (1981), believe that the new interest in urban conservation should be encouraged as it will help increase the overall level of awareness of the need for nature conservation amongst the general public. This new awareness should enable them to appreciate the 'wilder nature' found in more rural areas. Whatever the aims behind the involvement in urban conservation by conservation bodies, local urban groups and local authorities, it is generally agreed that the existence of urban habitats is beneficial to the local community and therefore such habitats should be identified and maintained.

1.2 The need for research in urban nature conservation

Management practices developed to conserve rural animal habitats cannot necessarily be transferred directly to the urban environment. Sukopp and Werner (1982) and Werner and Sukopp (1986) discussed the differences which exist between rural and urban ecosystems.

The weather conditions recorded in urban environments differ from those experienced in the surrounding rural areas. Different temperatures, rainfall totals, rainfall patterns, wind speeds and wind directions have been recorded. Urban heat islands are caused by high levels of particulate matter in the atmosphere in towns and cities. The energy flows in an urban ecosystem differ from those in a rural ecosystem. In urban areas the rate of consumption of secondary energy exceeds the levels of primary energy received. The physical existence of urban areas obviously has a tremendous impact on the land surface. Most of the natural land surface is covered by man's developments. Artificial drainage patterns are created and this in turn affects the nutrient balance of the soil. The topography of urban areas is altered either by development or by landscaping. The whole soil structure and composition undergo changes (Craul, 1985). A very heterogeneous pattern of land use exists in urban environments and this pattern is constantly changing as urban areas are very dynamic ecosystems.

The changes in climate, soil structure, topography and drainage all influence the plant and animal species which can survive in urban environments. As a city or town develops, there is generally a decline in the numbers of the original plant and animal species found in the area and an increase in the number of hybrids and species from warmer environments surviving in the urban environment.

In response to the differences between urban and rural wildlife habitats, Barrett (1985) identified a number of topics which needed investigation if the ecology of urban areas was to be understood and if urban wildlife habitats were to be managed correctly. He stated that it was necessary to investigate a suitable method to map and model key components and processes of urban ecosystems thus helping any assessment of the impact of land use changes on urban wildlife habitats.

This is the area of investigation which the Nature Conservancy Council wished to pursue with this research.

1.3 Local authorities and their involvement with urban nature conservation

The planning department of local authorities generally has the most involvement with urban conservation, although Environmental Health departments have made major contributions to a number of projects. For example, a study of pollution levels in the Blackbrook Valley has been carried out with the cooperation of the Environmental Health department of Dudley Metropolitan Borough Council (Wilson, 1987). Planners vary in the amount of ecological training which they have received and therefore they are not always capable of identifying and managing important urban wildlife habitats. Planning departments are increasingly keen to encourage wildlife in cities and to maintain or create 'wild' green areas, but they need a simple method of habitat identification and evaluation if they are to identify which are the most important areas for wildlife. They would find useful, information about the minimum size of a particular habitat necessary to support a self-sustaining animal or plant community of interest. If they are to be encouraged to develop, enhance and maintain ecological corridors for example, they need to be able to identify the sites where good urban wildlife habitats already exist, or where they could be created sensibly and hence add to the corridor system. An ecological corridor is a linear stretch of connected open green space consisting usually of a variety of different wildlife habitat types. Such corridors are very valuable for the movement of different plant and animal species through urban areas. Equally planners need to know which are the best sites to develop as wild green areas, "habitat islands", in the parts of the town or city lacking in suitable green space.

Many researchers have attempted to devise methods to evaluate wildlife habitats (Helliwell, 1969, 1973; Sukopp et. al., 1980; Tubbs and Blackwood, 1971; Yapp, 1973 and Wittig and Schreider, 1983) but most of these techniques have the disadvantage of trying to place a quantitative value on a subjective criteria.

There is therefore a need for an easy method to identify and evaluate urban wildlife habitats.

1.4 The Nature Conservancy Council's response

The Nature Conservancy Council is the government body which promotes nature conservation in Great Britain. It will give advice on conservation issues to both the government and any organisation or individual whose activities affect wildlife or wild places. All its work is based on detailed ecological research and survey. It is also responsible for managing the country's National Nature Reserves.

To help with their advisory role and provide planners and other organisations with the information they need about urban wildlife habitats, the Nature Conservancy Council requires a method to readily survey, monitor and evaluate urban wildlife habitats. With such information, they hope to be able to predict the affects of man's development on the wildlife habitats and species numbers in that area.

It is easy to survey a habitat before and after a development has taken place to determine the effect on the site's plant and animal populations but this is too late. Valuable habitats may have been destroyed. A method to predict the likely effects of man's activities on urban wildlife habitats is thus required. If the Nature Conservancy Council or planning authorities can readily determine the number of different species and the number of individuals of a particular species likely to be living at a particular site, this will provide an objective method to evaluate a particular wildlife habitat. With this information on hand, advice can be given or zoning policies can be developed, to minimise man's impact on the important urban wildlife habitat sites. The potential for site improvement can also be increased.

The Nature Conservancy Council believed that remotely sensed data, in this case large scale multispectral aerial photographs, may provide a suitable method to survey, monitor and quantify urban wildlife habitats. The research study investigates the feasibility of such a method.

1.5 The Nature Conservancy Council's involvement in urban nature conservation

The directives of the 1973 Nature Conservancy Act stressed the need to conserve the whole environment. There was no particular reference made to either rural or urban environments but until recently the Nature Conservancy Council has neglected urban conservation.

In the 1960's and early 1970's the Nature Conservancy Council considered urban areas only as having a detrimental impact on the surrounding rural environments. The general policy statement produced in 1973 stated that the Nature Conservancy Council should aim to protect the countryside from agriculture, forestry, urbanization, industry, tourism and recreation.

Before 1973 positive involvement in urban nature conservation was limited. The Nature Conservancy Council was purely concerned with elite sites in urban areas, for example, advice was given to Sutton Coldfield Local Authority about the management of Sutton Park. This is an urban park in the West Midlands which is a Site of Special Scientific Interest. The Nature Conservancy Council also had an advisory input into New Town Development Corporations such as Milton Keynes. The Corporation discussed its development plans with the Nature Conservancy Council to ensure the protection of semi-natural habitats.

A coordinated approach to urban nature conservation in Great Britain was sparked off by the Landscape Research Group whose conference in 1974 generated a new area of urban activity amongst planners, land managers, ecologists, and landscape architects (O'Connor, 1981). However the Nature Conservancy Council's contribution was negligible until 1977-1978 when the then director, R. E. Boote, commissioned a report from Land Use Consultants into the opportunities for nature conservation in urban areas (Cole, 1980). This report recognised the fact that wildlife can live in urban areas and the potential of urban sites can be realised through appropriate planning practices and creative land management.

Since the late 1970's the Nature Conservancy Council has begun to recognise to the opportunities available in urban nature conservation.

> "There are great opportunities for nature conservation in towns and cities - they contain - often unnoticed - many interesting wildlife habitats and geological sites" (The Nature Conservancy Council, 1980).

A number of urban conservation projects have since been financed by the organisation. Funds were granted to the Ecological Parks Trust for the William Curtis Ecological Park. Finance has been provided to employ staff to work in urban conservation, for example a conservation officer was funded for the London Wildlife Trust. It has also begun to sponsor a number of research projects into urban nature conservation. One of the Groundwork Trusts was commissioned to develop an urban habitat survey method. Cole (1980), a Nature Conservancy Council employee, produced a report about practical conservation projects in cities. Interest in the ecology of the West Midlands was sparked off by W. G. Teagle's publication 'The Endless Village' (1978). This was a Nature Conservancy Council publication. Since 1978 the organisation also started producing its own series of posters and leaflets about wildlife in the urban environment. This involvement of the Nature Conservancy Council in urban conservation has occurred relatively recently.

A positon statement issued by the Nature Conservancy Council in 1984 stated its reasons for its involvement. Although the organisation aims to try and protect any important wildlife areas in towns and cities, their occurrence is rare. The Nature Conservancy Council's prime aim therefore is to educate the general public, the decision makers and the planners about the value of contact with wildlife for the general well-being of the urban population.

> "The Conservancy has decided to develop its interest in urban areas because wildlife conservation has something to contribute to the resolution of the problem which is prevalent in all developed countries - that of urban decay" (O'Connor, 1981).

They aim to stress to various bodies that green areas in towns and cities can add to the public's enjoyment of their environment and can encourage pride in their surroundings. Such areas are especially important if young children living in inner cities are not to feel alienated from nature (Barker, 1986). As the Nature Conservancy Council has primarily been interested in the scientific aspects of ecology, this concentration on the social benefits of wildlife is relatively new. Millward (1987) questions how successful the Nature Conservancy Council can be at achieving these aims. She believes the Conservancy's limited budget and its primary involvement in the scientific aspects of nature conservation limit the resources it has available to urban conservation. The Nature Conservancy Council's corporate plan for 1986 to 1991 (Nature Conservancy Council, 1986) will do little to alleviate her concern, as urban nature conservation is only mentioned very briefly and did not warrant an individual section of the report.

The Nature Conservancy Council's involvement in urban nature conservation has increased over the past few years to the point where an Urban Coordinator has been appointed. One of his responsibilities is the production of 'Urban Wildlife News' four times a year. There is however still a vast void in the field of urban nature conservation which the Nature Conservancy Council could help to fill if adequate resources were available. Its involvement with the Blackbrook Valley project is one example of the contribution it can make. It is likely that the Nature Conservancy Council's involvement and committment to urban nature conservation will grow in the future as the awareness of the general public and environmental bodies about urban wildlife habitats increases.

1.6 The Nature Conservancy Council and the Blackbrook Valley

In 1980 the Council of Europe launched the European campaign for Urban Renaissance which aimed to help increase the quality of life in cities. Regional staff of the Nature Conservancy Council, members of the Landscape Institute and the Council for Environmental Conservation collaborated to set up a British project for this campaign. Their aim was to redirect the policy towards urban land from a short-term piecemeal policy of exploitation and cosmetic change to a more long-term environmentally sensitive approach. They hoped to encourage the conservation of urban wildlife habitats which already existed and also try to influence the development plans in urban areas so that impact of future development on wildlife habitats was lessened.

The Blackbrook Valley, Dudley, was chosen as an appropriate area having a representative selection of typical environmental problems experienced in the West Midlands. Land use policies had recently been approved and a proposal had been put forward by Dudley Metropolitan Borough Council to designate part of the Valley an Enterprise Zone.

In order to carry out the aims of the project, it was necessary to conduct a number of environmental surveys in the Valley and thus determine the ecological importance of the area. The Nature Conservancy Council commissioned a number of studies primarily in Saltwells Nature Reserve. Topics covered included surveys of the area's vegetation, soils, hydrology, land use, micro-fungi and molluscs.

As one of the survey methods, large scale multispectral aerial photographs were taken of the area. These not only provided a permanent data base of the area but were also valuable research tools. The Nature Conservancy Council approached the Department of Interdisciplinary Higher Degrees at Aston University to propose a research project to investigate the use of remotely sensed data for environmental monitoring, using the Blackbrook Valley as a study area.

KEY

— — — The Blackbrook Valley Small Projects Area including most of the Urban Renaissance project area.

+ + + Enterprise Zone boundary.

▨ Coverage of colour infra-red photography, 1984.

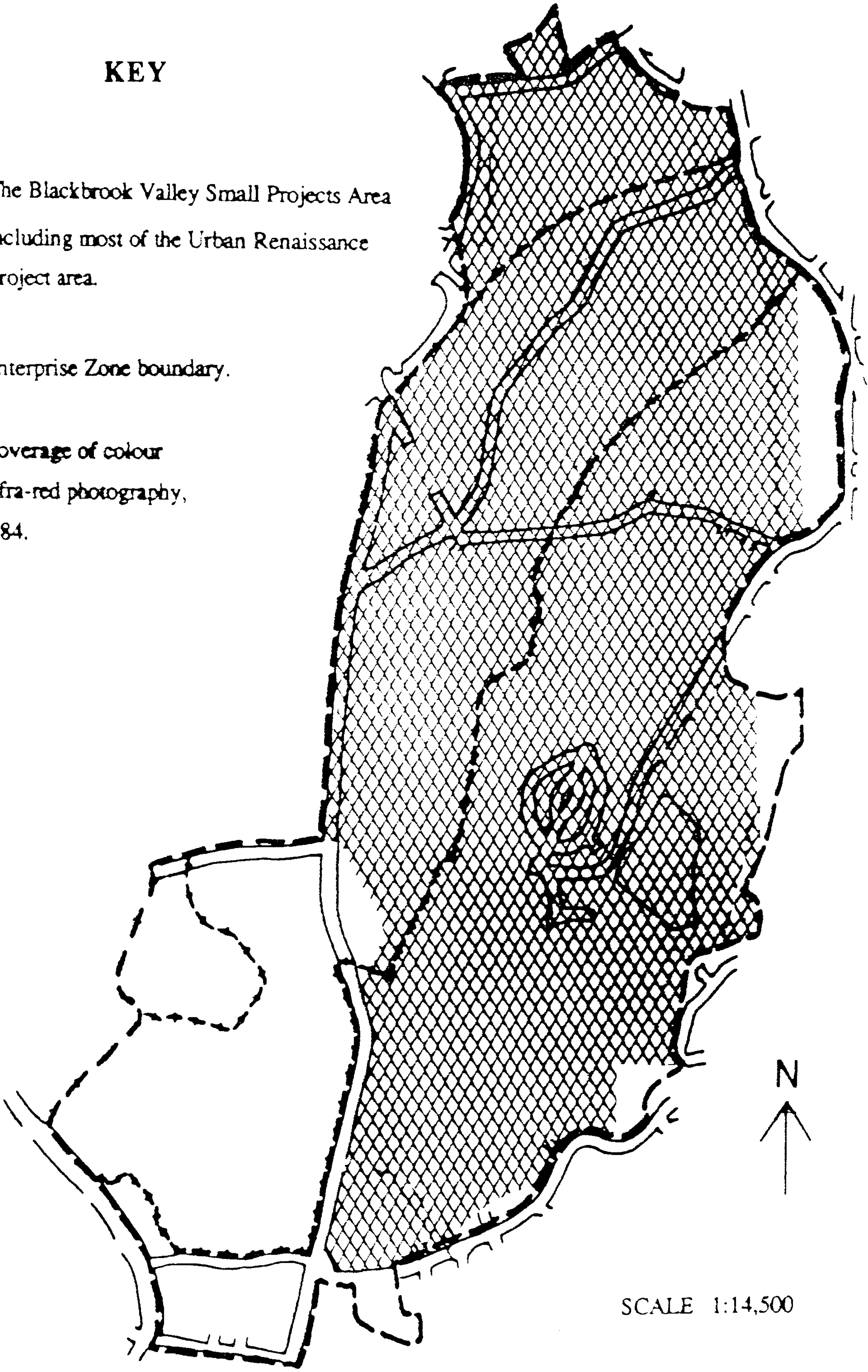


Figure 1.1 The Project Area, the Blackbrook Valley, Dudley.

1.7 The study area - the Blackbrook Valley, Dudley

The Blackbrook Valley is a linear patch of open land to the south of Dudley town centre, in the West Midlands. It separates the old industrial communities of Brierly Hill and Netherton. The area defined as the Urban Renaissance Project (an area of 380 hectares) overlaps the borough council's previously designated Small Projects Area (400 hectares). The Valley had been pinpointed by Dudley Metropolitan Borough Council for special investigation.

The research study area was limited to the part of the Blackbrook Valley within the boundaries of the Urban Renaissance Project Area and the Small Projects Area for which there was colour infra-red imagery for 1981 and 1984. This amounted to approximately 260 hectares of land on the eastern side of the Valley (see Figure 1.1). Two important areas of the Blackbrook Valley which were not included in the research project, due to lack of suitable imagery, were Merry Hill Farm and Round Oak Steel works. The changes which have taken place in this sector of the Valley have been discussed by Baines (1983).

1.7.1 The importance of the Blackbrook Valley in the West Midlands

The wildlife potential of green areas in the West Midlands came to light with the publication of 'The Endless Village' (Teagle, 1978). In response to this document, the West Midlands County Council conducted a habitat survey of all open space, in the county, greater than 0.5 hectares (West Midlands County Council, 1984). This survey identified 33,916 hectares of undeveloped land in the county, 10,542 hectares of this being classified as useful wildlife habitats. This represented 12 per cent of the county's total land area. The subsequent report stated that the County was dissected by a number of continuous, non-isolated green wedges which penetrated the built-up areas, thus bringing wildlife into the heart of the city.

The Blackbrook Valley was identified as one of the three most important areas for wildlife in the county, the others being Sutton Park and the Sandwell Valley. It was classified in the report as a 'wildlife reservoir' and it was one of two such reservoirs in the western half of the West Midlands. The importance of the Blackbrook Valley, as a wildlife area, is increased by the fact that the Valley is not isolated but is part of a larger ecological corridor being connected to two large areas of open green space.

The only local nature reserve in the county is Saltwells Local Nature Reserve which is in the south of the Blackbrook Valley. This was designated a Local Nature Reserve in

1981. Within the Valley there are two Sites of Special Scientific Interest; Doulton's Clay Pit which is part of the Local Nature Reserve and Brewins Canal Section. The Blackbrook Valley is therefore one of the most important wildlife areas in the County of the West Midlands.

1.7.2 The geology, topography and soils of the Blackbrook Valley

Dudley lies on the Birmingham plateau which is approximately 120 metres above sea level. The upper geological layer is composed of carboniferous coal measures which overlie Silurian rocks. Earth movements have resulted in surface outcrops of coal and of the older Silurian rocks in the study area. The geology on the western side of Netherton Hill and Saltwells Local Nature Reserve dips steeply to the west and on the eastern side (Lodge Farm Reservoir), it dips to the east (Culter, 1982). The geology of the area has had a great impact on its industrial development and its land use.

The present day landscape was shaped by ice action during the last glaciation between 2.5 million and 10,000 years ago. As a result the Blackbrook Valley is relatively hilly. The lowest elevation recorded on the 1:10,000 scale Ordnance Survey map is approximately 95 metres is found in the very south of the study area. A spot height of 189 metres indicates the highest point in the region. This is located in Netherton churchyard, on the east side of the Blackbrook Valley. Mining activities which have taken place in the area have resulted in underground disturbances which have contributed to the area's hummocky landscape.

Soils mapped in urban environments have been found often to differ from the soils in nearby rural areas even though the geology of the two areas may be similar. Craul (1985) identified several general characteristics of urban soils such as greater vertical and spatial variability, a more compact soil structure including the presence of a surface crust, restricted soil aeration, water drainage and nutrient activity, modified soil temperature regimes and the presence of man-made materials. He claims, in urban areas, human activity is the main cause of these features. Howells (1982) conducted a soil survey primarily of Saltwells Local Nature Reserve. Her findings agreed with Craul's, in that the soils in the Reserve were more the result of human activities than the natural active agents such as wind, water, ice, gravity and heat. She concluded that if no excavations had taken place, all the soils in the area would be of a light, sandy texture and well-drained. However, constant human disturbances had brought the underlying clay material to the surface producing a clay mix soil. Howells (1982) identified the same major soil types that had been recorded in an earlier survey by Shimwell (1982):

i) Bromyard series - brown earths developed over Downtonian marls and other Devonian siltstones,
ii) woodland series of ochreous brown earths over middle coal measures sandstones,
iii) undifferentiated alluvial soils,
iv) immature silty/clayey soils and
v) lithosols

Two of the woodland series soils are dominant in Saltwells Local Nature Reserve. The upper sandy layers of the ochreous brown earths are well drained but below this, there is a gleyed clay layer. In Doulton's Clay Pit the soils are very disturbed due to the clay extraction which has taken place in the past. The soil types recorded here vary from dry to moist depending on the relief of the site.

1.7.3 Land use in the Blackbrook Valley

Figure 1.2 provides a generalised picture of the present day land use in the Blackbrook Valley. The major categories are open land, industrial land, residential areas and water bodies.

The recent land use history of the Valley has been discussed by Rean (1982). Prior to the Industrial Revolution the region was primarily agricultural comprising small mixed holdings. A few farms remained in the area until the 1950's and Merry Hill Farm was finally destroyed as late as 1982. The grazing of cattle and horses still occurs on some privately and publically owned grassland such as the area between the two canals.

The industrial growth experienced in the nineteenth century was based on the area's natural resources of coal, iron ore, limestone and clay. It was accompanied by a population increase and thus a growth in markets and infrastructure. During this period, the Blackbrook Valley was considered an attractive area having a popular spa. In 1795 a large number of trees were replanted around the Saltwells spa in order to hide early evidence of industrial activity and hence make the area more attractive to visitors. Saltwells spa and wood were popular attractions in the area. The Blackbrook Valley as a whole was considered a local beauty spot until the 1940's. The heavy industry of the area began to decline in the 1920's and 1930's being replaced by lighter metal working factories. This trend has continued through to the 1980's with the establishment of the Enterprise Zone in the northern and western sections of the Valley. The Enterprise Zone aims to encourage the setting up of light manufacaturing and service industries to compensate for the reduced employment in the area's traditional metal working industries.

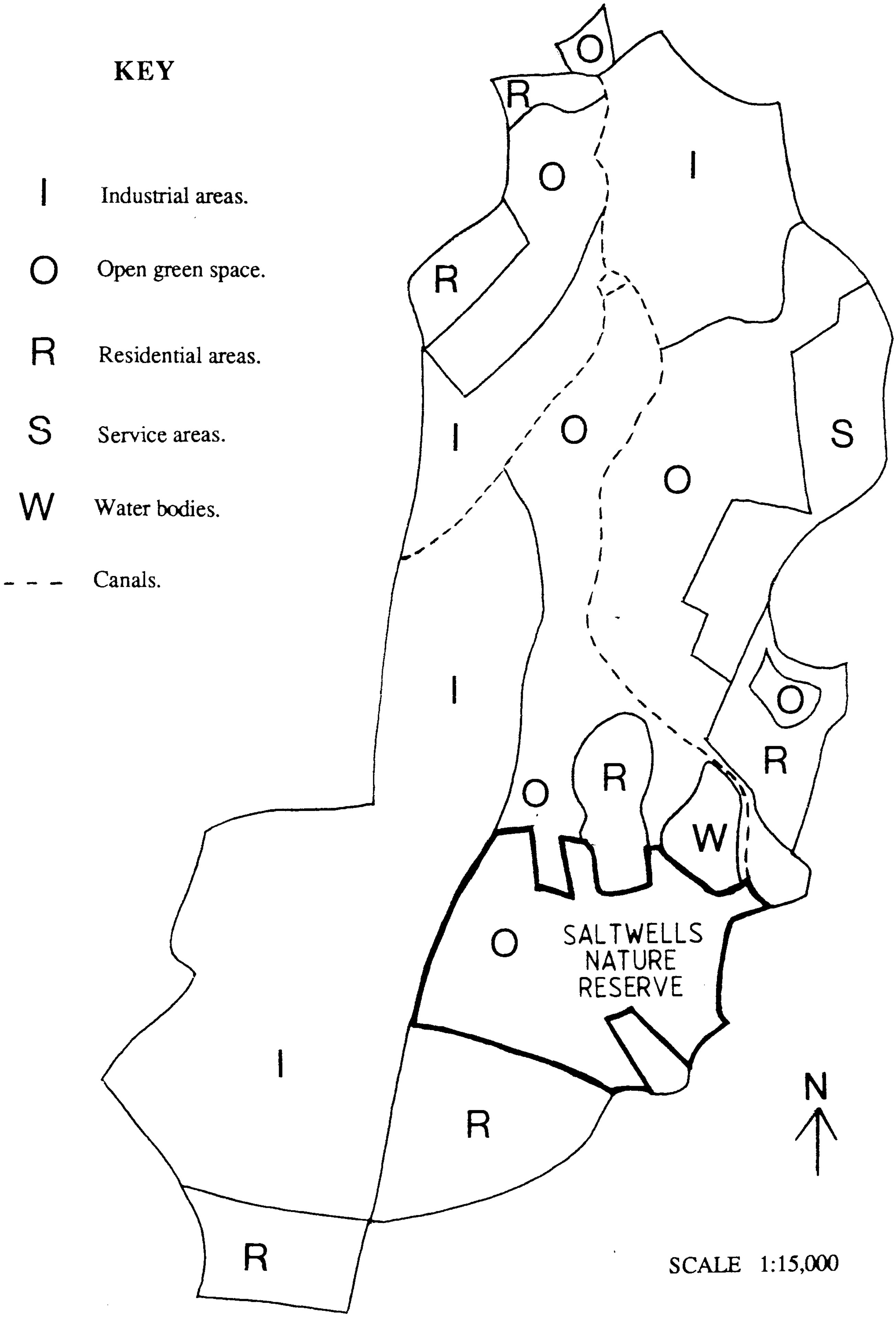


Figure 1.2 Land Use in the Blackbrook Valley, 1984.

The legacy of the area's industrial history is not purely detrimental. Doulton's Clay Pit, part of Saltwells Local Nature Reserve, and Lodge Farm Reservoir are both relics of the clay extractive industry. They now provide important wildlife habitats. Netherton Hill leading from Dudley Canal to Netherton Church is the result of the restoration in 1974 of an opencast coal site. This bank was seeded with *Ulex europaeus* . It is now a very attractive area in spring and the early summer months as well as being a very useful habitat for certain bird species.

The present landscape is a result of the industrial and agricultural practices of the recent past. The most important wildlife site in the Blackbrook Valley is Saltwells Local Nature Reserve. The reserve comprises a large area of mixed broadleaved woodland which was mostly planted at the end of the eighteenth century. The woodland area is cut through by two small brooks, one being the Blackbrook. The site of an abandonned fireclay pit, Doulton's Clay Pit, is also included within the reserve boundaries. On the west facing side of the pit, there is an excellent 30 metre section of Middle Coal Measures and as a result of this, the site was notified in 1955 as a geological Site of Scientific Interest.

The Reserve is owned by the local council who are responsible for its management. A management advisory plan is presently being drawn up. The main vegetation communities found in the reserve are discussed in more detail in Chapter Nine. Since its designation, derelict land grants, awarded by the Department of the Environment, have provided the funds to establish the reserve's infrastructure.

Excluding the Reserve, the remainder of the open space found in the Blackbrook Valley is rough pasture and scrubland. These areas are mostly remnants of the old agricultural landscape. Although the local council has tried to purchase much of this land for informal recreation, it has been unsuccessful as most of the land is owned by private development companies, industry, or is part of the Enterprise Zone. The council has been successful with the purchase of Netherton Hill which they plan to actively manage.

The water bodies which exist in the Valley make a valuable addition to the area's wildlife habitats. Two small streams, the Blackbrook and the Western Blackbrook provide areas of limited wetland habitat. The value of these streams has been reduced by man's activities. The course of the streams has been altered and pollutants are emitted into the streams by industry and the residents of the Valley. Parts of the Blackbrook, within the Reserve, are likely to silt up due to the transportation of loose material from the construction sites in the north of the project area. The two lines of the Dudley canal, which dissect the Blackbrook Valley, help maintain valuable wildlife corridors, as the canal banks are vegetated. Wetland plant communities have developed along the canal sides but these are only temporary as the canals are cleaned by the British Waterways Board at the beginning of each boating season. The canals provide the habitat for the majority of the wetland communities found in the project area. The artificially created Lodge Farm Reservoir could have wildlife and recreational value. Emergent plant communities have established themselves around its edges and the lake is popular for fishing. Unfortunately the lake is also used for sailing and water skiing and thus is treated with herbicides to control the submerged and emergent plants. These disturbances hinder the ecological development of the reservoir.

Most of the residential areas are found on the periphery of the Urban Renaissance Project Area, primarily on the east and southern edges. As most of the properties have gardens attached, they contribute to the range of habitats present in the area (Owen and Owen, 1975). Lodge Farm housing estate occupies a central position in the Blackbrook Valley . The close proximity of areas of housing to the Saltwells Local Nature Reserve, especially Lodge Farm estate can have a detrimental effect on the Reserve's ecological development. Non-related disturbances, for example vandalism, dumping, noise and domestic pets, can have an adverse effect on the wildlife habitats in the Reserve. However, studies conducted in other urban areas have shown that local communities do appreciate local woodlands and can gain many benefits, educational and recreational, from such areas (Tartaglia-Kershaw, 1982). One of the major aims of the Urban Renaissance Project is to encourage the local community to become interested in their environment and to become involved in its management. It was therefore hoped that the close proximity of Lodge Farm estate to the Reserve would be beneficial rather than damaging to the Reserve's wildlife habitats.

As previously mentioned, industrial developments have had a great impact on the area. Some of the changes which have occurred have been beneficial to the area's wildlife habitats, for example the creation of Doulton's Clay Pit. At the same time as the Urban Renaissance Project was beginning to take shape, the northern section of the study area was declared an Enterprise Zone (see Figure 1.1). This is a government initiative to try and encourage new industrial and manufacturing developments in the area and thus create employment. It was hoped that any improvements to the quality of the environment brought about by the Urban Renaissance Project would help encourage industrial development in the area. The designation of the Enterprise Zone was thus seen as an integral part of the whole project. The Blackbrook Valley Project Steering Group hoped that any initial conflicts between the two initiatives would be readily overcome and they were thus primarily concerned with monitoring the effects industrial development would have on the area's wildlife habitats. They visualised the impact of development on the area's wildlife could be kept to a minimum if the two initiatives worked together to develop wildlife sensitive plans for the area.

Existing and new firms gained from locating in the Enterprise Zone. There are financial and administrative advantages, such as exemption from development taxes, general rates and a 100 per cent capital allowance. The planning procedures are also simplified. Plans are drawn up by the local authority indicating the types of development permitted in each part of the Enterprise Zone. If developers conform to this zoning, they do not need apply for planning permission. Applications from any industries which do require planning permission are given priority. Although the planning restrictions within the Enterprise Zone are not relaxed, the Blackbrook Valley Project Steering Group had intended to press for even more stringent planning controls in the experimental area than normal, making landscaping compulsory and not allowing any developments on sites of interesting wildlife habitats.

The establishment of the Enterprise Zone has proved to be detrimental to some of the facets of the Urban Renaissance Project. It has proved impossible to develop the Enterprise Zone area along ecological principles of design and management. One concession has been made. A sensitive area along the edge of the Dudley canal was identified as such by the Enterprise Zone Authority (Dudley Metropolitan Borough) and as a result, no development is allowed in this strip until associated screening and landscaping has been approved. The value of this restriction is reduced by the fact it is an isolated example. The Blackbrook Valley Project Steering Group had hoped to see such restrictions on development imposed on all the ecological sensitive areas.

The Blackbrook Valley Project Steering Group would likely disagree with the comments of Lloyd (1984), relating to Enterprise Zones in general.

> "The evidence of the monitoring study suggests that there are no disbenefits associated with the streaming of statutory planning procedures." (Lloyd, 1984).

Originally the Blackbrook Valley Steering Group had hoped to gain the cooperation of the private landowners and developers and thus encourage them to develop the area following ecological principles. A landscape advisory body was established but little interest has been shown by the developers.

Ironically for the Urban Renaissance Project, studies, commissioned by the government into the success of Enterprise Zones, indicate that relaxed planning procedures are not considered as attractive to the new industries as the financial advantages.

> "Everyone - planners, developers, occupiers - seem to agree that the relaxed planning had virtually no effect on the kind of development regime that takes place." (Hall, 1984)

This suggests the Enterprise Zone may have been as successful without simplifying the planning procedure. Such a situation would have been more favourable in the Blackbrook Valley. One developer in the Enterprise Zone, Coal Contractors, have agreed to cooperate with the Blackbrook Valley Project Steering Group. Coal Contractors are in the process of stabilizing an area of land in the west of the Valley. As a by-product of this process, open cast coal is being mined for British Coal. The plans to restore this site have been drawn up considering the ecological characteristics of the Valley. If the plans are carried out, new wildlife habitats will be created in the area. However changes in company personnel and changes in the development company associations in the area have jeopardized the promising alliance between the developer and the Steering Group.

1.8 The aims of the research

Using the Blackbrook Valley as the study area, the aims of the research are two-fold:

1) To determine whether large-scale multispectral aerial photographs can be used to survey and monitor urban wildlife habitats. As urban areas are such dynamic environments, there is a constant need to resurvey urban green space, to identify what changes have occurred and try to identify how changes in the urban wildlife habitats relate to man's activities in the area.

   Aerial photographs have been used very successfully to survey rural wildlife habitats (see Grainger, 1971) and many benefits of this technique have been identified. Once a methodology has been developed, aerial photographs have provided extensive information, relatively quickly, without making great demands on staff resources. This method of mapping vegetation and wildlife habitats can be very economical especially if suitable imagery already exists for the specific task. Extensive surveys can be completed by a limited number of individuals and if a suitable methodology is developed, the surveys can be easily and consistently updated for monitoring purposes. Other benefits of aerial photographic surveys for rural vegetation studies are that they solve the problem of inaccessible environments and they provide a permanent, historical data base (see Chapter Two).

   The benefits identified for rural aerial surveys could also be applicable to urban vegetation surveys. Advantage could be taken of the large numbers of air photographs which already exist of urban environments. The major difference between rural habitat surveys, where air photographs have been used successfully and urban habitat surveys, is one of scale. Wildlife habitats found in urban environments are generally much smaller in area than habitats mapped in rural landscapes. Urban habitats are mainly composed of a small scale mosaic of plant communities. This is a result of the fragmentation of habitats which occurs and of the diversity of soil types found in towns and cities. It is therefore necessary to determine whether a technique used successfully to map rural habitats can be as successful in urban environments. The best photographic emulsion for urban habitat surveys needs to be identified and a suitable urban habitat classification has to be developed.

The research set out to determine whether large-scale multispectral imagery can compensate for the finer resolution required to survey urban wildlife habitats. If urban areas can be mapped at a sufficiently fine scale using aerial photographs, this will provide a standardised technique which would give useful comparative data for different urban areas.

2) To examine whether habitat features, identifiable from large-scale aerial photographs, can be used to predict the population numbers of selected groups of species expected to be found living in a particular habitat type. If so, this can be used as a method to quantify habitats, so providing an indication of their usefulness to that particular species. Such information could hopefully be considered by planners and developers when drawing up development plans.

It is first necessary to determine whether any habitat features, which have been identified in the literature as being correlated with species population numbers, can be mapped accurately from aerial photographs. If so, population numbers can be predicted. Research then has to determine whether significant changes to these habitat features can be identified using the remotely sensed data source. If this is feasible, it should be possible to estimate what effect different habitat changes will have on the population numbers of that habitat.

To carry out this part of the research project, analysis was restricted to an investigation of the usefulness of aerial photographs to predict the bird population number found in Saltwells Local Nature Reserve. It was felt it was feasible to restrict the analysis to bird populations as a number of studies have already been carried out looking into predictive relationships between bird numbers and habitat features, for example MacArthur and MacArthur, (1961) and Woolhouse, (1983). In addition, conservation organisations are increasingly using ornithological data as a method of assessing the broad environmental quality of areas (Fuller and Langslow, 1986).

A standard technique for the prediction of bird population numbers would be very useful to wildlife organisations.

CHAPTER TWO

A REVIEW OF THE EXISTING USES OF AERIAL PHOTOGRAPHS IN HABITAT STUDIES

2.1 Introduction

According to Goodier (1971), British ecologists have rarely used aerial photographs in their research. He, along with many other ecologists, for example J. A. Howard, who wrote the very comprehensive book "Aerial-Photo Ecology" (1971), recognised the potential of the data source to conduct physical, botanical and zoological surveys thus allowing the production of new and updated vegetation and thematic maps. One of the major advantages is considered to be the ease of boundary definition of major community types, (Kuchler, 1967).

Aerial photographs can be used to help study the relationship between the biotic and abiotic components of the natural environment.

Odum (1971) was very impressed with the ecological potential of remote sensing systems, such as the ability to provide information about species type, the structure, the volume, the quality of vegetation communities and abiotic details of the environment. Other authors have praised remotely sensed data sources for providing a realistic view of the ecological environment (Zonneveld, 1974).

> **"Remote sensing, as an operational habitat inventory system, can produce useful information about the variety of habitat elements at different scales." (Mayer, 1984).**

Nichol (1976) stated that the growing importance of aerial photographs for biological surveys was evident in the change in methodology of such surveys. Initially survey data was collected mainly in the field using aerial photographs purely as a backup. This procedure has now been reversed as often field work is conducted only to verify the boundaries identified on the photographs. However not all researchers are satisfied that the full potential of remotely sensed data, in ecological studies, has been recognised; (Goodier, 1971; Lavigne et al., 1977; St. Joseph, 1977 and Lindsay, 1981).

Lulla (1981) and Mayer (1984) both reviewed the use of satellite imagery in ecological studies. Satellite data has been widely used in forestry and rangeland surveys, (Lamprey, 1984). As the resolution of the imagery becomes more detailed, its ecological potential will increase, for example, the French Spot satellite provides colour digital data with a resolution of 20 metres and 10 metres in the panchromatic mode. As yet the resolution available has restricted the use of satellite imagery in urban vegetation studies, however Tylka and Cook (1987) have used 30 metre resolution imagery to survey the vegetation cover in St. Louis, U.S.A. At present satellite imagery has limited use in the field of urban ecology, but as improvements are made to its resolution, its potential shall increase and it could become a valuable data source if not too expensive.

One of the factors which may be restricting the use of aerial photographs is the problem of ecological classification. Poor results are generally obtained if habitat classifications devised for field study are used with aerial photographs, especially if the classifications are not hierarchical. This is a result of the method used to interpret vegetation types with aerial photographs. The criteria considered in aerial photographic surveys and field surveys differ. Frequently areas delineated on the photographs cannot only be defined on the basis of the component plant species and physiognomy but are often

> "the result of a complex interaction between the visual effects of geomorphology, soil type, moisture content and the vegetation." (Goodier and Grimes, 1970).

If aerial photographs are to be used more frequently for habitat studies, researchers must accept, that due to resolution differences, they will never be able to provide as much detail about plant and animal communities as ground surveys. In recompense however, aerial photographs do have some valuable advantages. They readily supply information about factors such as moisture content, soil type and landform. In ecological studies details about these factors are often invaluable. Aerial photographs can also provide an invaluable data base.

The amount of habitat information obtainable from aerial photographs depends mainly on the scale, the emulsion and the timing of the photography.

2.2 Scale of photography

The scale of photography required depends on the nature of the study area and the purpose of the study. If an area is of a uniform habitat type, small scale imagery (1:20,000) may be suitable. If an area is very diverse, a larger scale, such as 1:5000, is required to distinguish the extra detail. The scale of the imagery determines the ability to detect pattern. Even with large-scale photography, it is impossible to detect most of the very fine detail identifiable by ground survey. On the other hand, extensive patterns in vegetation communities may only be evident from the air and may reflect information about other environmental variables, such as soil type.

There are a number of examples of different scales of photography being used in ecological studies. Befort (1986) believes that, at present, there is a trend towards smaller aerial photographic scales and satellite data which will result in a loss of habitat detail. Photographs at a scale of 1:10,000 exist for much of Britain. According to Ward et al. (1971) and Brack (1975) this is a very adaptable and useful scale for ecological studies. However Ward et al. (1971) did state that for their particular study of Dartmoor, 1:10,000 scale photography was too detailed and 1:15,000 scale imagery would have been preferable. In America the most commonly used scale for habitat inventories is 1:15,840, however there has been a recent trend towards smaller scale photographs, 1:24,000 as this is more compatible with current maps (Mayer 1984).

Williams (1971) suggested that scales from 1:7500 to 1:40,000 could be used for general resource surveys. Goodier and Grimes (1970) used two sets of photographs, 1:10,000 and 1:5000, to map the Rhinog Mountains in Wales. They found using black and white 1:10,000 scale photography, they could adequately distinguish the most significant plant communities and although the 1:5000 scale photographs allowed for improved boundary definition, they revealed undesired intra-community complexity. Nevertheless, such large scales are often very useful. Driscoll (1974) was able to accurately identify shrub species using large-scale 1:1500 and 1:8000 colour infra-red photography, the smaller shrubs requiring the larger scales. Befort (1986) used 1:1000 scale photography to try to identify forest habitat types. He aimed to define sets of sample sites which would produce similar climax plant communities. To do this, he needed to ascertain whether species type, community structure and successional trends could be identified. This had not been successful with medium- scale aerial photographs as it proved impossible to obtain information about the under story. The results of his analysis with the large-scale imagery were 75 per cent accurate and thus show promise.

The range of photographic scales used in habitat studies is large. There is no general agreement about the optimum scale for particular studies and conditions, (Keech, 1974). It is sensible for practical and economic reasons to select the smallest scale of imagery that will provide the level of detail required. However if the data source is to be fully exploited, a number of environmental studies should be conducted. As a result, it is impossible to have the optimum scale for each study. It therefore seems sensible to obtain the largest scale photograhy possible within the budget restrictions of the project. For surveys which require information less detailed than the photographic resolution, the classification system used can restrict the amount of data recorded. The photographs will provide a permanent data source, which can be referred to at a later date if a greater resolution is required. The size of the study area will dictate the scale of photography affordable. As the Blackbrook Valley is a small geographical area, it was sensible to obtain large-scale imagery.

2.3 Timing of photography

The season and the time of the day the photographs are taken, is important. To obtain good quality, informative imagery for analysis, the photographs should be taken when the seasonal differences between the visual tones of the various habitat types are at a maximum and at the time of day when the sun's angle emphasises these tonal differences.

The best season for vegetation mapping varies with the different vegetation types. Williams (1971) claimed that the maximum contrast in tone and texture is when plants are flowering, sometime between May and September. He found June was the best time to map chalk grassland as most of the species are in flower. The photographs used by Goodier (1971), for a vegetation study of the Rhinog Mountains, were taken in June. At this time of the year he found it impossible to identify bracken, however Ward et al. (1971) found they could map most of the bracken communities on Dartmoor using June colour photography. This indicates that the timing of imagery cannot be considered in isolation from the emulsion type and the scale. Timing is critical for the surveying of woodland habitats. St. Joseph (1977) stated that spring photography when the trees are coming into leaf, is best for mapping and identifying species in deciduous woodlands. If information is required about the understorey layers of deciduous woodlands, it is necessary to obtain the imagery when the trees are without any leaves. In a study of the Great Dismal Swamp Area, U.S.A., Gammon and Carter (1979) used winter photography to map the understorey. In Britain, winter imagery is difficult to obtain due to unsuitable weather conditions.

The time of day aerial photographs are taken can have an important bearing on the accuracy of habitat surveys. Stearns (1970) claimed imagery for animal counts should be flown either early morning or evening, as then animals tend to be most active and therefore more visible. Unfortunately this is not the best time for photographs due to the low sun angle resulting in poor lighting conditions. For thermal imagery the time of day is not as important.

2.4 Film type

Opinions concerning the best emulsion to use in ecological studies, for example panchromatic, panchromatic infra-red, colour and colour infra-red, differ in the literature. Surprisingly a number of researchers have favoured black and white imagery because of its higher tonal constrast, its standard high processing quality and its lower costs, (Nichol, 1976).

Nichol (1976) used black and white photographs to identify and map habitats of conservation interest. Grimes and Hubbard (1969) claimed there were no advantages to be gained from using colour film in preference to black and white when mapping coastal marshland vegetation. In a study of wetland vegetation by Cowardin and Meyers (1974), black and white infra-red film was found to be the most successful emulsion for the identification of emergent vegetation.

However some authors believe true colour and colour infra-red film types are superior for vegetation studies (Arvantis and Newbourne, 1984). Williams (1971) claimed colour photographs should be taken whenever possible as a greater number of shades can be distinguished. A study completed by Benson et al. (1981) into the accuracy of vegetation surveys using a number of different emulsions, identified true colour as being the most precise film type. According to Grainger (1981), to optimise spectral discrimination, colour and colour infra-red emulsions are needed. Black and white film obscures small radiance differences making identification of ground features less accurate.

Colour infra-red imagery has been used in a number of habitat studies. The area of urban vegetation cover in Los Angeles was estimated using colour infra-red photographs by Brown and Winer (1986). The areal data was combined with field data to determine the leaf mass of urban habitats. Vegetation, due to its structure, has a very strong reflectance in the infra-red waveband. This emulsion has been used to identify a number of habitat features such as vegetation species, plant stress, plant disease, and leaf area index. Nichol (1976) suggested that too many false claims have been made about colour infra-red photography especially where vegetation stress is concerned, however Lillesand (1980) stated that this film type had been statistically proven to be superior to colour film in tree stress studies. Trees suffering from oak wilt have been successfully identified by Ulliman and French (1977).

In general it appears that colour and colour infra-red photographs have many advantages over black and white in ecological studies. Some of the earlier unfavourable opinions to these emulsions are perhaps not surprising when one considers how few colour and colour infra-red prints would have been available at the time. The expense involved in obtaining such prints may outweigh the advantages gained in analysis.

2.5 Aerial photographs in zoological studies

The above discussion has been concerned primarily with the use of aerial photographs in vegetation habitat studies, however one of the earliest uses of remotely sensed data was in zoological studies (Milton and Fraser-Darling, 1977) either to census population numbers or to obtain information about the preferred habitat types of specific animals. Lillesand and Kiefer (1979) listed a variety of animals which have been counted using vertical aerial photographs including moose, elephants, sheep, deer, sea lions and seals. Different scales and emulsions have been used. Thermal wavebands have proved useful as animals can be easily distinguished from the vegetation background and surveys can be conducted in poor light conditions (see Best et al., 1982). Generally this data has been digital as opposed to photographic. Lavigne and Oritsland (1974) used ultra-violet photography to count polar bears in snowy environments. Some failures have been recorded, for example Milton and Fraser-Darling (1977), using a visible wavelength emulsion, failed to identify and count the numbers of deer species found grazing in a moorland environment. The full potential of aerial photographs in zoological studies has yet to be reached (Milton and Fraser-Darling, 1977).

2.5.1 Aerial photographs in ornithological studies

Vertical aerial photographs have been used in bird studies to either census numbers, for example Best et al. (1982) or to map suitable bird habitats (Lee and McKelvey, 1984). Most bird census have been carried out on wildfowl populations as these species frequently congregate in large numbers in the more open habitat areas, such as lake shores or coast lines. This concentration of individuals and the lack of vegetation cover makes counting easy and more accurate (Stearns, 1970). Payne (1983) attempted to identify the spectral response of some woodland bird species in the visible and reflective infra-red portion of the spectrum. He tried to distinguish actual bird individuals from their vegetation habitat via differing spectral responses. This proved to be difficult. Light coloured bird species could be distinguished from species with darker features but it was impossible to identify actual species types. This project was perhaps too ambitious as even if actual bird species could be identified, complete bird counts would not be possible as some individuals will always be masked by the vegetation. As with other animals, aerial photographs can only be used successfully to census birds which are found in open habitats.

Rather than attempt to map actual bird locations, aerial photographs have been used to survey and locate likely bird habitats. Lancaster and Rees (1979), using aerial photographs, mapped buildings which would provide suitable nesting sites for birds in an urban environment. Skaley (1981) used a photographic data source to try and identify a limited number of shapes and patterns in the vegetation canopy which could be related to specific bird species. In common with other zoological studies, the full potential of remotely sensed imagery in ornithological research has yet to be reached. The identification of possible habitats for particular species and the monitoring of the changes which occur in these habitats is likely to be the most useful role of aerial photographs in bird studies.

2.6 The use of aerial photographs by the Nature Conservancy Council

> "Oblique and vertical aerial photographs are used as an aid throughout the Conservancy for purposes of research, conservation and publicity. It would be impossible to carry out its present range of activities without the aid of aerial photography." (Grimes and Hubbard, 1969).

The Nature Conservancy Council considers aerial photographs to be a useful data source. Photographs have been employed to survey and map areas of semi-natural vegetation; to revise existing boundary maps; to identify areas where change has occured; to prepare vegetation inventories; to identify disturbed or diseased vegetation, (primarily trees) and to map soil and geological features. Scott (1974) emphasised their importance by claiming the Nature Conservancy Council not only values aerial photographs as an aid to ecological survey but also as a main data source . They allow the effective use of time and resources in monitoring projects.

Some of the Nature Conservancy Council's scientific staff have been trained to use aerial photographs (see Goodier, 1971) and a technical services branch exists to complete the more technical photogrammetric plotting tasks. Experiments have been conducted to determine the most suitable scale and emulsion for the identification of species types, for example according to Scott (1974), colour infra-red photography has been found to be the most efficient to identify deciduous tree types and at a scale of 1:7500, it is the most suitable emulsion to map certain grasses, sedges and rushes. The value of different emulsions is being increasingly recognised by the Nature Conservancy Council. Previously panchromatic imagery was believed adequate for most tasks (Grimes and Hubbard, 1969).

The National Countryside Monitoring Project which is currently being conducted to measure the extent of change in habitats throughout Britain since the 1940's, relies on aerial photographs as the main data source.

Over the past fifteen years the Nature Conservancy Council has awarded grants to research institutes and conservation bodies either to investigate the usefulness of aerial photographs or to finance the purchase of such imagery. For example Yorkshire Wildlife Trust was given a grant to enable them to obtain photographic coverage of all their reserves. Research into the feasibility of using colour infra-red photographs to map estuarine vegetation by Portsmouth Polytechnic was financed by the Nature Conservancy

Council.

The Nature Conservancy Council's commitment to remotely sensed data for ecological survey purposes was emphasised recently by their contribution to the House of Lords Select Committee on Science and Technology (1984). Here they stressed the need for unduplicated, but more up-to-date imagery which would be especially useful to survey Sites of Special Scientific Interest.

Although the Nature Conservancy Council is investigating the value of digital survey data, this will be used in conjunction with vertical aerial photographs and not as a replacement. It will continue to use aerial photographs of different scales and emulsions for monitoring or primary survey purposes.

2.7 Conclusions

It is evident that aerial photographs do have a wide application in ecological studies providing data about the dominant plant communities, large animals, topography, soils and moisture conditions. This information may not be as finely detailed as that obtained from field surveys, but it has the advantages of being broad ranging, quicker to obtain and less expensive. Once broad habitat types have been identified, field surveys can easily be carried out.

There are some limitations to their use, for example in woodland surveys. Woodlands are very important habitats at both the canopy and understorey levels (Shaw, 1971) but aerial photographs can only provide accurate information about the upper canopy layer. Some studies have been conducted to obtain information about the understorey layers (Gammon and Carter, 1979 and Befort, 1986) but the success of these studies depends on there being a known correlation between the properties of the canopy layer and its undergrowth. Very often actual plant species cannot be identified from the air even by experts, due to the resolution of the photographs.

Aerial photographs are considered useful in habitat studies as they make boundary definition easier, (Kuchler, 1967). However the change on the ground from one vegetation type to another is normally transitional. Aerial photographic interpretation can lead to the identification of boundaries which are not clearly delineated in the field. A boundary drawn on a map may be the result of a subjective decision yet it will be viewed as an accurate representation of the real situation.

The value of aerial photographs to habitat studies depends on the type of imagery used and the type of study required. When obtaining new imagery, it is important to consider which is the best season to maximise the tonal differences of the vegetation; the size of the study area; the optimum scale of photography for this sized area and the best film type for the particular survey. Each situation needs to be assessed independently, however it is very rare that a unique set of photographs will be available for a particular project. Most aerial photographs are used for a number of different purposes and therefore they may not be the most suitable for the particular study but can still provide a good deal of useful information for ecological studies.

CHAPTER THREE

MATERIALS AND METHODS

3.1 The photographic data source

As part of the environmental monitoring programme of the Blackbrook Valley, the Nature Conservancy Council commissioned the flight of two sets of vertical aerial photographs. In the summers of 1981 and 1984, Cambridge University took panchromatic, colour and colour infra-red (C.I.R.) photographs of the whole area. In 1981 panchromatic oblique coverage was also acquired. For the three emulsions, complete stereo coverage was shot at a scale of approximately 1:2500. Although expensive, the Nature Conservancy Council recognised that these photographs would provide up to date information about the natural features in the area and thus be a permanent data base. The two dates of photography are necessary for monitoring purposes.

The 1984 coverage and the panchromatic 1981 photographs were 23 by 23 centimetres (9 by 9 inches) paper prints. The 1981 colour and colour infra-red photographs were diapositives and were viewed using a light table. Such transparencies have the advantage of better spatial resolution and colour fidelity but have the disadvantage of requiring additional equipment for interpretation.

The various film emulsions are sensitive to different wavelengths of electromagnetic energy. Black and white film is responsive to the part of the spectrum visible to the human eye (0.4 - 0.7μm) and to ultraviolet radiation (0.3 - 0.4μm). Colour film is also susceptible to the visible spectrum. It is designed to copy the response of the human eye which is sensitive to the three primary colours of blue, green and red. Colour photographs are useful as they provide a great deal more information than panchromatic images. The human eye can perceive more than 20,000 tints and shades of colour compared to 200 tones of grey (Ray and Fischer, 1957). Colour infra-red films are sensitive to the green, red and reflected infra-red wavelengths (0.5 - 0.9μm). Such films can provide images different from that which can be detected by the human eye. Examples of the three different film types used to photograph the Blackbrook Valley can be seen in Plates 3.1, 3.2, 3.3, 3.4, 3.5 and 3.6. All these photographs were taken in 1984.

Plate 3·1 Panchromatic 1:2500 scale image of the Lodge Farm housing estate, the Blackbrook Valley, 1984.

Plate 3·2 True colour 1:2500 scale image of Lodge Farm housing estate, 1984.

estate, 1984.

Plate 3·4 Panchromatic 1:2500 scale image of the north of the study area, 1984.

Plate 3·5 Colour 1:2500 scale image of the north of the study area, 1984.

Plate 3·6 Colour infra-red 1:2500 scale image of the northern sector of the Blackbrook Valley, 1984.

Colour infra-red films have been praised for vegetation studies (Hilderbrandt and Kenneweg, 1970; Lillesand, 1980 and Mayer, 1984). All the imagery is very detailed but the vegetation communities are more obvious on the colour infra-red photographs.

Colour infra-red films have an advantage over ordinary colour emulsions in vegetation studies because healthy vegetation records the greatest reflectance in the near infra-red wavelength (see Figure 3.1)

50

infrared film

Figure 3.1 The general pattern of vegetation reflectance
(Based on Lillesand and Kiefer, 1979)

Due to the arbitrary design of the dye structure of the colour infra-red film, a colour shift occurs. Objects which primarily reflect green radiation appear blue on the photographs, red objects appear green, and objects, for example vegetation communities which chiefly reflect infra-red radiation appear red. Due to the use of a yellow filter, blue radiation is not recorded on the film therefore objects which primarily reflect blue appear black. For more details of this process see Figure 3.2.

Figure 3.2 Colour information on colour infra-red film. (Based on Lillesand and Kiefer, 1979 and Curran, 1985)

However some researchers believe that the infra-red reflectance is more dependent on leaf physiological structure than pigmentation (Hilderbrandt and Kenneweg, 1970; Curran, 1985). Curran (1985) states that the combined effects of leaf pigments and physiological structure result in healthy leaves having a low reflectance in the near infra-red. Gausman (1974) claims that the amount of infra-red radiation reflected by a leaf is related to the amount of air space in that leaf. Different plant species reflect varying amounts of near infra-red radiation depending on leaf thickness. Thin leaves absorb very little infra-red radiation therefore have a strong reflectance. Thick leaves behave in the inverse manner therefore do not appear as bright red on the colour infra-red photographs. Due to the response of vegetation recorded by colour infra-red film, this emulsion type does seem to be the most favourable for vegetation studies.

Figures 3.3, 3.4 and 3.5 show the flight lines of the 1981 and 1984 photography. The study area was defined as that part of the Urban Rennaissance project area which was covered by 1981 and 1984 colour infra-red imagery .

3.2 Aerial photographic interpretation

The method of surveying and monitoring the urban habitats of the Blackbrook Valley can best be summarised with the aid of a flow diagram (see Figure 3.6). The most important part of the methodology is the development of a suitable classification so that the relevant information contained on the imagery can be extracted in an orderly and useful way. The design and the accuracy of the classification used for this study is discussed in the next chapter.

Once a classification system has been defined and tested, interpretation can commence. The accuracy tests and preliminary habitat studies conducted using this imagery (Clark and Phillips, 1983 and Dillon and Lavender, 1984) identified the colour infra-red emulsion as the most informative and the most exact for their habitat studies. This conclusion was confirmed by a pilot test of the two colour emulsions. The colour infra-red photography was thus used as the primary data source. The colour and panchromatic photographs were referred to when there was some query about the habitat type or for mapping vegetation in water bodies. Although the colour infra-red photographs proved to be the best to map emergent and floating vegetation as the red tones stand out very definitely against the dark blue-black of the water surface, submerged vegetation could be identified more readily using colour imagery. In Great Britain, due to the high standard of maps produced by the Ordnance Survey, the equipment required for aerial-photographic interpretation of vegetation habitats can be basic (Coombe,1977).

Figure 3.3 The Flight Lines of the Black & White Photography, 1981 and 1984.

Aston University

Illustration has been removed for copyright restrictions

Figure 3.4 The Flight Lines of the Colour Photography, 1981 and 1984.

Figure 3.5 The Flight Lines of the Colour Infra-red Photography, 1981 and 1984.

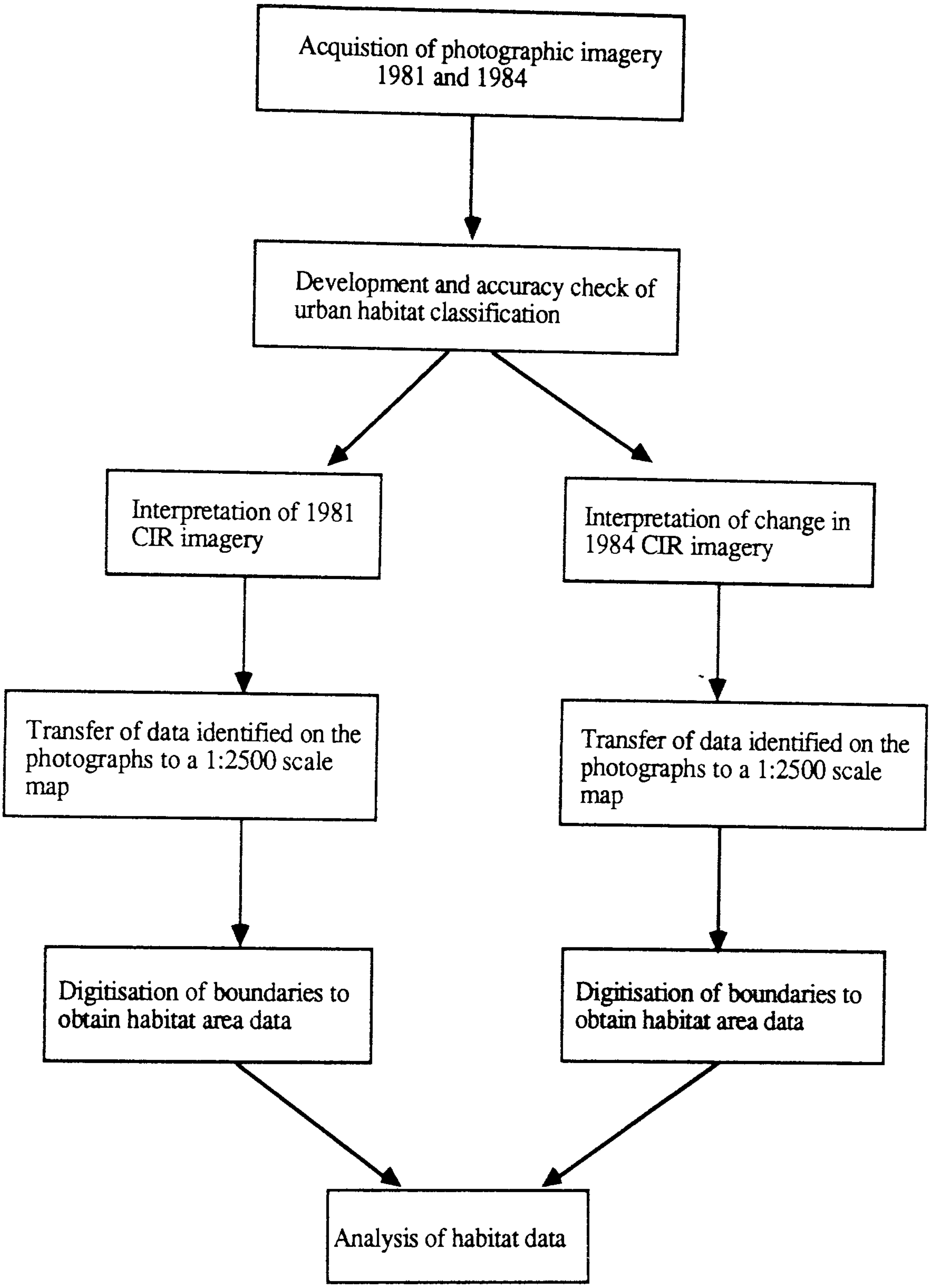


Figure 3.6 Stages in interpretation and analysis of aerial photographs for urban ecology

For this study stereo pairs of colour infra-red photographs were viewed using an Old Delft stereoscope. The use of a stereoscope and the 60 per cent overlap between each photograph allows the images to be seen in three-dimensions. The addition of this extra dimension aids interpretation as the vertical structure of the habitat is evident.

Aerial photographic interpretation generally involves several processes; detection, recognition, identification, analysis, deduction, classification and accuracy determination. For recognition and identification it is helpful to consider several factors.

i) Tone - the tone of a photograph represents the amount of radiation which has been reflected from the earth's surface and been recorded on the photographic film. Light tones indicate areas of high radiance, (low absorption) and dark tones represent areas or features of low radiance.

ii) Texture - the texture evident on a photograph is a result of the frequency of tonal changes which occur. Texture is more evident in small scale images.

iii) Pattern - this is the spatial arrangement of objects.

iv) Size and situation - the place of a feature is its location in relation to others in the vicinity.

v) Shape - this is the general outline or form of a feature.

vi) Shadows - often shadows aid interpretation by emphasising the texture and the vertical profile or the shape of a feature.

vii) Size - the size of an object is an important aid to identification. For example the shape, tone, texture and place of a dog kennel and a house may be similar but the size is very different.

These seven factors, plus field knowledge of the area (that is, knowing what one is likely to find in the study region) are considered when locating and identifying urban habitat types. All the information contained on the photographs was categorised according to the urban habitat classification (see Chapter Four). The habitat type and boundary location were marked on an acetate sheet covering the photograph (see Plates 4.1, 4.2, 4.3 and 4.4).

The 1981 imagery was interpreted in full. With the 1984 imagery it was believed it was necessary to map only the changes. However interpretation proved to be just as time consuming as the original survey. Constant referral to the 1981 photographs was required to ensure that real changes were mapped rather than the same habitats being classified differently on the 1981 and 1984 images. This constant reference to the 1981 interpretation provided a useful check of the habitat classification.

The next stage identified by the flow diagram (Figure 3.6) is the production of habitat maps. It is necessary to transfer the identified habitat categories on to a geometrically correct paper map. An aerial photograph cannot be directly used as an accurate map or plan. Scale distortions are present on the photograph as a result of camera tilt and ground relief. The scale of the final map can be different from that of the photographs and the scale distortions can be reduced by transferring the data by means of a transferscope. For this study, even though the habitat map was of a similar scale as the photographs, 1:2500, a monoscopic zoom transferscope was used to plot the habitat boundaries. Two 1:2500 scale maps were produced, one detailing all the mapped urban habitats identified from the 1981 imagery, the second mapping the changes which had occurred between 1981 and 1984 (see Figures 3.7 and 3.8). It was felt that it was unnecessary to replot all the habitats for the 1984 situation. In the future it is hoped that the habitat data can be stored on a computerised spatial data base. It will then be possible to produce maps easily of the complete habitat coverage in 1984.

The area of all the habitats mapped in 1981 and 1984 was measured using a manual electronic digitiser. A Hewlett Packard digitiser was attached to a B.B.C. micro-computer and the appropriate software calculated the area of each habitat and the length of the boundary. The use of the electronic digitiser allowed the digitisation of the area in the vector format, that is each boundary was defined by x, y coordinates. In the past, area totals have often been determined using a grid format (rastor based digitisation). Depending on the grid size chosen, the level of detail recorded is reduced. It was believed that vector digitisation would provide a more accurate representation of habitat size especially as a number of the recorded habitats are linear and often inaccurately measured by grid systems. Although the habitat information has been corrected for scale distortions, these measurments can be regarded only as approximations rather than photogrammetrically accurate. To produce very accurate measurements more sophisticated equipment would be necessary, for example a stereoplotter. As the lines drawn to define the habitat boundaries on the photographs introduce a degree of error into the area measurements, it was believed the accuracy of the measuring technique used was suitable for this project.

As an example of the measurement error which is present on the maps, an investigation was conducted into the area error which may occur due to the width of the lines drawn to outline the habitat boundaries. Attempts were made to draw the lines defining the habitats as finely as possible . The width of a random sample of pencil and ink lines was measured using a travelling microscope. It was found that the average width of an inked boundary was 0.32 millimetres and a pencil boundary was 0.23 millimetres. On a 1:2500 scale map this represents 0.8 metres and 0.58 metres on the ground respectively. This error does not appear very large but the width of the boundary can be multiplied by the length of the boundary to obtain the total error in the habitat area. This figure may be added or subtracted to the total area amount depending on whether the habitat measurements include or exclude the boundary line. This measurement error is evident for each habitat mapped and if it occurs in the same direction for each boundary it would make a significant difference to the habitat area totals. However, when digitising, attempts were made to follow the centre of the boundary line and it is hoped that the errors of addition and subtraction will have cancelled each other out. To further eliminate errors, each habitat boundary was digitised three times and the average of these three figures was accepted as the final area total.

As a result of the photographic habitat interpretation and digitisation, a vast amount of habitat area and boundary length data was available for analysis.

CHAPTER FOUR

THE HABITAT CLASSIFICATION

4.1 Why classify ?

Large-scale 1: 2500 aerial photographs provide a vast data source of a fine resolution. Various methods can be used to obtain this information.

i) Every identifiable piece of information can be extracted from the photograph to provide as complete a data base of the area as possible. Unfortunately this method is expensive as it is very time consuming especially if conducted manually.

ii) Only information which is related to a specific task is interpreted from the photographs, that is data extraction is more selective and therefore quicker .

For the majority of tasks the second method is the more appropriate. It is therefore necessary to use a classification system for the selective and consistent interpretation of data. The role of a classification system is recognised in a number of disciplines. Classification systems provide a logical method of ordering data for a particular purpose. They provide a convenient way of making a complex data source more manageable by grouping together areas with common features. It is easier to record and comprehend information about these groups and the data obtained will provide an accurate representation of the system as a whole (Rowe and Shead, 1981). Bunce and Shaw (1973) believed ecological classifications may allow the identification of important characteristics which can be used to make predictions about the unobserved properties. The major role of a classification system is to group together areas or entities with common features so that the data source becomes more manageable. The fact that the groups are based on common properties allows predictions or generalisations to be made from these broad categories about the whole population (Gilmour, 1951).

Whatever the task in hand, it is generally agreed that a classification is a valuable and often a very necessary aid which can make the system in question more manageable. However there is disagreement about how classification systems relate to the development of theories. One viewpoint is that classifications can be used to generate hypotheses about the system being studied (Bunce and Shaw, 1973). Others believe that it is important to devise a classification based on an existing hypothesis, the classification being a method by which data can be collected to test the theory (Rowe and Shead, 1981). Both methods have their uses.

The major aims of the study are to survey and monitor the land cover and ecology of the Blackbrook Valley and to test whether aerial photographs can provide enough detail about its wildlife habitats to provide quantitative population information. If this can be successfully carried out, it may be possible to delineate land units which are significant for the development and conservation of that area. A classification therefore has to be devised to provide information about the complete land cover in the Blackbrook Valley. This will include details of the man-made and semi-natural areas. In the developed sectors of the Valley, the classification will need to take into account land use as this can have a major influence on the ecology of the region. It needs to provide general details about land use and more specific information relating to the vegetation types.

For a study of urban ecology it is necessary to combine vegetation and urban land-use classifications. However even this may be problematic. As Shimwell (1983) suggested, it may not be advantageous to classify urban plant communities in the same way as rural communities.

> "In Britain and Western Europe opinions appear to be divided between the belief that the standard methods of description and classification are applicable to urban situations and the new alternative view that this special branch of ecology needs a new or modified methodology." (Shimwell 1983).

Although the need to classify is obvious, the development of a suitable classification is more difficult.

4.2 The choice between general or specific classifications

A global standard classification for all purposes would provide the ideal basis for comparative studies. However the existence of such a taxonomic system is unrealistic. Attempts have been made to develop standard classifications relating to one aspect of the global ecosystem, for example Fosberg (1967) tried to devise a general vegetation classification for the International Biological Program (I.B.P.). This was a large scale investigation and as such designated categories have to be more general than those defined for smaller geographical areas.

Generally classifications need to be designed for a specific purpose (Gilmore,1951). Even Fosberg (1967) agreed that for particular tasks specific taxonomic systems were preferable.

> "time spent searching for the one true classification is time wasted." (Rowe and Stead 1983).

Collins and MacDonald (1969) stated that a classification system groups subjects together based on certain common properties. The properties which are regarded as common depend on the aim of the classification and therefore no standard system is possible.

It is necessary to design an ecological classification to be used in an urban area with large-scale aerial photographs.

4.3 Classification design

Some decisions have to be made for all classifications whatever the purpose. Classifications can be *a priori* or *a posteriori*. With the former method, the classification system is devised before viewing the study area. The categories are chosen based on sub-divisions of the expected communities. This method has the advantage over other methods of being less dependent on preconceived ideas. Comparisons can readily be made between different study areas. The *a posteriori* method is based on field observations. The study area may be mapped and therefore classified. This technique is more flexible and is adapted to local conditions but as a result, it cannot be easily used in comparative studies. For vegetation mapping purposes Kuchler (1967) favoured the second method. Many classification systems result from a combination of the alternatives.

Once the basic units of interest have been identified, it is important to decide which attributes are to be considered in order to allocate these units into common groups. The choice of attributes can be made using single factors or multiple factors. Classification categories defined using a number of factors are believed to be more useful.

The arrangement of these categories is important. The classification can be single levelled or hierarchical. With a hierarchical classification the relationship between the categories is known. Every higher level is an aggregation of those immediately below it. The hierarchy can be developed in two ways, via aggregation or subdivision. With aggregation a population of individuals is grouped into larger related classes based on chosen attributes. With a sub-divisive classification the whole population in question is considered as one unit to be sub-divided into smaller parts. Either way a hierarchical classification is preferred to a single level as it is more flexible. Such a classification can be easily used with data sources of differing scales. For example a hierarchical classification may be designed with four levels but if the level of detail of the data source, such as small-scale aerial photographs, does not allow classification to the fourth level, interpretation can be carried out to a less detailed level.

A number of decisions concerning classification structure have to be made whatever the purpose.

4.3.1 Classifications for vegetation studies

Goldsmith et. al. (1986) described two major methods of vegetation description. Plant communities can be described by referring to

i) species composition, or to
ii) the appearance of the vegetation.

These characteristics can also be considered in the development of vegetation classifications. Two main attributes are used to describe vegetation appearance either separately or in combination; structure and function. The structure of the vegetation refers to its horizontal and vertical characteristics. Functional characteristics are the adaptations which the vegetation makes to its environment. Classifications based on the appearance of the vegetation tend to be more simple and thus are often preferred (Goldsmith et. al., 1986).

A number of vegetation classifications have been based on appearance. With hierarchical classifications, structural and functional properties are often used to define the major categories. If required, the actual species type can be recorded by finer divisions of the classification. Quite often however, the structural characteristics of the vegetation community are believed to be more important for descriptive purposes than the species composition (Danserau, 1951).

Fosberg (1967) based his vegetation classification on structural and functional characteristics. Communities were divided primarily on the basis of size, on the spacing of the vegetation and by functional features. Elton and Miller (1954), when devising a vegetation classification system to be used to describe animal habitats, grouped their categories by vegetation structure. Van Gils and Wijngaarden (1984) also developed a vegetation classification based on structure which was used with aerial photographs. They acknowledged however that it was generally impossible to identify more than two structural layers in the vegetation community. The Nature Conservancy Council's vegetation classifications used to map of Sites of Special Scientific Interest and the urban environment (Shimwell, 1983) are both based primarily on the structural characteristics of the vegetation, but include more detail by listing the dominant species recorded in each structural unit.

Vegetation classification can thus be based on species information, information relating to its appearance or a combination of both. The choice will depend on the aim of the classification and the resources available. Generally however vegetation surveys of large areas are conducted using physiognomic classifications. Such taxonomic systems are also more useful for aerial photographic studies as the resolution of the data source often precludes the identification of species.

4.3.2 Classifications for urban studies

Land use classifications are also based on the same general principles. Hierarchical systems are the most useful as again they are the most flexible. One of the problems in vegetation classifications is the concept of a vegetation continuum, that is that plant communities do not have distinct boundaries between the different categories therefore the imposition of classification perimeters is unnatural. Brady et. al. (1979) claimed a similar continuum situation exists between urban and rural environments. Hierarchical urban land use classifications are therefore beneficial as the categories can be further refined to include the rural environment. This is important for urban ecological studies as the surrounding rural areas will have an influence on the urban ecology.

4.3.3 Classifications for bird studies

Studies concerned with the relationship between bird populations and vegetation have generally been based on the classification of different habitat types (Rotenberry, 1981). The attributes considered in habitat classifications are very similar to those used in vegetation classifications as although the term habitat can be used to describe the living and non-living surroundings of an organism, it is often merely used to describe the vegetation.

The Nature Conservancy Council defines a habitat as:

> "a particular kind of environment inhabitated by organisms." (Nature Conservancy Council, 1982).

Bunce and Shaw (1973) stated it is valid to use vegetation as an index of the whole ecosystem as:-

i) The vegetation coverage is directly dependent on the environment.

ii) Vegetation is the primary producer upon which other organisms depend either directly or indirectly.

iii) Measurements of macro-vegetations are easy to obtain.

iv) Vegetation is a relatively permanent feature therefore no time dimension needs to be included in the collection of data.

Habitat classification can therefore be based on vegetation species and or appearance. Yapp (1955) developed a bird habitat classification based on both categories. He defined three major categories, terrestrial, aquatic and farm and homestead. Each of these divisions were further sub-divided based on structure, function and then species composition. He did however conclude that a number of different criteria could have been used to define the classification categories.

Emlen (1956) also claimed that the structure of the vegetation was very important in bird habitat classifications and for his classification the category divisions are made on the basis of foliage and twig types. Degraaf and Chadwick (1984) described bird habitats in terms of floristics and function.

Most of the bird population studies discussed have been concerned with relating bird species to habitat types thus habitat classifications have been used. In most instances the term habitat has been used to describe the vegetation community only and thus the classification systems developed have been based on similar attributes as used in vegetation taxonomic methods, for example floristic composition or the appearance of the vegetation community.

4.4 The development of a classification system for urban land cover and ecology

Consideration of previous classifications identified the features which should be incorporated into a new taxonomy. It is important to devise a classification for this particular study which provides an orderly method of mapping urban habitats using large-scale aerial photographs. Bastedo and Theberge (1983) identified a number of factors which a successful classification should fulfil. It should be ecologically valid, replicable, economic, flexible, applicable and communicable. By designing a classification for this project based on the most successful features of existing systems it was hoped that these ideals could be achieved.

Firstly it was important that the classification be hierarchical. This would allow for flexibility and should ensure that the system can be used by all interested parties whether biologists or planners. The different tiers of the system will allow the inclusion of fine botanical details if required. The basic land units for the classification were habitats. A habitat classification was chosen as it can describe semi-natural or man-made land cover types and thus satisfies the problem of the two major environmental types in the study area. Habitat classifications have been used very successfully in bird studies (Rotenberry, 1981) and such units can be strictly defined and readily identified (Buse, 1974). Habitat delineation is more suited to the resolution of aerial photographs as it is easier to identify and map a vegetation community than to map boundaries around single species patches. According to Nichol (1976) habitat classifications are preferred by planners as the data provided is not too fragmented.

The major attribute considered to identify the individual habitat units was appearance. For the man-made categories this was believed to be best described by reference to the land use of the units, for example residential or industrial habitats. Lillesand and Kiefer (1979) claimed land cover and land use information should not be intermixed. However for remote sensing studies they agreed that this combination was often the most practical standpoint. The U.S. Geological Survey combined these two categories to devise a classification system for use with remotely sensed data. For urban habitats both the structure and the land use of the developed land is important and thus it was felt that for this project the combination of the two categories was justified. The semi-natural habitat types were based on the structural divisions used by the Nature Conservancy Council (1982) and Shimwell (1983).

Shimwell's classification, adapted slightly by Handley (1985), has been used to survey the urban habitats found in the City of Nottingham (Rieley and Page, 1985). For the urban habitat classification, similar structural and functional features were used to classify vegetation types into different categories. Unfortunately due to the resolution of the aerial photographs, further sub-divisions of the habitat categories, depending on dominant species types or floristic composition, were not considered worth doing in view of the time involved. Due to its hierarchical nature, the habitat classification could, if necessary, be expanded to include this information. However for this study it was believed that the structural and functional details about the vegetation types were more important for habitat description than species information (Danserau, 1951; Fuller, 1982) and also more suitable for a photographic data source (Van Gils and Van Wijngaarden, 1984).

The urban habitat classification developed for this study is listed in Figure 4.1. It is an hierarchical classification. The different habitats are labelled with a consecutive numbering system. This is not the ideal situation as the addition of other habitat categories is very difficult. However when designed it was believed this system would be the most appropriate. It was intended originally to store the habitat data on a spatial computer data base. To reduce the risk of errors being made when entering the data on to a computerised system, a decision was made to restrict the habitat codes to as few digits as possible, in this case two digits. To code this classification in a hierarchical manner each label would have to contain at least four digits.

All the categories in the sections Land with no cover, Land with man-made cover and

Water cover are straightforward. With the exception of gardens, all the sub-divisions in the man-made cover category were unvegetated, covered either by man-made materials, for example tarmac, or by natural substances which had been transported into the area, for example gravels. All plots of semi-natural vegetation occuring for example in predominantly industrial or service areas, were classified as semi-natural communities, that is classification categories 27 to 60. Exceptions were the gardens attached to residential properties. Different garden types were included in the classification as in urban areas especially, they are valuable wildlife habitats (Owen and Owen 1975). It would be impractical however to individually categorise the vegetation types in each garden, therefore four common garden types were identified.

The semi-natural vegetation categories need more explanation. This section was divided into three structural layers, the tree layer above three metres, the shrub layer, below three metres and the field layer. Young trees, that is those below the height of three metres, were classified as shrubs as although species type may differ from the traditional shrub species, the structure of these trees will be very similar to shrubs. Van Gils and Van Wijngaarden (1984) claimed it is often very difficult to differentiate between trees and shrubs with aerial photographs. However, it was felt that with this study the large-scale of the imagery made such a distinction possible. The dividing line between trees and shrubs was set at an arbitrary level of three metres. The Nature Conservancy Council classifies woody species above five metres as being trees, however divisions of three metres have been used in other studies and this stratification appeared to be the most suitable for this particular environment.

Height measurements can be taken from the stereo pair of aerial photographs but the measurement of each tree or shrub would be very time consuming and in dense tree canopies impossible. It was therefore necessary to devise a method to determine whether the woody species were greater or smaller than three metres tall. A sample of trees and shrubs was taken to investigate whether there was a positive correlation between the canopy diameters and the height of the woody species. Unfortunately an element of bias was inevitable as in order to measure heights with a parallax bar, it is necessary to be able to see the ground near the tree, therefore only trees in open canopy situations could be used. As such trees can develop unhindered, it may be that their canopy diameters are larger than similar trees of the same height in a dense woodland situation. Lombardy populars *Populus Italica* were also excluded from the sample as although they have small canopy diameters they are tall species and can be readily recognised as such. A statistical correlation was found to exist between trees greater than three metres tall and their canopy diameters (see Appendix 1 for details of the method). This correlation allowed a gauge to be used to aid the photointerpretation of tree and shrub communities.

Figure 4.1 Urban Habitat Classification

1. Land with no cover
    2. Bare rock
    3. Bare soil

4. Land with man-made cover
    5. Buildings
        6. Service type buildings with accompanying hard surface
        7. Industrial buildings with accompanying hard surface
        8. Farm buildings with accompanying hard surface
        9. Recreational buildings with accompanying hard surface
        10. Residential with no garden
        11. Residential with garden predominantly lawn
        12. Residential with garden predominantly manicured
        13. Residential with garden predominantly trees and shrubs
        14. Residential with garden predominantly wild

    15. Rubbish covered surfaces
    16. Isolated hard surfaces
    17. Routeways
        18. Roads
        19. Railways
        20. Paths and tracks

21. Water cover
    22. Reservoir/Lake
    23. Canal
    24. River >4m wide
    25. Stream <4m wide
    26. Pond

27. Semi-natural vegetation cover

- 28. Tree cover, >3m height
    - 29. Broadleaved communities
        - 30. Single tree
        - 31. Closed wood
        - 32. Open wood
        - 33. Linear wood
        - 34. Tree/shrub
    - 35. Coniferous/evergreen communities
        - 36. Single tree
        - 37. Closed wood
        - 38. Open wood
        - 39. Linear wood
        - 40. Tree/shrub
- 41. Shrub cover <3m height
    - 42. Broadleaved communities
        - 43. Closed shrub
        - 44. Open shrub
        - 45. Linear shrub
    - 46. Coniferous/Ulex communities
        - 47. Closed shrub
        - 48. Open shrub
        - 49. Linear shrub
- 50. Herbaceous cover <1m
    - 51. Ruderal communities
    - 52. Tall herb and fern communities
    - 53. Rough tall grassland
    - 54. Wetland herbaceous communities
    - 55. Emergent communities
    - 56. Smooth turf grassland (unmanaged)
    - 57. Smooth turf grassland (managed)
    - 58. Rough turf grassland
    - 59. Floating vegetation
    - 60. Submerged vegetation

Single tree - There is no other tree within a distance of 1.5 times the diameter of the average size tree canopy.

Goldsmith (1974) criticised Fosberg's method of describing the density of wooded communities as being too impractical for use in the field however this method appears to be suitable for use with large-scale aerial photographs.

With the habitat classification, it is important to realise that the wood and shrub habitat categories do not reflect the area of the woody communities. They refer to the height of the vegetation and the spacing of the individual plants.

The habitat categories of the third structural layer, the herbaceous layer, are based on those identified by Shimwell in his urban habitat conspectus (1983). Again these habitats are defined on the basis of height, spacing and texture rather than floristic information. Each category can be identified by the following descriptions:-

Ruderal community - This is a very sparse grass or herb cover and consequently the soil or man-made surfaces can be easily seen. This habitat tends to occur on disturbed sites.

Tall herb and fern communities - These are dominated by tall herbs, ferns and grasses. The vegetation will appear very lush and almost bushy in appearance.

Tall rough grassland - These communities are of a similar height and density to the previous communities but as they are composed primarily of grasses they do not appear as lush.

Wetland herbaceous communities - Such communities are found in damp environments, for example marshes, flushes and swamps. They appear to be lush and are normally identified by the colour of the wetter environment.

Smooth turf grassland (unmown) - This describes short neat looking grassland cover without any evidence of mowing. This category may be grazed.

Smooth turf grassland (mown) - This category is very similar to the above but shows signs of maintenance, for example the patterns produced by mowing are visible

Rough turf grassland - Again this is a short grass community but its appearance is more patchy.

Emergent communities - This refers to the vegetation which is found along the edge of water bodies standing (rooted) for most of the time in the water.

Floating vegetation - This community occurs in water bodies but not necessarily at the edge. It may be found in the centre.

Submerged vegetation - Vegetation which is visable on the aerial photographs below the water's surface.

This habitat classification is a revised system. The original legend included more categories, for example individual categories for gorse communities and fern communities. A pilot test was conducted to determine the accuracy of interpretation of the original classification. Stratified random sampling identified a number of points in each vegetation habitat type. An unacceptably high level of inaccurate interpretations, 20 per cent, was obtained. The categories which were being repeatedly misinterpreted via errors of commission or omission were identified. It was found that fern communities could not be separated from herb communities and gorse habitats were frequently classified as coniferous shrubs. The classification was altered and these two habitat types were combined to create tall herb and fern and coniferous/Ulex communities. Plates 4.1, 4.2, 4.3, 4.4 illustrate how the classified habitat types appear on the colour infra-red imagery and also the method used to map this habitat information. The code number corresponds to the habitat category numbers listed in Figure 4.1. The appearance of these habitat categories in the field is illustrated by Plates 4.5 to 4.18.

Plate 4·1 An illustration of the classified urban habitats located around Netherton Church, 1984.

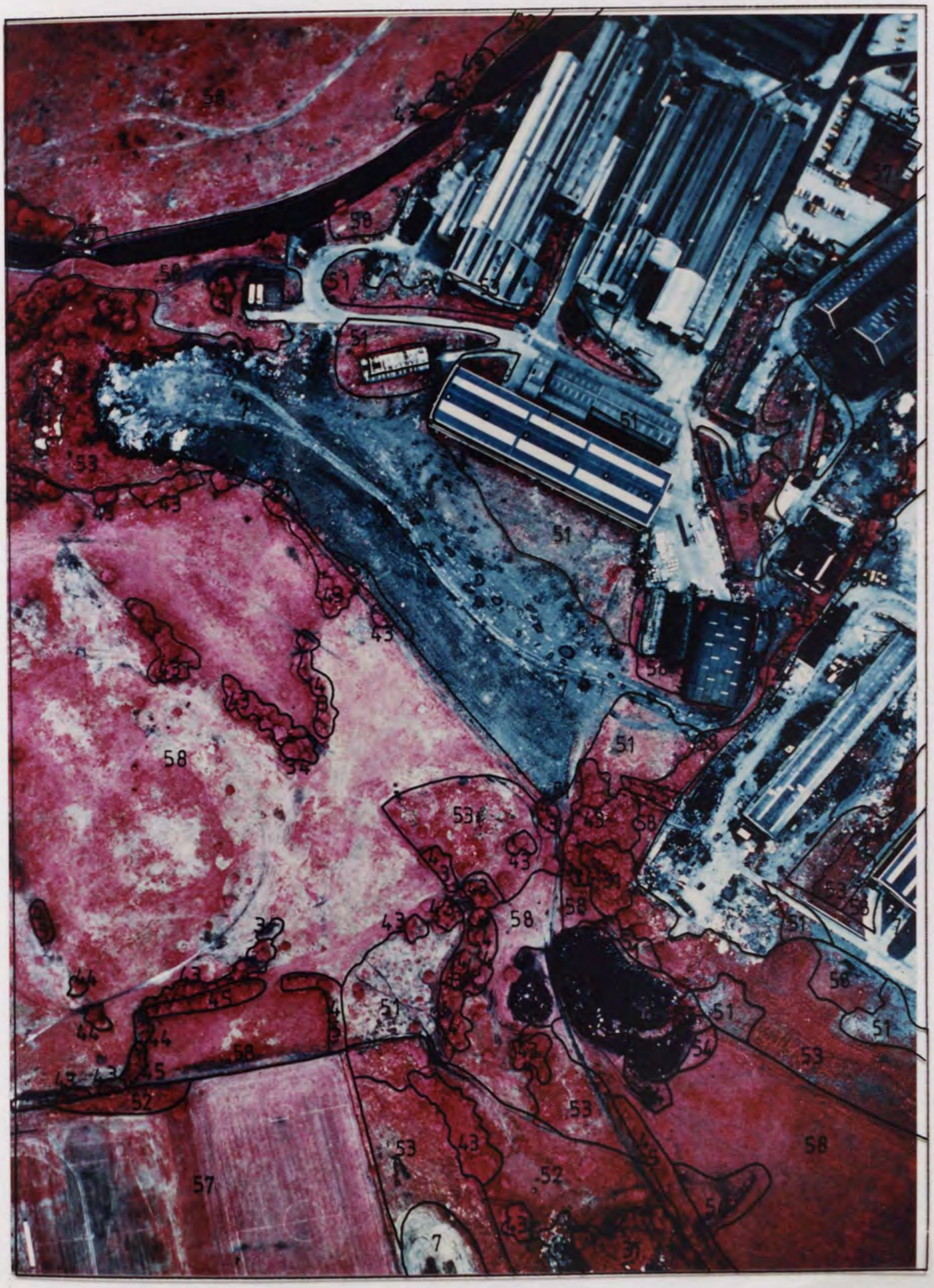


Plate 4·2 Classified urban habitats south of Peartree Lane.

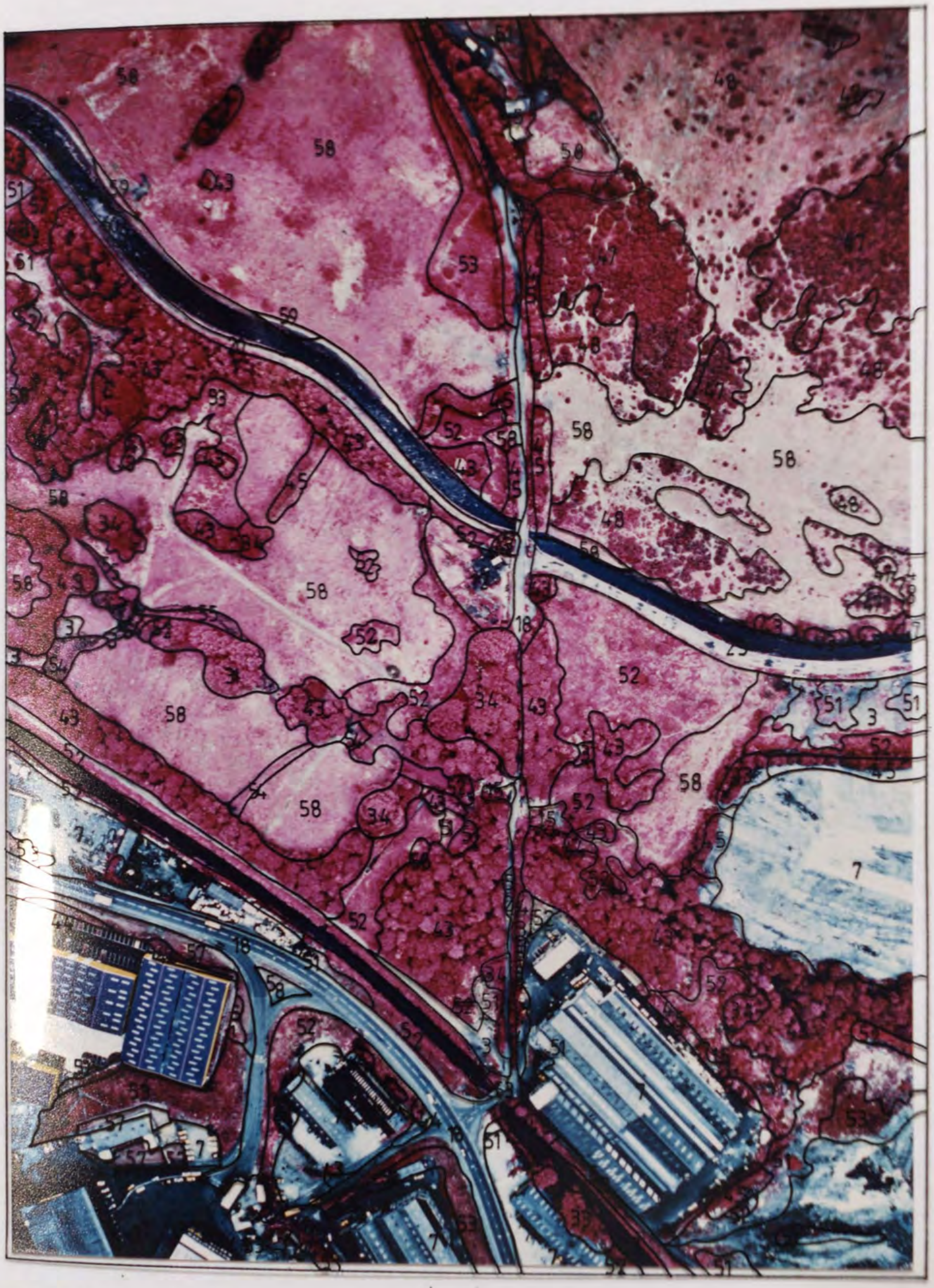


Plate 4·3 The habitats identified in a central sector of the valley.

Plate 4·4 Urban habitats in the south of the study area.

Plate 4.5 A developed area within the Enterprise Zone, illustrating urban habitat categories 7, 18, and 44.

Plate 4.6 The Industrial area adjacent to Saltwells Local Nature Reserve, illustrating habitat categories 7 and 44.

Plate 4.7 An industrial site (7) in the Enterprise Zone. A patch of closed broadleaved shrubland (43) is evident on the right of the picture.

Plate 4.8 Patches of closed broadleaved shrubland (43) which have been left standing in an area of industrial activity (7).

Plate 4.9 A north view of the Blackbrook Valley from Netherton Church, illustrating a number of different urban habitat categories; closed and open coniferous/ulex shrubland (47 and48), rough tall grassland and rough turf grassland (53 and58) and an industrial area (7).

Plate 4.10 A residential area without a front or back garden (10).

Plate 4.11 This photograph illustrates the habitat categories of rough tall grassland (53), rough turf grassland (57), closed broadleaved shrub (43) and closed broadleaved wood (31).

Plate 4.12 An area of gorse, bramble and rose bay willowherb. These vegetation communities are classified as tall herb and fern grassland (52), closed coniferous/ulex shrub and closed broadleaved shrub (43).

Plate 4.13 An area in Doulton's Clay Pit with closed coniferous/ulex shrub (47 and 48) and areas of bare soil (3).

Plate 4.14 Closed broadleaved shrub (43) and rough tall grassland.

Plate 4.15 The geological section found at Doulton's Clay Pit. The urban wildlife habitat categories illustrated include bare rock (2) and closed broadleaved shrub (43).

Plate 4.16 Saltwells Local Nature Reserve - an area of closed broadleaved woodland (31).

Plate 4.17 The banks of the canal (23) are vegetated with tall herb and fern grassland (52), tall rough grassland (53) and closed broadleaved woodland and shrubland (31 and 43).

Plate 4.18 Lodge Farm Reservoir (22) lined by broadleaved shrubland (45) and emergent vegetaion communities.

4.5 The determination of classification accuracy using sampling methods

It is generally agreed that if remote sensing is to be accepted as a feasible method for thematic mapping, the accuracy levels of the produced maps have to be determined. Draeger and Carneggie (1974) stated accuracies have to be tested to indicate the level of trade-off between time, expense and precision. Hord and Brooner (1976) claimed the major errors are classification error, boundary error and control point error, but to gain a measure of exactness all three categories can be combined. Generally a map is regarded as being of an acceptable standard if 85 per cent of the map has been classified correctly. This figure is the American standard recommended by their national mapping agency, the U.S. Geological Survey and it is applicable to vegetation maps as well as topographical and geological maps (U.S. Geological Survey, 1978). Usually accuracy studies test the quality of the interpretation of a classification. If this is acceptable the resultant map is also regarded as being of a similar accuracy standard.

Two methods are frequently used for accuracy assessment. Firstly, the remotely sensed map can be compared to a similar map of the same area based on an alternative data source. However, quite often, appropriate data is not available for comparison. An alternative option is the comparison of the classified map to ground survey data. The map is thus sampled to identify areas which are to be checked in the field. Opinions differ as to which sampling method is the best. In the literature there is a great deal of support for the stratified random sampling of all the individual classified categories (Van Genderen and Lock, 1977; Hay, 1979; Ginevan, 1979 and Aronoff, 1985). This method ensures that the smaller areas are sampled and the accuracy of each classification category is checked. For these reasons this method was used in the pilot test mentioned earlier. Frazier and Shovic (1980) favoured random sampling methods to ensure that no bias is incorporated into the sample. Random sampling is an ideal method to gain information about the percentage area of land cover types. As more sample points will be allocated in the dominant areas and fewer in the small plots, the relative areal importance of different land units can be estimated. However if the aim is to determine the accuracy of classification interpretation, it is important to ensure that samples are taken in all habitat categories and this may not be possible with strict random sampling methods. Rosenfield and Melley (1980) argued that systematic sampling is an acceptable alternative to random methods provided that any systematic trends in the data population are made ineffective, for example by randomly aligning the sampling grid axis. Grieg-Smith (1983) claimed systematic sampling methods are often preferred as they are more representative of variables over a wide area and are easier to carry out in the field.

Whatever the sampling frame chosen, there is a general agreement that the sample size has to be sufficiently large to portray landscape complexity without taking more samples than is necessary. Aronoff (1982) defined the sampling problem as

> "one of determining the optimal number (N) of map samples to be compared with ground area, and an allowable number (X) of misclassifications of these samples."

The size of the sample unit is also important. In theory the sample unit is often considered to be a point, but in practice it is almost impossible to locate a point on the ground. It is therefore necessary to decide on the size of the sampling unit which is located centrally on the chosen point in the field. Aronoff (1985) claimed that the sampling unit should be as large as the minimum mapping unit otherwise the thematic map will be tested at a level of resolution it was not designed to meet. On the other hand, if the sampling unit is too extensive it may overlap a number of different classification categories thus making the accuracy checks more complicated. Sampling frameworks thus need to be developed for each individual survey type (Draeger and Carneggie, 1974).

Most methodologies suggested in the literature aim to indicate the number of errors which are statistically acceptable in a given sample size for a specified accuracy level. Accuracy levels have been represented purely by simple percentages or more usefully as statistically significant percentages. Rosenfield and Fitzpatrick-Lins (1986) found that accuracy levels represented only by the total percentage of correct points tended to overestimate map accuracies when compared with other accuracy measures as the element of chance is not indicated in such percentage accuracy levels.

Snedecor and Cochran (1967) put forward an equation to statistically assess map accuracy at the 95 per cent confidence level.

$$\hat{p} \pm = \quad 1.96 \sqrt{\frac{\hat{p}\,(100 - \hat{p})}{n}} + \frac{50}{n}$$

where $\hat{p} \pm =$ the range of accuracy levels expressed as a percentage at the 95% confidence level

$\hat{p} =$ the percentage accuracy levels recorded

$n =$ number of samples taken

For example, if 90 per cent of the sampled points have been accurately mapped and p± is calculated to be ±3 per cent, it can be stated with 95 per cent confidence that accuracy of the map is between 87 and 93 per cent. As these figures exceed 85 per cent, the level recommended by the U.S. Geological Survey (1978), the map is accepted as accurate. Such statistics indicate the probability of accepting a map which is below the required accuracy level, that is, in the above example there is a 5 per cent chance that a map below 87 per cent accurate will be considered suitable.

These tests indicate the chance of accepting a map below par but both Ginevan (1979) and Aronoff (1982) believed it is also important to consider the probability of rejecting a map which is of a suitable standard. Ginevan (1979) identified the important criteria to be considered when determining map accuracies:-

i) There should be a low probability of accepting a map of low accuracy,

ii) there should be a high probability of accepting a map of high accuracy and

iii) a minimum number of ground data sample points are required.

To fulfil these requirements Ginevan and Aronoff both based their accuracy tests on a branch of statistics known as acceptance sampling. In acceptance sampling the binomial probability distribution is important. This is one of the most common probability distributions and is associated with the repetition of events where there are only two possible outcomes with an equal probability of occurrence. In this instance the two possible outcomes are either the habitat has been correctly classified or it has been misclassified.

They recognised the concepts of consumer and producer risks. Consumer risk indicates the probability of the consumer accepting an unsuitable map. The lowest level of acceptable accuracy to the consumer (for example 85 per cent (Q_2)) and the probability of rejecting a map below this accuracy level (for example 95 per cent (1-b)) are specified. Once these criteria have been chosen it is possible, via equations, to determine the number of samples (N) and the number of misclassifications (X) permitted to obtain statistically significant results. A map will be rejected if there are a greater number of errors than the specified allowable number of misclassifications. However if accuracy tests were based only on these parameters there would often be a very high probability of rejecting a suitably accurate map, therefore it is also necessary to consider producer risk (Q_1). Producer risk is the probability of rejecting a map of high accuracy. The levels of producer risk (quoted by both the authors) are 95 per cent, 97 per cent, and 99 per cent, that is the chance of rejecting a map which is for example 97 per cent accurate is considered. There needs to be a compromise between consumer and producer risk. The risk to the producer can be decreased by increasing the consumer risk or by increasing the sample size.

As the required accuracy levels become higher, the consumer and producer risks have to be lowered by increasing the sample size. However the extra accuracy occurs at a disproportionately high cost, thus in some instances if misclassifications are not costly, it will be reasonable to accept a higher consumer risk or lower accuracy levels than originally preferred. Aronoff (1985) included the concept of minimum accuracy value which indicates by what extent a map has failed to reach the required standard. For example, in some instances, even though the standard accuracy level is 85 per cent, it may be sensible to accept a map of 82 per cent if the producer and consumer risks are known to be reasonable. Thus the accuracy of classified photographs and maps can be determined with a degree of statistical confidence.

4.6 The accuracy of the habitat classification in the Blackbrook Valley

All accuracy levels were determined by comparing the original classified categories identified on the photographs to the site classification in the field. An error was recorded if the classified habitat type did not correspond exactly to that in the field. For example, an error would be noted if an area classified as tall herb and fern grassland (52) on the aerial photographs was found to be rough tall grassland (53) in the field, even though the habitat has been correctly classified as belonging to the herbaceous vegetation category. Error determination was made at the most detailed level of the hierarchical classification. As discussed earlier, the suitability of the original habitat classification was determined by a pilot study based on a stratified random sample of all the vegetation cover types. Commission and omission errors were identified and the classification was revised.

In order to determine the accuracy of the classification interpretation for all the habitat categories, further accuracy tests were completed. Sample photographs from 1981 and 1984 were randomly chosen and all the habitats on these images were demarked.

4.6.1 Interpretation accuracy of the 1981 photographs

For the 1981 test, colour and colour infra-red photographs were used. Originally the aim was to sample 100 points per emulsion but due to the impracticalities of locating some of these points in the field and the re-definition of the study area, a smaller sample was actually taken. The test sites were chosen via a systematic sampling frame. This was believed to be appropriate due to the random distribution of the habitat types (Rosenfield and Melley, 1980). For the photographic classification to be accepted, it had to be 85 per cent accurate.

Table 4.1 Results of 1981 habitat interpretation

	Colour Interpretation	Colour Infra-red Interpretation
Number of points sampled	79	89
Number of errors	16	9
% accuracy	79.7%	89.9%
% accuracy at 95% confidence level (Snedecor and Cochran,1967)	70.2% - 89.2%	83.1% - 96.7%

Table 4.1 indicates that the accuracy levels recorded differ with emulsion type. It is apparent that habitats can be identified more accurately using colour infra-red than colour photographs. If the percentage of accurate points is considered, it appears that the accuracy of the colour infra-red interpretation is reasonable but the colour habitat map is below par. However as mentioned by Rosenfield and Fitzpatrick-Lins (1986), simple percentages can give an inflated impression of the actual accuracy as they do not consider the affect chance can play on the number of errors recorded. Thus the actual accuracy may be below the percentage figure. In order to consider the statistical significance of these percentage totals, the equation suggested by Snedecor and Cochran (1967) was used. This indicated that there was 95 per cent probability that the colour infra-red interpretation was at least 83.1 per cent accurate. Unfortunately this is below the acceptable 85 per cent level. The colour interpretation could be as inaccurate as 70.2 per cent at a 95 per cent confidence level. This is clearly unsuitable. As a final check to the accuracy levels of these two emulsion types, the tables produced by Aronoff (1985) were

consulted. The interpretation would be considered suitable if there was a 5 per cent chance that a map less than 85 per cent accurate would be accepted (consumer risk) and a 5 per cent chance that a map of 95 per cent accuracy would be rejected (producer risk). Both the colour and colour infra-red interpretations failed to meet these criteria, however for the colour infra-red emulsion, Aronoff identified that there was a 5 per cent chance of accepting a map which is 82.2 per cent accurate (minimum accuracy value). The colour infra-red phographic interpretation is therefore just below the required standard.

The poor results however do not necessarily reflect the unsuitability of the classification or the standard of photographic interpretation. Unfortunately there was a time delay of three years between the date of the photographs (1981) and the field checks (1984). As urban environments are dynamic ecosystems, a great number of changes can occur in a period of three years. This is especially the case in Blackbrook Valley with the establishment of the Enterprise Zone in 1981. The author is confident that at least two of the recorded errors were the result of developments which had taken place at the sample site near Peartree Lane. If these errors were excluded, the accuracy of the colour infra-red interpretation would be acceptable fulfilling the consumer and producer criteria. A number of recorded misclassifications (three) occurred in residential gardens and therefore are not believed to be real errors of interpretation for two reasons:

i) Gardens are very dynamic features. Due to the intensity of human mangement, the whole pattern of a garden may change from year to year especially if there is a change of house occupier.

ii) Residential areas were generally classified depending on the dominant garden type. This resulted in blocks of similar residential categories. However in each block there may be a garden type which differed from the dominant. On rare occasions the sample point may have been located in this exception thus contributing to the level of error recorded.

Although the accuracy figures for the 1981 interpretation do appear to be below standard, it was felt that the major cause was not the suitability of the classification or the standard of interpretation, but the time delay between the date of the photography and the field survey. Thus the habitat classification was used to interpret the remainder of the 1981 and 1984 photographs. However the results did emphasise the superiority of the colour infra-red emulsion to the colour emulsion and thus colour infra-red photography was used as the main data source for the rest of the study.

4.6.2 Interpretation accuracy of the 1984 photographs

For the 1984 accuracy test, only the colour infra-red photographs were used. The same points were sampled as in the 1981 test, although additional points were added in areas where a large amount of change had taken place.

It is evident from Table 4.2, the accuracy levels recorded for the 1984 photographs were superior to those recorded in 1981. The number of misclassifications is very low and well within the acceptable number calculated by Aronoff (1985). These figures easily fulfil the conditions stated previously, that is, there is a 5 per cent chance of accepting a map less than 85 per cent accurate and a 5 per cent chance of rejecting a map which is 95 per cent accurate. These figures would fulfil more rigorous accuracy definitions.

Table 4.2 Results of the 1984 habitat interpretation

	Colour Infra-red Interpretation
Number of points sampled	198
Number of errors	5
% accuracy	97.5%
% accuracy at 95% confidence level (Snedecor and Cochran)	95.1% - 99.9%

As the classification used with the 1981 and 1984 photographs remained the same, the improved levels of accuracy are primarily due to the reduced time interval between the date of the photography and the date of the field survey and the improved skills of the interpreter.

4.7 Conclusions

An hierarchical structural classification appears to be a suitable option to map urban habitats. Semi-natural and man-made features can be incorporated, solving the problem of the two major contributors to an urban ecosystem.

However there are limitations to the classification. There is disagreement as to whether it is necesary to define a minimum size area to be mapped. This often improves the clarity of the finished product. Collins and MacDonald (1969) claimed a hierarchical classification should go as far as the smallest recognisable and geographically identifiable unit. Fosberg (1967) did not specify a minimum size and was criticised by Goldsmith (1974) for this. Whether a minimum mapping unit is necessary and is defined will depend to some extent on the aim of the project, for example researchers may be only interested in parcels of land which are larger than 0.5 hectares, and thus it is not necessary to map units at a finer scale. For this project the aim was to extract as much information as possible using the classification. Planners, environmental managers and conservationists may require information at different levels of detail, therefore it is more sensible to have a detailed classification and amalgamate categories when necessary. This will be very easy if the habitat information is digitised and stored on a computerised spatial data-base. For this particular project it was decided to investigate bird populations. Many of the habitat units identified may be too small to be of any significance to bird populations but in the future this data may be used to look at the population levels of other species such as snails, or carabid beetles and thus fine habitat divisions would be necessary. If the equipment and funds are available the author believes it is better to map as much detail as possible, especially if there is the possibility of the data being stored in a computerised data bank.

The accuracy of habitat interpretation and thus of the resulting habitat maps, was found to be acceptable. However the actual location of the boundaries between habitat types was not checked. As one of the advantages of using aerial photographs is claimed to be the identification of boundaries between different units, it was assumed that if the habitat type had been correctly identified, its boundary had also been accurately located. This assumption was believed to be more than adequate for the man-made structures and open water habitats, as usually there are very definite distinctions between different units. However there is more of a problem with the vegetated habitats.

There is a difference of opinion as to whether or not any boundaries can be drawn between different plant communities. One school of thought states that the change between vegetation types is transitional and as such no perimeter can be identified. On the other hand, some people believe that boundaries can be drawn with great precision depending on the presence or absence of a single species. It is unlikely that, due to the resolution of aerial photographs, habitat perimeters could be drawn on this criteria, unless dealing with tree species and therefore boundaries are located where the vegetation appearance obviously changes. The accuracy of these divisions from aerial photographs cannot be tested as there is not absolute agreement about their location in the field.

Even if the man-made and semi-natural habitat types have been accurately identified and located, there is no guarantee that these divisions are ecologically significant to the fauna in the area (Bastedo and Theberge, 1983; Plachter, 1980). Plant communities have been accepted as a suitable index to describe ecological relationships, for example how animals relate to the environment. However, as animals are mobile there is no real indication that the relatively static botanical boundaries have an important bearing on their behaviour. Plachter (1980) concluded that in order to map animal populations, special habitats need to be identified which are not necessarily based on vegetation characteristics, for example church towers can provide suitable habitats for birds. He believed an animal habitat map should be combined with a vegetation map at a later date. With the urban habitat classification, although not restricted only to vegetation categories, the man-made structures are not classified in such a way as to be of optimum value in wildlife studies. For example, as the classification is to be used on this occasion for bird population studies, information about the ledges on the sides of buildings may have been useful. However due to the plan view provided by the aerial photographs such structural features are not always visible. Although vegetation characteristics may not adequately describe animal habitats, it is not always possible to identify what the important features to the fauna are, via field or aerial survey. Vegetative habitat descriptions should be recognised as limited, but in many instances they may provide the best that can be acheived with the resources available.

The suitability of the urban habitat classification can best be determined when the results of the analysis are known. It is then possible to discover whether the characteristics of value have been adequately described and whether any major features have been ignored. The devised habitat classification was used to survey all the habitats in the Blackbrood Valley to the greatest level of detail possible.

CHAPTER FIVE

URBAN HABITATS IN THE BLACKBROOK VALLEY

5.1 Introduction

Using the methodology and the classification described in the previous two chapters, the urban habitats in the Blackbrook Valley were mapped and monitored. The area of the whole study region is approximately 260 hectares. The main habitat characteristics of interest are

i) the number of units per habitat category,

ii) the area of the individual units and

iii) the total area per habitat category.

The digitising programme used for area measurements also calculated the length of individual habitat perimeters but these measurements are not considered here. The success of the remote sensing data source to provide details about the area's ecology can best be determined by considering the accuracy and the usefulness of the results obtained.

5.2 Habitats in the Blackbrook Valley in 1981

Of the sixty habitat classification categories defined, only forty-three habitat types were mapped in the Blackbrook Valley in 1981, (see Figure 3.7). This discrepancy was caused by the absence of certain habitat categories and the actual structure of the classification. Due to the large scale of the photographs, the more general habitat categories, such as those listed below, were not mapped as it was possible to classify the area's habitats to a greater level of detail. An exception was category 5, 'Buildings'. This classification category was used to classify seven units where land-use was not obvious from the photographs and therefore more detailed classification was not possible. Even though the following listed classes are redundant in this study, it is important that they remain as an integral part of the taxonomic system as they will be necessary for imagery of a smaller scale or of inferior clarity.

The habitat classification categories which were absent in the Blackbrook Valley are listed below.

1.	Land with no cover
4.	Land with man-made cover
21.	Water cover
27.	Semi-natural vegetation cover
28.	Tree cover
29 and 42.	Broadleaved communities
35.	Coniferous/evergreen communities
46.	Coniferous /Ulex communities
41.	Shrub cover < 3m
50.	Herbaceous communities

Some of the more detailed habitat sub-divisions do not exist in the area, for example rivers (24) and some coniferous wood and shrub communities (36, 37, 40, 49). Although these categories do not occur in the Blackbrook Valley in 1981, they contribute to the classifications adaptability and therefore should remain.

Of the forty-three classes which were mapped, area data was obtained for thirty-nine of these. Due to the linear nature of roads, railways, canals and streams, these features were not digitised. Areas of vegetation occuring alongside or on these features, for example floating vegetation (59) were recorded.

The total area of habitats mapped in 1981 was 245.57 hectares. This is 14.43 hectares below the total area of the Blackbrook Valley study region. Most of this discrepancy can be accounted for in the following three ways.

i) The combined area of roads, railways, canals and streams,

ii) Less importantly, the rounding up of the digitised area data from metres squared to hectares.

iii) The errors which occur in the digitising process. As already discussed in Chapter Three, the boundary line around each habitat type represents a width of between 0.6 and 0.8 metres on the ground.

Table 5.1 The area of habitats in the Blackbrook Valley, 1981

Habitat category.	Area (ha.).	Percentage of total area (260ha).	Number of units.	Average size per unit.
2	0.04	0.02	3	0.01
3	3.65	1.4	61	0.06
5	0.18	0.07	7	0.03
6	1.89	0.7	7	0.27
7	47.28	18.2	36	1.31
8	0.02	0.007	1	0.02
9	0.26	0.1	3	0.09
10	0.29	0.1	6	0.05
11	6.76	2.6	42	0.16
12	7.77	3.00	57	0.14
13	0.91	0.4	17	0.05
14	4.38	1.7	50	0.09
15	0.19	0.07	14	0.01
16	0.43	0.2	2	0.22
20	0.12	0.05	3	0.04
22	4.98	1.9	1	4.98
26	0.37	0.1	6	0.06
30	0.22	0.08	25	0.009
31	18.07	6.95	30	0.6
32	0.1	0.04	2	0.05
33	0.92	0.4	11	0.08
34	10.24	3.9	75	0.14
38	0.007	0.002	1	0.007
39	0.01	0.003	1	0.01
43	22.74	8.7	329	0.07
44	3.77	1.5	210	0.02
45	3.43	1.3	22	0.16
47	2.07	0.8	49	0.04
48	8.99	3.5	20	0.45
51	10.39	4.0	230	0.05
52	16.23	6.2	183	0.09
53	10.64	4.1	159	0.07
54	0.58	0.22	19	0.03
55	0.87	0.3	49	0.02
56	0.52	0.2	17	0.03
57	14.17	5.4	38	0.37
58	45.66	17.56	122	0.37
59	0.53	0.2	26	0.02
60	0.12	0.05	7	0.02
	$\Sigma = 245.57$		$\Sigma = 1941$	

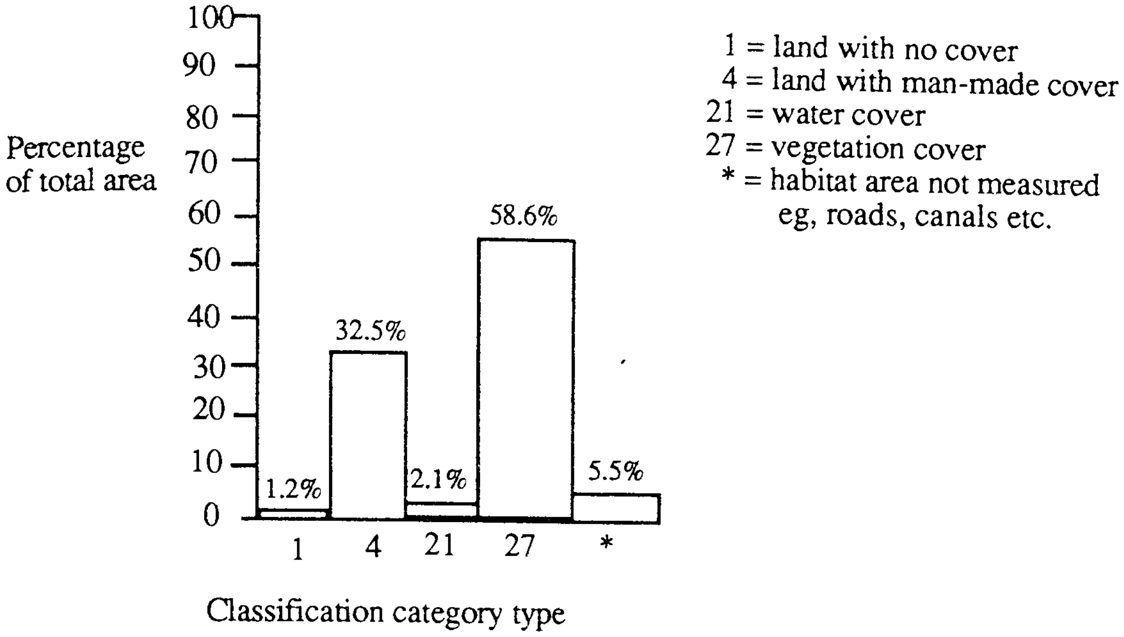


Figure 5.1 Percentage of total area covered by four major land cover classes

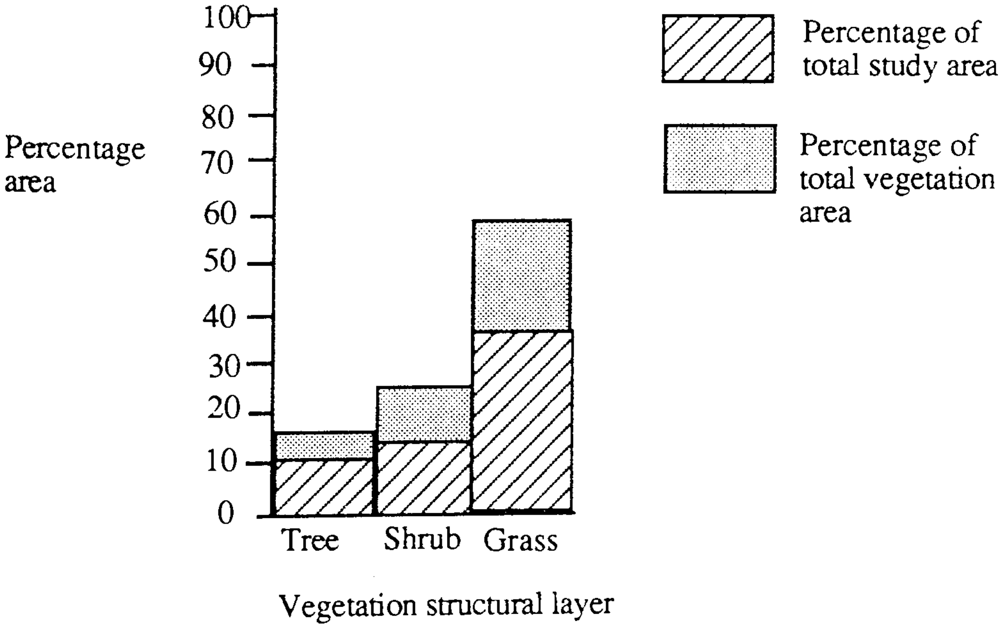


Figure 5.2 Percentage of total vegetation area occupied by trees, shrub or grassland in 1981

Figure 5.1 illustrates that the dominant land cover type in 1981 was vegetation cover, accounting for 65.4 per cent of the total land area. Built-up land occurred in over one-quarter of the study area (27.1%) and the amount of land in the other two categories was minimal. Of the vegetation categories, the herbaceous habitat types were the most common, accounting for 38.23 per cent of the total land area and 58.56 per cent of the total vegetation area (see Figure 5.2). The shrub layer was the second most dominant group, followed lastly by the tree layer. It is thus obvious that, in the Blackbrook Valley, the less structurally complex vegetation habitat types dominated. This is likely to be a result of the dynamic nature of the urban area. Vegetation communities are frequently disturbed and often do not have the time or the correct soil conditions to evolve into more structurally complex communities.

Table 5.1 indicates the total area of each habitat type and what percentage this represents of the Valley's area as a whole. No one habitat type covered more than 18.2 per cent of the total land surface. Of the thirty-nine habitat categories listed, only seventeen accounted for more than one per cent of the total area. This indicates that many of the habitat types occur in small patches. High levels of habitat patchiness are considered characteristic of urban environments. This is generally the result of the diversity of environmental influences in an urban area. A more detailed investigation into habitat patchiness in the Blackbrook Valley is discussed in the following chapter. The major habitat type in the Blackbrook Valley was industrial land accounting for 18.2 per cent (47.28 ha.) of the total land area.

Of the vegetation classes, only fifty per cent had area totals or more than one per cent. The smallest habitat units recorded were open and linear coniferous evergreen woodland categories (38, 39). In each instance, only one habitat unit was mapped. Coniferous evergreen trees very rarely occur in the Blackbrook Valley. They are only recorded in Netherton church yard.

The size of a habitat does not however necessarily reflect its importance to wildlife. The other mapped vegetation communities which were small in terms of total area and unit size were those found in the water bodies, that is, tall fragmentary marginal communities (55), floating vegetation (59), and submerged vegetation (60). The size of these habitat types is limited by the size, shape and nature of the water body as well as the management techniques or recreational activities undertaken. For example floating vegetation (59) which in this area is primarily composed of duckweed *Lemna minor* and *Lemna trisulca* is most frequently found in still, sunny waters. The British Waterways Board tidy up the canals in the Valley every April, before the beginning of the boating season and in addition the canals are cleaned thoroughly every six to seven years. These habitat types therefore only have a limited period to establish themselves. Although these wetland communities are small in area, they are very important habitat types and should not be ignored.

The most dominant vegetation type was rough turf grassland (58) but as no one habitat category accounts for over 20 per cent of the total area, it can be concluded that there was a great diversity of habitats occurring in the Blackbrook Valley in 1981. Although industrial land was the most widespread individual habitat type, the majority of the study area was covered by vegetation.

Table 5.1 also lists the number of units of each habitat type and the average size per unit. The most frequently occuring habitat type in the area was closed broadleaved shrub (43). As this only accounted for 8.71 per cent of the total land area, this indicates that this category must occur in small patches. The average size unit is 0.07 hectares. This trend of small habitat patches was evident for most of vegetation habitat types especially the shrub and grassland habitat types. The most frequent grassland community was ruderal vegetation (51). Such habitats are found in hostile environments, for example a number of patches have been recorded in the industrial areas. It is an early vegetation succession stage and if undisturbed may develop into a more complex community. The number of shrub communities recorded may also be a result of disturbances in the study area. The shrub habitats mapped may be either the climax vegetation type of a harsh environment or they may be a successional stage and may eventually develop into climax woodland, for example Doulton's Clay Pit. Many of the shrub patches identified appeared to be the remnants of a former habitat type, for example sections of old hedgerows on old agricultural land.

Since the average size per unit of each habitat type (with the exception of industrial land and the lake) was below 0.6 hectares, this indicates that not only was there a great diversity of habitats in the area but also that these habitat types were very scattered in their distribution .

From Table 5.1 it appears that only the lake and industrial land occurred in large units. These figures are slightly misleading, as in the reserve there is large area of closed broadleaved woodland (15.13 ha.) which is not obvious due to the average figures quoted. However the mean unit size of the broadleaved closed woodland (31) emphasises the fact that the units of this habitat outside the reserve boundaries were very small. The large blocks of industrial habitat were the result of a concentration of industrial complexes in the northern section of the study region, along Peartree Lane and Pedmore Road.

5.2.1 Habitats in Saltwells Local Nature Reserve in 1981

Due to the large number of individual habitat units recorded, it was necessary to reduce the extent of the study area for more detailed research. To consider whether it is possible to determine animal population numbers from habitat information obtained from aerial photographs, it was convenient to limit the study area to Saltwells Local Nature Reserve. It was necessary therefore to isolate the habitats recorded in the reserve in 1981, from the total number mapped in the Blackbrook Valley study area (see Table 5.2).

Figure 3.7 indicates that the reserve in the Blackbrook Valley could be divided into two sections, the western half was composed of large habitat units and the more easterly section comprised a number of small, more diverse habitats. These divisions corresponded to the areas known as Saltwells Wood and Doulton's Clay Pit.

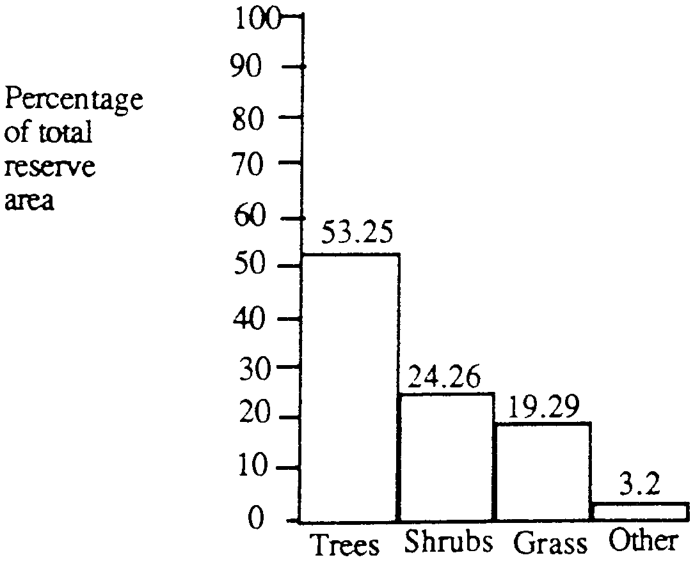


Figure 5.3 Percentage of total reserve area in 1981 occupied by the tree, shrub and herbaceous layers

Table 5.2 The area of habitats in Saltwells Local Nature Reserve in 1981.

Habitat category	Area (ha.)	Percentage of total area	Number of units	Average area per unit
2	0.04	0.1	3	0.01
3	0.81	1.97	16	0.05
5	0.03	0.07	1	0.03
6	0.1	0.24	1	0.01
7	0.23	0.56	3	0.08
15	0.02	0.05	2	0.01
20	0.05	0.12	2	0.03
26	0.04	0.1	2	0.02
31	15.13	36.67	4	3.78
34	6.84	16.58	18	0.38
43	8.1	19.63	46	0.18
44	0.96	2.33	45	0.02
45	0.17	0.41	7	0.02
47	0.66	1.6	9	0.07
48	0.12	0.29	3	0.04
51	0.84	2.04	32	0.03
52	1.6	3.88	34	0.05
53	0.9	2.18	25	0.04
54	0.16	0.39	5	0.03
55	0.1	0.24	1	0.1
57	0.13	0.32	4	0.03
58	4.23	10.25	33	0.13
	$\sum = 245.57$	$\sum = 100$	$\sum = 1941$	

As expected, Figure 5.3 indicates that vegetation habitat types dominated Saltwells Local Nature Reserve. However, of the other land cover types recorded, bare soil (3) accounted for 1.97 per cent of the total reserve area. This represents a larger percentage than some of the vegetation habitat types. Most of the bare soil was mapped in Doulton's Clay Pit. Here the west slope of the pit was unstable and signs of gullying were evident in the bare soil surface. As vegetation habitats become more established, this will be reduced. Other patches of bare soil have resulted from the degradation of the vegetation due to recreational activities which have taken place in the reserve, such as motor-bike scrambling.

Figure 5.3 is almost a mirror image of Figure 5.1. Broadleaved woodland habitats were the most important classification category in the reserve, followed by shrubland and finally by the herbaceous layer. This situation is the reverse of that recorded for the Blackbrook Valley as a whole. As it is the most complex habitat type which dominates the reserve, this suggests that this region has been allowed to develop with little detrimental interference, unlike the areas outside the reserve boundary. The majority of the woodland was planted at the end of the eighteenth century and has since been regarded as a permanent feature. Of the woodland habitats, broadleaved closed woodland (31) accounted for 36.67 per cent of the reserve area and broadleaved woody shrub (43) covered 16.58 per cent of the reserve area.

The area of the these woodland habitat types mapped from the aerial photographs will be relatively accurate as the full extent of these communities is visable on the photographs. However, the extent of the shrub and grassland communities are likely to be underestimated as patches of these habitat types which occur below dense woodland are not visible and hence are not mapped. Closed broadleaved shrubland (43) was recorded as occupying 19.63 per cent of the reserve area. As this figure will be an underestimate of the true total , it is obvious that this is a very widespread habitat type in the reserve.

Even in the reserve, some vegetated habitat types are rare. As in the total study area, both coniferous/evergreen and coniferous/Ulex habitat types were scarce. In the reserve, coniferous/Ulex shrubs were restricted to Doulton's Clay Pit. The vegetated habitat types found in water bodies were also very infrequent. This could be a result of lack of suitable water habitats, or more likely, due to the fact that the ponds and streams which occur in the reserve were generally well masked by the tall tree and shrub communities and therefore it was not possible to determine whether these aquatic vegetation types were present.

Again, broadleaved closed shrub (43) was the most frequently recorded habitat type. Forty-six patches were identified in the reserve. As is the situation in the overall study area, the average size plot of closed broadleaved shrub (43) was small, that is 0.18 hectares. However the mean unit size is larger in the reserve than outside. This is as expected due to the nature reserve being a more protected environment therefore favouring later successional stages.

Closed broadleaved woodland (31) was by far the largest habitat type in the reserve in terms of total area and average unit size. It is a valauble wildlife habitat for a number of animal species due to its structural complexity and its stability.

5.2.2 Habitats in the Blackbrook Valley in 1981- a summary

The quantitative information stored on the map produced of the area can allow conclusions to be drawn about the habitats found in the Blackbrook Valley area in 1981.

The Valley is composed of a variety of habitat types which tend to occur in small patches. In the area as a whole, industrial land cover dominates in terms of total hectarage and in terms of individual unit size. This illustrates the importance of industry in the Blackbrook Valley and also suggests that industrial activities are likely to have a major impact on the other habitat types in the area. Of the vegetated habitats mapped, the less structurally complex habitat types occur most frequently, such as rough turf grassland (58). Closed broadleaved shrubland (43) is a common habitat type in the whole valley. Outside the reserve, the small habitat patches of broadleaved shrubland which have been mapped are likely either to be the remnants of a former habitat type such as an old hedgerow, or are the result of shrubs beginning to establish themselves in undisturbed grassland areas.

Within Saltwells Local Nature Reserve, vegetated habitat types dominate. Although the bulk of the broadleaved woodland was planted artifically, reduced human disturbances such as industrial and residential activities, has allowed the vegetated habitats to evolve into more complex and stable communities. This is evident by the presence of mature habitats such as closed braodleaved woodland (31) and also by the increased size of habitat patches in the reserve in comparison with the rest of the vegetated habitats in the Valley.

5.3 Habitats in the Blackbrook Valley in 1984

As stated in Chapter Three, it was felt unnecessary to remap the total area using the 1984 imagery. Interpretation concentrated on the areas of habitat change. Human intervention rather than natural succession has been responsible for most of the transformations which have occurred. Most habitat modifications have taken place in the west and northern side of the valley which corresponds to the Enterprise Zone area (see Figure 3.8). On the eastern side of the valley, man-made developments have occurred but natural succession and changes in management policies are also evident.

Figure 5.4 indicates that, as in 1981, vegetated habitats were still dominant in the

Blackbrook Valley but the percentage total had decreased from 65.4 per cent in 1981 to 58.6 per cent in 1984. As the major classification category groups 1 and 21 had remained fairly stable, the decrease in vegetated units was the result of an increase in land with man-made cover. This had risen from 27.1 per cent of the total land area in 1981 to 32.5 per cent in 1984. Although these changes from vegetated habitats to man-made surfaces only account for approximately five to seven per cent of the total land area, this trend, if it continues, will be very detrimental to the wildlife in the Valley. It is important that development is allowed and encouraged but that the location of such development sites is controlled or at least influenced to minimise environmental stress.

Table 5.3 lists the thirty-nine habitat types which were digitised. Again the area of roads, railways, streams and canals, although important linear features, was not measured.

The area of each habitat and what percentage of the total area this constitutes is listed. Due to the manner in which the 1984 photographs were interpreted, the extraction of the number of units of each habitat type is a very tedious process and therefore on this occasion has not been calculated. Such information should be readily available if the map is stored on a spatial data-base. The total number of units of change is however available.

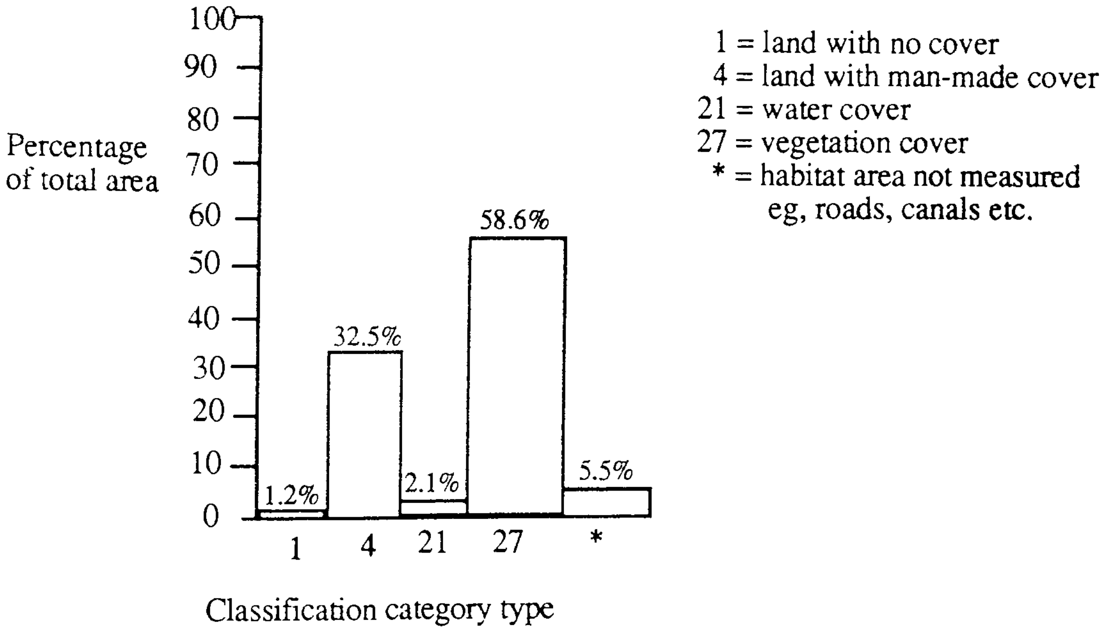


Figure 5.4 Percentage of total area covered by the four major land cover classes

The general trends illustrated by Figure 5.1 for 1981 pertain to the 1984 situation. Of the man-made cover categories, industrial land is the most widespread cover type. It has increased by 30.56 per cent since 1981

The pattern displayed by the vegetated habitat types was very similar to that found in 1981. Rough turf grassland (58) was still the most widespread vegetation type although its area had decreased by 35.05 per cent. Broadleaved closed woodland (31) and shrubland (43) were the most frequent habitat categories in the tree and shrub layers but again the area totals of these habitat types had decreased between 1981 and 1984. There has been a large increase in the amount of closed coniferous/Ulex shrub (47) recorded in the area (59.4%) although this habitat still only represented 1.27 per cent of the total study area. This increase is probably a result of natural development, as Ulex communities mapped as open coniferous/Ulex shrub (48) have matured and spread to form a closed canopy. Correspondently there is a decrease in the amount of open coniferous/Ulex shrubland (48) recorded.

In the herbaceous layer, there was a decrease in the amount of tall herb and fern habitat (52) mapped. This category is an important grassland habitat as it can provide valuable food and shelter. Ruderal (51) and tall grassland communities (53) increased in area, perhaps at the expense of tall herb and fern habitats (52). These habitat types tend to be found in the more disturbed and more hostile sites.

The wetland habitat types (54, 55, 59, 60) still accounted for a very small percentage of the total area. Unfortunately there was a decrease in area of the habitat categories which support the most diverse and interesting wildlife (54,55).

Table 5.3 The area of habitats in the Blackbrook Valley in 1984

Habitat type	Area (ha.)	Percentage of total area	Percentage change between 1981 and 1984
2	0.04	0.02	0
3	3.07	1.18	-15.89
5	0.18	0.07	0
6	1.47	0.57	-22.2
7	61.73	23.74	+30.56
8	0.02	0.007	0
9	0.27	0.1	+3.85
10	0.29	0.1	0
11	7.03	2.7	+3.99
12	8.09	3.1	+4.12
13	0.79	0.3	-13.18
14	3.85	1.48	-12.1
15	0.17	0.07	-10.53
16	0.74	0.28	+72.09
20	0.15	0.06	+20
22	5.02	1.93	+20.24
26	0.51	0.2	+37.84
30	0.18	0.07	-18.18
31	16.72	6.43	-7.47
32	0.18	0.07	+80
33	0.91	0.35	-1.09
34	10.76	4.14	+5.08
38	0.007	0.003	0
39	0.01	0.004	0
43	20.81	8.0	-8.49
44	3.04	1.17	-19.36
45	2.82	1.08	-17.78
47	3.3	1.27	+59.4
48	7.86	3.02	-12.57
51	12.97	4.99	+24.83
52	10.88	3.88	-32.96
53	13.02	5.01	+22.37
54	0.41	0.16	-29.31
55	0.65	0.25	-25.29
56	0.89	0.34	+71.15
57	14.61	5.62	+3.11
58	31.06	11.95	-35.05
59	1.15	0.44	+116.98
60	0.08	0.03	-33.3
	$\sum = 254.74$		

The area of wetland herbaceous habitats (54) has decreased by nearly 30 per cent, tall marginal communities (55) have shown a decline of 25.29 per cent and the area of submerged vegetation (60) mapped has been reduced by 33 per cent.

The decrease in the amount of submerged vegetation mapped may be a result of the increase of floating vegetation (59) recorded. The presence of floating vegetation may either hide the submerged communities or by reducing the amount of light available to underwater plant species, may discourage their growth completely. Although the wetland plant communities are considered very valuable ecologically, the increase in floating vegetation is not necessarily beneficial. The major components of the floating vegetation recorded were *Lemna minor* and *Lemna trisulca* (Wright, 1982). If the correct conditions prevail, these species can spread very rapidly to the detriment of other plant and animal species and thus reduce the diversity of the ecosystem.

In order to draw conclusions about the ecological transformations which have taken place in the Blackbrook Valley, it is essential to identify the types of changes which have occurred. Table 5.4 is a change matrix for the Blackbrook Valley excluding the Saltwells Local Nature Reserve. All the units of change which have occurred between 1981 and 1984 are listed and the most common habitat transformations have been identified.

Of the thirty-seven habitat types listed, all experienced some kind of change except open and closed coniferous/evergreen woodland (38, 39). Habitat categories, paths and tracks (20), open broadleaved woodland (32) and linear broadleaved woodland (33) gained a number of additional habitat units. Other habitat categories gained new habitat units but this increase was compensated for by a loss of some of the original habitat units. Eighteen of the thirty-seven habitats listed lost more habitat units than they gained, especially the shrub and herbaceous communities and thus the total number of habitat units mapped in 1984 was less than in 1981 for some habitat types.

The most common habitat change between 1981 and 1984 was to industrial land (7). Two hundred and sixty-one new habitat units of industrial land were recorded. The most frequent transformation was from ruderal vegetation (51) to industrial land (7) (fifty-one habitat units). This suggests that industrial developments have taken place in either neglected areas which are generally not perceived as a valuable landscape (although ecologically this is not necessarily the case, (Gemmell et al.,1983) or in areas which were already earmarked for development in 1981 and thus the previous habitat type had already been destroyed resulting in the colonisation of a ruderal community (51) on the disturbed site. Other habitat types which lost a large number of units to industrial uses were closed and open broadleaved shrub (43, 44), tall herb and fern grassland (52),

Table 5.4 Habitat changes in the Blackbrook Valley, 1981-1984 rough tall grassland (53) and rough turf grassland (58).

This was not merely a one way process, a large number of industrial habitats mapped in 1981 were recorded as vegetation habitats in 1984, (144 units). There are two main explanations for this change.

i) A number of industrial land sites were derelict and as a result plant communities such as ruderal vegetation (51) and rough turf grassland (58) began to establish themselves in areas of suitable ground, for example gravel surfaces.

ii) On some industrial sites, landscaping had been carried out. In 1981, the area to the west of Saltwells Local Nature Reserve, towards Pedmore Road had been cleared ready for development and thus was classified as industrial land (7). By 1984 a number of factory units had been built and although the area was still primarily industrial, small patches of land had been planted and landscaped. These small landscaped blocks are the major cause of the large number of changes from industrial to vegetation habitat types recorded.

In 1984 one hundred and sixty new patches of ruderal habitat (51) were mapped. Thirty-one of these were located on sites classified as industrial land (7) in 1981. The explanations listed above provide some insight into the reasons for these changes. Eighty-three habitat patches mapped in 1981 as tall herb and fern communities (52), rough tall grassland (53) and rough turf grassland (58) were recorded as ruderal habitats in 1984. This indicates that using aerial photographs, recognisable changes in the composition of grassland habitats can occur in a three year time period. Many of the changes monitored were at sites near to areas of industrial development. For example, a number of herbaceous and shrubland habitats mapped in 1981 as categories 52, 53, 58 and 43 were recorded as patches of ruderal vegetation in 1984. These habitats were located very near to the open cast coal site in the west of the Blackbrook Valley. This suggests that the influence of the mine on the Valley's habitats is experienced over a larger area than the actual open cast coal site.

One hundred and fifty units classified as ruderal vegetation in 1981were classified differently in the 1984 survey. The most frequent change was from ruderal vegetation (51) to industrial land (7). Thirty-nine of the ruderal sites did develop into either tall herb and fern or tall rough grassland communities. This suggests that if left relatively undisturbed, ruderal habitats in the Valley can develop into more dense grassland communities.

One hundred and forty-nine units were added to the rough tall grassland category (53). This is mainly caused by changes to tall herb and fern communities (52) and short turf grassland habitats. A change from 52 to 53 suggests that there has been a reduction in the number of flowering plants recorded at that particular site. This may have occurred either due to a disturbance or as a result of inaccurate photographic interpretation, as the habitat categories are quite similar in appearance when viewed from the air. The transformation from 58 to 53 will most likely be the result of the natural succession of a grass community on an undisturbed site.

As a general trend, the habitats which appear to gain a large number of units also lose a large number of habitat patches. Of the areas mapped as rough tall grassland (53) in 1981, 136 of these had developed into another habitat type by 1984. Most changed to industrial, ruderal or rough turf grassland communities.

The number of units of closed broadleaved shrub (43) increased by 113. The most frequently recorded transformation was from industrial land to shrubland. Again, this will be due to either site dereliction encouraging plant recolonisation, or more likely, due to man's landscaping. Thirty-nine areas mapped as open broadleaved shrub (44) and tall herb and fern grassland (52) in 1981 were recorded as closed broadleaved shrubland (43) in 1984. The change from 44 to 43 is likely to be the result of three years of species growth making the habitats more mature. The transformation from 52 to 43 is however more surprising. In some instances this recorded change may have been caused by an error of interpretation of the 1981 photographs. As the accuracy of the map is determined by sampling, it is possible that some misinterpretations remain undetected. On some sites, it is likely that in 1981 shrub seedlings were growing in the patches classified as 52 but were not developed enough in height or structure to be seen on the aerial photographs. By 1984 they may have grown enough to be distinguished from the tall herbs and ferns and thus be mapped as shrub communities.

Of the closed broadleaved shrub units (43) which were lost over this time period, the major changes were to industrial (7) or ruderal habitats (51). This is a frequent occurrence with a number of habitat types and it illustrates the severe effect of industrial development on the area's ecology.

These are some of the major types of habitat change which occurred between 1981 and 1984. It is obvious that the designation of the Enterprise Zone and the development of land which has taken place, has had a major effect on the habitat types recorded in the area. Other than the frequent changes to industrial and ruderal habitats, the most frequent habitat transformations occur within the herbaceous and shrubland communities.

Herbaceous and shrubland communities change more rapidly than woodland communities and this is probably the main reason why so many changes have been identified in these two major habitat types. The woodland communities in the Valley appear to have remained relatively stable over the three years.

Some of the changes identified do seem unlikely, for example a transformation from ruderal vegetation (51) to tree/shrub (34). Rather than tree/shrub colonising ruderal habitats in three years, it is more likely that the ruderal areas were adjacent to the tree/shrub communities. In the three year periods the trees and shrubs will have grown and thus the size of their canopies will have increased. When viewed from above, these canopies are likely to obscure the areas of ruderal vegetation. One area mapped as tall rough grassland in 1981 was classified as submerged vegetation in 1984. On first impressions this appears inaccurate, but in the Enterprise Zone two artificial pools have been created on the site of rough tall grassland.

By considering the type of habitat, its location and its area, an accurate picture can be obtained of the ecology of the whole of the Blackbrook Valley in 1981 and 1984. By taking into account the major changes which have occurred in the types of habitats mapped during this time period, conclusions can be drawn about the dominant influences on the area's ecology. In the area of the Blackbrook Valley outside the Saltwells Local Nature Reserve, industrial development has had a major effect on the types of habitat found.

5.3.1 Habitats in Saltwells Local Nature Reserve in 1984

Table 5.5 lists the habitat types and their area mapped in the reserve in 1984. This information is required to determine the amount of change which has taken place in the reserve. The area was designated a Local Nature Reserve in the summer of 1981, the same time as the first set of imagery was flown. Since 1981, the area has been under the management of the appointed wardens who have supervised a number of environmental improvement tasks and have increased the security of the site thus reducing the vandalism. The 1984 photographs should thus indicate what improvements have been carried out in the reserve.

Figure 5.5 indicates that the percentage of each habitat type in the three structural layers has remained fairly constant. Between 1981 and 1984, there has been a decrease by just over one per cent in the area of woodland habitats and an increase by about one per cent in the area of shrubland. The other two categories plotted on the histogram have altered very little. The areas of change in the reserve have been mapped in Figure 5.7.

Table 5.5 The area of habitats in Saltwells Local Nature Reserve in 1984

Habitat type	Area (ha.)	Percentage of total reserve area (260ha.)	Number of units	Average size per unit
2	0.04	0.1	3	0.01
3	0.72	1.75	16	0.05
5	0.03	0.07	1	0.03
6	0.13	0.32	1	0.13
20	0.05	0.12	2	0.03
26	0.02	0.05	1	0.02
30	0.004	0.01	1	0.004
31	14.43	35.05	4	3.61
34	7.00	17.00	21	0.33
43	8.93	21.69	56	0.16
44	0.85	2.06	47	0.02
45	0.18	0.44	9	0.02
47	0.59	1.43	8	0.07
48	0.1	0.24	2	0.05
51	0.51	1.24	20	0.03
52	1.97	4.79	43	0.05
53	1.32	3.2	20	0.07
54	0.09	0.22	3	0.03
57	0.28	0.68	5	0.06
58	3.92	9.52	22	0.18
59	0.01	0.02	1	0.01
	$\Sigma = 41.17$	$\Sigma = 100$	$\Sigma = 286$	

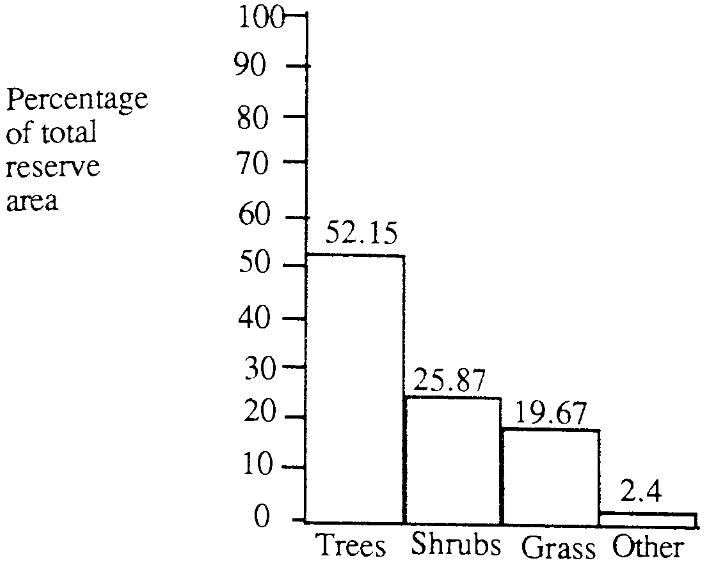


Figure 5.5 Percentage of total reserve area in 1984 occupied by the tree, shrub and herbaceous layers

The habitat types recorded in the reserve in 1984 (Table 5.5) differ slightly to those mapped in 1981 (Table 5.2). Additional categories in 1984 are single broadleaved trees (30), and floating vegetation (59). Habitat types which are absent are industrial land (7), rubbish covered surfaces (15) and tall fragmentary marginal communities (55).

As in 1981, closed broadleaved woodland (31) was still the dominant category, followed by broadleaved closed shrub (43). Of the herbaceous communities, rough turf grassland was the most important in terms of area.

It is evident that the habitats mapped in Saltwells Local Nature Reserve have remained relatively constant over the three year period. Table 5.6 lists the percentage change in habitat area which has occurred between 1981 and 1984.

The largest increase between 1981 and 1984 was in the area of smooth turf grassland (57), (+115.38%), however the total area of this particular habitat type is still only 0.28 hectares, thus accounting for 0.68 per cent of the total reserve area. Large percentage increases or decreases illustrated in Table 5.6 do not indicate the areal importance of a particular habitat type. The greatest changes in percentages have occurred in the herbaceous communities but in each instance they represent a small alteration to the total habitat area. The area of the woodland and shrubland communities remained fairly constant over the three years. There was a slight decrease in the area of closed broadleaved woodland (31) and open broadleaved shrubland (44) and a slight increase in the extent of tree/shrub (34) and closed broadleaved shrubland (43).

Table 5.6 The percentage change in area of the habitats in Saltwells Nature Reserve beween 1981 and 1984

Habitat types	Area (ha.) 1981	Area (ha.) 1981	Percentage change
2	0.04	0.04	0
3	0.81	0.72	-11.1
5	0.03	0.03	0
6	0.1	0.13	+30
7	0.23	-	-100
15	0.02	-	-100
20	0.05	0.05	0
26	0.04	0.02	-50
30	-	0.004	+
31	15.13	14.43	-4.63
34	6.84	7.00	+2.34
43	8.1	8.93	+10.25
44	0.96	0.85	-11.46
45	0.17	0.18	+5.88
47	0.66	0.59	-10.61
48	0.12	0.1	-16.67
51	0.84	0.51	+39.29
52	1.6	1.97	+23.13
53	0.9	1.32	+46.67
54	0.16	0.09	-43.75
55	0.1	-	-100
57	0.13	0.28	+115.38
58	4.23	3.92	-7.33
59	-	0.01	+

The number of units of each individual habitat type remained fairly stable over the time period. There was an increase in the number of units of closed broadleaved shrub (43), tree/shrub (34), tall herb and fern (52) and rough and smooth turf grassland (57 and 58) which corresponded to an increase in area of these habitat types. A decrease in the number of units and area has been recorded for ruderal (51) rough tall grass (53) and wetland herbaceous (54) communities. The open broadleaved shrubland (44) habitat was found to have decreased in area yet there was an increase in the number of units recorded. This habitat has become more fragmented.

To identify whether any habitat transformations were more frequent than others, that is, whether it was possible to reveal a specific pattern, a change matrix was constructed. As with Table 5.4, the number of changes which occurred between two habitat types between 1981 and 1984 are listed, (see Table 5.7). Very little change occurred to the non-vegetated habitat types. Seven new units of bare soil (3) were recorded in 1984. These were located in sites previously covered by vegetation. This increase in the number of habitat patches mapped occurred even though the total area of this habitat type had decreased.

The two most frequent transformations were identified.

i) Nine areas of broadleaved open shrubland (44) changed to broadleaved closed shrub (43) in 1984.

ii) Nine units of rough tall grassland developed from ruderal communities (51).

Both of these changes are likely to be the result of natural succession over a period of three years.

The addition of nine units of open shrub to the closed shrub category (43) was one of the main causes for the increase in area of this habitat type. Broadleaved closed shrub (43) was mapped on sites which in 1981 were covered by herbaceous communities (52 and 58). This increase in the number of patches of broadleaved closed shrub is most probably the result of the maturity of the shrub species. The shrub canopies will have increased in size and thus will cover the herbaceous communities below. The reduction of light available to these grassland comunities may have resulted in a change in species composition and thus a change in the habitat classification category but with aerial photographs this is impossible to determine. The maturity of the closed shrub category (43) in this time period is evident by the fact that four units mapped as closed shrub (43) in 1981 were interpreted as broadleaved tree/shrub (34) in 1984.

Table 5.7 Habitat changes in Saltwells Local Nature Reserve, 1981-1984

Table 5.7 The number of changed habitat units in Saltwells Local Nature Reserve, 1981-1984

	1984	2	3	5	6	7	15	20	26	30	31	34	43	44	45	47	48	51	52	53	54	55	57	58	59	Total
1981																										
2																										0
3														2					1							3
5																										0
6																										0
7													1					1		1						3
15																			2							2
20																										0
26			1																							1
30																										0
31					1					1		1	4	1				4	6	2			1			21
34														1					1							2
43			1									4			1				1						1	8
44												2	9						2							13
45																										0
47			2											1							1					4
48													1	1												2
51			1									2	1	4						9				6		23
52			1										5	1				2						1		10
53					2						1	1	1	1	2			1	3				2	4		18
54													3	1					2							6
55			1																							1
57																			1							1
58			1								1	4	5	5				1	6	2			1			26
59																										0
Total units gained		0	8	0	3	0	0	0	0	1	2	14	30	18	3	0	0	9	23	14	1	0	4	11	1	Σ = 144

The area of closed broadleaved woodland (31) mapped in 1984 had slightly decreased. Twenty-one units of closed broadleaved woodland were lost primarily to other vegetation habitat types, mainly closed broadleaved shrub (43) and tall herb and fern grassland (52). It is believed management carried out by the wardens was responsible for the loss. For example a large patch of closed broadleaved woodland (0.4 ha.), north of Saltwells House (see Figure 3.8), has been felled and replanted and thus classified as closed broadleaved shrubland (43).

Of the herbaceous communities, there was a large increase (twenty-five) in the number of units of tall herb and fern grassland (52) mapped. These patches generally resulted from the clearance of closed broadleaved wood (31) due to management practices or to the maturity of previously less dense grassland communities, for example, rough turf grassland (58). In 1984 nine new patches of ruderal grassland (51) were mapped but twenty-three of the patches identified of this habitat type in 1981 had changed. As a result the total number of units of ruderal grassland mapped in the reserve in 1984 had decreased. This is in contrast to the situation outside the reserve where there was a slight increase in the number of ruderal communties recorded. Only one of the ruderal patches became a less complex habitat type, twenty-three patches matured to more complicated vegetation communities, primarily tall herb and fern grassland (52) and smooth turf grassland (57). This increase was a result of the management practices being conducted in the area. For example, the prevention of motorbike scrambling and industrial land use in the reserve area has allowed vegetation communities to develop unhindered, thus reducing the areas of ruderal communities (51), rough turf grassland (58) and industrial habitats (7).

In conclusion the main changes which have occurred in the reserve between 1981 and 1984 have been identified. Most changes have occurred in the vegetated areas. Either vegetation communities have been allowed to develop into more complex habitats or management practices have removed certain vegetation categories to encourage the growth of less common or less resiliant species.

5.4 Summary

Information provided by the interpretation of large-scale aerial photographs has allowed conclusions to be drawn about the wildlife habitats present in the Blackbrook Valley. This chapter concentrated on identifying the type of habitats present, their location, their size, the major changes which have occurred between 1981 and 1984 and the factors which were responsible for these transformations.

When the Blackbrook Valley is viewed in total, it is found to have a diverse collection of habitat types, which due to the size of individual units, appear to be very scattered. The most dominant individual habitat type in the area is industrial land, although the majority of the study area is vegetated. The major changes which have occurred between 1981 and 1984 are related to the development of the Enterprise Zone. The area of the industrial and ruderal habitats has increased over the three years by 14.45 and 2.58 hectares respectively. Changes recorded in the vegetation communities occurred more frequently in the herbaceous and shrub layers than in the tree layer and are due either to natural development, or in most instances human interference.

When the habitats in Saltwells Local Nature Reserve are considered separately from the rest of the Valley, the pattern is different. Closed broadleaved woodland (31) is the dominant habitat recorded in the wood, followed by shrub and herbaceous communities. There are very few unvegetated habitats present. It appears that the reserve is a less dynamic environment than the rest of the valley and over the three years no major changes have taken place. Gradual developments of the habitat categories have been recorded. In most instances, these can be attributed to the maturity of the vegetation categories. Any dramatic changes, for example the felling of a patch of closed woodland, were the result of management practices by the wardens.

CHAPTER SIX

HABITAT PATCHINESS IN THE BLACKBROOK VALLEY

6.1 The importance of habitat patches in ecological studies

Vegetation patches were described by Forman and Godron (1981) as communities or species assemblages surrounded by a matrix with a different structure. The internal structure of the patch is a result of species composition, physiognomy, density and population dispersion. Vegetation patches exist either as a result of environmental or man-induced disturbances and the amount of disturbance dictates the size, density and frequency of the habitat patches.

The previous chapter discussed the habitat characteristics which are distinguishable from aerial photographs. Many ecologists believe that as well as recording biotic type, size, shape, number and configuration of vegetation habitats, it is also important to determine the degree of patchiness in the environment.

According to Noss (1983) the aim of many management plans is to maintain a high degree of habitat patchiness in an area. This is considered beneficial as it is directly related to the amount of edge habitat present and thus the species diversity of an area. Patchy environments have large areas of edge habitat. They are desirable to environmental managers as compared with more homogenous areas, they provide a greater number of niches for a greater number of animal and plant species. Edge communities are particularly valuable habitats as they represent the transitional stage between two vegetation types and thus tend to be inherently rich in species (Spray, 1980). The edges which are present between habitat patches can be either sharp, for example woodland to agricultural land boundaries, or gradual such as woodland to shrubland habitats. Gradual edge gradients may be more conductive to the movement of species between patch and matrix.

The principles of the island biogeography theory suggest that larger islands will have a greater number of plant and animal species living in equilibrium. Whether the theory is correct and area is the causal factor is uncertain, nevertheless large individual habitat patches have been recorded as having a greater species diversity than smaller units. The species recorded in a patch will be a combination of edge and interior species. However this area relationship is complicated as the shape of the habitat patch influences its species diversity. Linear habitat patches may be totally composed of edge species and thus are detrimental to the existence of interior species (Forman and Godron, 1981).

The relationship between habitat patch size and species diversity seems to indicate that larger patches will be beneficial to a greater number of wildlife species. However, research conducted into the number of species found on large nature reserves in comparison with a number of smaller reserves of combined equal area, does not support this conclusion (Nilsson, 1978). Dobson et. al. (1985) claimed that in Great Britain, a number of smaller woodland habitats were found to hold more of the species pool than one single area. This seems to indicate that although within-patch species diversity increases with area, the number of species which can survive in a comparable area of small patches is greater than in one homogeneous unit. This is due to an increase in the amount of edge habitat available with increased habitat patchiness.

A high index of patchiness therefore represents a valuable wildlife area but excessive fragmentation can be detrimental, for example Dobson et. al. (1985) found that the increase in the number of bird species in smaller nature reserves may be a result of a predominance of edge species at the expense of woodland interior species. In Great Britain this is not a great problem as most true interior bird species are already extinct or have adapted to the edge conditions caused by woodland fragmentation. Woodland fragmentation is however a current problem in America and may affect the number of species breeding in a wooded area. Although Nilsson's study (1978) stated that smaller habitat patches are more favourable than one large patch, he did qualify his conclusion by stating that many of the birds in his study avoided nesting in patches below one to four hectares.

It therefore appears that in a vegetated area, a number of different habitat patches are preferable to one homogenous habitat type. A fine balance is however required. The shape and size of the habitat patch is important to ensure that it is above the minimum critical size necessary to support a particular population. The desire to increase species diversity and habitat edge by habitat fragmentation should not be encouraged to the extent that interior species are detrimentally affected.

6.2 The difference in habitat patchiness between urban and rural areas

Although human influences have greatly modified both the rural and the urban environment, urban areas have experienced a greater degree of fragmentation by a large number of parties. The number of different land uses recorded in an urban area is far greater than the number recorded in rural areas of a comparable size, that is, the degree of habitat patchiness is greater in urban regions. Sukopp and Werner (1982) stated that human influences have produced a mosaic of dispersed vegetation habitats in the urban regions. Urban vegetation studies have provided evidence about the importance of patchiness. Studies have indicated that more plant species are to be encountered in urban green spaces than on equally large surfaces of surrounding rural land. This trend is especially evident at the edges of the city which are very rich in plant species (Walter, 1970). In Greater London, Gill and Bonnet (1973) recorded 1,835 plant species and 203 bird species between 1960 and 1970. These are relatively high populations in comparison with other biotopes such as agricultural landscapes or forests. A high level of habitat patchiness is obviously partially responsible for the high species numbers.

As mentioned in the previous section, small habitat patches may be of little use to wildlife. Davis and Glick (1978) believed that this problem was exaggerated in the urban environment where habitat patches may not only be small but may also be very isolated. This results in a decrease in species diversity levels and an increase in habitat vulnerability to disturbance. In comparison with a rural environment, the increase in habitat patchiness occuring in an urban environment can be beneficial for species diversity levels but again it is important to ensure that habitat patches are not too small or too isolated to be of any use as urban wildlife habitats.

6.3 Habitat patchiness in urban and rural studies: a comparative test

A test was conducted to determine whether the conclusion about the increase in patchiness in urban areas was applicable in the Blackbrook Valley. Panchromatic, 1:12000 scale aerial photography was available for both the Blackbrook Valley and for an agricultural area in South Staffordshire. Staffordshire was chosen as it was the closest region of agricultural land on the same flight path as the Blackbrook Valley. It was an area of arable fields broken up by hedgerows and farm settlements. The aerial photographs were taken in 1971 and although the areas may have changed greatly in this time period, this was considered unimportant as the study was designed only as a comparison between the rural and urban areas at one moment of time. The urban habitat classification developed for this research project was used to map the habitats in both the study areas. Due to the scale of the photography, the level of habitat detail mapped was less than that recorded in the Blackbrook Valley in 1981 or 1984 (see Figures 6.1 and 6.2). For the sake of clarity, it was decided not to label each habitat unit on these maps but each demarked area represents a different habitat type.

For each area two sample sites were chosen. In the Blackbrook Valley, Site 1 was a mixture of vegetation, water and residential habitat types. The existence of man-made habitat types is one of the major causes of increasing habitat patchiness in an urban area. The level of man's influence in the urban environment may also affect the level of patchiness in areas covered only by vegetation habitat types. In the Blackbrook Valley,

Figure 6.1 Habitat Patches mapped in the Blackbrook Valley, 1971.

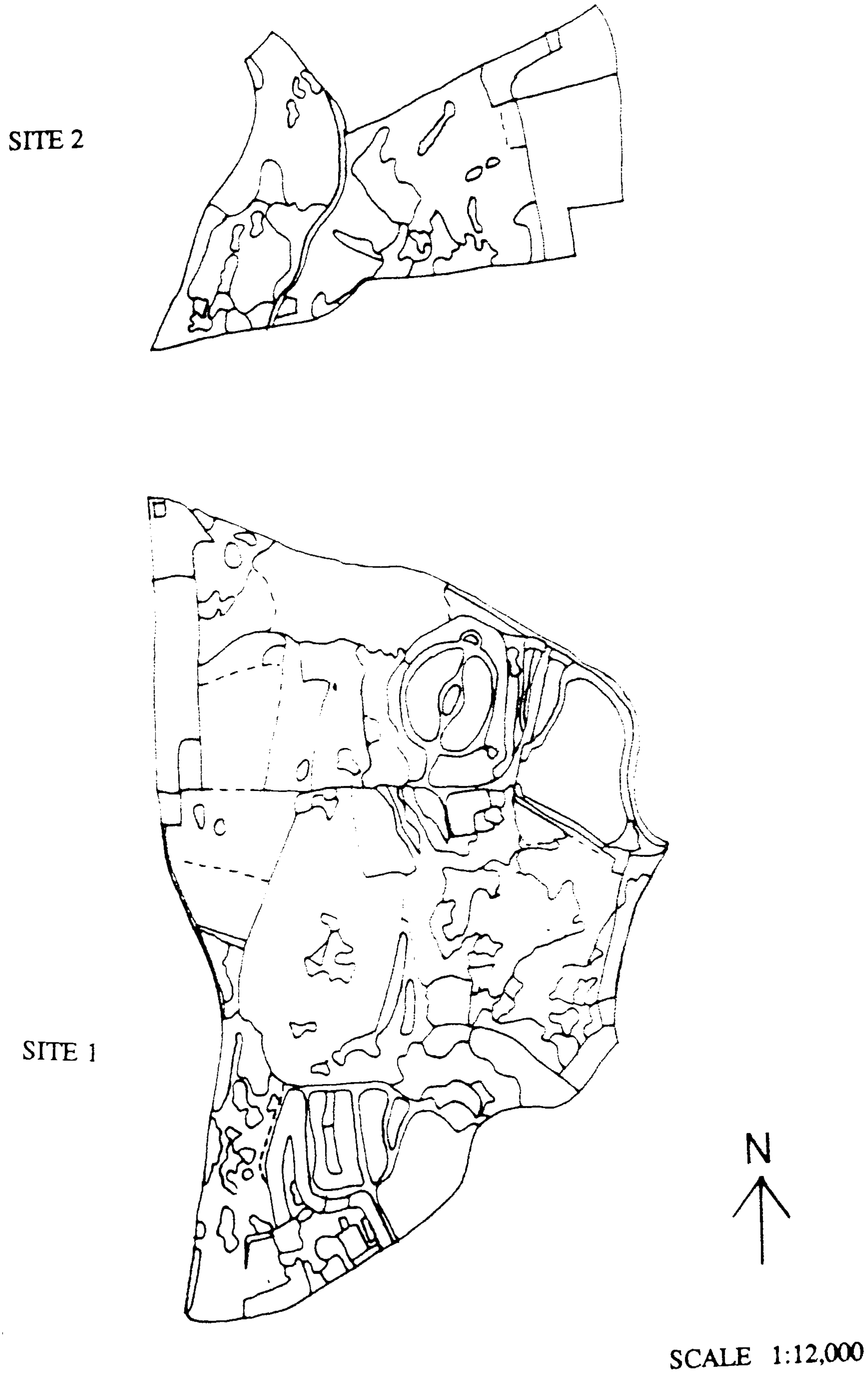
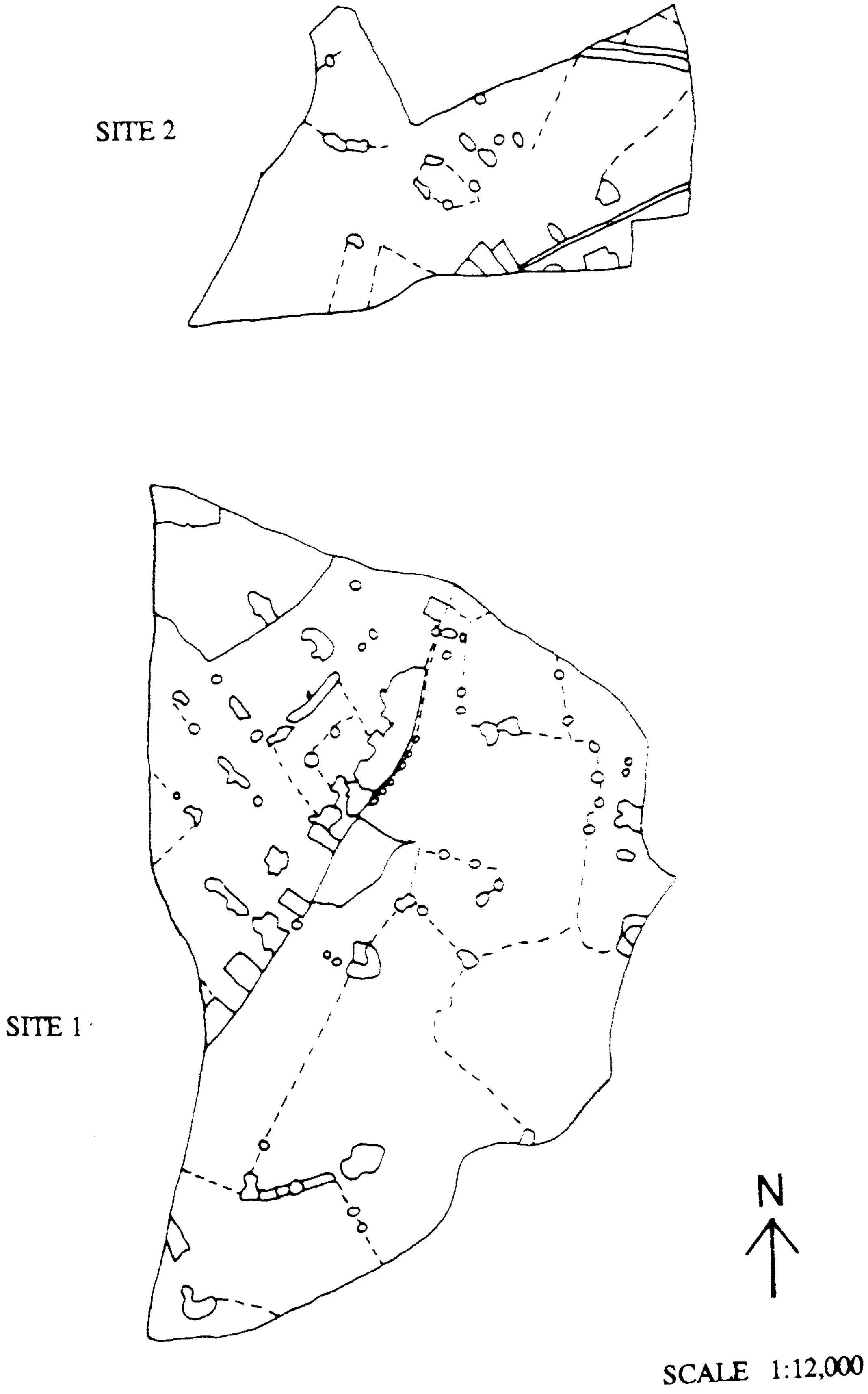


Figure 6.2 Habitat Patches mapped in an area of South Staffordshire, 1971.



Site 2 was composed only of vegetation habitats. This was designed to determine whether the degree of habitat patchiness differed between vegetated rural and urban areas.

To determine the degree of habitat patchiness in the urban and rural test areas, it was necessary to calculate the number of habitat units and the length of habitat edge per unit. The results are shown in Table 6.1.

Table 6.1 Habitat patchiness in urban and rural areas determined from aerial photographs

	Urban		Rural	
	The Blackbrook Valley		South Staffordshire	
	Site 1	Site 2	Site 1	Site 2
Area of sample site	51.43ha	15.64ha	51.43ha	15.64ha
Total number of habitat patches	133	38	105	35
Number of habitat patches per hectare	2.59	2.43	2.04	2.24
Total length of habitat edge	40224.19m	10989.18	20237.28m	8019.83
Average length of habitat edge per patch	302.43m	289.19	192.74	229.14
$\frac{\text{Total number of habitat patches}}{\text{Total amount of habitat edge}} \times 100$	0.33	0.35	0.52	0.44

Table 6.1 illustrates that there are more individual habitat patches in sample sites 1 and 2 in the Blackbrook Valley than in Staffordshire. These results back up the conclusions made about the increasing degree of habitat patchiness found in urban environments as compared to rural areas. The difference in the level of patchiness is greater in the larger sample site, Site 1. In the Blackbrook Valley this sample contained industrial and residential habitats. The differences between the two vegetated sample sites, Sites 2, are proportionally lower. The figures do however indicate that a greater degree of habitat patchiness is still likely in urban environments even if developed land is excluded. As may be expected, the total amount of habitat edge in the sample sites increases with the increase in habitat units. When calculating the amount of edge in an area, measurements are restricted to the length of the edge only.

Although the influence of edge communities extends into habitat interiors, the width of a habitat edge community is difficult to determine and frequently alters with aspect. As stated by Ranney et. al. (1981), for quantification purposes, edges should be measured as linear structures providing objective statistics only, rather than attempt to determine the more subjective width measurements.

When comparing a homogenous habitat sample with a heterogeneous sample of the same size, one would expect to find an increase in the amount of edge habitat recorded in the latter. The combined edge total of a number of small habitat patches in the heterogeneous sample will always exceed the edge dimensions of a single habitat patch. This is especially so in this study where all edges between adjacent habitat patches were digitised twice, thus contributing to the total edge length of each of the adjoining habitats. It is therefore likely that an index of habitat patchiness could be developed from a ratio of the total number of habitat units to the total amount of habitat edges. The index figure would represent the number of habitats which share one metre of the habitat edge and thus, along with the number of habitat units, would provide an indication of habitat patchiness. However in this study of urban and rural patchiness, the sample size is too small to indicate whether the index figure is useful.

From the number of habitat units recorded and the length of habitat edge in the urban and rural samples, it appears that the conclusions drawn about the increased habitat patchiness found in urban areas holds true for the Blackbrook Valley.

6.4 Habitat patchiness in the Blackbrook Valley measured using aerial photographs : an evaluation

Analysis was conducted to determine whether the degree of habitat patchiness in the Blackbrook Valley had changed between 1981 and 1984 and to discover whether a difference existed in habitat patchiness recorded in the developed areas (for example, residential, service and industrial areas) and the vegetated areas.

The 1: 2500 scale urban habitat maps produced by the aerial photographic survey provided the raw data. Due to the level of detail recorded on the 1981 and 1984 habitat maps, it was necessary to restrict the habitat patchiness analysis to a sample of habitat data. Hammond and McCullagh (1978) stated that to achieve a representative picture of the real population, a ten per cent sample is the minimum requirement. As the mapped study area is approximately 260 hectares, 30 one hectare square samples were considered to represent a suitable sample size. A stratified random sampling method was used to position the sample squares. As one of the aims of the analysis was to distinguish whether any differences in habitat patchiness existed between predominantly developed

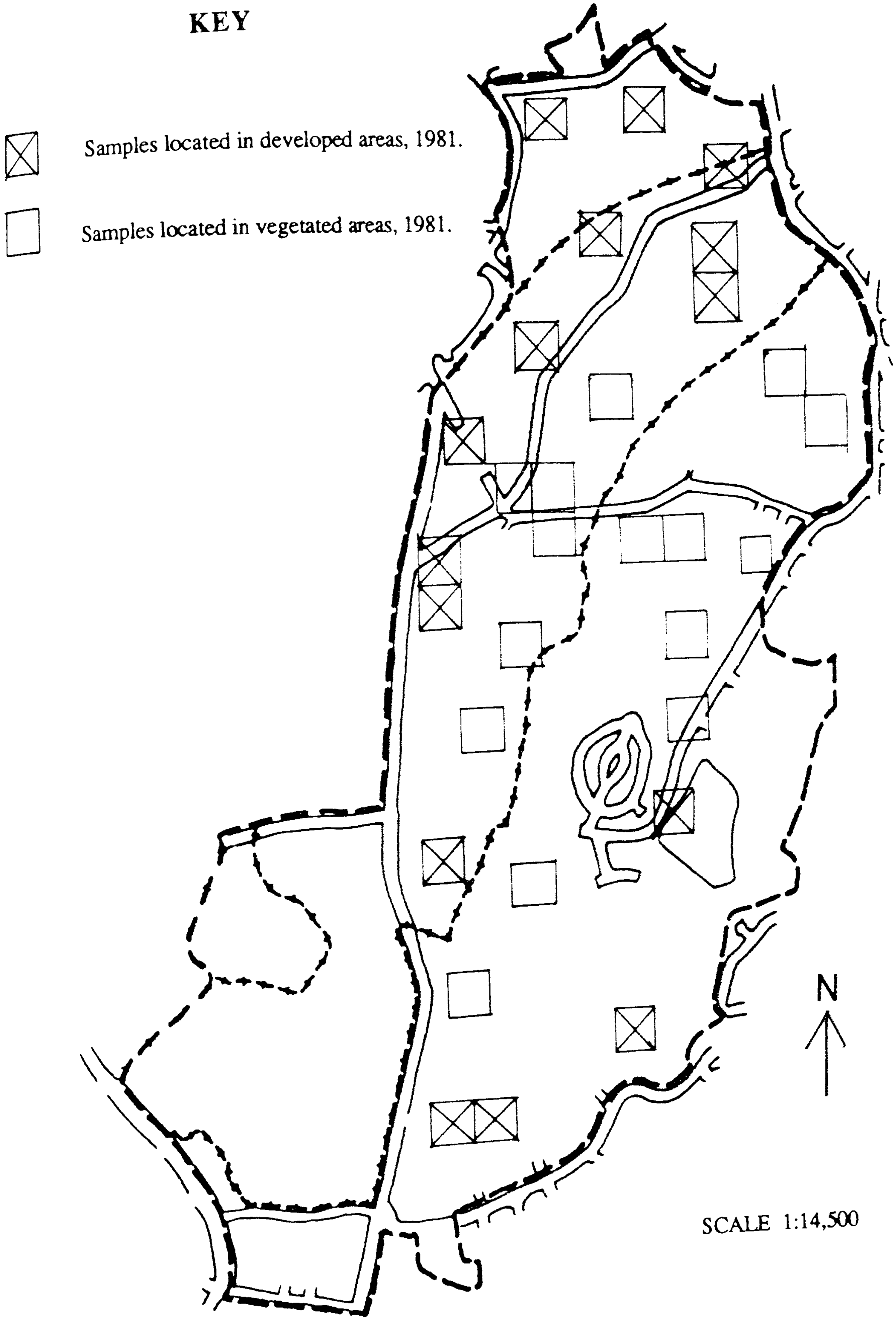


Figure 6.3 The Location of the Samples (1 ha.) analysed to determine Habitat Patchiness.

sites and vegetated sites, the Blackbrook Valley was divided into these two very broad land use divisions (see Figure 6.3). As areas of water cover, whether natural or artificial, can provide valuable wildlife habitats, these habitats were included in the vegetated land use category.

Fifteen hectare squares were thus randomly located in both the two broad land use categories. In most instances the sample square fell totally within the chosen category, but on some occasions a slight overlap occurred. This was considered acceptable as the total exclusion of each land use type would be almost impossible to acheive, especially in the man-made category where small patches of vegetation habitats have frequently been mapped. The total number of habitat units found and the total length of habitat edges (whatever the adjoining habitat types) were digitised. The results can be seen in Tables 6.2, 6.3, 6.4 and 6.5.

Table 6.2 The degree of habitat patchiness in predominantly vegetated sample units, 1981.

1ha samples	Total length of Edge (H)	Total number of patches	Total number of habitat	Average length of habitat types	Total number of habitat patches / Total amount of habitat edge x100
	a	b		a/b	
1	1383.84	8	6	172.98	0.58
2	2124.23	25	14	151.73	1.18
3	1257.24	10	5	125.72	0.8
4	2156.27	25	14	86.25	1.16
5	689.98	4	4	172.5	0.58
6	1165.43	9	5	129.49	0.77
7	1640.88	14	9	117.21	0.85
8	1669.74	16	10	104.36	0.96
9	1338.75	12	8	111.65	0.9
10	1626.68	16	9	101.67	0.98
11	729.3	4	4	182.33	0.55
12	1697.37	18	11	94.3	1.06
13	2165.42	26	13	83.29	1.2
14	1681.47	12	6	140.12	0.71
15	1604.14	12	6	133.68	0.75
Σ	22936.2	212.0	122.0	1907.28	13.03
x	1529.081	14.13	8.13	127.15	0.87
Ón-1	± 451.77	±7.09	±3.48	±31.86	± 0.22

Table 6.3 The degrees of patchiness in predominantly developed sample squares, 1981.

1ha samples	Total length of Edge (H) a	Total number of patches b	Total number of habitat types	Average length of habitat edge a/b	Total number of habitat patches ------x100 Total amount of habitat edge
16	1100.21	7	4	157.72	0.64
17	2098.25	21	10	99.92	1.00
18	2057.3	19	9	108.28	0.92
19	1820.45	13	5	140.03	0.71
20	2772.52	28	15	99.02	1.01
21	1771.17	17	10	104.19	0.96
22	1346.79	11	5	122.44	0.82
23	1533.59	12	7	127.8	0.78
24	2059.5	19	11	108.39	0.92
25	1459.36	12	8	121.61	0.82
26	1945.91	14	5	138.99	0.72
27	1713.06	18	10	95.17	1.05
28	1865.24	16	10	116.58	0.86
29	2097.46	15	10	139.83	0.72
30	1318.45	10	6	131.85	0.76
Σ	26959.26	232.0	125.0	1811.82	12.69
x	1797.28	15.47	8.3	120.79	0.85
Ón-1	± 414.47	±5.18	± 2.99	± 18.46	±0.13

Table 6.4 The degree of patchiness in predominantly vegetated habitat sample units, 1984.

1ha samples	Total length of Edge (M) a	Total number of patches b	Total number of habitat types	Average length of habitat edge a/b	$\frac{\text{Total number of habitat patches}}{\text{Total amount of habitat edge}} \times 100$
1	402.51	1	1	402.51	0.25
2	1863.5	23	14	81.02	1.23
3	1555.76	14	7	222.25	0.9
4	2218.35	27	16	82.16	1.22
5	689.98	4	4	172.5	0.56
6	1232.49	15	8	82.17	1.22
7	1640.88	14	9	117.21	0.85
8	1643.12	19	11	86.48	1.16
9	1435.3	11	7	130.48	0.77
10	1252.07	10	4	125.21	0.8
11	974.8	8	8	121.85	0.82
12	1795.07	22	11	81.59	1.23
13	1992.92	26	13	76.65	1.3
14	1709.56	13	7	131.50	0.76
15	1729.51	17	8	101.74	0.98
Σ	22135.82	224.0	128.0	2015.32	14.06
x	1475.72	14.9	8.5	134.35	0.94
Ón-1	±491.58	±7.61	±3.99	±84.26	± 0.29

Table 6.5 The degree of patchiness in predominantly developed sample squares, 1984.

1ha samples	Total length of Edge a	Total number of patches b	Total number of habitat types	Average length of habitat edge a/b	$\frac{\text{Total number of habitat patches}}{\text{Total amount of habitat edge}} \text{x}100$
16	1864.83	25	5	74.59	1.34
17	2071.12	23	11	90.05	1.11
18	1847.47	20	9	92.37	1.08
19	1352.88	16	4	84.56	1.18
20	2772.52	28	15	99.02	1.01
21	1982.3	21	11	94.39	1.06
22	1503.68	19	5	79.14	1.26
23	1533.59	12	7	127.8	0.78
24	2059.5	19	11	108.39	0.92
25	1279.39	12	9	106.61	0.94
26	1626.95	13	4	125.15	0.8
27	1403.13	13	8	107.93	0.93
28	1929.35	19	11	101.54	0.98
29	2170.13	14	10	155.01	0.65
30	1375.49	13	6	105.81	0.95
Σ	26772.29	267.0	126.0	1552.36	14.89
x	1784.82	17.8	8.4	103.49	0.99
Ón-1	± 403.03	± 5.05	± 3.2	± 20.65	± 0.18

Using Spearman's rank correlation test, statistically significant relationships ($\propto = 0.5$) were found to exist between the amount of edge and the number of habitat units and between the number of habitat units and the index of patchiness (for details of the calculations, see Appendix 2)

In 1981 the total number of habitat patches and the total amount of habitat edge was greater in the samples located on developed land than those found in vegetated areas, however the total habitat index was slightly lower. As the number of patches, the length of habitat edge and the index of patchiness are all positively correlated, it is considered that this difference in magnitude is insignificant, a random occurrence.

To determine whether the differences between the number of habitat units and the index of patchiness recorded for the developed and vegetated land in 1981 are significant, the Mann-Whitney U test (see Appendix 3) was carried out to determine which of the following hypotheses are correct.

H_0 = There is no significant difference between the degree of habitat patchiness recorded in the developed and vegetated samples in 1981.

H_1 = The degree of habitat patchiness measured in the developed areas in 1981 is greater than that found in the vegetated sample sites.

For a one-tailed test (directional) at the 95 per cent confidence level, there was no significant difference in 1981 between the degree of habitat patchiness described by either the number of habitat units or by the index of patchiness in these two broad land use categories.

Similar tests were conducted (using the two measures of patchiness for the habitats) to determine whether a significant difference existed between the habitat patchiness of the following populations.

a) the habitats mapped in the developed and vegetated samples in 1984,
b) the degree of patchiness recorded in all the developed sample sites in 1981 and 1984 and
c) the level of habitat patchiness measure in the vegetation sample sites in 1981 and 1984.

No significant difference was found in the analysis of the populations described as a) and c), (see Appendix 3). When comparing the habitat patchiness index recorded in developed land in 1981 and 1984, a statistically significant difference was recorded (95 per cent confidence level). However the test comparing the number of units found in these sample sites, in these years, did not echo the same positive results. As the number of habitat units was found to be correlated with the habitat patchiness index, it is believed unwise to place too much emphasis on this positive result as significant results at the 95 per cent confidence level still have a 5 per cent probability of occurring completely by chance. This may have happened on this occasion.

6.5 Conclusions

It therefore appears that the habitat patchiness of an area can be determined from large-scale aerial photographs. The degree of habitat patchiness can best be described by statistics based on the number of habitat patches per unit area or by quoting a habitat index figure per unit area. In this study the habitat index is calculated by dividing the number of habitats identified by the measured amount of edge. This represents the number of habitat units sharing one metre of habitat edge. As the figures produced by these two methods of patchiness description are closely correlated, either can be used. As information relating to the number of habitat units per sample area is easier to obtain and the figure may be more readily comprehended, this measure of habitat patchiness may be the most preferable.

Although the Blackbrook Valley is a more patchy environment than near-by rural areas, there is little difference between the degree of habitat patchiness within the Valley. The numbers of habitat units recorded in the developed and vegetated sectors of the valley were very similar although naturally there were individual exceptions. The samples taken in the developed areas did appear to be more patchy although the differences were not large enough to be statistically significant. Such a pattern would be expected in an urban environment as both industrial, residential and vegetation habitat types are likely to occur in close proximity. The man-made developments create small scattered vegetation habitats. The habitat types found in the vegetation sample sites appear to be larger vegetation units. If one was interested only in the degree of vegetation habitat patchiness, different results would be obtained. The level of patchiness would be much greater in the vegetation sample sites, as in many of the developed sites the vegetation habitat patches are adjacent to man-made developments and thus would not be considered important.

Between 1981 and 1984 changes did occur in the degree of habitat patchiness recorded in the Blackbrook Valley. For example in sample site 1, eight vegetation habitat units were destroyed and were replaced by a single unit of industrial land. On the whole, there appears to be an increase in the number of habitat units in the area in 1984. This is likely to be due to the man-made developments which have taken place over this time period, causing fragmentation of existing habitat units. The amount of increase is not statistically significant with this sample.

CHAPTER SEVEN

ANALYSIS OF THE BLACKBROOK VALLEY HABITAT SURVEY

7.1 Introduction

The previous two chapters have described methods by which large-scale aerial photography can be used to survey and monitor urban habitats providing quantitative information. It is important to consider the outcome of such analysis to determine how useful the results are.

7.2 The results of the surveying of the habitats in the Blackbrook Valley

As stated in Chapter Five, it is necessary to consider the usefulness and accuracy of the results obtained in order to determine whether aerial photographs can be successfully used to survey and monitor urban habitats.

A number of factors are considered important in ecological surveys. Some of the criteria studied are often linked together to describe the diversity of a habitat. Noss (1983) claimed there is a traditional interest in maintaining maximum habitat diversity. A number of factors are considered in ecological studies, such as habitat type, area, maturity, location, contiguity, patchiness, vegetation structure, environmental conditions and management practices.

Generally to impose some form of order in an ecological survey, units are defined and mapped within the framework of a classification. Such units are often termed habitats and frequently defined in terms of botanical characteristics and or vegetation structure. Bunce and Shaw (1973) suggested a methodology for a standardized ecological survey in which they recorded vegetation species types, species dominance and the diameter breast heights of trees and shrubs, that is, they defined habitat categories in terms of vegetation structure and species type. It is important to identify the habitat or vegetation community types which occur in the study area.

The area of the defined habitat type is also considered important in ecological studies. The extent of a habitat will have an influence on its value to wildlife species. In some surveys, it is necessary, if possible, to define the minimal areas of each type necessary to ensure the survival of wildlife communities in an area. Such information is often required by planners. Other dimensional information which may be important is the length of habitat perimeters and the shape of habitat units, for example, whether habitats are linear. Such information is not obvious from the area of the habitat alone.

The degree of habitat fragmentation is also an important habitat variable to be determined. If a green area comprises a number of different habitat types, this can increase the diversity of the area. However the advantages of such habitat patchiness can be lost if the patches are below the area necessary for wildlife species to survive in that environment.

The diversity of an area is affected by the maturity of different habitat types, as the plants and animals of a new community are different to those of long established communities. Many surveys therefore consider the age of different habitat types.

The location of the habitat is important. Its value to wildlife may be reduced if it is isolated. Research has shown that isolated units tend to have a lower diversity than similar connected habitats. This is emphasized by the importance attached to ecological corridors which are composed of a number of connected habitats and therefore provide pathways for the easy movement of plant and animal species. The contiguity of different habitat patches is desired to encourage stability.

Many ecological surveys also take into consideration environmental factors other than botanical variables. For example, studies often include information about an area's topography, geology, soils, hydrology and climate. As an ecological survey concerns the relationship between living organisms and the biotic and abiotic environment, such factors are important.

Management practices are also noted in ecological surveys as the management of a particular habitat type can affect the diversity of an area, for example, coppiced woodland is a more favourable woodland habitat for many species than plantation woodland.

Using large-scale aerial photographs some of these criteria can be identified more accurately than others. In the ecological survey of the Blackbrook Valley the following major ecological factors were identified.

i) Habitat type. This includes information about the structural vegetation characteristics of the habitat. These data can be used to determine the habitat diversity of the area.

ii) Habitat location. The maps of the habitat types recorded in the Valley illustrate the location of each habitat unit. The degree of isolation can thus be determined.

iii) Habitat area. The area of each mapped unit was measured providing individual measurements as well as combined habitat totals. By counting the number of units of each habitat type, it was also possible to determine the average size of each habitat category unit. Perimeter lengths can also be calulated to indicate the extent of edge communities. The shape of the habitat units can also be examined.

iv) Habitat patchiness. Measurements of habitat patchiness were determined by considering both the area of each habitat and the lenght of the habitat perimeter. It was possible to produce a quantitative estimate of the area's habitat diversity by considering the number of habitat patches per unit area. For some studies it may be beneficial to use a more detailed method of quantifying the distribution and size of habitats, for example using the habitat index discussed.

v) The changes which have occurred in habitat type, area and location can be mapped and hopefully the cause of these transformations can be identified.

It is therefore apparent that some of the major variables included in ecological surveys can be extracted from aerial photographs. There are some limitations however. It is not possible to interpret botanical information to the same level of detail as in field surveys, but such botanical specifications are not always necessary. Although the maturity and management of different habitat types are not positively stated, inferences about these factors can often be made from the classification categories used for this study. For example, broadleaved closed woodland is likely to be a more mature community than broadleaved closed shrubland.

The abiotic environmental conditions in the Blackbrook Valley have not been surveyed. Topographic and hydrological information could readily be determined from the aerial photographs. It may be possible to obtain details from the photographs about the geology and the soils found in the area, but the success of this would be limited in most locations by the dense vegetation coverage. It would be easier to obtain information about the climate from an alternative source, although it would be possible to make deductions from the vegetation community types.

Thus aerial photographs have proved to be very useful to survey the ecology of the Blackbrook Valley. Most of the major parameters considered in ecological studies can be determined. Although this information is often less detailed than field survey data, compensations do exist, for example, the monitoring project can be carried out in a shorter time period and or conducted over larger areas.

As stated earlier, the success of the ecological survey is also dependent on the accuracy of the results obtained. In Chapter Four, the accuracy of the classification interpretation was found to be acceptable. This suggests that the habitat maps (Figures 3.7 and 3.8) provide a representative picture of the habitats found in the Blackbrook Valley in 1981 and 1984. However as the accuracy levels were determined by sampling, it is still possible that some incorrect interpretations have been undetected and therefore perpetuated. The change matrices listed in Chapter Five (Tables 5.4 and 5.7) help identify some false classifications. It is important when questioning the classification of a habitat type, to consider its location.

The accuracy of the habitats' area data needs to be considered. As discussed in Chapter Three, it is inevitable that some errors will occur in the digitising process. These errors will constitute a larger percentage of the area of small habitat units than large habitat units. This is one reason why it may be preferable to decide on a minimum mapping resolution (Drummond, 1984). It is believed that areal errors caused by digitising different parts of the boundary line, that is the outside or inside edge, will compensate for each other.

The area of visible habitat types recorded can be regarded as being representative of the true situation. Discrepancies occur when the total area of the invisible habitats are discussed. For example, the area of woodland habitat in the Blackbrook Valley can be stated confidently. However area totals of the shrubland and grassland communities are not so realistic.With aerial photographic data, it is impossible to determine the extent of occurrence of these two structural layers below a dense woodland canopy. The areas of shrubland and grassland communities quoted are thus based on the measurement made when these habitat types were the dominant communities and do not represent the absolute total amount of these community types in the Blackbrook Valley. Field survey measurements would not result in this inaccuracy, but such measurements of habitat area are far more complicated and time-consuming.

However this problem is not always eliminated by field surveys, for example the botanical survey carried out in the City of Nottingham initially only recorded the dominant species types. No record was made of the grassland communities below tree canopies until the second more geographically limited phase of the survey was conducted (Rieley and Page, 1985).

So long as this factor is considered, area measurements, obtained from aerial photographs, can be used successfully in ecological studies. As always, it is necessary to choose the most suitable data source for the aims of the study. In this instance, it is the author's opinion that large-scale aerial photographs can be successfully used to survey and monitor urban habitats.

The following chapters will attempt to expand on the usefulness of aerial photographs in ecological studies by concentrating more fully on one example. The aim is to investigate whether large-scale aerial photographs can be used to determine information about the size of common bird populations in urban woodlands. Remotely sensed data could prove to be very useful for such wildlife studies as the method of analysis should be objective, therefore suitable for comparative studies. Other advantages to be gained include the possibility of conducting such a study on a historical data source and therefore, gain an indication of the likely past population numbers. It should be possible to conduct extensive studies of an area's habitats more rapidly and more cheaply than can be achieved by field survey alone. Chapter Nine aims to determine whether aerial photographs are a means to obtain information about the habitat variables which influence woodland bird population numbers. If so, aerial photographs will provide a relatively accessible data source which can be readily analysed. However, before this analysis can be carried out, it is necessary to investigate what quantitative relationships have been identified between bird population numbers and habitat characteristics and whether information about these habitat variables can be determined from the aerial photographs.

CHAPTER EIGHT

A REVIEW OF THE PREDICTIVE RELATIONSHIPS IDENTIFIED BETWEEN BIRD COMMUNITIES AND THEIR HABITATS

8.1 Introduction

There is great interest shown in bird population numbers and composition. This is evident by the number of regular bird counts which are conducted globally by reputable organisations, academics and enthusiasts. For a number of reasons, such as environmental management and planning purposes, attempts have been made to investigate how the bird population relates to the environment. Research has concentrated on trying to identify key habitat features. Bird census are often accompanied by vegetation surveys. Wiens and Rotenberry (1981) believe this documentation is vital if predictive relationships are to be identified.

The identification of a relationship between a breeding bird community and its habitat would be very valuable. A number of studies have been conducted to try and determine a quantitative relationship between habitat characteristics and bird populations. If such a quantitative relationship can be described, it may be possible to make detailed assumptions about the probable breeding bird community in a particular environment based primarily on habitat surveys. These may be conducted more rapidly and less expensively than a bird census which requires frequent site visits throughout the breeding season. Knowledge about the relationship between bird communities and their habitats could also be useful to predict the possible effects of habitat changes on the breeding community.

Standardised methods of bird census and vegetation survey would facilitate the use of existing predictive relationships, help identify new correlations and allow comparisons to be made between different sites. National breeding bird counts have encouraged the development of standard survey techniques, for example The British Trust of Ornithology's (B.T.O.) Common Bird Census. Guidelines produced by the B.T.O. allow a number of volunteers to produce comparable survey results. A standardised method of habitat survey would be very useful especially in situations where information is collected at a number of sites by a number of individuals. James and Shugart (1970) recognised this need and suggested a methodology for the quantitative description of bird habitats. Measurements were made of tree and shrub density, basal area, frequency and canopy height and of the percentage ground and canopy cover present. However this technique has not been accepted as a standard in America or elsewhere.

Remote sensing techniques may be of value for habitat surveys. Surveys based on aerial photographs can help overcome the problem of a lack of objectivity of habitat description in two ways:

i) Although fewer vegetation parameters can be surveyed, they can be more strictly defined, therefore the classification category and structural information should be comparable between different sites.

ii) As aerial photographic surveys are less time-consuming and more flexible geographically, the same interpreter may be able to survey all the habitats in question, thereby ensuring a high standard of consistency.

Remote sensing imagery has been used in studies of bird population prediction, (Skaley, 1981; Lancaster and Rees, 1979). The techniques suggested have been either extremely complicated or the photographs have been used merely as an addition to the field data rather than as a primary data source.

Aerial photographs have been used to determine the abundance of mammals in an urban settlement in the U.S.A. (Van Druff and Rowse, 1986). A study of the association between mammals and urban habitats in Syracuse, New York, found that the variables measured from aerial photographs, mainly relating to the area of certain land uses, accounted for more of the variability in mammal abundance than did detailed field measurements of on-site physical or biotic conditions.

The aims of this chapter are two-fold:

i) To review the quantitative relationships which have been proposed between bird communities and habitat characteristics. Various studies have attempted to identify the botanical parameters which have the most influence on the bird populations.

ii) To discuss the feasibility of using large-scale aerial photography to obtain the required information about the predictive variables..

8.2 The predictive relationships between bird populations and their habitats: A review of the literature

Birds select the habitats which provide the species with all the requisites for survival and reproduction. On a global scale, several major factors influence bird distribution and habitat selection. Van Tyne and Berger (1976) listed the major elements as historical; referring to time and geology, physical barriers, for example, water; environmental requirements; ecological tolerances and finally behavioural factors. These variables also influence local distributions. Balda (1975) suggested bird communities were controlled by habitat independent variables, for example, geological history and habitat dependent variables, such as a suitable vegetation structure. Karr (1980) proposed a 'tentative' set of primary variables and interactions which he believed dictated a bird's use of a specific area and therefore, needed to be considered when researching into the relationship between a bird's nesting and feeding behaviour and its habitat usage (see Figure 8.1).

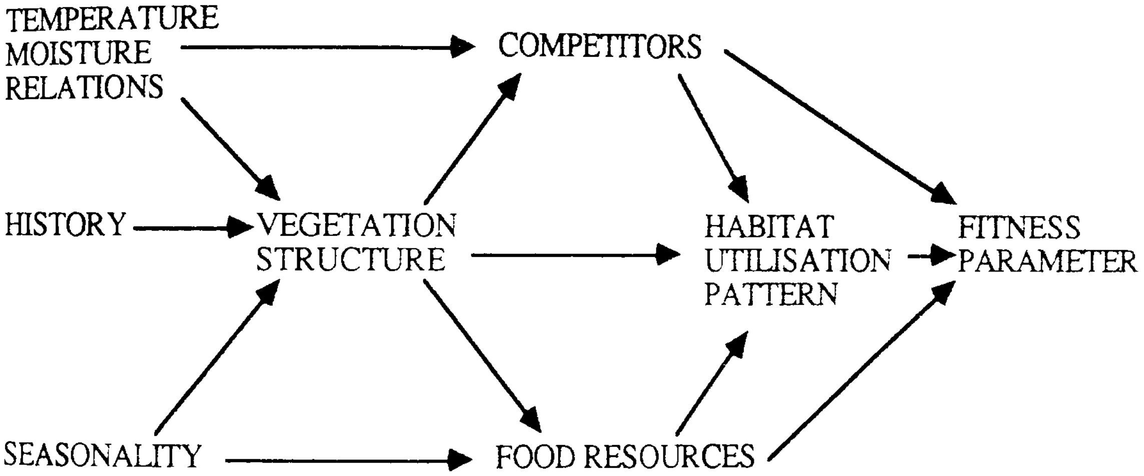


Figure 8.1 Primary variables to be considered in bird ecological studies. After Karr (1980)

A number of bird species forming a community will identify the optimum available habitat to fulfil their breeding, feeding and song post requirements. This process is termed habitat selection. Brown (1969) predicted that when a critical population density is reached in the preferred habitat, individuals will begin to move into alternative, but less suitable habitats. This is due to the territorial behaviour of the males successfully established in the primary habitat. Thus the population of birds in the optimum habitat should remain relatively constant at its carrying capacity. The distribution of the birds in the secondary habitats will be less stable depending on the overall bird abundances in that area. If population levels are high, species have to use the less suitable habitats. If population levels are low, for example as a result of a severe winter, all species may find suitable territories within the optimum habitat. Thus the distribution of bird populations in a specific habitat will depend on its quality and the overall bird population levels.

The arrangement of birds within a habitat is complex. Edington and Edington (1972) claimed that different species use different parts of a habitat and thus they are spatially segregated. Species using the same habitat can be separated vertically, horizontally and temporally. This spatial distribution is often the result of the demands for food.

The vertical separation of bird species in a habitat is a result of the different ways which they move, feed and nest within it. Some species survive entirely in the upper tree canopy while others may only inhabit the ground vegetation. Species may be found in the same geographical location but they do not compete with each other as they survive in different tiers. Species which feed on similar food types from similar vertical zones have been found to separate horizontally. Ideally bird species or individuals with similar requirements will separate horizontally over the area of suitable habitat. They will establish geographically distinct territories which are large enough to fulfil their needs and thus eliminate the need to compete for resources. Horizontally segregated territories may only comprise one vegetational layer and so the vegetation above and below may also be part of the territory of a different species thus the habitat would be vertically and horizontally divided.

It is also possible that the same habitat resources can be divided between different species which have different breeding seasons. However the temporal separation of species which use the same food supply, does not necessarily result in both species being able to survive successfully in the same habitat. A population boom for the first species may result in a food shortage for the birds which breed later in the season.

It is evident from this brief discussion that the relationship between birds and their habitats is very complicated. Research into this aspect of bird ecology therefore needs to be limited to a small number of well chosen parameters. Skaley (1981) claimed, to identify how birds use particular habitat types, it is necessary to identify correlations between certain basic habitat shapes and patterns and the bird communities they support.

The earliest studies (since 1960), into the relationship between bird communities and habitats, aimed to predict bird numbers. Investigations were conducted to identify whether individual habitat parameters were correlated with bird species richness, bird abundance or bird species diversity. If a quantitative correlation was found to exist, predictions could be made (MacArthur and MacArthur, 1961; Balda, 1975; Moore and Hooper, 1975 and Rafe et al., 1985). There is a body of opinion which believes that it is impossible to relate the populations of animal or plant species to a single variable. A number of bird studies have therefore attempted to identify which combination of specific environmental variables influence bird population densities. These are designed to aid management decisions and have involved a number of structural and landscape variables, (for example Balda et al., 1983 and Boecklen, 1986).

Predictive relationships can be used in two ways. Relationships identified by sampling a small section of a homogeneous area can be extrapolated over larger areas where field surveys would be too time-consuming and expensive. This was the procedure used by Bilcke (1980). As he was working in a varied landscape, he conducted a field bird census of three representative plots, 50 hectares, 19.5 hectares and 14 hectares. The vegetation structure for the whole region (708 hectares) was mapped using aerial photographs. He superimposed the bird and vegetation data and attempted to identify any qualitative habitat patterns in the sampled plots which could then be extrapolated over the whole area. Alternatively, if correlations were identified between bird populations and habitats, this information could be employed to estimate bird numbers in similar habitats in different locations.

8.2.1 Variables used to describe bird populations

A list of quantitative relationships between bird populations and woodland habitats can be seen in Table 8.1. These relationships may not be restricted to the geographical location where they were developed. Bird population statistics which have been correlated with habitat variables are :-

i) bird species richness;
ii) bird abundance, which is the number of breeding pairs; and
iii) bird species diversity, (B.S.D.).

Bird species richness and bird abundance are self-explanatory terms however bird species diversity needs more explanation. Bird species diversity is a statistic based on the number of species and the number of individuals of each species. It indicates how evenly the species are distributed in a habitat. A community with only one species will have zero diversity, a two species community - one with ninety-nine individuals, the other with a single individual will have a diversity of 0.056 (the figure is close to zero); a two species community with an equal number of species, fifty each, will have a larger diversity index: 0.694. Bird species diversity is calculated using the Shannon Weaver diversity formula.

$$\text{B.S.D.} = -\Sigma P_i \ln P_i$$

where P_i = proportion of the total population formed by the ith species.
ln = the natural logarithm.

Table 8.1 Variables used in bird prediction studies

Table 8.1 Variables used in bird prediction studies									
Author	Date	Country	Type of Environment	Independent Variables	Dependent Variables	Relationship	Equation	Accuracy	Comments
MacArthur R.H. MacArthur J.W.	1961	America	Broadleaved temperate woodland homogeneous 3 acres	Plant species diversity Foliage height diversity 0-2', 2-25'>25'	Bird species diversity	Linear relationship BSD + FHD	BSD = 2.01 FHD + 0.46		Size woodland constant eliminate area differences, homogeneous habitats. Community in equilibrium. Addition to each vegetation layer, results in equal addition to BSD as each vegetation layer equal.
Trainer E.J.	1969	America	9 common types: marshes, grasslands, shrubslands, deserts, coniferous forests, mixed forest, open broadleaved forest, tropical woodlands.	Bird species diversity	Species richness	Linear relationship BSD + SPP richness	BSD H' = 0.941 (log25) - 0.251	r = 0.972	Heterogeneous habitat types. Homogeneity vegetation structure within habitat
Wilson M.F.	1974	Illinois, America	Variety of habitats, mainly broadleaved	Foliage height diversity Percentage cover vegetation canopy 0-1.5m, 1.5-9m, >9m	Bird species diversity	Linear relationship BSD + FHD Curvilinear relationship BSD + PCVC	All communities y = 0.551 + 1.442 x no equation	r = 0.856 r = 0.747	For woodland communities no relationship between FHD and BSD. Contradictory to MacArthur's. Believe addition of trees has disproportionate affect on species. Different layers have biological relevance.
Moore N.W Hooper M.D.	1975	England	400 broadleaved and coniferous woodlands. 0.001 ha - 100.0 ha	Area	Species richness	Linear relationship area + species richess log S = K log A + log C	log S = 0.271 log A + log 0.26	R = 0.84 R = 70	Isolation regarded as constant
Balda R.P.	1975	America	South eastern Arizona, some woodland and succulent areas.	Plant species diversity	Bird species diversity	Linear relationship PSD + BSD	BSD = 0.44 PSD + 3.22		Succulent environment
Galli Lack Forman	1976								
Cyr A.	1977	Canada	Forest environments	Diversity of stratification 5 strata, 0-0.5m, 0.5-2m, 2-6m, 6-10m, >10m. Canopy cover 0-25%, 26-50%, 51-75%, 76-100%	Bird density abundance	Correlation between diversity of stratification and bird abundance	No equation	Statistically significant	BSD can then be calculated as highly correlated (r = 0.878, p<0.0001) with bird abundance
Moss D.	1978	Scotland	Coniferous and broadleaved woodland	Foliage height diversity 0-0.6m, 0.6-6.0m, 6-15m, >15m	1) Bird species diversity	1) Linear relationship FHD + BSD	1) BSD = 1.089 PSD + 0.962	1) r = 0.887 P = 0.1	Claims equation can be used for northern woodlands
				(Better correlation 0-1.0m, 1.0-7.0m, 7-15m, >15m)	2) Bird abundance per pair	2) Linear relationship FHD + bird abundance	2) No equation	2) r = 0.367 (0.403) P = 0.1	Existence of correlation more important than actual figures as figures will vary as method of measurement varies
				(Better correlation with 0-0.6m, 0.6-3.0m, 3-15m, >15m	3) Bird species richness	3) Linear relationship FHD + species richness	3) No equation	3) r = 0.52(0.523)	

Table 8.1 *Variables used in bird prediction studies (continued)*

Lancaster R K Rees W E	1979	Canada	Urban vegetation	Foliage height diversity, 6 layers tall trees, short trees, tall shrubs, short shrubs, lawn, gardens	Bird species diversity	Linear relationship FHD + BSD	BSD = 0.86 + 0.96 FHD	P = <0.05	Structural features relating to urban vegetation
O'Connor R J	1981	England	Southern woods	Foliage height diversity	Bird species diversity	Linear relationship FHD + BSD	BSD = 0.92 FHD + 1.67	r = 0.726 P<0.02	Quoting relation stated by Pearson. Stressing relationship only relevant for 1 year due to intraspecific competion by species for preferred habitats, that is habitats used in study may be secondary habitats therefore not in equilibrium
Skaley J E	1981	America	Forest plots	Physiognomic canopy diversity (PCD)	Bird species diversity	Positive linear relationship between PSD + BSD	No equation		
Woolhouse M J	1983	England	Broadleaved or mixed woodland 3.6 ha – 40.1 ha	Area	1) Bird species richness 2) Bird abundance per pair territories	1) Linear relationship area + species richness 2) Linear relationship area + species abundance	1a) lnS = 0.227lnA + 2.632 1b) lnS = 0.347lnA + (1.538 + 0.347lnp) p = 10 2) lnI = 0.679lnA + 3.082		Based on passive sampling hypotheses 2 equations suggested area and species abundance 1a - believes areas sampled equally 1b - suggested used by author adjusted to fit passive sampling hypothesis
Balda R P Gaud W S Brown J D	1983	America	Ponderosa pine forest	7 habitat variables, 4 climatic variables	Bird abundance pairs	Relationship between number of variables and bird abundance Temperature during dispersal, DISPL, snag density, total foliage volume, winter mean temperatures importance of oak, snow precipitation, mean low temperatures, mean high temperatures	Violet green swallow Density = 4.22 – 3.14 (DISPL) + 0.06 (SNAG) + 0.004 (FVTOT) Overall density 157.07 – 4.25 (TRNK) 1.65 (VOAK) + 0.27 SNAG	R = 0.83 P<0.0001 R = 0.83 P<0.0001	Talking about secondry cavity nesters
Reed T M	1983	Britain	Islands – different habitat types	Habitat variables area, latitude, longitude, index habitat variety island elevation, distance to mainland	Bird species richness	1) Relationship between area + species richness 2) Relationship between number of habitats and species richness	1) log S = 3.09 log A 2) No equation	r = 0.85 R = 71.6	Mixed habitat types that is not only woodland
Luniak M	1983	Poland	40 urban woodlands <3 ha – >100 ha 50 years or younger	Area	Species richness	Log normal relationship between area and species richness	Graph of relationship No equation	r = 0.84	Looking at woodlands with high to medium antropogenic influence
Opdam P Van Dorp D Braak C J F	1984	Netherlands	Small mature broadleaved woodlands <30 ha	Area size, distance to source pool OS distance to nearest wood ON area wood with 3km area wood with 5km	Species richness	Relationship betwen species richness and woodland size + area of woodland isolation within 3km	1) lnS = 0.93 + 0.37 lnA 2) lnS = 0.89 + 0.32 lnA + 0.25lnAF3 3) lnS = 1.27 + 0.34lnA + 0.16 lnDS	54% variance 60.6% v R = 63.9 60.4% v R 63.7	Shrub and ground layer considered constant. Just looking at species living in tree layer

Table 8.1 Variables used in bird prediction studies (continued)

Opdam P Rijsdijk G. Hustings F	1985	Netherlands	Small mature broadleaved woods 2 areas of study	5 habitat variables, 9 landscape variables. Woodland area, distance to large forest, woodland species type.	Species richness	Relationship between species richness and wood area, distance to large forest and wood species type. BO = beech/oak POP = popular/alder BIO = birch/oak	1) first area $S = 5.24 - 0.53 \ln DLF + 0.87 \ln A + 1.30 BO$ 2) second area $S' = 6.00 + 1.61 \ln A - 0.85 DLF - 2.69 POP - 1.37 BIO$	47.2% v R 51.2 86.5% v R 88.5	Only looked at total woodland species Isolation not as important as first believed Semi-log form of equation more accurate
Van Burskink J	1985	America	Small islands in Lake Michigan 3.0m - 20.6 ha, coniferous trees dominant	Area	Species richness	Positive linear relationship between area and species richness	$\log S = 4.33 + 0.341 \log A$	$r = 0.957$ $P = 0.00001$	
Usher M.B Rafe R.W Jefferson R.G.	1985	England	RSPB reserves, 1-4400 ha, different habitat types, woodland and heathland, freshwater wetland, lowlying coast, coastal cliff, islands.	1) Area	Species richness	1) Linear relationship between area and species richness	1) All community types $\log S = 1.16 + 0.176 \log A$ 1) Woodland communities $\log S = 1.45 - 0.128 \log A$	34% variance $p<0.001$ 55% variance $P = 0.002$	log base 10 Using BTO classification and subdivision for habitat numbers Even woodland example not only woodland - woodland and heath communities
						2) Linear relationship between habitat number and species richness	All communities $\log H = 0.305 + 0.174 \log A$ $\log S = 1.13 + 0.607 \log H$ $\log S = 1.01 + 0.483 \log H + 0.094 \log A$	$r = 24$ $P<0.001$ $r = 52$ $P<0.001$ $R = 581$ $P<0.05$	- area and habitat number regarded as separate but correlated variables
Boecklen W	1986	Northern Coast America	Coniferous and broadleaved woodland 5.6 ha - 23.9 ha	Area, tree density, basal area, number of tree species, number of tree diameter DBH at 8-15cm, 15-23cm, 23-38cm, >38cm, percentage ground cover, percentage canopy cover, canopy height	Species richness	1) Linear relationship between area and species richness 2) For passerines linear relationship between habitat heterogenity and species richness	1a) All species $\log S = 0.737 + 0.486 \log A$ 1b) For passerines $\log S = 0.816 + 0.315 \log A$ 2) No equation	$R = 29.4\%$ $P = 0.001$ $R = 22.1\%$ $P = 0.01$	Habitat heterogeneity an important influence on habitats
Goldstein E.L. Gross M DeGraff R.M.	1986	America	1 ha woody plots of vegetation in urban environment. Broadleaved and coniferous	Average height of woody plots, average stem diameter, number of woody plots. Volume of vegetation in cubic feet	Bird species richness	Linear relationship between volume and species richness	$\ln S = S(\ln V) + B$ A = regression coefficient. B = constant		Found 49.6% of variation of bird numbers in plots due to total vegetation volume.

For a given number of species, N, the diversity is greatest when all the species are equally common. The diversity value is then equal to ln N. MacArthur and MacArthur (1961) believed B.S.D. was a better measure than actual species numbers. It is the author's opinion that quoted by itself, B.S.D. is not a very useful or descriptive statistic and therefore, is not very helpful in mangement decisions. It provides no indication of the number of bird species in a habitat. The statistic could refer to two or 200 evenly distributed species. If quoted with information about bird species richness and abundance, it is very informative but unfortunately most predictive studies concentrate on B.S.D. alone. However, Tramer (1969) identified a statistical correlation between B.S.D. and species richness for nine different habitat types.

$$\text{B.S.D.} = 0.941\ (\ln S) - 0.251$$

$$\text{or} \quad \ln S = \frac{\text{B.S.D.} + 0.251}{0.941}$$

where S = species richness.

This equation suggests that the abundance levels of every bird species are constant in a particular habitat type, thus B.S.D. and species richness can be determined without knowledge of abundance levels. Bird abundancy levels may remain relatively constant (that is, within the range of natural fluctuations and within a limited geographical area) in the optimum habitat sites, but as discussed earlier, the population abundances in the sub-optimal sites can vary greaatly depending on the overall population levels. It therefore seems unlikely that abundance levels will remain constant in a particular habitat type. However, if the relationship suggested by Tramer (1969) is found to exist for individual habitat types, for example broadleaved woodland, it would make the statistic B.S.D. more useful in practical studies.

8.2.2 The relationship between habitat structure and bird communities

The structure of a habitat has long been considered to have an important causal influence on a bird community.

> "It is well known there is a general correlation between the physical arrangement of vegetation in a habitat and the bird species which occur there." (Edington and Edington, 1972).

James and Shugart (1970) felt the causal nature of this relationship has been over emphasised but they agreed that

> "the structure of the vegetation required by any particular bird species is quite specific".(James andShugart, 1971).

8.2.2.1 Foliage height diversity

In 1961 MacArthur and MacArthur published a very influential predictive study based on a structural parameter. They believed it was unlikely that species territories were scattered randomly over a habitat. It seemed to be more plausible for birds to use some subtle difference in the local habitat as criteria for settlement. In homogeneous, five acre wooded plots, which were regarded as being in a state of equilibrium (Pearson 1975), MacArthur and MacArthur (1961) found a strong correlation between bird species diversity and foliage height diversity (F.H.D.).

Foliage height diversity is a measure of the percentage and distribution of foliage in each structural layer of the vegetation community. It provides information about the arrangement of the vegetation layers in a chosen habitat. The field data is collected using vertical transects to measure the mean proportion of leaf area at different heights. As a result the F.H.D. statistic refers to a limited geographical area only. If a number of F.H.D. measurements are taken in a study area, these will also provide information about the horizontal patchiness of the region (MacArthur, 1964). F.H.D. is calculated using the same equation as B.S.D. but in this instance Pi is the amount of foliage found in the ith horizontal layer, expressed as a proportion of the total layered foliage in the census plot. By dividing the habitats into three structural layers; 0-2 feet, 2-25 feet, and more than 25 feet, MacArthur and MacArthur (1961) suggested a positive linear relationship between B.S.D. and F.H.D.

$$\text{B.S.D.} = 2.01\ \text{FHD} + 0.46$$

As this relationship was linear, they concluded that each foliage layer of a habitat is equally important and a similar increase in B.S.D. will result with an addition of any one of the foliage layers. They assumed that the addition of species to an area required the addition of recognisably different patches of habitat and it was irrelevant to the birds whether new patches were in the tree layer or ground layer.

F.H.D. can be calculated by measuring the vertical or horizontal profiles of a woodland habitat. The number of leaves and thus the leaf area is measured in the field for each structural layer. For coniferous woodlands, MacArthur and MacArthur (1961) found it was more convenient to estimate leaf numbers from assessments about the fraction of sky unobscured by foliage. They suggested that for coniferous woodlands in particular, this could be determined using vertical aerial photographs and a densitometer.

The methods of collecting the foliage data for F.H.D. calculations are quite complex and generally involve sophisticated field work. However Balda (1975) believed it was a straightforward procedure and his opinion has been backed up by the number of studies where F.H.D. has been used. Nevertheless, apart from the example mentioned above, aerial photographs have not been used to calculate F.H.D. in these studies.

Although the correlation between B.S.D. and F.H.D. was strong, MacArthur (1964) was aware of its limitations. Although he had suggested that each structural layer is of equal value to birds, in reality he agreed this is not the case, for example, ferns. In an environment where ferns dominate one structural layer, it is probable that B.S.D. will be overestimated. Also he recognised the fact that some species will choose a habitat on the grounds of food supply rather than foliage structure, for example the Crossbill *Loxia curvirostra* which primarily considers the available fruit supply. The diversity of such species cannot thus be predicted from F.H.D.

He recognized the influence of horizontal patchiness on bird species distribution and concluded that although F.H.D. could be used to predict B.S.D. in homogeneous habitats, in the more complex environments, other variables also have to be considered. However additional data presented by MacArthur, MacArthur and Preer (1962) indicated that this relationship was not restricted to homogeneous woodland environments. They found that bird species types and densities could be predicted from measurements of habitat patchiness in bushy fields and in habitats in the early succession stages. However no quantitative relationship was suggested.

Other researchers have echoed Balda's opinion about F.H.D. and B.S.D. relationships. Moss (1978) and O'Connor (1981) carried out studies into this correlation in British woodlands. Moss (1978) conducted a study in 18 wooded plots in Scotland, the average size being 9 hectares. Twelve of these plots were coniferous plantations, the remainder were composed primarily of broadleaved species. He employed a simpler method to determine F.H.D. than MacArthur and MacArthur (1961) or MacArthur and Horn (1969). For each vegetation component (canopy, understorey and ground layer), the maximum and minimum foliage heights were measured along with details of the height at which the vegetation was most widespread. The percentage of canopy cover in each layer was also recorded. For the height ranges 0-0.6 metres, 0.6-6.0 metres, 6-15 metres and more than 15 metres he obtained a correlation between B.S.D. and F.H.D.

$$\text{B.S.D.} = 1.089\ \text{F.H.D.} + 0.962 \qquad (r = 0.887,\ \ P = 0.1\%)$$

Moss also looked at the relationship between F.H.D. and bird species numbers and abundances but these correlations were weak. The main conclusion of his study was that a relationship exists in temperate woodlands between F.H.D. and B.S.D. The above equation can be used to predict B.S.D. in northern Britain and similar woodlands provided F.H.D. is measured in the same way. Moss stressed that the identification of a strong correlation between F.H.D. and B.S.D. in this environment is more important than the equation prosposed, as the numerical variables used will depend on the way the vegetation is measured. Although Moss uses a simple method to determine F.H.D., the quantitative information required about the lower vegetation layers cannot be accurately obtained soley using aerial photogaraphs.

O'Connor (1981) quoted a study carried out by Pearson (1975) into the relationship between bird distributions and habitat structure. The research was based on common bird census data for twelve woodlands in southern England. Again a statistically significant relationship was found to exist between F.H.D. and B.S.D..

$$\text{B.S.D.} = 0.92\ \text{F.H.D.} + 1.67 \qquad (r = 0.726, \quad P = 0.02\%)$$

The graph constants quoted in these three studies all differ. One would expect dissimilarities between British and American studies purely due to geographic location. The regression slope of Pearson's study is lower than that suggested by MacArthur and MacArthur (1961) and it is claimed that this may be due to the census data being collected at a time of high bird population when the less suitable habitats (with lower F.H.D.) are being used. Geographical location could also be responsible for the discrepancies which occur between the constants in the two British studies, although the coniferous broadleaved difference is probably more important.

Balda (1975), in a review of a number of American studies, concluded that the complexity of the vegetation plays an important role in determining B.S.D. and the evidence seems to suggest that F.H.D. is the best factor for predictive purposes.

However there have been some criticisms of this relationship, for example, Willson (1974). She not only questioned the overall validity of using F.H.D. to predict B.S.D., but also the biological justification for doing so.

> "We probably should be hard pressed to justify measuring F.H.D. for the prediction of B.S.D. when we do not really know what it means" .(Willson, 1974).

Willson conducted her research in a variety of habitat types in Illinois. When all the habitats were considered together there was a positive relationship between B.S.D. and F.H.D.

$$\text{B.S.D.} = 1.442\ \text{F.H.D.} + 0.551 \qquad (r = 0.856)$$

However when only the woodland habitats were considered, no correlation was apparent. This contradicts MacArthur's results. She divided the vegetation canopy into three layers 0-1.5 metres, 1.5-9 metres, more than 9 metres. Although these intervals differ to those used by MacArthur, Willson believed they most accurately represented the foliage structure of the habitats and therefore, were not responsible for the negative result. She did, however, identify a relationship curve between B.S.D. and the percentage vegetation cover, (P.C.V.C.), in each layer. This is a measure of the total volume of vegetation in each tier (the maximum total being 300%) and as such will be easier to determine than F.H.D. As it still requires details of the lower vegetation layers, it cannot be estimated from aerial photographs alone. The curvilinear relationship suggests that the mere existence of a tree layer is more closely associated with the addition of more bird species than the total amount of foliage or its distribution among the layers. Willson's study indicated that although vegetation structure is very important to bird population distribution, a simple analysis of habitat structure may be as informative as the more complex measures, for example F.H.D. Although the relationship between B.S.D. and P.C.V.C. may be less predictive due to its curved nature, it may have more biological meaning, as its percentage values correspond to actual vegetation layers. Willson found the largest B.S.D. values in the shrub and young tree layer. This suggests the presence of specific layers is important to bird species, a conclusion contradicting MacArthur and MacArthur's theory (1961) that each vegetation layer is equally important. Willson's findings do seem to be more probable. Her major criticism was the ready acceptance of the term F.H.D. which she claimed may have no biological importance to bird species, yet it has been frequently used due to the existence of a linear relationship which makes extrapolation and therefore, prediction easy.

Despite Willson's criticisms, researchers still felt that the relationship between F.H.D. and B.S.D. was worthy of investigation, for example Moss (1978) and O'Connor (1981). Some authors have adapted the structural diversity measurements to suit their projects. Lancaster and Rees (1979) examined the connection between F.H.D. and B.S.D. in urban habitats. For this study, F.H.D. was the sum of the diversity in six structural layers; tall trees, short trees, tall shrubs, short shrubs, lawns and gardens. They considered six structural layers were necessary to represent an urban environment. Generally the habitat is divided into three layers, four in more tropical environments. A positive linear relationship was identified between B.S.D. and F.H.D..

$$\text{B.S.D.} = 0.96\ \text{F.H.D.} + 0.86 \qquad (P < 0.05)$$

They tried to broaden the F.H.D. category even further by including man-made structural features, such as slanted and flat roof buildings. This addition allowed the conclusion to be drawn that B.S.D. is inversely related to a man-made increase in F.H.D., but no mathematical relationship was suggested.

Cyr (1977), in contrast to Willson (1974), claimed a more detailed method is required to describe a habitat's structure than that proposed by MacArthur and MacArthur (1961). He looked at the relationship between bird abundance and the diversity of stratification. To determine the stratification diversity of a wooded habitat he considered five strata 0-0.5 metres, 0.5-2 metres, 2-6 metres, 6-10 metres and more than 10 metres and four cover diversity classes; 0-25 per cent, 26-50 per cent, 51-75 per cent, 76-100 per cent. This index is therefore a combination of the parameters used to measure F.H.D. and P.C.V.C. Again the Shannon Weaver diversity index was used.

$$H = \sum P_i \ln P_i$$

where H = the diversity of stratification

P_i = the proportion of mean cover density of a stratum over the total possible maximum cover of all the strata together.

Cyr (1977) found a statistically significant correlation between stratification diversity and bird abundances, but the relationship between stratification and B.S.D. was poor.

Although there is general agreement about the influence of vegetation structure on bird populations, there is a conflict of opinion about the usefulness of F.H.D. as a measurement of foliage structure. Since it was first suggested in 1961, it has been used successfully in a number of studies, generally relating F.H.D. to B.S.D. Nevertheless it remains unclear how useful the measure of foliage height diversity is for habitat management. Balda (1975) found that even though the foliage volume of a ponderosa pine *Pinus ponderosa* forest plot had been reduced by felling by 18 per cent, there had been no change in its F.H.D.. This is due to no height classes being lost and the fact that there was no change in the proportion of foliage present in each height class. The concept of foliage height diversity indicates the need for vertical and horizontal patchiness in a habitat in order to increase the number of available niches, but it does not provide a clearly understandable quantitative figure which can be used by environmental managers. It is also improbable that for broadleaved woodlands F.H.D. could be determined for aerial photographs.

8.2.2.2 Plant species diversity

Both MacArthur and MacArthur (1961), and Balda (1975) have considered the possibilities of correlations between plant species diversity (P.S.D.) and a habitat's bird community. The Shannon-Weaver equation was used to determine P.S.D., where Pi equals the total area of leaves of the ith species expressed as a portion of the total leaf area of all the plant species in the census.

MacArthur and MacArthur (1961) found P.S.D. was a good predictor of B.S.D. but it did not provide any additional information to F.H.D. although it required more detailed field surveys. Balda (1975) has examined the possible link between B.S.D. and P.S.D. in a variety of habitat types including a habitat composed of trees, shrubs and succulents in Arizona. A significant correlation was evident.

$$\text{B.S.D.} = 0.44\ \text{P.S.D.} + 3.22$$

He concluded that P.S.D. can be used in some instances as an indicator of B.S.D. but he did not elaborate. P.S.D. has rarely been used in woodland bird studies, researchers preferring F.H.D. relationships. As with F.H.D., it would be impossible to determine P.S.D. from aerial photographs as even more detailed structural informtion is required. The value of calculating P.S.D. is doubtful as it only provides information about the B.S.D. of a habitat , a statistic which may be of little use to the people concerned with habitat management.

Vegetation structure is only one of the criteria important in bird habitat selection. Nevertheless most researchers believe it to be very important and therefore, a great deal of time has been spent examining the correlations between structure and bird populations. Laudenslayer and Balda (1976) were critical of some of these studies as they were based on the assumption that the birds utilize the entire habitat. Laudenslayer and Balda do not believe this happens. They claimed the structural requirements of a bird will be less complex than the actual structure of a particular habitat. The habitat is thus under-utilized and therefore the actual B.S.D. will be much lower than the levels predicted. In order to gain an accurate indication of B.S.D. they believe it is necessary to restrict measurements to the sections of used habitat. Despite these criticisms the results obtained from the research projects have been promising, although the existence of a statistical correlation is not evidence of causuality but of probability.

8.2.3 The relationship between area of habitat and bird populations

The area of a habitat is an important variable which has been used by itself in a number of studies about bird populations. The obvious relationship between area size and species numbers was first quantified by Arrhenius (1921).

$$S = c(A)^z$$

where S = number of species (species richness)
A = area
c and z = constants

He derived this equation using information about the numbers of plant species in particular habitats, but this relationship has also been applied in bird studies. The species-area relationship has been widely investigated. As evident from Table 8.1, the area parameter has regained popularity above other structural parameters in recent years. As with all studies involving structural parameters, the habitats under investigation are assumed to be stable.

8.2.3.1 Species-area hypothesis

Three mechanisms have been proposed to account for the species-area relationship. The habitat diversity hypothesis was suggested by Williams (1964) and since then it has been thoroughly investigated. He claims the species-area relationship is a result of a correlation between area and habitat diversity. As the area of vegetation increases, the number of habitat patches also increases. This is evident in rural environments but as discussed in Chapter Six, this occurs to an even greater extent in urban green open spaces. Each habitat patch has an associated set of species, therefore the number of species found in an area is multiplied. He believed the relationship between the rate of increment and area was non-linear.

MacArthur and Wilson (1967) put forward the dynamic equilibrium hypothesis. This has two components; dynamic and static. Although this hypothesis relates to island situations, it is frequently used for isolated mainland sites. The dynamic component, (the number of species on an island), is a result of the balance between immigration and extinction. The area and level of isolation (the static element) determines this balance and thus species richness. It assumes extinction rates are negatively correlated with population size which is positively correlated with area. Rare species are more likely to be found on the larger islands. The implication of the theory is that smaller sites will have higher extinction rates thus producing a relationship between area and species richness.

The third possible explanation is the passive sampling hypothesis proposed by Connor and McCoy (1979). This suggests that apparent species numbers are a product of sampling intensity. As the area sampled decreases, the number of individuals recorded is reduced. As fewer individuals are identified, fewer species will also be identified. The larger sites simply provide a larger sample of the overall species pool. The idea of the sample influencing the species-area relationship was also discussed by Kobayashi (1974). Whilst looking at the relationship between habitat size, arthropods and plant species numbers, he concluded that the form of the species-area curve depended on the sampling method as well as biotic characteristics. Generally the curve obtained by combining random samples will rise more steeply than one derived from a continuous expansion of the sampling area.

8.2.3.2 Species-area models

The mathematical descriptions of the relationship also vary. Connor and McCoy (1979) reviewed the three major linear species-area models which have been used in bird population studies; the untransformed model, the exponential model and the power function model.

The untransformed model suggests that species richness is directly related to area (species-area).

Gleason (1922) proposed that the best-fit model was exponential (species-log area)

$$S = \ln c + z (\ln A)$$

Williams (1964) used the exponential model as he believed it emphasised habitat heterogeneity. In the past this was considered the most important alternative but as a result of Preston's research (1962), the power function model (log species-log area) became almost universally accepted.

The relationship first proposed by Arrhenius was a power function.

$$S = c(A)^z$$

which is often represented by a double natural logarithmic transformation to

$$\ln S = \ln c + z (\ln A)$$

Preston's assumptions for the power function model were very similar to those of the dynamic equilibrium hypothesis. As a result, the hypothesis and the model are seen as proof of each other. Studies have attempted to interpret the slope and the intercept of the power function model graph exclusively in the context of the equilibrium hypothesis. Connor and McCoy (1979) claimed that the power function model has been frequently used in a number of studies without any consideration of its underlying assumptions. In their investigation into the alternative models available, they found that although the log species-log area model adequately linearized the species -area relationship in 75 out of 100 studies, it was the best fit alternative in only 36 instances. They believed its unquestionned use may have masked valuable biological information. Various authors have attempted to relate the constants to measures of isolation and species density. However Connor and McCoy (1979) concluded that whatever model is used in bird studies, the constants should be viewed simply as constants, devoid of any specific biological meaning. This recommendation has been criticised, for example, Martin (1984) suggested that the constants do represent biological patterns, but their meanings are sometimes obscured when heterogeneous data sets are used.

Polynormal (curved) models of the species-area relationship also exist. These are used less frequently as they are more complex than linear models. Kobayashi (1974) discussed the possibility of the species-area relationship becoming sigmoidal when a wide range of areas are sampled. If a homogeneous community continues to expand, it will possibly reach a stage when its available supply of new bird species will be exhausted. No new species will be added with increasing area. This results in a sigmoidal relationship. Hairston (1959) criticised this theory. He believed that as the habitat area increases, new rare species would be added to the total species number. Kobayashi echoed Hairston's opinion, as in view of the theory of vegetation continuum, there will always be a chance of encountering new species, therefore a sigmoidal curve is unlikely.

Although it is generally agreed that there is a significant correlation between area size and species number, the exact cause and nature of this relationship is unknown. A number of studies, comparing bird species richness with area, have been conducted in wooded habitats using different models.

8.2.3.3 Practical examples of the species-area relationship

Research has been carried out in a number of British broadleaved or mixedwoodlands. Fuller (1982) claimed that the area of woodland was a useful but general predictor of the number of breeding species in British woods. He found the relationship was stronger in some parts of Britain than others, for example, in Scotland there was very little correlation between species richness and area. His conclusions suggest the relationship is tentative and needs to be used with care. Nevertheless, a number of studies have produced promising results.

Moore and Hooper (1975) conducted a census of breeding bird species in over 400 woods, (mainly broadleaved) between 1967 and 1974. The woods varied in size from 0.001 hectares to over 100 hectares. The field data was compared with the species richness estimates from three different models, the exponential model, the power function model and a mathematical model taking into account the effects of a woodland edge. The highest correlation coefficient (R = 84) was achieved using the power-function model with base 10 logarithms (personal communication).

$$\log S = z \log A + \log c$$
$$\log_{10} S = 0.271 \ \log_{10} A + {}^{-}0.26$$

They found this equation produced a statistically significant estimate of species numbers but they statedthat

> "it does not necessarily follow that the number of bird species present depends upon the geography rather than the ecology of the area". (Moore and Hooper, 1975)

The size of a woodland may not have more influence than the botanical characteristics. Moore and Hooper (1975) were aware that they had ignored the influence of isolation, an important factor in the island equilibrium theory, but they concluded that the power function model of the species-area relationship can be used in British woodlands.

Woolhouse (1983) investigated the relationships of species richness and abundance with area. He used data from mature broadleaved woodland which had been censused by the B.T.O. The average size wood was 17.86 hectares but they ranged from 3.6 to 40.1 hectares. Of the variables considered, area, habitat type and geographical position, he only found a positive correlation between species richness and area. He believed the passive sampling hypothesis was the most likely explanation of the correlation. He proposed two equations to describe this relationship, the former representing the field data, the second being derived theoretically.

i) $\ln S = 0.227 \ln A + 2.632$

ii) $\ln S = 0.347 \ln A + (1.538 + 0.347 \ln d)$

$d = 10$

He claimed the second equation was more useful (personal communication) as it takes into account discrepancies which may arise from sampling, for example, inequality in the time spent in different size woods. He stated that species abundance was also correlated with area:

$$\ln I = 0.679 \ln A + 3.082$$

where I = the number of breeding pairs

Woolhouse was able to relate I, A, S to each other by accepting Preston's theory (1962) concerning species richness This assumes a constant density of individuals in each sampling site. The linear species richness-abundance relationship proposed by Preston was for isolated sites. He stated a non-linear (curved) relationship existed between species richness and abundance for sampled sites, for example, the B.T.O. sites used in this study. The sites used by Woolhouse were sample sites. However as he found the range of I values to be small, he concluded the shape of the sampled sites can be assumed to be constant, (a linear relationship) and therefore, I can be predicted from A. If a linear relationship exists between abundance, I, and area, A, theoretically a linear relationship can also be expected between area, A, and species richness, S. If no positive correlation exists between I and A, the species richness-area relationship can only be an approximation and extrapolation from such a curve may provide misleading results. In this study, Woolhouse derived significant estimates of species numbers and abundance but he concluded that the species-area relationship was not as simple as it originally appeared and should therefore be used carefully.

Rafe et. al. (1985) looked at the species-area relationship in a number of Royal Society for the Protection of Birds (R.S.P.B.) reserves which had been censused by the British Trust of Ornithology. A number of habitat types were found in these reserve sites, the combined category of broadleaved woodland and scrub being only one of the habitat types investigated. The authors were examining the credibility of the habitat diversity hypothesis to explain the species-area relationship. For all the habitat types investigated, they found a statistically significant relationship which accounted for 34 per cent of the variance.

$$\log_{10} S = 1.16 + 0.176 \log_{10} A \quad (P<0.002)$$

For the fifteen woodland scrub sites

$$\log_{10} S = 1.45 + 0.128 \log_{10} A \quad (P<0.002)$$

The second equation accounted for 55 per cent of the variance in woodland sites. The estimates of species numbers from the area of habitat were statistically significant. As these equations are based on data collected in ornithological nature reserves, they will overestimate the number of species likely to be found in a non-reserve woodland and therefore, their usefulness is limited.

Galli et al. (1976) identified a relationship curve between species richness and forest size in a study of forested islands in New Jersey.

$$S = 0.81 + 4.54(A)^{0.5} \qquad (R = 0.92)$$

They then investiged whether any correlation existed between F.H.D. and area. Such a correlation would suggest that species richness increased with area size due to increased F.H.D. However no correlation was found to exist. They concluded that the increase in bird species richness with habitat area is probably a result of the area of the habitat becoming larger than the critical minimum territory size for different species. This conclusion suggests that the area of a habitat is a far more important variable than F.H.D.

Evidence of a relationship in Poland between species richness and the area of urban woodlands has been provided by Luniak (1983). He censused woodlands ranging from 5 to 100 hectares with a high to medium degree of hemeroby (anthropogenic changes - Sukopp and Werner, 1982). He produced a graph of the relationship between area and species richness for three habitat types, woodlands, allotments and open land. For the former, the graph indicated a steep rate of increase in species richness with area up to 20 hectares. Above this level a much slower rate of growth was recorded. Although he did not state a quantitative equation for the relationship, the graph can be used to determine the expected number of bird species in an urban woodland.

The idea of a correlation between species richness and area has its critics. Helliwell (1976) analysed sixty British woodlands of various sizes. He concluded size and isolation were minor influences on bird species numbers. Woodland structure and the composition of the flora were more powerful factors. Reed (1983), in a study of bird communities on British islands, suggested that the habitat patchiness of an island was a better predictor of species numbers than area. Other authors have claimed that habitat area should be combined with other variables to improve the accuracy for predictive studies.

As previously mentioned Rafe et. al. (1985) found a significant relationship between habitat size and species richness. However, this association was improved upon when the level of habitat heterogeneity (patchiness) was included in the equation. They identified a correlation between species numbers and the total habitat area (for all the habitat types) and the number of habitat sub-classifications (classification categories defined by the B.T.O.). This correlation was used to predict the likely number of bird species.

$$\log_{10} S = 1.01 + 0.483 \log_{10} H + 0.094 \log_{10} A$$

where H = the number of secondary habitats from the B.T.O. classification.

Two studies conducted in the Netherlands examined the influence of isolation and area size on species richness in mature woodlands. On both occasions, the studies were restricted to bird species which lived totally within woodland habitats. Opdam et al. (1984) identified a species-area relationship.

$$\ln S = 0.95 + 0.37 \ln A \qquad (54\% \text{ variance})$$

The amount of variance accounted for increased when variables relating to isolation were included.

$$\ln S = 0.89 + 0.32 \ln A + 0.25 \ln AF3 \qquad (60.6\% \text{ variance})$$

where AF3 = area of woodland within a radius of 3km.

Opdam et al. (1985) looked at the impact of isolation on bird species in patchy woodland habitats. They analysed very homogeneous habitats to try to eliminate the affects of habitat diversity. Again they claimed the best predictor of species richness was patch size. The effects of isolation were not so clear cut. When considering the total number of bird species in a habitat, isolation was found to have a minimal effect. Nevertheless when the number of species was narrowed down to fifteen specific woodland species, isolation and size of woodland were both significantly correlated with species richness.

These studies indicate that the influence of isolation on species-area relationships is variable. The extent of its impact depends on the distance of the woodlot to other wooded areas and how much the woodland bird species can use the surrounding environment, for example agricultural land.

Thus there are a number of studies to suggest a significant relationship exists between area and species richness. Again this relationship cannot be considered to be causal but it has been used in a number of studies to produce adequate estimates of species numbers in stable woodland environments. As long as the habitat categories recognisable on aerial photogaraphs correspond to the habitats surveyed for model development, aerial photographs can readily provide the habitat area information necessary for these models.

8.2.4 Multiparameter studies

Criticisms have been voiced about the use of a limited number of variables in bird distribution studies, for example

> "Ecology can never be modelled or understood using a single dimension." (Reed, 1983).

However single variable studies have remained popular. Multivariable studies have often identified one major parameter which alone explains a large proportion of the variance in population numbers. However, if more variables are included in the analysis, it should be possible to account for more of the variance. In recent years multivariable studies have become more popular. Attempts have frequently been made to identify the habitat requirements of individual species rather than the whole community. These studies are based on the assumption that communities are composed of species which respond to ecological variations, largely independently of one another (Wiens and Rotenberry, 1981), therefore, it is misleading to try and account for the whole community using a single parameter.

The major variables considered in such studies relate to habitat structure and diversity, species composition, area, global and local location, and climate. Boecklen (1986) looked at the correlations between habitat heterogeneity, area and species richness in a number of broadleaved and coniferous woodlands in America. He found a significant relationship existed between species numbers and both area and habitat heterogeneity. To measure habitat heterogeneity, a variety of categories were used; tree density, basal area, the number of tree species, the number of trees with specific breast height diameters, the percentage ground cover, the percentage canopy cover and canopy height. These factors were used in a principle component analysis. The first six principle components explained 93 per cent of the variance. For species richness, the most important factors identified were the density of intermediate size trees, the number of large canopy trees, the percentage ground cover, the number of understorey trees and canopy height.

Balda et al. (1983) tried to identify the variables which were important for the breeding biology of individual species. He considered four climatic and seven vegetation factors and found that he could predict the density of snag breeding birds (birds which nest in decaying tree stumps) by using different combinations of three variables (see Table 8.1). The use of different variables for the different species made the prediction process very complicated. The factors identified as being important to the species sometimes seemed dubious, for example, as every bird examined in this study nested in snags, it would be reasonable to assume that the density of snags in the habitat would be one of the more important variables to all the species, but this was not the case. Obtaining such variable information about an individual species in a large community would be very time consuming. Once identified, the predictive relationships may only be applicable to the original area of investigation as different factors may be important to the bird species in different geographical locations, for example, the influence of climate may change.

Multivariate studies have identified some interesting parameters influencing bird distributions. However as a result of these factors being more specific, their use may be restricted to particular bird species or to particular geographical locations.

8.3 Conclusions

Certain habitat parameters can be used to provide estimates about bird populations. Single and multivariate studies have been conducted to identify relationships between a habitat and its bird communities, allowing predictions to be made. It is generally agreed that it is limiting to try and describe ecology using a single parameter, thus multivariate studies are more accurate. However the latter are more time-consuming, requiring very detailed field data. The type of test chosen should therefore depend on the aims and limits of the project. For detailed surveys of a particular area, for example, for management plans, information about the requirements of individual bird species would be necessary. If the facilities are available, multivariate studies should be conducted since the results obtained are applicable to that particular area. On the other hand, if facilities are limited or if information about the bird community as a whole is required, equations using one variable can provide a reasonable estimation. As these studies have been based on more general criteria, they should also be more adaptable to other geographical locations. The variables identified as being important for such predictive equations, for example, area and foliage structure, tend to be the parameters responsible for explaining the greatest levels of variance in the multivariate studies. Whatever model is used, the significant relationships identified cannot be regarded as being causal and meaningful to bird species, thus as far as the management of habitat is concerned, it would be unwise to rely entirely on the results produced by either method as they merely provide probability estimates.

The habitat variables used in the predictive studies discussed, have related to the area of the habitat, its patchiness or its physical structure. Depending on the resolution of the aerial photography, it should be possible to obtain information about habitat area and heterogeneity. It is unlikely that the relevant structural data can be extracted purely from aerial photographs. They can be used to provide information about the upper foliage layers but information about the understorey would have to be obtained by field sampling the understorey layers.

CHAPTER NINE

QUANTITATIVE PREDICTIONS OF BREEDING BIRD POPULATION NUMBERS FROM AIR PHOTOGRAPHS

9.1 Can area be used to predict breeding bird species numbers and abundances in Saltwells Local Nature Reserve?

In the previous chapter it was concluded that multivariate techniques are preferable in bird prediction studies, especially for detailed surveys of a particular area. This chapter will concentrate on attempting to predict bird species richness and abundance in Saltwells Local Nature Reserve in the south of the Blackbrook Valley. As a specific area is being investigated, this suggests it would be more suitable to identify which variables affect the bird community so these could be considered in management policies. However the analysis will be based on a single variable for the following reasons:

i) The overall aim of the project is to try and develop a technique which can be used in similar urban habitats and therefore concentrating on specific variables in Saltwells Local Nature Reserve may restrict the usefulness of the technique.

ii) Any analysis has to be based on the data available. As the research project is to investigate the feasibility of using air photographs for ecological studies, research into the possible prediction of bird community characteristics is limited to the parameters which are identifiable from the aerial photographic data source.

Chapter Five illustrated that the area of a habitat can be readily and accurately identified using air photographs. As a positive linear relationship has been identified between the area of woodland and breeding bird species numbers in British woodlands (Moore and Hooper, 1975; Woolhouse, 1983 and Usher et al., 1985) and in urban woods (Luniak, 1983) it was decided that this would be the most logical variable to investigate.

The area analysis has been divided into two parts. Firstly its apparent influence on the total bird community is considered. Secondly the analysis attempts to determine whether the area of a habitat has an affect on the breeding of individual species. The major questions to be answered are:

i) Is there any relationship between the area of a habitat and the size and diversity of the bird community?
ii) Does the area of habitat affect the likelihood of breeding of specific woodland bird species?

9.2 Saltwells Local Nature Reserve - The study area

Saltwells Local Nature Reserve was declared a Local Nature Reserve in September 1981. This reserve is approximately 40 hectares and is the main focal point of the Blackbrook Valley Project. It is composed of a large area of mixed broadleaved woodland, which was planted at the end of the eighteenth century, and of Doulton's clay pit. This is an abandoned fireclay pit where the vegetation has been allowed to re-establish naturally. This section is important geologically as well as ecologically. By primarily considering the floristic composition of the ground vegetation (rather than the canopy composition and structure) Shimwell (1982) defined four major types of woodland to be found in the reserve.

i) Species-poor oak, oak-birch woodland and scrub on dry, well drained, acidic brown earths and disturbed ground. The most common woodland community in this category is dominated by mature Common Oak *Quercus robur*. Its relatively open canopy allows Creeping Soft Grass *Holcus mollis* and Bracken *Pteridium aquilinum* to dominate the field layer. In the younger stands to the east of the claypit the closed tree canopy is dominated by two species; Common Oak *Quercus robur* and Silver Birch *Betula pendula*.

ii) Mature, mixed broadleaved plantation woodland on disturbed ground. The main tree species in this group are Sycamore *Acer pseudoplatanus*, Common Beech *Fagus sylvatica*, Common Ash *Fraxinus excelsior*, and Common Oak *Quercus robur*. The greater shade caused by these species, especially Sycamore *Acer pseudoplatanus*, encourages roosting birds which in turn results in a shrub layer of fruit bearing plants such as Elder *Sambucus nigra*, Holly *Ilex aquifolium*, Blackberry *Rubus fruticosus*, and Rowan *Sorbus aucuparia*. The seeds of these shrubs have primarily been dispersed by the birds. The existence of a shrub layer and the greater degree of shade discourages development in the field layer.

iii) Species-rich mixed broadleaved woodland on moist neutral brown earth soils. The canopy is dominated by Common Oak *Quercus robur*, Common Beech *Fagus sylvatica*, and Sycamore *Acer pseudoplatanus*, underneath which is a dense shrub layer of Hazel *Corylus avellana* and Hawthorn *Crataegus monogyna*. The field layer is composed of a greater variety of herbs than found in the previous two categories where the more acidic soil conditions have limited the field species present.

iv) Wood and shrubland on frequently flooded sites; Alder *Alnus glutinosa*, Sallow *Salix cinerea* and Silver Birch *Betula pendula* species tend to dominate the tree canopies on the wetter sites. These woodland patches are found close to the streams or at the base of the poorly drained clay pit.

Shimwell (1982) also identified gorse *Ulex*, grassland and swamp communities within the reserve. In terms of mature oak woodlands, Saltwells Local Nature Reserve is relatively young and although none of the vegetation types recognised may be considered rare on a national or regional scale, the existence of a mature oak woodland of this size is rare on a local scale. Within a radius of 3 kilometres of Saltwells Local Nature Reserve there is only a further 9.58 hectares of woodland recorded by the Ordnance Survey. The vegetation of the wood is diverse and thus the site has great potential as an ecological reserve (Shimwell, 1982). More importantly to bird species, the canopy structure of the wood is varied, for example Doulton's clay pit, thus providing a greater number of niches for bird species.

The botanical classification devised by Shimwell (1982) provides a satisfactory insight into the vegetation communities of the reserve. Generally however for bird studies, botanical species information is not as important as structural details of the vegetation (Fuller, 1982). This view is not held by Rotenberry (1985). He believed that while birds may differentiate between gross habitat types on the basis of physiognomy, their classification within these habitats is dictated by plant composition. He felt studies concentrating on only the structure of vegetation had often missed vital linkages. His conclusions however were a result of a study conducted in grassland habitats. It is the author's opinion that, if possible, both structure and species compostion should be considered. With an aerial photographic data source however, it is easier to extract information about the tree canopy structure and therefore in light of Fuller's conclusions (1982), consideration of woodland structure rather than species concentration was believed to be acceptable.

9.3. The field data

Field data for the area exists for 1 year; 1983. The Nature Conservancy Council commissioned a census of the bird species found in Saltwells Local Nature Reserve. Harrison and Normand (1984) surveyed the area of closed woodland and the clay pit but excluded Saltwells meadow to the north of the reserve. Two different surveys were conducted. First a simplified common bird census was conducted based on the B.T.O. Common Bird Census. Ten visits were made to the reserve during the breeding season of 1983. The location of nest sites and the position of all singing birds, as well as birds seen carrying food or feeding young, were plotted on a map of the area. This method determined the exact number and position of species territories but not their full extent. Secondly, a habitat survey was carried out to identify the types of habitats present in the wood and thus determine which species are expected to be present in the reserve.

The results of the common bird census can be seen in Table 9.1. Twenty-four species were identified as definitely breeding and three others; the Great Spotted Woodpecker *Denrocopos major*, the Jay *Garrulus glandarius* and the Redpoll *Carduelis flammea* were recorded as probably nesting. For the following analysis it was decided that these three species would be regarded as breeding, making the total up to 27 breeding species. Species abundance, that is the number of breeding pairs, was counted as 134. This figure does not take into account the numbers of the three additional species, therefore the actual abundance is greater. If these three species are assumed to have one breeding pair each the species abundance figure totals 137. As well as providing information about the species present and their abundance, the field survey data also records in what layer the species were found nesting and the location of the nests within the reserve (see Figure 9.1).

This information allows a comparison to be made between the habitat structure identified in the field survey and the vegetation structure mapped from the air photos. This will produce some indication of the similarity of habitat definition and therefore the accuracy of the two studies. Although Harrison and Normand (1984) identified the layer where the bird's nests were found, they did not specify whether this was the highest vegetation strata at that particular location. For example, a bird's nest which was located in the field layer may be below a shrub and tree layer. For the investigation this situation is assumed to occur. It was also presumed that all tree canopies identified on air photographs were covering a shrub and field layer suitable for nesting birds. The comparison illustrated in Figure 9.1 can only be regarded as an indication of the similarity of the habitat's structure recorded by the field study and by the photographic survey. This is due to the small scale of the field study maps resulting in an approximate location of the nests sites rather than an accurate siting. As the compared maps were of different scales, they were superimposed using the zoom transferscope.

Of the 47 birds identified as breeding in the field layer by Harrison and Normand (1984), 46 of these nest sites were found in the field layer of the air photographic map. Only two of the nests recorded by the field survey to be in the shrub layer were misplaced on the photographic habitat map. This suggests that the field and shrub layers have been mapped accurately on both maps. One would expect a greater inaccuracy in the tree canopy nest locations. Of the 48 nests found in the tree canopy in the field data, 14 of these were inaccurately located on the habitat map, that is these nests were not sited in a woodland habitat classification category. However 12 of these misplaced nests were found in the dense broadleaved scrub category, (43). These inaccuracies may be a result of a number of factors.

Table 9.1 Summary of the Birds recorded breeding in Saltwells Local Nature Reserve 1983

Species	Number of breeding pairs			Main habitat			Casual sightings
	C	P	T	G	S	T	
Stockdove *Columba oenas*1	1		1			√	
Woodpigeon *Columba palumbus*		2	2		√		
Great Spotted *Dendrocopus major* Woodpecker *	-	-	-	-	-	-	11
Wren *Troglodytes troglodytes*	3	9	12	√			
Dunnock *Prunella modularis*	1	4	5		√		
Robin *Erithacus rubecula*	4	11	15	√			
Blackbird *Turdus merula*	2	9	11		√		
Song Thrush *Turdus philomelos*	1	1	2		√		
Mistle Thrush *Turdus viscivorus*		3	3			√	
Whitethroat *Sylvia communis*	1		1		√		
Blackcap *Sylvia atricapilla*	5		5		√		
Wood Warbler *Phylloscopus sibilatrix*	6	7	3	√			
Chiffchaff *Phylloscopus collybita*	4		4	√			
Willow Warbler *Phylloscopus trochilus*	1	2	13	√			
Spotted Flycatcher *Muscicapa striata*	1		1			√	
Blue Tit *Parus caeruleus*	4	9	13			√	
Great Tit *Parus major*	5	3	8			√	
Nuthatch *Sitta europaea*	2		2			√	
Tree Creeper *Certhia familiaris*	1		1			√	
Jay * *Garrulus glandarius*	-	-	-	-	-	-	6
Magpie *Pica pica*	1		1		√		
Starling *Sturnus vulgaris*	19		19			√	
Chaffinch *Fringilla coelebs*	2	2	4		√		
Greenfinch *Carduelis chloris*		2	2		√		
Linnet *Carduelis cannabina*	1		1	√			
Redpoll * *Carduelis flammea*	-	-	-	-	-	-	4
Bullfinch *Pyrrhula pyrrhula*	2	3	5		√		
Total	65	69	134				21

* = Species regularly sighted so almost certainly breeding.

C = confirmed breeding pairs; P = probable breeding pairs; Total = total number

T=Tree layer; S = Shrub layer; G = ground or field layer.

Adapted from Harrison and Normand, (1984)

The location of nest sites identifie
by Harrison and Normand, 1984.

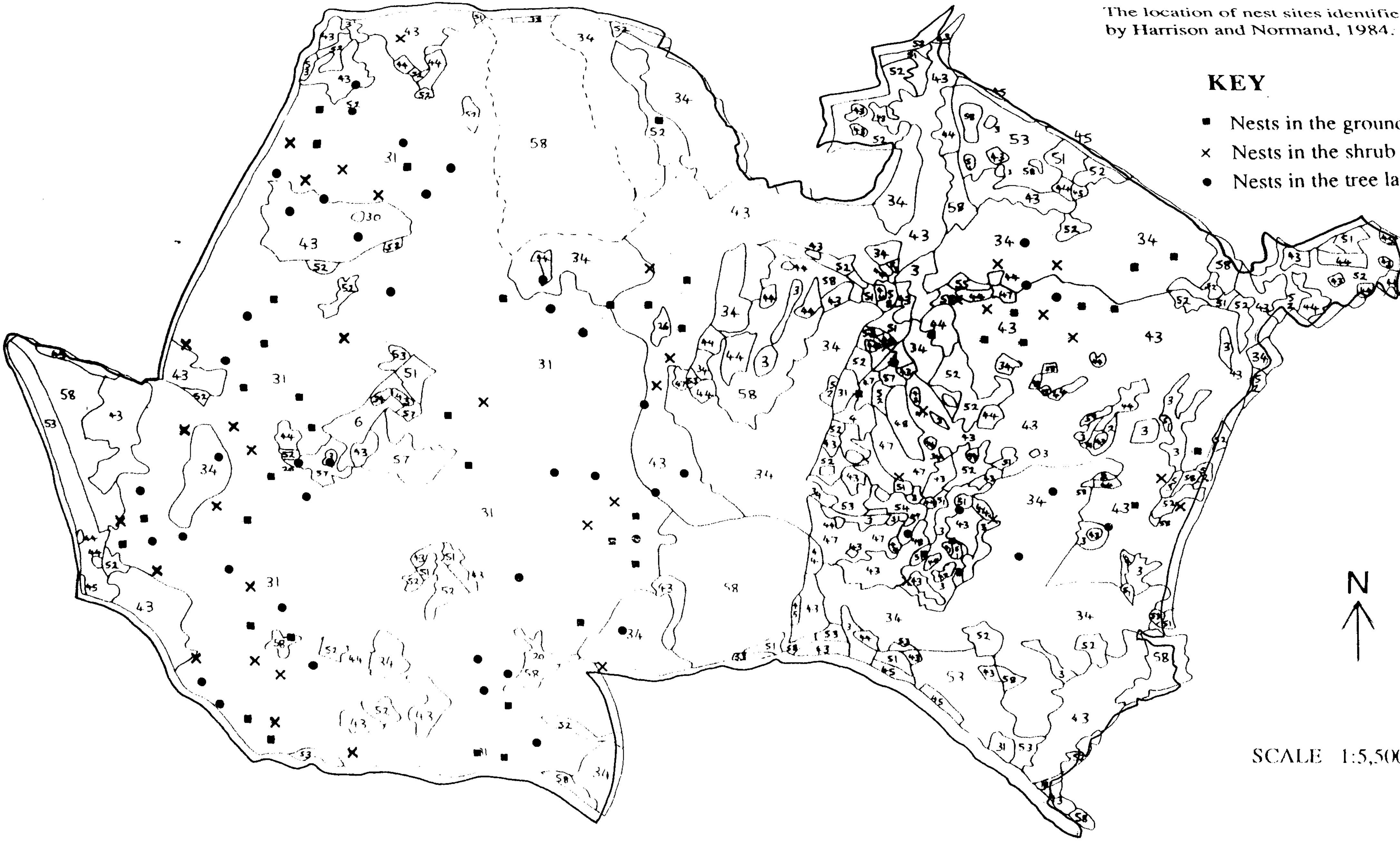


Figure 9.1 Nest Sites and Habitat Categories in Saltwells Local Nature Reserve, 1984.

i) The woodland and shrubland categories identified in both studies may differ slightly.

ii) The nests may be in isolated trees within a shrub community and such trees may not have been identified on the air photographs.

iii) Very often the broadleaved closed shrubland category (43) is very near to broadleaved closed woodland (31) and broadleaved tree/shrub (34) categories. This apparent discrepancy in nest location could therefore be due to inaccurate nest or habitat boundary location in both studies.

Overall however, the habitats mapped by the air photographic survey correspond very well to the habitats identified by the field survey.

Harrison and Normand (1984) investigated how the population figures from an urban wood compared with figures from similar size rural woods censused by the B.T.O. 1982 Common Bird Census (C.B.C.) quoted by Marchant (1983) and from the B.T.O. Sites Register of bird data (1973-1977), (Fuller, 1982). Saltwells Local Nature Reserve has between 65-85 per cent of the number of breeding species recorded in these rural surveys. The C.B.C. has an average of 40 species in woods of a similar size. The Nature Reserve did contain four of the more rare woodland species, (that is, present in less than 50 per cent of the C.B.C. woodlands); the Sparrowhawk *Accipiter nisus*, Kestrel *Falco tinnunculus*, Stockdove *Columba oenas* and Wood Warbler *Phylloscopus sibilatix*. Although many common species are missing, the reserve provides suitable habitats for some of the more rare species. Three major reasons were suggested by Harrison and Normand (1984) for the paucity of the bird community:-

i) isolation

ii) habitat structure

iii) length of habitat edge

Saltwells Local Nature Reserve is an isolated patch of woodland within an urban environment. The area of the total reserve is approximately 40 hectares. Figures calculated by the author from Ordnance Survey maps indicate that within 5 kilometres of Saltwells Local Nature Reserve, there are 18 patches of broadleaved or mixed woodland with a total area of only 85.6 hectares. The average size of each patch is 4.76 hectares, with a standard deviation of ±6.1 hectares. Therefore a wooded patch of 40 hectares is quite exceptional in this area. The nearest large botanically comparable forest is the Wyre Forest which is a distance of 22.5 kilometres away. This and other woods found in the area, such as Sutton Park, Clent Hills and the Lickey Hills are possible species sources for Saltwells Local Nature Reserve. Harrison and Normand (1984) suggested that if isolation was having an effect on the bird species numbers in the wood, this would be more pronounced in the numbers of residential species than the numbers of summer visitors. They found, when comparing the data with figures from the C.B.C. census and the Sites Register that 75-80 per cent of the expected migrant species were recorded in the reserve and only 63-71 per cent of the expected residential species were present. This suggests that isolation does have an effect.

The structure of the habitat is also responsible for the numbers of species being below the average totals of similar sized woodlands. There are very few coniferous trees in Saltwells Local Nature Reserve therefore common species such as the Goldcrest *Regulus regulus* and Coal Tit *Parus ater* are absent. Species which tend to nest in the shrub layer are less well represented in Saltwells Local Nature Reserve than species which nest in the field or tree canopy layers. This is due to the lack of a well developed shrub layer in certain parts of the wood.

Harrison and Normand (1984) also suggested that the length of the woodland perimeter may also have an affect on bird abundance totals. They found that the majority of species nesting are near to the perimeter of the woodland. However as Saltwells Local Nature Reserve is a regular shape, its perimeter is shorter than many other woods of a similar area, therefore it has less woodland edge available to nesting birds. Nevertheless there are criticisms of the theory that a large ratio of perimeter length to area of reserve encourages more species to breed. Blouin and Conner (1985) stated that linear reserves, that is reserves with a long perimeter, are inferior to more circular reserves as dispersal rates within the reserve may be too low to prevent local extinctions occuring.

One very important reason for the paucity of bird species in Saltwells Local Nature Reserve not specifically mentioned by Harrison and Normand (1984) is the urban location of the Nature Reserve. It is usual for any habitat type in an urban area to have an impoverished species list in comparison with an rural area, (Goldstein et al., 1983 and Simms, 1975). As discussed in Chapter Six, this may be a result of the increased level of habitat patchiness and the likely decrease in habitat size found in an urban environment.

Thus the field survey data provides information about species richness, abundance and the geographical and structural nest locations. From Harrison and Normand's survey (1984), one would expect bird population predictions, based on area totals, to overestimate the actual number, as the bird community of this reserve is below the average for woods of a similar size in a rural environment.

9.4 The relationship between the total habitat area and the bird community

The main focus of this chapter is to discover whether the predictive area relationship (suggested in the literature) can be used to predict accurately the numbers of species found in an urban woodland. It is necessary to identify which habitat classification categories should be combined to produce the area totals used in this relationship, that is, it is important to detect which of the habitat classification categories best mirror the conditions of woodlands which were censused to provide the raw data for the predictive linear relationships.

The predictive models used in this analysis were suggested by Moore and Hooper (1975), Woolhouse (1983) and Luniak (1983). The first two were chosen as they were developed by analysing bird data in British broadleaved woodlands, the latter because although the field surveys were carried out in Poland, it is one of the few studies concerned with the number of birds in urban woodland environments.

As well as the models being developed in similar environments, that is British broadleaved woodlands and broadleaved urban woodlands, it is also important to check that the bird species recorded in the models and in Saltwells Local Nature Reserve are of the same basic population. This is especially important for the Polish study.

Moore and Hooper (1975) recorded information about 53 common woodland species. The breeding bird species recorded in Saltwells Local Nature Reserve are adequately covered by this species selection as only the Wood Warbler *Phylloscopus sibilatrix* is absent from Moore and Hooper's list.

Woolhouse (1983) based his model on the woodland bird species which are censused in the B.T.O. Common Bird Census. Sixty bird species were considered. Of the 27 breeding species found in Saltwells Local Nature Reserve, 25 of these were included in his field data. He did not include information on Starlings *Sturnus vulgaris* or Woodpigeons *Columba palumbus*. This model may thus be expected to under predict species richness and species abundance. This under prediction may however be compensated for by the fact the model, based on data collected in rural areas, should over predict the levels of species richness found in an urban situation. The author feels that the absence of Starlings *Sturnus vulgaris* and Woodpigeons *Columba palumbus* from Woolhouses's raw data will not have a significant affect on the calculated figures.

Luniak (1983) based his model on data from 91 species. Although he has censused urban woodlands, there may be an important difference between the background bird population found in Polish woods and those found in British woods. Twenty-five of the 27 species found breeding in Saltwells Local Nature Reserve were included in the Polish study. The two species which were missing were the Mistle Thrush *Turdus viscivorus*, and the Linnet *Carduelis cannabina* . This means that four breeding pairs from the two species would not be considered in the Luniak model. It is the number of species which are missing which is more important than the abundance levels, as the Luniak equation does not try to predict bird densities. In a comparison of the species list used by Luniak (1983) with the species recorded in woodland habitats by the B.T.O. Common Bird Census 1983-1984 (Marchant 1985), 36 of the 47 species listed by the C.B.C. are included in Luniak's list, that is 76 per cent. As some of this discrepancy will be due to the different species likely to occur in a rural and urban environment, for example one of the 47 species considered by the B.T.O. is a pheasant, a very unlikely occupant of an urban environment, the author believes the bird populations of Polish and British woodlands are sufficiently similar to allow the use of the Luniak model. The majourity of the species listed by Luniak (1983) which were not included in the British woodland species lists were either non-woodland species such as the Swallow *Hirundo rustica*, Skylark *Alauda arvensis*, House Sparrow *Passer domesticus*, the House Martin *Delichon urbica*, Mallard *Anas platyrhynchos* and the Moorhen *Gallinula chloropus* or were species which rarely breed in Britain, for example the Golden Oriole *Oriolus oriolus* and the Icterine Warbler *Hippolais icterina*.

The relationships suggested by Moore and Hooper (1975) and Woolhouse (1983) are represented by equations. Luniak (1983) has recorded the relationship between species richness and area in a graph form.

The species richness-area models are:
Moore and Hooper (1975)

Eq i) $\log_{10} S = 0.271 \log_{10} A + -0.26$ (R = 0.84)

Woolhouse (1983)

Eq ii) $\ln S = 0.227 \ln A + 2.632$ (F = 109.6)

Eq iii) $\ln S = 0.347 \ln A + (1.538 + 0.347 \ln d)$ $d=10$

Luniak (1983)
The relationship between area of woodland and species richness in Polish urban woodlands is illustrated in Figure 9.2.

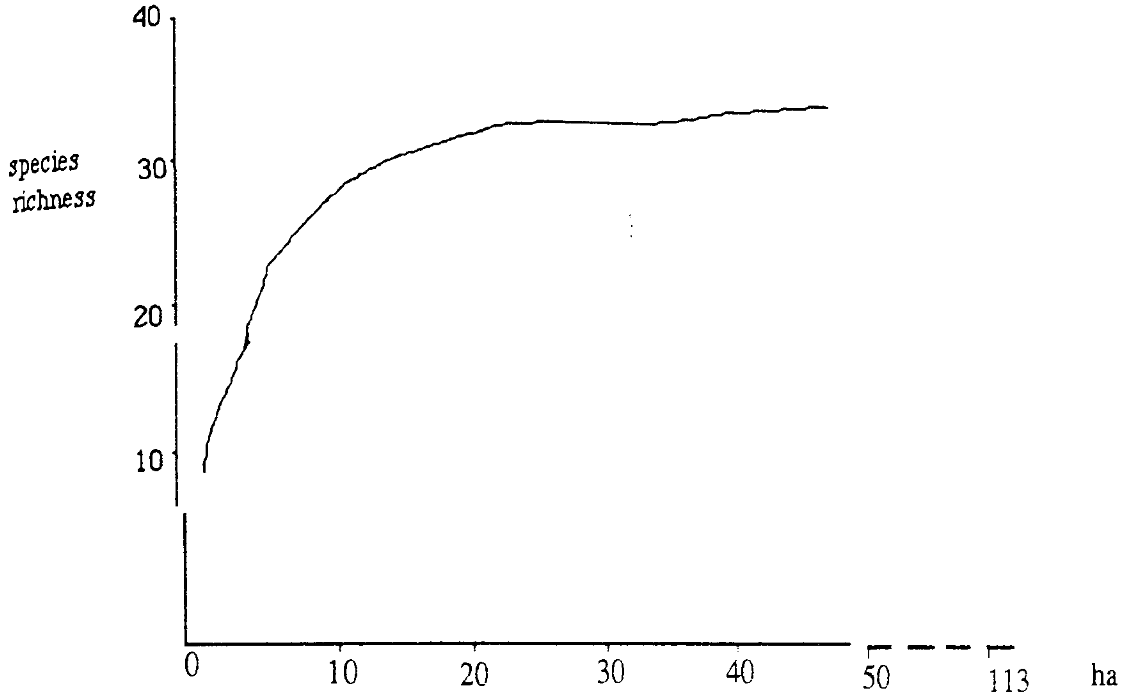


Figure 9.2 The species-area relationship in Polish urban woods. Adapted from Luniak (1983)

Analysis was carried out to discover which, if any, of these four models, using different combinations of classification categories could accurately predict the number of bird species which were found in Saltwells Local Nature Reserve.

It is evident from Table 9.2 that the model suggested by Moore and Hooper (1975) consistently underpredicts the numbers of expected species. The estimates are significantly below those resulting from equations ii, iii, and iv. It is therefore obvious that this equation cannot be used in species-area prediction studies. Although the slope of the line in the Moore and Hooper model, 0.27 is consistent with the slopes suggested by Woolhouse (1983) and is within the recommended range of 0.2-0.4 quoted by McCoy and Conner (1979), the problem occurs with the slope intercept of $^{-}0.26$. This is well below those quoted by other authors. Unfortunately Moore and Hooper (1975) do not provide any raw data in their paper to allow the model to be tested.

A non-parametric analysis of variance test conducted on the data from equations ii, iii, and iv indicated that at the 0.05 probability level, the species figures produced by the three equations ii, iii, and iv for all the habitat totals were not significantly different (see Appendix 4). The linear relationships suggested by Woolhouse (1983) and Luniak (1983) for the species-area relationship thus produce similar results even though they were developed in different environments in different countries.

Table 9.2 The relationship between woodland area and the number of bird species

Total area of habitat ha. in reserve 1984	Eq i	*	Eq ii	*	Eq iii	*	Graph iv	*
Area of reserve 41.2	1.5	-25.5	32.2	+5.2	37.34	+10.34	33	+6
Area of vegetation in reserve 40.2	1.5	-25.5	32.1	+5.1	37.55	+10.35	32.5	+5.5
Area of 31 14.4	1.13	-25.87	25.66	-1.34	26.16	-0.84	28	+1
Area of 34 7.0	0.93	-26.07	21.59	-5.4	20.39	-6.61	20	-7
Area of 31 + 34 21.4	1.26	-25.74	27.84	+0.84	30.05	+3.05	31	+4
Area of 43 8.93	0.99	-26.01	22.8	-4.2	22.19	-4.81	23	-4
Area of 44 0.85	0.53	-26.47	13.36	-13.64	9.82	-17.18	-	-
Area of 43 + 44 9.78	1.02	-25.98	23.33	-3.67	22.9	-4.1	24.5	-2.5
Area of 31 + 34 + 43 + 44 31.18	1.4	-25.6	30.35	+3.35	34.25	+7.25	32	+5
		Σ*-232.73		Σ*-13.76		Σ*-2.55		Σ*+8

* = the difference between the actual number of species, 27, and the predicted number

As expected the area of broadleaved closed woodland (31) or a combination of categories 31 and broadleaved tree/shrub (34) produce the most accurate estimates of the numbers of breeding bird species. These habitat categories will be the most common in the environments used in the field surveys. For example, Woolhouse (1983) described the woodlands in his study as having "at least 80 per cent tree cover, including 50 per cent closed canopy". When other habitat categories are included, the predicted figures are less accurate. The total area of the reserve overestimates the number of bird species likely to be found. This result is foreseeable as areas of shrubland and grassland are included in the total. Although these habitat types are still valuable to bird species, they are less complex so they provided suitable niches for fewer species. Luniak (1983), as well as identifying a relationship between the number of breeding bird species and area of urban woodland (see Figure 9.2), plotted species-area curves for allotments and open areas. Both these curves were below the level of the woodland curve. For example, in an area of 10 hectares of woodland, one would expect to find approximately 25 breeding bird species. In equivalent sized areas of allotments and open space, 15 and 7 bird species respectively are predicted to breed. The combination of all the woody habitat categories, that is trees and shrubs, overpredicts the number of species present as the value of shrubs to bird species is over estimated. It is important therefore that the models are only used with the woodland habitat categories. This restricts the models to classification categories 31, 32, 33, 34, 37, 38, 39, 40. Of these eight categories only closed broadleaved woodland (31) and broadleaved tree/shrub (34) are found in the Nature Reserve.

Models iii and iv suggest that the area of category 31 produces the most accurate predictions, whereas model ii estimates that the combined areas of 31 and 34 provide the most accurate results. Table 9.4 is a summary of the important categories listed in Table 9.3

Table 9.3 The relationship between woodland area and the number of bird species

	Eq ii	*	Eq iii	*	Eq iv	*
Area of 31 14.4	25.66	-1.34	26.16	-0.84	28	+1
Area of 31 + 34 21.4	27.84	+0.84	30.05	+3.05	31	+4

The combined area totals of categories 31 and 34 used with models iii and iv overpredict species numbers. The broadleaved tree/shrub habitat category (34) is a combination of trees and shrubs. This habitat category, by definition, forms a closed canopy when viewed from the air but in the field this habitat is in fact an open canopied mature woodland with a dense understory of shrub species.

It is unlikely that the broadleaved tree/shrub category accurately represents the closed canopy woodland used in the model development. The shrubs, by providing fewer niches than trees, are not as valuable to bird species. By including the area of 34 in the model equation, one is assuming that shrub species are as useful, therefore resulting in an overprediction of species numbers. Equation ii, proposed by Woolhouse (1983) indicates that the combined area totals of categories 31 and 34 provide the most accurate results. However in personal communication with Woolhouse he claimed equation iii should be used in preference to equation ii.

It can be inferred that the habitat category of broadleaved closed woodland (31) most closely resembles the woodland habitats used by Woolhouse (1983) and Luniak (1983) in the development of their statistically significant models.

It can be concluded that for this study there is a close correlation between the expected species numbers, prediced from the total area of broadleaved closed woodland in 1984 and the actual species numbers found in the reserve by Harrison and Normand (1984). As yet, these conclusions can only be tentatively accepted. Although the models produced by the above mentioned authors produce statistically significant results in the environments where they were developed, the apparent correlation between bird species richness and area which occurs in Saltwells Local Nature Reserve may have occurred by chance. The fact that all models produce similar results with the habitat data suggests that each individual model is proof of the accuracy of the others. However the results cannot be statistically tested as there is only one year of field data for this woodland area.

The results however can be compared to the map derived from the superimposition of nest location data collected in the field and the habitat category map (Figure 9.1). If, as the models predict, the number of breeding species in Saltwells Local Nature Reserve can be predicted from the area of broadleaved closed woodland, one would expect the 27 breeding species identified by Harrison and Normand (1984), to nest in this closed woodland category. From the map, 21 of the 27 breeding species are found to nest in this category. Of the six "missing" species, the Linnet *Carduelis cannabina* and the Whitethroat *Sylvia communis* are found to nest in coniferous/Ulex communities which are the preferred habitat types of these species. The nests of three of the six species; the Great Spotted Woodpecker *Dendrocopus major*, the Jay *Garrulus glandarius* and the Redpoll *Carduelis flammea* were not mapped and therefore could not be included as such. However records of the locations of the sightings of the first two species indicate they have been seen in the broadleaved closed woodland habitat. It therefore appears that the majority of the breeding species in Saltwells Local Nature Reserve nest in this closed broadleaved woodland habitat. Thus the field data backs the predictive models.

9.5 Predicting species richness using two variable models

The models investigated have been restricted to one predictive variable, that is area. In the literature review, studies have been identified which estimated the species richness of woodlands using additional variables.

Opdam et al. (1984) concluded that levels of species richness could be predicted by combining area and isolation variables. Usher et al. (1985) found that a combination of area and habitat heterogenity parameters gave the most accurate estimates of species richness. Both the author's models are unsuitable for Saltwells Local Nature Reserve. Although the model developed by Usher et al. (1985) was based on bird census data collected in Britain, it was restricted to bird reserves. Consequently the model inflates the likely species numbers in a woodland which is not managed as a ornithological reserve. The model developed by Opdam, in the Netherlands, was also unsuitable as it was based on a restricted number of bird species.

9.6 The prediction of species abundance from area data

Woolhouse (1983) also suggested a model to predict bird abundance from the area of a woodland habitat. The model was derived from the same field data as the species-area equation.

$$\ln I = 0.679 \ln A + 3.082$$

where I = number of territories.

If the area of broadleaved closed woodland is used, the model predicts a species abundance of 133.36. Harrison and Normand (1984) quoted species abundance to be 134 breeding bird pairs. These figures are very closely correlated. However a species abundance figure of 134 pairs fails to take into account the number of pairs of the Great Spotted Woodpecker *Dendrocopus major*, the Jay *Garrulus glandarius* and the Redpoll

Carduelis flammea, which for this study, have been regarded as breeding. If each species is assumed to have one breeding pair the species abundance total becomes 137. This figure suggests that, in this instance, the Woolhouse estimate has underpredicted by 4 pairs. However as mentioned earlier the Woolhouse estimate was expected to be low as he did not include information about Starlings *Sturnus vulgaris* or Woodpigeons *Columba palumbus* in his field data. Both species have been identified as breeding in Saltwells Local Nature Reserve and account for 21 pairs (2 breeding pairs of Woodpigeons *Columba palumbus* and 19 pairs of Starlings *Sturnus vulgaris* were recorded in the field census). The estimate produced by the Woolhouse model is therefore not as low as might be expected especially when one remembers that bird abundances in urban areas are usually greater than in rural areas where the data for the model was collected (Nuorteva, 1971).

These figures suggest that when the area of broadleaved closed woodland in 1984 is considered, there is a very good correlation between the number of species territories (estimated using the Woolhouse model, 1983) and the actual species abundances recorded by Harrison and Normand (1984). Again however the correlation cannot be statistically proven.

A check can however be made with the field data. If the area of broadleaved closed woodland can predict the numbers of bird territories, one would expect those bird territories to be located in the area of closed woodland mapped from the air photographs. The comparison of the nesting locations (described in the field data) and the habitat classification map (described earlier in section 9.3) identified 76 bird nests in the broadleaved closed woodland habitat. This figure does not take into account the 15 casual sightings of the Jay *Garrulus glandarius*, the Great Spotted Woodpecker *Dendrocopus major* and the Redpoll *Carduelis flammea* as the nesting locations of these species have not been as accurately pinpointed. The number of bird territories actually in the broadleaved closed woodland category therefore is well below the predicted figure of 133.36 yet the actual number of bird territories within the whole reserve is very close to 133.36. The question remaining unanswered is whether the area of broadleaved closed woodland can be used to predict the level of species abundance of the whole reserve where other habitat types are also influential.

As far as predictions about the bird community are concerned, if the models relating species richness and abundance to woodland habitat area are accepted as being able to provide statistically significant estimates, the habitat information extractable from aerial photographs can be used for these predictions.

9.7 The relationship between the area of a habitat and the breeding of individual bird species

The previous analysis has suggested that a relationship exists between the area of a woodland and species richness. This relationship, described by a number of models, considers the bird community as a single unit. The next logical stage of the analysis is to investigate whether air photographs can be used to identify a relationship between the area of a habitat and the likelihood of a particular species breeding. Habitat area data for individual species is to be considered rather than information for the whole community. The field data identified 27 breeding species in Saltwells Local Nature Reserve but a greater number of species are known to breed in similar woodland environments, for example, Woolhouse (1983) based his study on 60 bird species. The intention is to try to assess whether the amount of suitable habitat available to a bird in a region (information extracted from the air photographs), influences its breeding success.

In order to do this, it is necessary to determine whether the habitat requirements of woodland birds can be described in terms of the habitat classification categories. This will involve using all the habitat types identified in the reserve rather than being restricted to the wooded communities as in the previous analysis.

9.7.1 Identification of woodland bird species

Lack and Venables (1939) tried to define a woodland bird. They claimed the term is artificial, as different bird species have diverse requirements which are satisfied to various degrees within a woodland habitat. When defining woodland bird species there are two options. Firstly, one can include only those species which rely totally and exclusively on the woodland habitat for their survival. For example, Opdam et al. (1985) based their research on 'pure' wooodland species even to the extent that they chose species that relied entirely on the tree layer and would not be affected by variability in the shrub or herb layer. Alternatively and more realistically, woodland birds can be defined as species which are likely to reside in a woodland habitat as it fulfils some, although not necessarily all, of their feeding, breeding and roosting requirements. However a definition based on this criteria becomes very arbitrary. Lack and Venables (1939) discussed the problems of woodland edge birds, for example the Tree sparrow *Passer montanus* and the Woodcock *Scolopax rusticola*. They concluded that they should not be regarded as woodland birds as although they use wooded habitats, they tend to nest in more open country. Shrubland species are also problematic. Such species, for example the Wren *Troglodytes troglodytes* and the Willow Warbler *Phylloscopus trochilus* do not need trees for their survival but as the majority of shrubland occurs within woodlands, these species can be found in such an environment, as well as other favourable habitats such as hedgerows and gardens. The best definition of a woodland species therefore appears to be based on the frequency of occurrence of a bird species within a woodland environment. Yapp (1962) identified 19 species which he found the most common in pedunculate oak *Quercus robur* woodlands in the summer months. He found his species list corresponded very well with lists produced by Lack and Venables (1939). Of these 19 species, 15 were found to breed in Saltwells Local Nature Reserve.

For this analysis it was decided that a woodland bird species would be a species which has a high probability of being recorded as breeding in a woodland habitat, independent of whether all its needs are satisfied by that habitat. To draw up a list of bird species which could possibly breed in Saltwells Local Nature Reserve, three data sources were consulted. To identify the most common bird species in woodland habitats of a similar size, the British Trust of Ornithology's Common Bird Census and Sites Register were considered. The average size woodland plot surveyed in the Common Bird Census between 1981 and 1984, was approximately 20 hectares. The Sites Register data was collected in plots between 20 and 40 hectares. A problem with these data sources is a southern bias. This is especially apparent with the C.B.C. where most of the plots censused are in the south or south-east of England. As not to include birds in the analysis which are unlikely to breed in the West Midlands, Sharrock's Atlas of Breeding Birds (1976) was consulted. Only bird species which were found nesting within the West Midlands conurbation (12, 10km squares) were included.

Thus 59 bird species were identified as probable breeding species in a woodland in the West Midlands. Whether they breed depends on whether their requirements are satisfied by the particular habitat. The next stage is therefore to relate their breeding and feeding requirements to the habitat classification categories identified. For this, it is necessary to assume that the major needs of the bird species are provided by the classification category types identified.

9.7.2 Methods of describing bird habitat use

In the literature a number of methods have been used to allocate bird communities or individual species to specific habitat types. If a relationship is identified between a particular habitat and bird community or species, management policies can be readily devised. James (1971) suggested that each species has a niche-gestalt, that is an ecological niche defined by a characteristic vegetation structure. This is based on this concept that each species has a characteristic perceptive world. It will perceive a certain vegetation community as capable of fulfilling its nesting and feeding needs. However the identification of such niches is not a straightforward process. Karr (1980) claimed it was unlikely that the human and bird perceptions of a same habitat were similar. Nevertheless this problem may be overcome. The identification of bird habitats from air photographs is a human perception however there may be a link between the human and bird overview of the habitats which will allow species to be allocated to certain habitat types.

Fifty-nine common woodland bird species have been identified as probable breeders in the West Midlands. It is necessary to identify how many of these species are likely to breed in Saltwells Local Nature Reserve. A bird species is likely to breed if a suitable habitat is available. It is therefore important to establish whether the habitat classification categories adequately represent the breeding habitats of these species and if so how much suitable habitat is available to the species. As discussed earlier, the presence of a particular species in a particular habitat is dependent on a number of conditions, the primary influences being the provision of adequate breeding and feeding facilities.

The guild concept suggested by Root (1967) and discussed by Verner (1984) is based on these criteria. Here individual bird species are combined into groups based on similarities in feeding and breeding requirements. The aim is to make the planning of reserve management more convenient. The concept stated that a group of species which rely on similar habitat characteristics are likely to be affected in the same way by changes to that habitat.

Suitable habitat types were identified for the 59 probable breeding species. The habitat types which satisfied the summer breeding and feeding requirements of the species were identified. Often however species need different nesting and feeding sites, for example, some species nest in trees yet feed in grassland. This is especially common with species that live in the woodland edge such as the Carrion Crow *Corvus corone*. This was taken into account by listing the two conditional habitat types necessary. The allocation of breeding habitats to bird species was not restricted to their optimum habitat types but included the habitats where breeding was possible. O'Connor (1981) stated that if population numbers are high, bird species often have to breed in sub-optimum habitats. As the availability of suitable habitats for woodland bird species is limited in an urban environment, this may also result in such species breeding in less favourable conditions. As a result a number of different habitat types were regarded as possible breeding habitats for the bird species in question. This multiplicity of habitat types is plausible as common woodland birds are not restricted to unique habitat types.

The decision about the possible breeding habitats of the bird species was based on the habitat information quoted in the Handbook of Breeding Birds (Witherby et al.,1965). Habitat types which were known not to exist in the area, for example heathland and coniferous woodlands, were not included in the listings. This restriction reduces the amount of data to be processed and is believed to be acceptable due to the detailed knowledge of the area. If the technique was to be carried out in areas where information about the habitat types present was not as complete, all the suitable breeding habitat types would have to be included.

To simplify the habitat category allocation, a number of assumptions were made.

i) Only the summer breeding and feeding requirements of the birds were considered as the aerial survey was completed in this season. This solves the problem of resident bird species feeding in different habitats during the summer and winter months. For example, the Chaffinch *Fringilla coelebs* feeds in woods and thickets in the breeding season and grassland and stubble areas later in the year.

ii) As the urban habitat classification is based on habitat structure, it records information about the top vegetation layer. Different species will nest and feed in the different structural layers of a woodland habitat. Species which nest in tall trees will not be found in a shrubland habitat however species which nest in shrubs or in the field layer may still be found below a tree canopy if the structural layers below are suitable. It is therefore necessary for species which nest and feed on the ground, for example the Woodcock *Scolopax rusticola* or in the shrub layer such as the Wren *Troglodytes troglodytes*, to list areas with more complicated structures than actually required as suitable habitats, for example closed broadleaved woodlands.

iii) If the habitat of a bird species was described as mixed woodland (by Witherby et al.,1965) it was assumed to be able to breed in a purely broadleaved woodland too.

iv) Witherby et al. (1965) stated some species need a dense shrub layer for nesting. For such species, the shrubland habitat categories were listed as well as the open woodland category. Even though these species may not need trees for nesting or feeding, they can live successfully beneath a tree canopy if a suitable shrub canopy is available. Harrison and Normand (1984) claimed that the shrub layer in Saltwells Local Nature Reserve was below par. This is a result of a number of conditions, including the dense tree canopy found in the western side of the reserve. It was assumed therefore that a dense shrub layer would only be found below an open woodland canopy and not below a closed canopy.

One problem of making bird habitat preference decisions based on information recorded by other researchers, is the confusion which may arise due to the lack of definition of some of the descriptive vegetation terms, for example thicket. The perception of what constitutes a thicket may vary with different researchers. It was therefore important to try to ensure that the terms used by Witherby et al. (1965) to describe species habitats were translated, as accurately and as consistently as possible, to the categories used in the habitat classification. In all instances, the vegetation was assumed to be broadleaved unless specifically stated to be coniferous. The open and closed woodland conditions they described were considered directly comparable to the classification categories similarily labelled. Copses were regarded as being either open or closed woodland or tree/shrub. Witherby's thickets and shrubberies were classified as open or closed shrubland and hedgerows were regarded as being composed of either shrubs or trees. One term which was frequently used by Witherby et al. (1965) and which could not be directly related to the classification was 'parkland'. The description of a vegetation community as parkland is common and it is therefore a fault of the classification that this habitat could not be adequately represented. No parkland habitat exists in the Blackbrook Valley but it is a common and useful habitat type and should in future be included in the classification. For this study, bird species breeding in parkland habitats were listed as needing trees and grassland habitats. However this description is unsatisfactory, as it provides no indication of the spatial distribution of the trees and grassland.

Table 9.4 contains the list of suitable habitats and the total area of these habitat types in Saltwells Local Nature Reserve for 56 common bird species. Suitable habitat types which are listed in the classification but which are absent from the study area of Saltwells Local Nature Reserve, for example broadleaved open woodland, are not included in the list. For this table, it was decided to exclude information on the Starling *Sturnus vulgaris* as it is now an ubiquitous species and breeds in many habitat types having a "catholic choice of haunts" (Witherby et al., 1965). It is assumed to certainly breed in Saltwells Local Nature Reserve.

Out of the 59 species considered likely to breed in the West Midlands, 56 are included in this table, but as mentioned previously Starlings *Sturnus vulgaris* have been excluded. Carrion Crows *Corvus corone* and Goldcrests *Regulus regulus* are not included as no suitable habitat exists for these species in Saltwells Local Nature Reserve.

An explanation of habitat listings quoted in Table 9.4

31/34 = suitable habitat types are closed broadleaved wood or broadleaved tree/shrub.

31 + 52 = suitable habitat types are closed broadleaved wood and tall herb and fern grassland.

31/34 + 51/52 = suitable habitat types are closed broadleaved wood or broadleaved tree/shrub and ruderal or tall herb grassland.

31(30 + 52/53) = suitable habitat types are closed broadleaved woodland or parkland (single broadleaved trees and tall herb and fern or tall rough grassland).

Table 9.4 The suitable habitat types and area for common woodland bird species in Saltwells Local Nature Reserve.

Species	Habitat classification categories	Total area of suitable habitats (ha.)
Collared Dove *Streptopelia decaocto*	31/34/43/44/45 + 52/53/58	38.61
Blue Tit *Parus caeruleus* Chaffinch *Fringilla coelebs* Great Tit *Parus major* Robin *Erithacus rubecula* Sung Thrush *Turdus philomelos* Wren *Troglodytes troglodytes*	31/34/43/44/45	31.39
Mistle Thrush *Turdus viscivorus* Tree Creeper *Certhnis familiaris*	31/34/(30 + 52/53/58)	28.66
Woodpigeon *Columba palumbus*	30/31/34 + 52/53/58	28.66
Turtle Dove *Streptopelia turtur*	34/43/44/45 + 52/53/58	24.18
Nuthatch *Sitta europaea*	31(30 + 52/53/58)	21.66
Sparrow Hawk *Accipiter nisus*	31 + 52/53/58	21.65
Kestrel *Falco tinnunculus* Tree Sparrow *Passer montanus*	30/31/34	21.44
Hawfinch *Coccothraustes coccothraustes* Tawny Owl *Strix aluco* Coal Tit *Parus ater* Great Spotted Woodpecker *Dendrocopus major*	31/34	21.43
Linnet *Carduelis cannabina*	47/48/43/44/45 + 51/52/53/58	18.38

Longtailed Tit *Aegithalos caudatus*	34/43/44/45/47/48	17.65
Whitethroat *Sylvia communis*		
Willow Tit *Parus montanus*	34/43/44/45 + water	16.96
Blackbird *Turdus merula* Redpoll *Carduelis flammea*	34/43/44/45	16.96
Greenfinch *Carduelis chloris*	34/43/44	16.78
Bullfinch *Pyrrhula pyrrhula* Jay *Garrulus glandarius* Lesser Whitethroat *Sylvia curruca* Nightingale *Lusinia megarhynchos*	34/43/45	16.12
Cuckoo *Cuculus canorus*	34/43	15.93
Pheasant *Phasianus colchicus*	34/30/45 + 52/53/54/58	14.5
Wood Warbler *Phylloscopus sibilatrix*	31	14.43
Redstart *Phoenicurus phoenicurus*	34(30 + 52/53/58)	14.22
Magpie *Pica pica* Tree Pipet *Anthus trivialis*	30/34 + 52/53/58	14.22
Woodcock *Scolopax rusticola*	43/44 + 52 + water	11.75
Sedge Warbler *Acrocephalus schoenobaenus*	54/43/44/45	10.05
Dunnock *Prunella modularis*	43/44/45	9.96
Grasshopper Warbler *Locostella naevia*	44 + 52/53/58	8.06

Little Owl *Athene noctua*	30/45 + 52/53/58	7.41
Yellow Hammer *Emberiza citrinella*		
Goldfinch *Carduelis carduelis*	30 + 52/53/58	7.22
Green Woodpecker *Picus viridis*		
Jackdaw *Corvus monedula*		
Lesser Spotted Woodpecker *Dendrocopus minor*		
Spotted Flycatcher *Muscicapa striata*		
Stockdove *Columba oenas*		
Marsh Tit *Parus palustris*	34/45	7.19
Blackcap *Sylvia atricapilla*	34	7.00
Chiffchaff *Phylloscopus collybita*		
Garden Warbler *Sylvia borin*		
Meadow Pipet *Anthus pratensis*	51/53/58	5.76
Yellow Wagtail *Motacilla flava*	53/54/58	5.34
Nightjar *Caprimulgus europaeus*	44/48/52	2.92
Willow Warbler *Phylloscopus trochilus*	44/45	1.03

The breeding requirements of the 56 species are represented by 32 habitat patterns. This repetition of habitat patterns would be expected when describing the breeding needs of common woodland species as they often occur together and the habitat classification is based on structure only. It is difficult of check the accuracy of these habitat allocations.

Yapp (1962) suggested that summer pedunculate oak *Quercus robur* woodlands are dominated by seven species: Robin *Erithacus rubecula*, Chaffinch *Fringilla coelebs*, Blue Tit *Parus caeruleus*, Great Tit *Parus major*, Willow Warbler *Phylloscopus trochilus*, Wren *Troglodytes troglodytes* and Blackbird *Turdus merula*.. He claimed competition for resources between these species was rare with the occasional exception of the Blue and Great Tits.

The habitat allocations quoted for these species are however very similar.

Robin *Erithacus rubecula*	31/34/43/44/45
Chaffinch *Fringilla coelebs*	
Blue Tit *Parus caeruleus*	
Great Tit *Parus major*	
Willow Warbler *Phylloscopus trochilus*	44/45
Wren *Troglodytes troglodytes*	31/34/43/44/45
Blackbird *Turdus merula*	34/43/44/45

As these are common woodland species, it is the author's belief that their optimal habitats will be similar. This does not necessarily indicate that these species are competing with each other. For example, the Wren *Troglodytes troglodytes* is primarily a shrubland bird yet closed broadleaved woodland (31) has been quoted as being a suitable habitat type. This is because a Wren *Troglodytes troglodytes* will nest in shrubland whether shrubs are the upper strata of the habitat or whether they are found below a tree canopy. The listing of 31 as a suitable habitat type does not necessarily mean that a Wren *Troglodytes troglodytes* needs a tall tree but that it uses the layers which can occur beneath a tree canopy. Although the habitat types listed for the above species are alike, this does not indicate that each species is using the same part of that habitat and thus these patterns are not contradictory to Yapp's opinion (1962).

However the fact that these patterns resemble each other suggests that there is room for the habitat pattern allocation to be more detailed, providing information about the structural level where breeding takes place.

It was felt that on the whole, the habitat conditions described for each species by Witherby et al. (1965) were easily transferable to the habitat classification categories developed, the one exception being the parkland habitat.

Thus according to these habitat patterns, areas of suitable habitat exist in Saltwells Local Nature Reserve for 57 species (including Starlings, *Sturnus vulgaris*) and yet the field data indicates that only 27 bird species breed in the wood.

9.7.3 Investigation of the habitat species patterns and the species-area relationship

Before analysing whether the amount of suitable habitat available to each species has an effect on whether it breeds in an area, it is relevant to refer back to the species-area analysis. To recap, when the models of Woolhouse (1983) and Luniak (1983) are used with the area totals of closed broadleaved woodland in Saltwells Local Nature Reserve they accurately predict the numbers of species breeding in the Saltwells Local Nature Reserve. As mentioned previously, due to the restriction of only one year of field data, these results could not be statistically tested. However the identification of habitat patterns allows a backup test to be conducted.

If the relationship between the total habitat area of closed broadleaved woodland (31) and the total number of breeding species was real, one would expect all the species which do breed to have category 31 as one of their suitable habitat types. Of the 27 breeding species only 13 species have closed broadleaved woodland listed as one of their suitable habitat types. Two conflicting conclusions can be drawn. The apparent relationship between the actual number of breeding birds and the numbers extracted by the Woolhouse and Luniak models is purely a chance occurrence or the relationship is real but the habitat patterns allocated to each bird species are inaccurate. The species which do breed in the area but have been allocated habitat patterns minus habitat category 31 are: Linnet *Carduelis cannabina*, Whitethroat *Sylvia communis*, Blackbird *Turdus merula*, Redpoll *Carduelis flammea*, Greenfinch *Carduelis chloris*, Bullfinch *Pyrrhula pyrrhula*, Jay *Garrulus glandarius*, Magpie *Pica pica*, Dunnock *Prunella modularis*, Spotted Flycatcher *Muscicapa striata*, Stockdove *Columba oenas*, Blackcap *Sylvia atricapilla*, Chiffchaff *Fringilla coelebs* and the Willow Warbler *Phylloscopus trochilus*. The first two species are definitely species of broadleaved shrubland environments and therefore the absence of habitat category 31 is understandable. The Stockdove *Columba oenas* and Spotted Flycatcher *Muscicapa striata* are both regarded as parkland species and as such category 31 should not be included in their habitat patterns. However the rest of the species have all been recorded in mature broadleaved woodlands but they have been recorded as requiring a dense shrub layer.

One of the assumptions behind the habitat allocations to bird species was that dense shrubland would only be found beneath open broadleaved mature woodland and not closed broadleaved mature woodland. If this assumption was not made all these bird species except the four mentioned above would have had category 31 included in their habitat patterns. This would result in 23 of the 27 known breeding species to have category 31 listed as a suitable habitat type. Although the relationship between the numbers of breeding species and the area of closed broadleaved woodland cannot be statistically accepted, it is evident that if the above mentioned assumption had not been made the predicted and field data figures would have been found to be more in agreement. It may be that the assumption and therefore the habitat patterns are incorrect rather than the species-area models.

9.7.4 Analysis of the habitat area data for individual bird species

As explained in section 9.7 this analysis is an expansion of the idea of the species-area relationship. Instead of considering the bird community as a whole, the intention is to investigate whether the area of habitat available, identified on the air photographs, has an influential effect on the breeding of individual species.

Are the bird species with the greatest amounts of suitable habitat available more likely to breed? Statistical tests were carried out on different habitat totals. A non-parametric test, the Mann-Whitney U Test was carried out to investigate whether the available habitat totals for the breeding and non-breeding species were from the same populations or whether there was a significant difference between the means of the two samples, thus indicating that they are from different populations.

The null hypothesis H_0 was the total area of suitable habitat for breeding and non-breeding birds forms part of the same distribution and the differences between them are the result of chance variations and therefore are not significant.

The alternative hypothesis H_i was the amount of suitable habitat area available to breeding birds was significantly higher. The test was directional, therefore one tailed. The rejection level was set at α=0.05. (see Appendix 5 for statistical calculations).

The calculated value of z was 2.13 therefore at the 0.05 rejection level, for a one tailed test, the null hypothesis can be rejected. This test indicates that species with the largest area of suitable habitat available are more likely to breed in Saltwells Local Nature Reserve. However this test does not identify the magnitude of the difference between the two populations nor does it provide any indication of a critical area value above which bird species are likely to breed. This analysis does not suggest a critical parameter size which could be used for predictions of the likelihood of bird species breeding in a particular habitat.

The previous analysis considered the total area of suitable habitat available to breeding and non-breeding birds. More detailed relationships however need to be identified if predictions based on habitat area are to be possible. As evident from Table 9.4 some of the habitat requirements of the bird species are complex. A number of species require both woodland and grassland habitats. In the previous test the total habitat area for each species was analysed. However the result of this is for the species requiring woodland and grassland habitats the total area of suitable vegetation was overestimated.

A similar test was conducted using the same hypotheses and the same rejection level. However the area totals for the complex habitats, for example 31/34 + 52/53/54, were halved. The calculated z value was 0.016 which again indicated that the null hypothesis should be rejected. This reemphasised the theory that bird species with the greater amount of habitat available are far more likely to breed (see Appendix 6 for statistical test).

The next stage was to analyse whether the species with more complex habitat requirements are less likely to breed than those with simple requirements. A complex habitat is regarded as a habitat composed of two structural layers such as woodland and grassland, for example 31/34 + 52/53/54. It was discovered that 31 per cent of the breeding species had complex habitats compared to 50 per cent of the non-breeding species. If the distribution of complex and simple habitats was completely random, one would expect a distribution of 50 per cent of complex habitats in both populations. This quantitative result suggests that bird species with uncomplicated habitat requirements are more likely to breed, however this relationship was not statistically significant (see Appendix 7 for Chi^2 test).

The influence of competition between species for the available habitat area was also briefly considered. It was necessary to assume that there was equal competition between all the species for the areas of suitable habitat which they shared. The amount of acceptable habitat available to each species was therefore adjusted to allow each species to have an equal share of the suitable vegetation type. The null hypothesis was the species with the largest amount of suitable habitat available to them, after allowing for equal competition between the species, are most likely to breed. At the 0.05 rejection level the null hypothesis could not be rejected. The means of the two populations, breeding and non-breeding birds were not significantly different (see Appendix 8).

Thus although the total amount of acceptable habitat area available has an influence on the possibility of individual species breeding in Saltwells Local Nature Reserve, the role of the complexity of the habitat or the influence of competition between the species cannot be determined from the data extracted from the air photographs.

Further tests were conducted to identify whether any other differences could be identified from the air photographs between the habitats of breeding and non-breeding species. It is likely that the distribution of the suitable habitats in the Reserve will have an influence on whether a bird species breeds there. The previous investigation looked at the relationship between the total area of suitable habitat and the breeding of individual bird species. However, in reality, the total area of a habitat type is made up of a number of small units rather than individual large blocks. This fragmentation may result in the acceptable habitat blocks being below the territorial requirements of the individual species so being of little use. It therefore seems logical to assume that the bird species with the least divided habitat will be more likely to breed, as they will have more chance of finding a suitable sized block of the required habitat type. It is easy to identify the number of units of each habitat type from the air photographs.

Three null hypotheses were proposed:

i) There is no significant difference between the total number of units of suitable habitat for breeding and non-breeding birds.
ii) There is no significant difference between the amount of area per unit habitat for breeding and non-breeding birds.
iii) There is no significant difference between the average number of units per habitat type for breeding or non-breeding birds.

In each instance the Mann-Whitney U Test was conducted to investigate whether the area totals per habitat type available to breeding and non-breeding species were from different populations (see Appendix 9, 10 and 11). In each instance the rejection level was set at 0.05. None of the three null hypotheses could be rejected. Although the level of habitat dispersion is likely to have an affect on the bird species which breed and do not breed, no statistical conclusions about this can be made using this data source. The means of the populations of breeding and non-breeding birds are not sufficiently different to rule out a chance occurrence.

9.8. Conclusions of data analysis

In Saltwells Local Nature Reserve a predictive relationship appears to exist between the number of breeding bird species in the area and the total amount of closed broadleaved woodland habitat recorded from the air photographs. However due to the lack of field data, this relationship cannot be statistically tested and therefore should be used with reservations.

Predictive relationships between the area and nature of suitable habitat available in Saltwells Local Nature Reserve and the breeding of individual bird species are not evident. A statistical relationship exists between the area of acceptable vegetation available and the breeding of individual bird species but as the influence of habitat complexity, dispersion or competition cannot be determined, predictive relationships cannot be developed. Critical values for the breeding of species, for example critical habitat areas above which species are likely to breed, cannot be identified.

9.9. The prediction of species numbers and abundance in the Reserve in 1981

The results of the species-area analysis suggest that the models discussed can be used tentatively to predict the numbers of species which were likely to be found in the Nature Reserve in 1981. In 1981 the area of closed broadleaved woodland mapped from the air photographs was 15.13 hectares. This is a very slight increase on the 1984 total. As the area figures vary so little it can then be concluded that the species richness and abundance figures will also be similar for the two years. The species richness figures were estimated using the models of Woolhouse and Luniak which provided the best results for the 1984 photographs.

The Woolhouse model predicts 26.65 species would be found in Saltwells Local Nature Reserve in 1981. The Luniak model predicts 29 species would be breeding in the woods in 1981. Both figures are slightly above the 1984 figures.

Table 9.5 Comparison between the number of breeding bird species in Saltwells Local Nature Reserve between 1981 and 1984

	Area of closed woodland	Woolhouse Model (iii)	Luniak Model
1981	15.13ha.	26.65	29
1984	14.4ha.	26.16	28

The Woolhouse equation was also used to predict species abundance in the Reserve in 1981

$$\ln I = 0.679 \ln A + 3.082$$

Estimated species abundance is 137.9 which is also slightly higher than the figure predicted for 1984.

These totals indicate that if the area of closed broadleaved woodland can be used to predict the bird population levels in Saltwells Local Nature Reserve, there has been very little change in species richness or abundance between 1981 and 1984. However these models do not indicate what affect, if any, changes in other habitat types in the reserve will have on the bird population numbers.

CHAPTER TEN

ANALYSIS OF THE WOODLAND BIRD POPULATION PREDICTIONS

10.1 The results of the species-area relationship

As evident from the literature a number of variables have been considered in attempts to identify relationships between habitat types and species numbers. In this study, efforts have been made to estimate information about bird populations in an urban woodland. Of all the habitat parameters possible, the area of woodland was the major variable investigated as it can be accurately determined from the air photographic data source.

The species-area analysis followed two pathways.

i) The influence of the total habitat area on the breeding of the whole bird community.
ii) The effect of available habitat area on the breeding of individual woodland species.

Using relationships identified in the literature it was found that for the bird community, the estimated species richness and abundance totals were very closely related to the actual figures recorded in Saltwells Local Nature Reserve in 1983/4. It was also found that in this study area in 1983/4 the individual bird species, with the greatest amount of suitable habitat available to them, were more likely to breed. The dispersion of the habitat area, for example into individual units, was found not to have a significant influence on breeding probability.

Although the results are promising for the 1983/4 species-area relationships in Saltwells Local Nature Reserve, it is important to analyse the outcome more closely, before using these relationships to predict either temporal changes in the bird community in the study area, or using this technique in other similar locations. A number of factors may reduce the credibility of the apparent relationship, relating to general factors concerning bird ecology discussed in sections 10.2, 10.3 and 10.4 and more specifically to the techniques used in the analysis

10.2 Limitations of the field data

The major problem with the field data collected by Harrison and Normand (1984) is the fact that information exists for only one breeding season, 1983. This reduces the significance of any relationships found between the habitats and the bird community. Apparent correlations may be due purely to chance. However in research the ideal situation rarely exists and therefore the best use has to be made of whatever is available. This project can therefore identify relationships which exist only at a particular location at a specific time. Nevertheless, evidence of apparent relationships on a limited scale can provide useful information on trends. To statistically identify a species-area relationship, it would be necessary to have field data for a number of years.

Hammond and McCullagh (1978) suggested 30 observations should be taken for a pilot sample. It is unlikely however that standard bird census data will have been collected for a period of 30 years in an individual woodland. The standard mapping method used by the British Trust of Ornithology (B.T.O.) is based on the technique devised by Enemar in 1959, less than thirty years ago. The B.T.O. Common Bird Census (C.B.C.) was not started until 1961 (at the request of the Nature Conservancy Council) and over this time period, the plots which have been censused have changed due to observers leaving the scheme. In Great Britain, therefore, it is very unlikely that consistent field data will be available for an individual woodland over such a long time period.

An alternative situation is the use of field data collected from a number of similar wooded sites over a shorter time scale making up 30 observations. As woodlands are stable habitat types, the natural change in the area of a woodland is likely to be slight. The repeated testing of an individual stable woodland would identify whether a constant area results in a constant bird population size, taking in to consideration natural population fluctuations. The inclusion of other wooded sites in the field data should identify whether the relationship is evident in other geographical locations.

These two alternatives would provide ideal field data. However the situation is further complicated by the need to have aerial photographic coverage of the 30 woodlands in question. It is very unlikely that the optimum situation is likely to exist without long-term planning and expense, thus research into the species-area relationship has to be based on the best available data source. In this instance, this consists of one year of field data provided by Harrison and Normand (1984). A consequence of this is that any results have to be considered very carefully and any extrapolations of the relationship to other similar areas have to be undertaken with caution (Wiens, 1981).

The estimated figures of species richness and abundance need to be compared with the field census figures. Harrison and Normand (1984) used the mapping method to census Saltwells Local Nature Reserve, thus identifying species richness, species abundance and species location. They made no attempt to determine the extent and actual boundary location of breeding territories. Although the rules of the mapping method have been strictly defined, it is based on a sampling technique and therefore does not provide an exact figure for the bird population size in a particular habitat. Williamson and Homes (1964) found the accuracy levels of the C.B.C. to be acceptable but it is generally agreed that the technique clearly underestimates the size and extent of bird populations. (Fuller et al., 1985).

Best (1975) identified two major sources of error with this technique.

i) The observation errors. A number of factors cause variability in original census recordings, for example the weather at the time of census (O'Connor and Hicks, 1980), the time of day, the length of time spent in the field (Fuller and Langslow, 1984) and the conspicuousness of the bird species being mapped. The main cause however is variability in observers. Although the field workers are trained in census methods, the skill of the individual in detecting bird species will always vary. If the censuses are conducted by a number of individuals, there will be variations in bird population detections between plots and between different years.

ii) The interpretation errors. Once detailed records have been made of the location of breeding birds, this information is analysed to identify the size and shape of territories. This analysis is generally carried out by trained ornithologists working for the census agency rather than by the observers. Best (1975) argued that the bird population results obtained would vary with different interpreters. However O'Connor (1981) disagreed that this was a major source of error. Nevertheless, it is generally accepted that the most accurate use of the mapping method is to provide information about the rates of change of bird populations numbers, that is a population index, rather than provide information about absolute densities. It is considered that even though observers vary, the same observer will consistently map a particular habitat over a number of years, reducing the influence of error.

It is therefore evident that the predicted population figures are being compared with field data figures which are known to be inaccurate, especially when considering absolute population figures, as is the case in this study. However some of the causes of the errors have been reduced in the Saltwells field census as both the recordings of bird species and the interpretation of these figures were completed by the same observers. Although the inaccuracies of the mapping method are well known, it is still believed to be one of the most efficient techniques of obtaining bird census data and therefore for this study, the results of the field data must be seen to provide an acceptable base line for the comparison of predicted population figures.

10.3 The affects of natural population fluctuations

A major complicating factor to census analysis is the fluctuations which occur in natural populations. Such variation in populations levels makes it difficult to determine the accuracy of predicted population totals against the real population figures. Apparently inaccurate figures may be correct if they fall within the population range. Equally so, inaccurate figures from inadequate techniques may be accepted as they also fall within the natural population variations. It is therefore difficult to determine how accurate the figures predicted for Saltwells Local Nature Reserve really are.

The models proposed in the literature to determine bird population characteristics do not include any provision for population fluctuations, as only one estimate is derived. No indications are given as to whether this estimate is supposed to represent the middle point of population variance. The models do not include any details about the range of estimated populations. It is more likely that the predicted figures are meant to represent either the exact level of species richness or species abundance or the maximum level possible. If the former position is correct then a major flaw of the models is the lack of consideration of random population fluctuations. If the latter case is accepted, then an indication of the likely minimum population parameters should also be made.

Hypothetically even if all external variables were to remain constant over a number of years, the populations of a natural community, for example birds, would be seen to vary. The oscillations in population numbers are due to a number of influences, for example seasonal cycles, random environmental influences such as droughts, random populations cycles and demographic stochasticity.

As the causes of such fluctuations are varied, population changes are difficult to predict. Johnston (1981) claimed too little attention has been given to annual variations in bird populations in wildlife habitat studies. Frequently habitat conditions have no influence on such population changes. He believed that if population studies pertain to a single study area in a single year, any observed measurements are acceptable. However if the intention is to extrapolate the population data, great care is required to ensure the study area is representative of the type of habitat in question and also attention must be paid to the possible natural population variations. Long-term studies are required into population patterns before such extrapolations can be made with adequate confidence. Williamson and Batten (1977) stated that over the two decades of the 1960s and 1970s, the bird populations recorded by the C.B.C. in Great Britain, have varied two to three fold. A great deal of this recorded variation will be the result of climate, for example, severe winters reduce bird population numbers, but also a percentage of the population fluctuations will be a result of natural random variations.

As an added complication to bird census figures, Davis and Glick (1978) stated that bird populations in urban environments are less stable and thus more prone to population fluctuations than birds in a rural environment.

Luniak (1983) noted the changes in bird population numbers which occur in urban woodlands. He found a similarity of 67-91per cent (x=80%) in numbers in successive years. This percentage decreased as the intervals between population censuses increased, for example after a pause of one to three years the similarity levels were 63-78 percent (x=70%). If these figures are translated they indicate that between successive years the populations varied on average by 20 per cent, 30 per cent with longer time intervals.

Johnston (1981) claimed that to obtain an adequate picture of fluctuations, details other than the mean population figures are required. Elseth and Baumgardner (1981) discussed the various methods of determining population variance via the coefficient of variation, the coefficient of fluctuation and standard deviations. The last method is probably the easiest to compute and the most readily understood.

In order to determine an estimate of bird population variance in British woodlands, Common Bird Census data quoted by Woolhouse (1983) was analysed. The differences which occur in species richness and bird abundances were considered. Two 30 site samples were taken. For each sample there was five years of data (1976-1980). The mean population figure and its standard deviation was calculated for the five years. From this figure the percentage of variances from the mean was obtained (see Table 10.1)

For species richness, Table 10.1 indicates that for the 30 sample sites over a period of five years, the population fluctuates at an average of 17.78 per cent (±8.59) per year, per site. Species abundance, has an annual variation of 33.5 per cent (±14.64) per site.

Table 10.1 Population fluctuations in species richness and species abundance in British woods (figures based on C.B.C. - Woolhouse 1983)

$\bar{x}$ species richness 1976-1980	σn-1 1976-80	% variance of σn-1 for the $\bar{x}$	$\bar{x}$ species abundance 1976-1980	σn-1 1976-80	% variance of σn-1 for the $\bar{x}$
19.6	4.2	42.86	67.4	22.55	66.91
29.8	2.39	16.04	257.8	36.83	28.57
25.4	3.13	24.64	94	20.83	44.32
21.6	1.52	14.07	80.2	2.49	6.21
22.8	2.16	18.94	105.8	9.98	18.87
20.3	3.62	35.67	91.6	11.19	24.43
28.4	2.3	16.2	171.6	33.75	39.34
27.8	1.79	12.88	232.6	20.56	17.68
33.4	2.5	14.97	319	48.42	30.36
20.4	2.19	21.47	116.2	12.05	20.74
33	1.22	7.39	275	35.56	25.86
25.8	1.09	8.45	140	20.43	29.19
27	3.94	29.19	178.6	50.82	56.91
20.2	2.77	27.43	60.4	10.67	35.33
32.6	2.51	15.4	203	23.47	23.12
25.2	1.92	15.24	199.4	48.93	49.07
26.6	1.34	10.08	125.8	26.13	41.54
25.2	2.28	18.1	149	24.94	33.48
19.8	2.17	21.92	63.8	11.9	37.3
17.2	1.92	22.34	43.2	12.34	57.13
17.8	1.3	14.61	47.2	6.06	25.68
28.6	3.21	22.45	162.2	40.05	49.38
24.2	0.84	6.94	105.4	10.31	19.56
26.4	6.5	49.24	92.2	19.87	43.1
37.2	1.1	5.91	244.4	34.95	28.6
37.6	3.43	21.04	241.8	57.85	47.85
29	1	6.9	138.6	18.73	27.03
27.2	1.3	9.56	144.4	4.72	6.54
31.4	3.78	24.08	208.2	48.47	46.56
22	1.58	14.36	124	15.36	24.77

$\bar{x}$= 17.78%

σn-1 ± 8.59%

SE $\bar{x}$ = 1.56

$\bar{x}$=33.5%

σn-1 ±14.64%

SE $\bar{x}$ = 6.11

The calculation of the standard error allows estimates to be made about the real population fluctuations as opposed to those of the sample population. In a wood of an average size of 16 hectares sampled by the C.B.C., there is a probability of 95 per cent that the mean level of population fluctuation in species richness is between 14.66 per cent and 20.9 per cent. Under the same conditions, the fluctuations in species abundance can be predicted to be between 21.29 per cent and 45.72 per cent at a 95 per cent confidence level.

Such levels of natural population fluctuation complicate the prediction of bird species richness and especially bird abundance. The number of breeding bird pairs likely to be found in the same woodland in successive years is variable. These variance percentages can be applied to the population figures recorded in Saltwells Local Nature Reserve by Harrison and Normand (1984). They recorded 27 breeding bird species and 137 breeding pairs. Assuming that all environmental influences remained constant, if the above percentage variances are applied, one could expect in the following year's census, to obtain population figures of between 21 and 32 species (using percentage variance of 20.91%) and 74 to 200 breeding pairs (using 45.72%). Such differences would be due to random variations in the natural bird populations. Thus predictions within this range of figures could not be termed inaccurate with any degree of confidence. These population variance figures have been calculated from census data collected by the C.B.C. in rural woodlands. According to the literature, the rates of population fluctuations of birds in urban woodlands are even greater and therefore it is more difficult to determine whether methods of predicting bird populations numbers are producing accurate results or whether they happen by chance to fall into the broad categories of possible natural population levels.

Due to the large natural variations in population levels, an estimated population total, even though it does not coincide exactly with the field data figures, may still be correct, if it falls within the limits of the population fluctuations. This is especially true if predictions are made about the population levels of a particular community for a year without actual field data and accuracy comparisons are being made with 'historical' data.

This is seen to happen in Saltwells Local Nature Reserve. The population predictions based on area, fall very close to the field data and are certainly within the natural population ranges. When considering the accuracy of predicted figures, it is necessary to check these within the context of the natural population fluctuations. Results which seem inaccurate may in fact be within the allowable limits.

However the existence of such broad population ranges may result in inappropriate techniques producing what appear to be acceptable results. The large levels of population variance means there is a greater likelihood of a prediction based on an unsound technique, falling within the permitted limits. This may have occurred purely by chance. It is therefore important to be very cautious when checking the accuracy of population predictions especially as the predictive models make no allowances for population variations over time. Both the Luniak (1983) and Woolhouse (1983) models' estimate one population level for a particular area of woodland. They do not provide any indication of whether this is believed to be an exact parameter or a maximum figure. If the figures produced by these two models for Saltwells Local Nature Reserve are supposed to predict exact population levels from area then the results obtained compare very closely to the field data and could be accepted. If they are intended to indicate the maximum number of species one is likely to find in a woodland of a particular size, that is, the carrying capacity of that woodland, then they are inaccurate. The models predict between 26 and 28 species are likely to be found breeding in Saltwells Local Nature Reserve. This tallies very well with the field data figure of 27. However if the estimated figures are supposed to represent the maximum number of bird species in an area of woodland of a particular size, the levels of natural population fluctuations calculated suggest that up to 32 species could breed in such a wood and thus the correlation between the two is not so great. Thus the apparently excellent theoretical estimates of the bird population in Saltwells Local Nature Reserve have to be interpreted with care.

10..4 The influences of an urban environment on bird populations

Saltwells Local Nature Reserve is in an urban environment. It is immediately surrounded by residential and industrial land uses. Most predictive bird studies have been based on data collected in rural woodlands and thus it is important to consider what influence the urban environment will have on breeding bird populations. Luniak (1983) claimedthat urban birds are subject to a high degree of hemeroby (anthropogenic changes) and thus in urban bird population studies, it is important to consider anthropogenic influences, for example, the vicinity of urban developments and the affect human activities have on birds' feeding and breeding habits. Some examples of the major disturbances which are found in the urban environment include human management and recreation activities (Van der Zande, 1984) and the predation of domestic pets. Luniak (1983) believed such criteria will have far more influence than the factors studied in rural environments, for example soil type, vegetation cover and the amount of dead wood. Nevertheless for this study, the influential factors investigated were dictated by what could be identified from the air photographs, that is details about the vegetation habitats rather than about human activities in woodlands. However Davis and Glick (1978) claimed the area-species relationship which is found in rural environments appears to be common in urban ecosystems.

A number of investigations have been carried out into bird communities in urban environments and three main differences between the urban and rural patterns have been identified (Tomialojc and Profus, 1977; Degraff and Wentworth, 1981; Sukopp and Wemer, 1982 and Mason, 1985)

i) These studies have all noted a decrease in diversity of species in urban woodlands. Mason (1985) found diversity was reduced as fewer native species were recorded in the urban environment. Luniak (1983) believed that the decrease may be due to the lack of suitable undergrowth for shrub and ground nesters.

ii) The ratio of grain feeders to insectivores increases with increasing urbanisation. This suggests that the bird species which can most readily adapt to a human food supply are more successful.

iii) Although species diversity was reduced, species abundance levels in urban woodlands were found to be above those in comparable rural areas. A number of reasons have been suggested. Luniak (1983) believed this increase in biomass was primarily due to large populations of Rooks *Corvus frugilegus* and Woodpigeons *Columba palumbus*. Sukopp and Wemer (1982) emphasised the lack of competition in urban woods, that is very few prey-predator relationships, and so most bird mortalities are caused by traffic or power lines. Nuorteva (1971) found that the bird biomass in cental Helsinki was ten times that of the surrounding forests and farmland. He believed this resulted from extended breeding seasons promoted by a favourable microclimate and a tendency for bird species to have reduced territory requirements, as a result of increased food supplies. The idea of urban birds having smaller territories, hence more birds per unit area, was also put forward by Cousins (1981). He found the urban bird species tended to be smaller than rural bird species and as Schoener (1968) had shown that the size of a bird's territory is positively correlated to its body size, smaller bird species result in smaller territories and thus more territories per unit area. Whatever the causal factors, it is generally agreed that an urban woodland will have fewer species but more individual birds than a rural woodland of comparable size.

From these conclusions, it is evident that the prediction of urban bird numbers using models developed in a rural environment, is not an optimal situation. For these reasons, the species-area analysis included two models, one from an urban and one from a rural environment. The fact that these two models produce very similar results about species richness is therefore surprising. In fact, the Luniak model (1983) estimates greater species richness figures than the Woolhouse model (1983). The models are not directly comparable as although they were both developed in similar sized woodlands, (Woolhouse, average size woodland of 16.86 hectares, ±10.22, Luniak 12.33 hectares, ±7.46) they were based on information collected in different countries by different census methods. However as discussed in Chapter Nine, it was believed that the bird species recorded by each census were sufficiently comparable with each other and with the field data to allow the use of both models. One explanation why these models predict very similar results when they were developed from data collected from different populations is that the models are too insensitive. Although they are based on the concept that the area of a habitat is primarily responsible for bird population figures, they do not take any other influential factors into consideration. The idea of using one variable in predictive studies has been repeatedly criticised for such reasons, (Karr, 1980). If these models produce similar results due to insensitivity, this then casts doubts on their usefulness.

Such a conclusion could only be derived if the models were developed from similar populations. As stated in Chapter Nine, it was felt that the species considered for the Polish model were sufficiently similar to those recorded by the C.B.C. and Harrison and Normand (1984) to allow its use. However Luniak based his model on information recorded for 91 species. The Woolhouse model was based on 60 species. This difference in the numbers of species in the parent populations may be the reason why the Luniak model apparently overestimates urban bird species numbers.

For an area of approximately 14 hectares, Luniak predicts that 28 of the parent 91 species are likely to breed. If one looks at the ratio between the estimated number of species and the species composition of the total population, in both cases a different picture emerges. Luniak predicts that 30.8 per cent of the parent population species should breed in the area of question, whereas Woolhouse estimates 43.3 per cent of his parent population are likely to be found in a similar environment. Therefore, from this viewpoint, it appears that the estimated number of species in an urban environment is proportionally lower than in a rural environment and as such, the predicted figures echo the expected conditions from the literature. Definite conclusions cannot be drawn from such an analysis but it does indicate that the models cannot be described as being too insensitive to be of any use without further investigations.

In summary neither model was ideal for the species-area analysis. The British model was developed in a rural environment and thus ignores the well documented fact that urbanisation has an effect on the bird population numbers. Unfortunately the urban model was developed in another European country and although there are similarities between the common bird populations of Poland and Britain, there are also some differences which would have been included in the model. However the results produced by each model are promising and suggest that the technique of predicting bird species numbers from area of woodland is useful as long as the results are seen in context.

Woolhouse developed a model to predict bird species abundance from the area of habitat. Again this was developed from census figures obtained in a rural environment. According to the literature, in an urban environment, the number of bird individuals is greater than in a comparable rural environment. The correlation between estimated species abundance and actual species abundance in Saltwells Local Nature Reserve is very close however, one would expect the predicted figure to be less than the census figure. It is not evident why this is so. Luniak (1983) did however state that the increased biomass found in urban environments was partially the result of the number of breeding Woodpigeons *Columba palumbus* and Rooks *Corvus frugilegus*.

In Saltwells Local Nature Reserve, no Rooks *Corvus frugilegus* were sighted and only two pairs of Woodpigeons *Columba palumbus* were recorded, therefore the lack of abundance of these two species may explain why the correlation between the predicted and the real abundance number is better than expected. The species-abundance equation developed by Woolhouse (1983) provides good results on this occasion and in other urban closed wood environments, it may provide a useful indication of the minimum numbers of birds likely to be found breeding.

10.5 Can the area of closed broadleaved woodland be used to predict the numbers of bird species

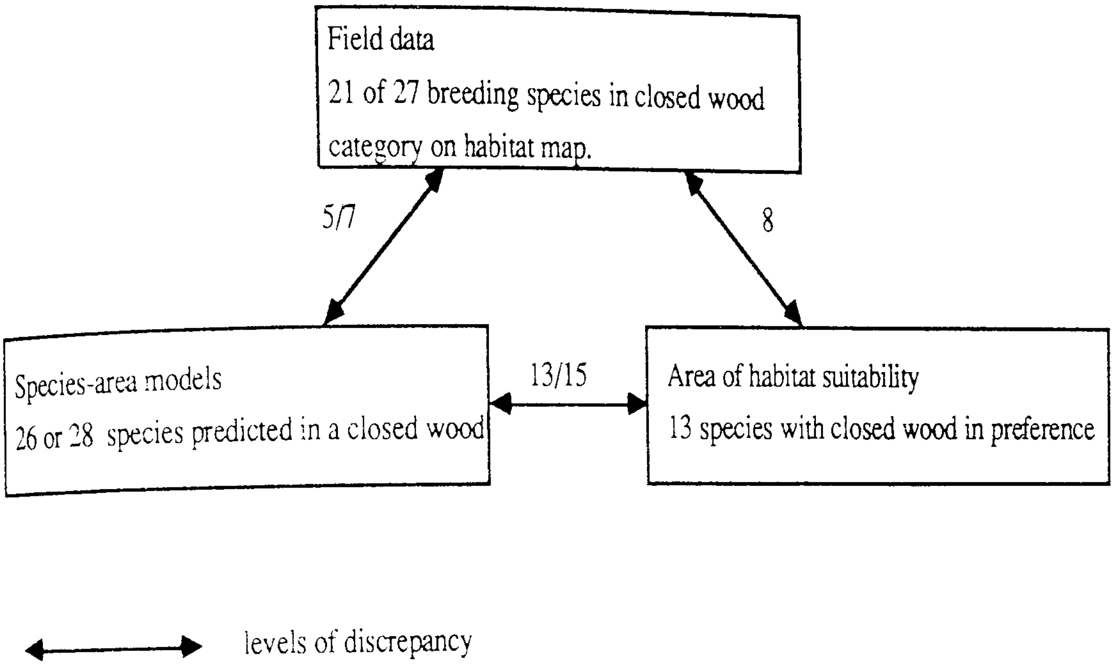


Figure 10.1 The relationship between the area of closed broadleavedwoodland, the 2 analytical techniques and the field data.

It is evident from the diagram that discrepancies exist between the actual number of species found to breed in the closed broadleaved woodland habitat and the numbers estimated to do so from the two methods of analysis. It is important to consider how real the relationship is between the area of closed broadleaved woodland (31) and species richness.

The accuracy of the models is being assessed against the number of breeding birds recorded in the field. Using the area of closed broadleaved woodland (14.4 hectares), the species richness predicted by both models was very closely correlated to the actual number of species recorded as breeding in Saltwells Local Nature Reserve. Twenty-one of the twenty-seven species identified as breeding in the field study were found to nest in the closed broadleaved woodland habitat category (31). However the area of closed broadleaved wood (31) only amounts to a third of the total area of the reserve. The remaining two-thirds of the reserve must have an influence on bird species richness and abundance. The analysis did consider the fact that some species do have complex habitat requirements, for example needing both woodland and grassland habitats. The existence of such prerequisites can partially explain the discrepancy in the area totals of closed broadleaved woodland (31) and the whole reserve, but some of the species which are known to breed in the reserve do not live in closed broadleaved woodland habitats, for example Linnet *Carduelis flammea* and Whitethroat *Sylvia communis*. Thus the accuracy of the models is being assessed against the number of breeding birds recorded in the field, however not all of these species censused are found to feed or nest in a closed broadleaved woodland habitat (31) and therefore they should not be included in the model's estimates. If these species are not considered, the models are seen to overestimate species richness therefore suggesting either their inaccuracy or thus emphasising the paucity of the bird community in Saltwells Local Nature Reserve. Another explanation for this discrepancy could be that the species which appear not to breed or feed in the closed broadleaved woodland (31) are still reliant on that habitat type for some of their requirements, for example, roosting and thus would be less likely to live in the reserve if patches of closed broadleaved woodland (31) were absent.

The second half of the analysis investigated the relationship between the amount of suitable habitat available and the breeding of individual bird species. Here the area of habitat was not restricted to closed broadleaved broadleaved wood but included all the habitat types. Suitable habitat patterns were identified for all the common woodland species (see Table 9.4). In Chapter Nine these habitat patterns were used as a check of the suitability of the area of closed broadleaved woodland (31) being used with the Luniak (1983) and Woolhouse (1983) models, that is, how many of the species known to breed have closed broadleaved woodland (31) listed as one of their suitable habitat types. It appears that the second part of the analysis does not verify the first part, as it was found that only 13 of the 27 breeding species had classification category closed broadleaved woodland (31) as a requirement.

However this does not necessarily indicate that it is unsatisfactory to use the area of closed broadleaved woodland (31), in the species-area models. It could be seen as an indication of inaccurate habitat patterns. The result of this discrepancy may result from one of the assumptions made for habitat allocation, that is, species which need a good shrub layer will not nest in closed broadleaved woodland (31). From the nesting locations identified in the field study, this assumption appears to be incorrect. If closed broadleaved woodland (31) is then included in the habitat patterns of species requiring a dense undergrowth, the discrepancy between the two figures is reduced, that is , 23 of the 27 breeding species have closed broadleaved woodland identified in their habitat patterns. This however would alter the amount of suitable area available to each species. Further Mann-Whitney U tests were carried out using the new habitat area totals and the new totals for habitat units but the results remained the same, that is, a significant positive relationship was identified between the amount of habitat available and the breeding of individual species and no relationship was found between the number of suitable habitat units and the likelihood of a species breeding.

The inclusion of closed broadleaved woodland (31) in the habitat preferences of those species who require dense undergrowth, for example Blackbird *Turdus merula* and Bullfinch *Pyrrhula pyrrhula*, does not affect the overall results of the second part of the area analysis, that is relating to the amount of suitable habitat per species, but it does improve the relationship between the habitat suitability patterns, the field data and the species-area models. It emphasises the importance of the closed broadleaved woodland (31) to the breeding bird species in Saltwells Local Nature Reserve.

Even after considering the above two factors, it appears that from the investigations into species richness and species abundance, the best correlations with the field data are obtained by using the area of closed broadleaved woodland (31). Unfortunately there are no areas of open broadleaved woodland (32) in the reserve therefore its influence cannot be determined. Future investigations may show that the area of the open broadleaved woodland (32) habitat should also be included in the species-area relationships.

10.6 What variables other than area could be used with air photographs in predictive studies?

From the literature review in Chapter Eight, it was decided that the area of a habitat type would be the most accurately determined parameter using air photographs. As mentioned previously, however, studies based on a single variable have been criticised, for example O'Connor (1981) and Karr (1980), as it is considered that the relationship between bird species and a habitat is far too complex to be described using one parameter. Single variable studies generally have been based on structural habitat characteristics as this was believed to be more important to bird species than actual vegetation species (Fuller, 1982) however even this assumption has been questioned, for example by Rotenberry (1985). In the past he has found strong patterns of association between bird community structure and the 'physical configuration of the environment', but more detailed studies, in a grassland environment, indicated that floristics were more important than structure in determining habitat associations of shrub-steppe bird communities. He suggested that the scale of the investigation plays an important part in determining the most influential habitat parameter for bird communities. Birds may differentiate between gross habitat types on the basis of structural configurations but locate themselves within that broad habitat category on the basis of plant composition. His study was restricted to grassland birds but he claimed similar results have been obtained in other habitat types. As the structure of different plant species will vary in some way, the relationships described by Rotenberry between bird communities and floristic composition may still be based on the structure of the plant. The investigation is being conducted in more detail and this point may be resolved.

Whatever habitat variable or combination of variables is chosen depends on the aims of the study. For detailed studies about specific bird species, relationships with particular plant species for food sources etcetera, may be very important. However such studies would need to be conducted in the field. If the habitat variables considered become more broad, such as the area of a habitat or the degree of isolation of the habitat, the results of the study will also be more general, for example, information may be obtained about the bird community rather than individual species.

The level of detail about the variables chosen for investigation will depend on the resources and expertise available. Investigations using a large-scale aerial photographic data source will be based on more general parameters than field studies. However the data source can still provide very useful information for particular purposes, for example, quick surveys of woodland bird communities. If more specific relationships between bird species and communities are required, it may be possible to conduct multivariable studies using air photographs or more probably, it will be necessary to base the investigation on field survey data.

In Table 8.1 the variables used in a number of predictive studies are listed. These studies have been based primarily on ground field data. However it will be interesting to determine how many of these parameters have been or can be identified for hardwood species from large-scale air photographs.

It is assumed that any characteristics which have been identified or quantified in the literature on colour or black and white emulsions and on smaller scales than 1:2500, will also be recognisable on colour infra-red 1:2500 scale photography.

Table 10.2 briefly lists whether data about the variables used in the studies listed in Table 8.1 can be derived using air photographs. The information is based on literature surveys of measurement techniques.

For woodland bird habitat studies, information about the trees found in the study area is believed to be important. The extent to which woodland tree features can be determined varies. The accuracy of any measurements depends on the scale of the photography, the density and species complexity of the tree stand. The predictive parameters can be measured directly or indirectly. Direct measurements of features such as tree numbers, tree heights, percentage canopy cover will be more accurate if the woodland is open as then all of the trees and some of the ground surface will be visible.

Table 10.2 Identification of predictive variables from air photographs

Parameters used in predictive studies	Identifiable on Air Photographs	Comments
Number of trees	√	Sometimes only 50% accurate (see Seely, 1960). Dependent on scale of photography.
Tree height	√	Dependent on scale of photography. Easier for isolated trees than dense canopy as with individual trees can see ground or tree shadow for measurement (see Howard, 1970).
Tree density	√	Possible if number of trees identified.
Tree species	√	Dependent on scale and season (see Gammon and Carter, 1979 and Howard, 1970). More difficult for hardwood species.
Importance of oak	X	Oak can be identified but its importance is a subjective decision.
Canopy height	√	See Howard, (1970).
Percentage canopy cover	√	Percentage of ground area covered by a vertical projection of the tree crowns. See Paine, (1981).
Foliage volume	?	Indirect measurement. Need to identify individual species types. Dependent on linear relationship between measurable crown characteristics, for exampe, crown area, crown density, crown diameter and volume for each species type.

Number of trees with x diameter breast high.	?	Need to identify individual species types. Indirect measurement. May be correlated with tree canopy diameter or tree height for individual species types. Details of relationships available for coniferous species. No mention of relationship for hardwoods (see Paine, 1981).
Trunk volume	?	Indirect measurement. Need to identify individual species types. Estimates of coniferous volumes made from tree height and vertical crown diameter for individual species. Standard deviations high. No mention of relationship for hardwoods (see Paine, 1981).
Foliage height diversity	X	Knowledge required about all structural layers of the habitat therefore air photographs not suitable.
Plant species diversity	X	MacArthur and MacArthur (1981) used air photographs to calculate 1 component of P.S.D., that is, the area of leaf for particular species in the tree canopy.
Diversity of vegetation stratification	X	Need information about all layers of canopy.
Shrub species	?	Dependent on shrub layer being visible. Also depends on scale of photography.
Shrub density	?	Depends on visibility of shrub layer.
Shrub height	?	Depends on visibility of shrub layer.
Grass height	X	Height difference between ground level and upper grass layer will be too slight .
Percentage grass cover	?	Depends on visibility of grass layer.

Habitat heterogeneity	√	See Bilke (1979). Patchiness of habitat can be determined. Dependent on classification used.
Area	√	Accuracy depends on accuracy of classification and interpretation.
Area of wood within 3km/5km	√	Depends on scale of photography. Easily determined from map.
Distance from nearest source pool	√	Depends on scale of photography. Easily determined from map.
Distance from nearest wood	√	Depends on scale of photography. Easily determined from map.
Litter depth	X	Dependent on visability of this layer. Can determine litter area. May be a relationship between area and depth in the study region.
Amount of snags	X	Found in forested environment therefore not visible due to tree canopies.
Latitude	X	Easily obtained from other sources.
Longitude	X	Easily obtained from other sources.
Elevation	?	Possible if ground surface visible but more easily obtained from other sources
Mean high temperatures	X	Easily obtained from other sources.
Mean low temperatures	X	Easily obtained from other sources.
Temperature during dispersal	X	Easily obtained from other sources.
Winter mean temperatures	X	Easily obtained from other sources.

Dense tree canopies result in only the uppermost canopies being counted. Indirect measurement from the air photographs of features such as diameter breast height (D.B.H.) and foliage volume rely on there being a standard correlation between these features and the directly measurable feature, that is, those which are actually visible on the photographs. Such relationships are complex as they vary with geographical region, with actual site quality and with different tree species.

In areas of commercial forestry, relationships have been identified for particular species between crown diameter, tree height, D.B.H. and volume. The accuracy levels of these techniques are inferior to ground surveys with standard deviations up to four times larger. However these correlations may be useful in stands of one species in a commercial forestry environment for example, but they are very time-consuming to determine in a mixed woodland. Thus few dependent relationships have been developed for broadleaved species.

As most of the woodland in Saltwells Local Nature Reserve is dense mixed broadleaved woodland, it would be very difficult to calculate the value of most of these parameters. The accuracy levels of some of the simplest parameters such as tree heights and tree numbers may not be acceptable due to the density of the canopy cover.

The availability of information about other structural layers, for example shrub, grass and litter layers depends solely on the density of the tree canopy or the season of the photography. Gammon and Carter (1979) were able to map shrubland species in a broadleaved woodland environment in the autumn, after the leaf fall. Even with open woodland canopies areas of shrub and grass will be masked. Extrapolation of data from clearings may be possible for the covered areas but the fact that these areas are shaded will alter the structure, height, density and species content of the grasses and shrubs. To obtain details about the shrub, grass and litter layers in a wooded environment, air photographic data is not adequate and field sampling is necessary.

Studies about the structural diversity, for example foliage height diversity (F.H.D.), of a habitat, have not been conducted using air photographs because commercial foresters are not immediately interested in such parameters and bird habitat ecologists do not tend to use air photographs for data collection. Again, however, it would be difficult to determine such measures due to the invisibility of the lower structural layers.

The other variables discussed in the table are related either to geographical locations or climatic influences. The quantitative information for these parameters could be readily obtained from other sources.

Thus the area of a habitat and the habitat heterogeneity of a region can be most readily determined from the air photographs with the greatest degree of objectivity. However the suitability of these results is dependent on the habitat classification used. Fortunately the classification categories can be strictly defined and are therefore transferable. As no suitable models have been developed for bird community predictions based on woodland habitat heterogeneity, the analysis for this project was based on the area parameter and thus the air photographs could be used as the sole data source.

The results obtained were promising and warrant further investigation. A technique based on parameters obtained solely from the photographs has important monitoring implications. If the photographic materials are available, it may be possible to regularly estimate the size of bird communities in woodlands and thus identify rates of change. This technique can be used on dated air photographs to predict the likely bird population numbers which may have been found in a particular woodland. This would be very useful for wooded sites which have no historical field census records. It should be possible to use some of the other predictive parameters discussed, for example foliage height diversity or tree volume, if the air photographs are used in conjunction with vegetation field samples. The use of air photographs alone to determine these parameters would be too subjective.

10.7 Conclusions

Two different methods of analysis, based on the area of habitat types, were conducted in an attempt to estimate bird population totals from air photographs. The results of the first technique based on species-area models appears to be promising. The results of the second method based on the amount of suitable habitat available to individual bird species were inconclusive.

The species-area relationship estimates need to be considered with care. A number of external variables discussed in this chapter can affect their usefulness in prediction studies. It does however appear that of all the parameters used in bird prediction studies, the area of a habitat is the most objective variable to use with air photographs. The accuracy levels relating to the use of other variables, for example volume, foliage height and diversity, quoted in the literature, are not superior to those methods based on area and yet they require data obtained by field work. Thus it appears that in predictive bird studies, the area of a habitat obtained from large-scale air photographs, is a useful independent variable.

CHAPTER ELEVEN

THE CONCLUSIONS

11.1 Introduction

For the concluding chapter it is appropriate to critically discuss how well the methodology and the analysis discussed in the previous chapters have fulfilled the original aims of the thesis. Such discussions will identify whether similar studies in other urban areas should be carried out by the Nature Conservancy Council or other authorities or individuals. Suggestions will also be made as to how future studies could improve on this work.

11.2 The aims of the thesis

The original aims of this thesis are stated in Chapter One, section 1.7, and thus they will only be briefly repeated here.

i) To determine whether large-scale multispectral aerial photographs can be used to survey and monitor urban wildlife habitats, to an acceptable level of detail. The success of aerial photographs in rural habitat studies is discussed in Chapter Two. It was necessary to investigate whether aerial photographs could be used as successfully in urban environments where the wildlife habitat units are generally smaller, more fragmented and change more rapidly. The best photographic emulsion and scale, had to be identified and a suitable urban wildlife habitat classification needed to be devised for this study.

ii) To examine whether certain habitat characteristics, identifiable from the aerial photographs, could be used to predict population numbers of selected groups of animals, expected to be found living in a particular habitat type. This aspect of the thesis was restricted to investigating whether air photographs could provide the necessary data to predict bird population numbers in Saltwells Local Nature Reserve.

The thesis can thus be divided into three sections. Chapters One, Two, Three and Four set the scene, Chapters Five, Six and Seven discuss the use of air photographs to map the urban wildlife habitats found in the Blackbrook Valley and Chapters Eight, Nine and Ten investigate the possibilities of using habitat data obtained from the aerial photographic data source to predict bird population numbers.

11.3 The urban habitat survey - its success

11.3.1 The aerial photographs

As with rural aerial photographic surveys (see Chapter Two), great care needs to be taken when choosing the most suitable air photographs for an urban wildlife habitat survey. The aim of the survey needs to be strictly defined before decisions are made about the optimum photographic data source. The survey resolution required will dictate the most suitable scale of imagery to use. The fact that an aerial vegetation survey will not provide as detailed botanical information as a ground survey needs to recognised at the start, but in recompense, the aerial survey will readily provide information about other important environmental factors.

In vegetation studies, the scale of aerial photographs used has varied greatly depending on the subject matter and the resources available. As wildlife habitats in urban areas are more fragmented and generally smaller in area than rural habitat units, larger scale aerial photographs are required for urban habitat surveys than rural studies if a similar level of accuracy is to be achieved.

For the Blackbrook Valley survey, 1:2500 scale photography was available for 1981 and 1984. Comparisons between photographs of similar emulsions but of different scales could not be made due to a lack of suitable imagery. It was felt however that 1:2500 scale photography is an ideal scale to map urban wildlife habitats. For large habitat units, for example areas of woodland and shrubland, 1:5000 scale photography would have provided equally as good results, but the mapping accuracy of the many small wetland communities in the area would have suffered. For the very small habitat patches in the Valley, such as aquatic plant communities, 1:1000 scale imagery would have been preferable. Due to the diversity of habitat types and great variation in habitat unit size found in urban environments, 1:2500 scale photography is considered a reasonable comprise.

A major factor affecting the scale of photography to use in an urban wildlife habitat survey is the dynamic nature of the environment. If up-to-date results are to be available, habitat surveys need to be carried out at regular intervals, for example every three years. Obviously the greater the scale of the photography used, the greater the cost of obtaining full coverage of the urban area in question. In some instances the costs of obtaining 1:2500 scale photography may be prohibitive and thus the scale used will depend on the resources available. It may be possible however if frequent habitat surveys are to be conducted, to alternatively obtain 1:2500 scale photography and smaller scale imagery for example 1:5000 which would be adequate to update the original survey.

The photographic emulsion chosen can influence the scale of photography required. Results from this study suggest that for urban wildlife habitat surveys, colour infra-red imagery provides more accurate results than colour and panchromatic imagery of a similar scale (see Chapter Five). Patches of sparse vegetation cover which are often missed on the colour and panchromatic photographs, can be easily identified and mapped using the colour infra-red photographs. The colour infra-red imagery was found to be superior to map all the urban habitat types listed in the urban habitat classification (see Chapter Four) except for submerged vegetation communities (habitat classification category 60). Submerged vegetation communities could be more easily mapped using colour imagery. As both colour infra-red and colour photographs were available for this study, all the habitat categories could be mapped in full. However for some projects, a choice about the most suitable imagery emulsion to map the urban wildlife habitats will have to be made. If the area in question comprises a large percentage of water bodies or the aim of the study is to map aquatic vegetation communities, colour aerial photographs will provide the best results, otherwise colour infra-red imagery is superior for urban wildlife habitat surveys.

Unfortunately colour infra-red photographs are not as readily available as colour or panchromatic imagery. Even though this emulsion will provide the most accurate results, the cost of obtaining new colour infra-red photographs may not be justified for the increase in accuracy levels obtained. Although colour infra-red photographs can be recommended as the best imagery to use for urban wildlife habitat surveys, each project needs to be examined individually to determine the best emulsion to use within the constraints and the aims of the project.

The timing of the imagery is important to ensure that the photographs actually record the required information. With reference to this project, the urban wildlife habitat survey is only one part of a larger ecological survey of the Blackbrook Valley. The photographs were commissioned to provide a generalised data-base of the area. The best time to obtain the aerial photographs was when the vegetation was at its maximum development, that is during the summer months. Different aims may require the photographs to be taken at other times of the year or at different times of the day.

11.3.2 The ecological detail

A large amount of information was extracted from the aerial photographs. Data about the characteristics considered important in ecological studies was obtained, such as habitat type, area, habitat structure, location, overall habitat diversity and habitat patchiness. As two years of photography existed, it was also possible to identify changes in the urban wildlife habitats. Although such analysis was not carried out in this project, it would be relatively easy to determine from aerial photographs, quantitative values to describe the degree of habitat contiguity, connectivity and shape.

As discussed in Chapter Five, the information about the urban wildlife habitats was extracted from the photographs at an acceptable level of accuracy.

One of the major limitations to the usefulness of aerial photographs in urban habitat surveys is the classification used to organise photographic interpretation. The information extracted from the photographs can only be as good as the classification used, therefore it is vital to design an urban habitat classification which will fulfil the aims of the study. However as long as the classification used is suitable, large scale aerial photographs, especially colour infra-red, can provide very detailed information about urban wildlife habitats.

11.4 The urban habitat classification

The development of the urban habitat classification was discussed in detail in Chapter Four. As said above, the actual classification used in aerial photographic surveys is the major influence on the quality of data obtained.

For this project, the aim was to devise a classification which could be used to map the urban wildlife habitats in the Blackbrook Valley but which could also be used in similar urban environments. The development of a classification to be used for urban habitat studies is very complex due to the number of abiotic influences on the habitats in urban areas. These external influences, for example land-use, management and recreation use need to be taken into account in urban habitat studies. Thus an urban wildlife habitat classification needs to be, at the least, a vegetation and a land use classification.

The urban wildlife habitat classification used for this research project was not ideal and could be improved. For example one of the environments frequently used to describe the habitat requirements of a number of common bird species, parkland, was not included in the classification.

The aim was to develop an hierarchical classification, the sub-divisions being based on habitat structure, but it sometimes proved difficult to devise a consistent classification. The hierarchical nature of the classification was lost in the numbering system used. The habitat categories were numbered concurrently thus making it difficult to add new habitat divisions. The numbering system used was developed as a result of plans to store the habitat boundary information on a spatial database. The habitat coding was thus kept down to the minimum number of digits possible, to reduce the chance of error, when entering the data codes on to the computer. Ideally the habitat classification coding system should be flexible enough to allow the addition of new habitat categories on the relevant tier of the classification.

The botanical detail interpretated using the urban habitat classification is restricted to information relating to the structure and density of the vegetation communities, for example woodland, shrubland and grassland. No serious attempts were made to try and identify the actual species present in the Valley. The scale of the aerial photographs used, should allow the identification of the tree and shrub species. This amount of detail was believed unnecessary for this particular study but the classification was designed to allow the inclusion of species information in the next hierarchical tier, if required.

The aim was to devise a classification which could be used for other studies in similar areas therefore helping to provide consistent information about urban wildlife habitats. This aim may not be realistic. The vegetation section of the urban habitat classification is based on the categories identified by Shimwell (1983) for the Nature Conservancy Council. Although Shimwell's conspectus was developed as a result of field work in a large number of different urban environments, trials of his classification conducted in Nottingham, Norwich and Tyne and Wear have identified a number of plant communities, commonly found in urban areas, which are not included, (Shepherd and Sanders,1987). If the missing plant communities were added, this would result in an urban habitat classification of over 200 plant communities which would make the system too unwieldy to use in the field. Although this classification has been devised for use in the field, similar problems may arise with the development of a natural urban habitat classification to be used with remotely sensed data. Surveys of urban wildlife habitats outside the Blackbrook Valley should therefore adapt the urban habitat classification, listed in Chapter Four, to suit their own area. If this classification is adapted rather than redesigned totally, it may be possible to maintain a degree of consistency in the results obtained therefore allowing comparisons between different urban areas.

11.5 Summary of conclusions about air photographs in urban wildlife habitat surveys

Large scale colour infra-red aerial photographs provide a very good data source for the surveying of urban wildlife habitats. Large amounts of detailed habitat information can be obtained.

At present such aerial photographic imagery is the best available for surveys of urban wildlife habitats. The resolution of satellite data has not yet reached a point where it can provide comparable detailed information. If the resolution of satellite data continues to improve and does not become cost prohibitive, digital satellite imagery may be able to replace large scale aerial photographs for this kind of survey.

The main limitation to the use of large-scale aerial photographs, especially colour infra-red, is the lack of suitable imagery currently available. A lot of imagery available for urban areas is of a smaller scale than 1:2500 due to the large geographical areas which it is necessary to cover. Although large scale, colour infra-red imagery has proven itself to be the best for urban wildlife habitat surveys, careful consideration will have to be given for each individual project as to whether the cost of obtaining such imagery is justified. If it is necessary to fly new imagery for a project, 1:2500 colour infra-red photographs will provide a very good data source for urban wildlife habitat studies.

11.6 The usefulness of large-scale aerial photographs in bird population prediction models

11.6.1 The usefulness of bird population predictive models

The review of bird population prediction studies (Chapter Eight) indicates that a good deal of research has been conducted into this topic, especially in the last 25 years. Primarily such studies have attempted to develop a predictive model of bird population numbers using a single habitat variable. With the increasing popularity of computers, investigations have also concentrated on developing population models based on a number of habitat variables. Generally these models have been restricted to quantifiable habitat variables, for example, habitat area and tree canopy diameters, although some studies have included more subjective variables such as the importance of oak (Balda, Gaud and Brown, 1983). Correlations identified between quantifiable habitat variables and bird population numbers are likely to be easier to repeat than correlations based on subjective variables.

Of all the variables used in bird predictive population models, the area of a woodland habitat is the most suitable variable to be obtained from aerial photographs. The area of a habitat can be accurately determined from air photographs.

Although the aim of this part of the analysis was to investigate whether air photographs could provide the information necessary to use with predictive models, the usefulness of such models is questionable. It is unlikely that breeding bird population numbers can be predicted by considering a single habitat variable. The area of a habitat will be an important influence on the breeding of bird species, but there is no agreement about this being the main influential habitat characteristic. The lack of knowledge about what factors are the most important to breeding bird species is emphasised by the number of different habitat variables used in breeding bird prediction models.

To overcome this problem, a number of multivariate predictive models have been devised but such studies tend to be too specific, relating to one particular bird species in one particular location (Balda, Gaud and Brawn, 1983). Thus these studies have little significance outside the area of investigation.

The reliance of predictive bird population studies on quantifiable variables is also another questionable aspect as psychological factors are likely to influence whether a bird will nest in a particular site (Van Tyne and Berger, 1976). James (1971) suggested that the likelihood of a particular bird species breeding in a site depends on the occurrence of a combination of particular habitat requirements occurring at one site, combining to form *the niche gestalt*. This theory implies that each bird has a characteristic perception field and makes its nesting decisions based on a predetermined set of specific search images. If this theory is correct, it is unlikely that real quantitative relationships between habitat variables and breeding bird species numbers will be identified.

It is therefore obvious that a good deal of research needs to be undertaken into bird population prediction models. The prime aim of this research project was not to develop new predictive models but to investigate whether air photographs could provide the information to input into existing population models. The results obtained however can only be as good as the original predictive model.

11.6.2 The relationship betwen the area of closed broadleaved woodland and breeding bird population numbers

Three species-area models were identified as being the most suitable to use for Saltwells Local Nature Reserve. The models were developed in similar wooded environments. Good correlations between the number of breeding bird species determined from the area of closed woodland were obtained using two of these models (Woolhouse, 1983 and Luniak, 1983). The predicted breeding bird species numbers was very close to the actual number of breeding bird species identified in a field survey by Harrison and Normand (1983). However if this relationship was real, one would expect all the breeding bird species to nest in areas of closed woodland. This was not the case. In addition the model to predict the number of individual breeding bird pairs from the area of closed broadleaved woodland developed also by Woolhouse (1983) produced inaccurate results.

These tests indicate that the area of closed broadleaved woodland measured from air photographs can be used successfully as an input into such models. Unfortunately the relationship between the predicted species numbers and the real species numbers could not be statistically tested as only one year of field data was available.

11.6.3 The relationship between the area of suitable available habitat and the breeding of individual bird species

As an extension of the investigations into the relationship between the area of habitat and the breeding bird population numbers, further tests were conducted to investigate whether any correlations existed between the total area of suitable habitats in Saltwells Local Nature Reserve and the likelihood of breeding of individual species. Although a significant relationship was found to exist between the amount of area of habitat and likelihood of species breeding, further tests into complexity of habitats, fragmentation of habitats and competition for habitats and species breeding were inconclusive. Again the statistical significance of these results is unknown due to the lack of more field data.

Although in Chapter Ten, the limitations of these results are discussed, the positive results identified indicate that further research into the relationship between the area of habitats and breeding bird population numbers may be worthwhile. This reseach indicates that habitat area information obtained from aerial photographs could provide the area data for these studies. However if bird population studies are to be based on multivariate models, large-scale aerial photographs will only be able to provide some of the data necessary, as only a few of the variables used in such studies to date, can be extracted from such imagery.

11.7 Methods to improve the study

The methodology for this project was very simple requiring a limited amount of equipment and capital expenditure. Although this can be advantageous, the methodology could be improved if the habitat data extracted from the aerial photographs could be stored on a computerized spatial data base.

At present there are four alternative approaches which could be used to improve the methodology of this study, making data analysis easier and making the data interpretated from the photographs more adaptable.

i) Manual photointerpretation and semi-automatic digitisation. The habitat boundaries, identified manually on the photographs, could be transferred on to a spatial data base using a manual digitiser. The coordinates of each boundary would be stored in a data base in vector format. Commercial digital mapping packages can be purchased relatively cheaply to use on micro or mainframe computers.

ii) Manual photointerpretation and automatic digitisation. Digitisation of habitat boundaries is completed using an automatic scanner which follows the boundaries and records the information in a vector format. Such scanners are expensive and still require intensive human involvement.

Both these methods record habitat boundaries which have been identified manually using habitat classification systems. Such systems should be designed to ensure the photographs are interpreted at the finest level of detail practical so that large amounts of data can be stored on the data-base and information can be manipulated to suit different aims.

iii) Digitised air photographs. The air photographs are digitised using video equipment. The reflectance of each part of the photograph is stored on video tape and can be analysed using image processing equipment. Areas of different pixel values are classified automatically by the system into different habitat types. The resolution of the automatic classification can only be as fine as the size of the individual pixel.

iv) Digital remotely sensed data. Such information is recorded originally in a digital format by sensors mounted on satellites or aeroplanes. The scale of this data depends on the sensor platform used. The data again is classified and analysed using an image processing system. Such image processing systems are very expensive and thus are not generally available for use.

Methods 1 or 3 are likely to be the most feasible for urban wildlife habitat studies, but whatever method is chosen, the existence of digital habitat data offers the potential for computer based automatic map production. This can increase the amount of data available for analysis and also make analysis more easy. As long as the photographic data is classified to the smallest level of classification possible, it should be easy to manipulate the data so that it can be used for other projects. For example, in this study, the habitat information interpreted from the air photographs was used in species-area models for breeding bird species. However if the habitat information had been stored on a computerised spatial data base, via data manipulation, it may have been possible to try and predict the population numbers of other species for example snails *Helix* species. The storage of the habitat data in a computerized spatial data-base would make the habitat information more adaptable to the aims of other projects.

Computerized habitat data could make a valuable input into a geographical information system. The data could then be analysed alone or combined with other relevant information, such as geomorphical data or land use details. If the habitat information was stored on such a system, it would be relatively easy to identify how the habitats have changed in relation to man's activities.

Large scale aerial photography, especially colour infra-red, can provide a very valuable data source to map urban wildlife habitats. The data obtained is very detailed and informative and maximum use can be made of this information if it is stored and analysed by computer. The Nature Conservancy Council has already set up a digital mapping system to use with aerial photographs, for the National Countryside Monitoring Project. The habitat information obtained from this study should be transferred on to this mapping system and any future urban habitat studies conducted by the Nature Conservancy Council should make use of this digital mapping system if possible.

Although digital data storage would be the ideal situation, authorities without such equipment, can still be able to produce very useful urban wildlife habitat studies using large-scale aerial photography and very simple equipment. Population predictions may be possible, but even if this is not so, the aerial photographs will provide a very useful and detailed data-base which should not be undervalued.

Appendix 1

The measurement of tree and shrub heights

A parallax bar was used to determine the height of a random sample of trees and shrubs. To calculate tree heights the difference between the levels recorded at the base of the species and the top of the canopy were measured.

The following equation was used to determine tree height

$$h = \frac{H^1 \times \Delta p}{b \times \Delta p}$$

h = tree height
H^1 = height of plane above ground = 420m
b = photographic scale
Δp = the difference between the measurements of ground level and tree canopy

For each tree, three measurements were recorded and the average of these figures was considered to be the tree height. To obtain canopy diameter measurements, the photographs were magnified and the canopies were measured on a millimetre scale. Two measurements, at right angles to each other, were taken and the mean of these two figures was considered to represent the canopy diameter.

The Mann-Whitney U Test for independent samples was calculated to determine whether there was a significant difference between the canopy diameters of trees above and below three metres.

H_0 the canopy diameters of species above and below three metres tall form part of the same distribution and the differences between them are the result of chance variations and therefore not significant.

H_1 canopy diameter of woody species more than three metres tall are significantly larger.

As the alternative hypothesis (H_1) specifies direction, a one-tailed test was needed. The rejection level was $\alpha = 0.05$ (95% probability level)

Table A1.1

Trees > 3 metres tall			Shrubs < 3 metres tall		
a	b	R_1	a'	b'	R_2
height (m)	canopy diameter (mm)	Rank of b	height (m)	canopy diameter (mm)	Rank of b'
2.17	2	17.5	3.4	4.5	30
1.4	1	2.5	3.09	1.75	12.5
2.03	1.25	7	8.9	3.5	26
2.76	2	17.5	4.38	2.25	21
2.4	2	17.5	3.78	2	17.5
2	2	17.5	4	4	29
1.9	3.5	26	5.47	3.5	26
1.9	1.25	7	5.47	6.5	33.5
1.9	3.25	24	4.6	1.25	7
1.48	1.5	10	4.4	3	22.5
1.85	1	2.5	8.7	3.75	28
1.85	1	2.5	8.07	6	31.5
0.92	1.25	7	9	6.5	33.5
1.04	1	2.5	9	6	31.5
2	1.75	12.5	9	1.25	7
1.08	1.75	12.5	9	2	17.5
1.75	1.75	12.5	9	3	22.5

$n_1 = 17$ $\bar{x} = 1.69$ $\Sigma R_1 = 198.5$ $n_2 = 17$ $\bar{x} = 3.57$ $\Sigma R_2 = 396.5$

$U_1 = n_1\, n_2 + 1/2\, n_1\, (n_1 + 1) - R_1$
$= 17 \times 17 + 1/2 \times 17\, (17 + 1) - 198.5$

$U = n_1\, n_2 + 1/2\, n_2\, (n+1) - R_2$
$= 17 \times 17 + 1/2 \times 17(17 + 1) - 396.5$

$U_1 = 243.5$

$U_2 = 45.5$

The lowest value of U is required thus

$U = n_1\, n_2 - U_1$
$17 \times 17 - 243.5$
$U = 45.5$

The critical value of U for a one-tailed test at $\alpha = 0.05$ (95% probability) and $n_1 = 17$ and

$n_2 = 17$ is 96.

For the null hypothesis to be rejected the calculated value of U (45.5) has to be less than the critical value of U (96). Thus we can accept the alternative hypothesis that there is a significant difference between the canopy diameters of woody species above and below three metres tall. However there will be an overlap in canopy diameter sizes. Thus the two distinct tree canopy populations can be visually represented.

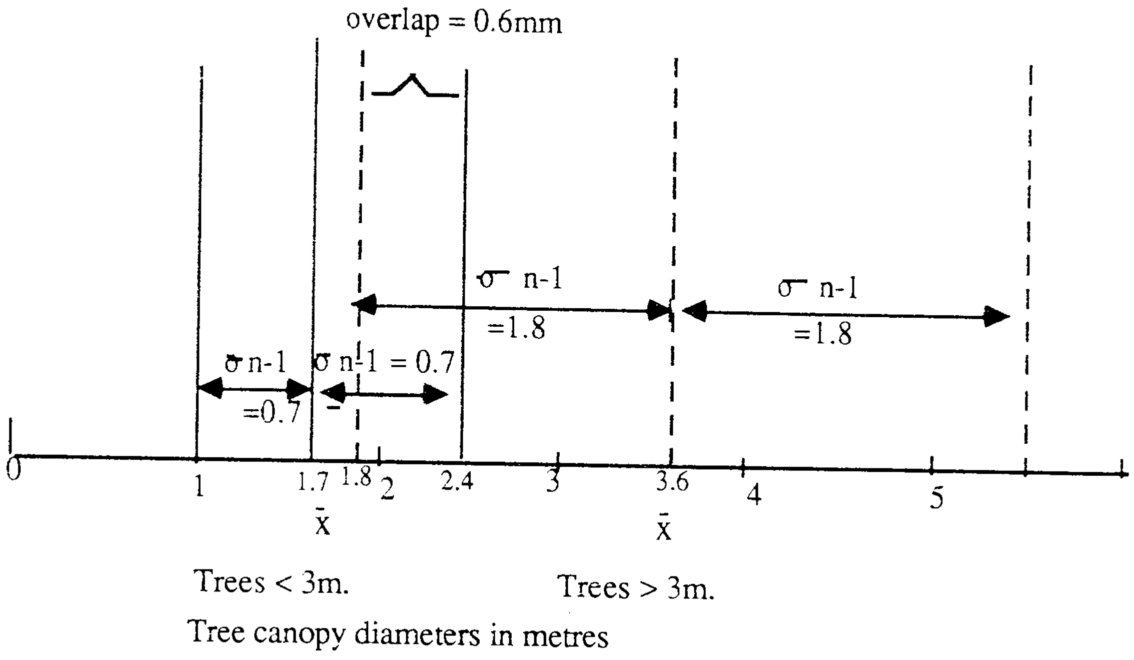


Figure A1.1 A sketch of the average canopy widths of trees above and below 3 metres tall.

The standard deviations of the canopy means were plotted. There is an overlap between the first standard deviations of both populatons of 0.6mm. This indicates that there is an approximate overlap of 15 per cent in the size of canopies of woody species above and below three metres. For interpretation purposes, it was decided to split this overlap. Species with a diameter of less than 2.1mm (1.8mm and 0.3mm) will be regarded as less than three metres tall and so classified as shrubs. Species with a diameter of more than 2.1mm are classified as trees as they are believed to be more than three metres in height.

Although this division is coarse the author believes it is adequate for the photo-interpretation purposes as the actual method of measuring height data from aerial photographs using a parallax bar is prone to error . At best however the height data can only be regarded as an estimate.

Appendix 2

Spearman's Rank Correlation Coefficient r_s

This test is used to determine the degree of association between two sets of values. It is a distribution-free test and it has a power-efficiency of about 91 per cent compared to the more rigid Product Moment correlation coefficient (r).

This test was used to determine whether there was any degree of association between
1) the number of habitat units and the amount of habitat edge per sample square and
2) the number of habitat units and the habitat patchiness index.

The following formula was used

$$r_s = 1 - \frac{6\Sigma d^2}{n^3 - n}$$

where r_s = the correlation coefficient
d^2 = the difference between the ranks of the two populations in question, squared
n = the size of populations

The hypotheses used for this analysis were:-

a) H_0 = no relationship exists between the number of habitat units and the amount of habitat edge (or the number of habitat units and the habitat unit index).

b) H_1 = there is a positive correlation between the variables.

In order to reject the null hypotheses with 95 per cent confidence, the calculated value of r_s had to be equal or more than the critical value of r_s which was 0.456. This is representative of the statistically significant value for a one-tailed directional test.

Table A. 2.1 The value of r_s calculated for the habitat patchiness analysis

Sample populations	r_s value	Statistically significant $\alpha = 0.5$
1981 developed land, habitat units/edge	0.87	√
1981 developed land, habitat units/index	0.81	√
1981 vegetated land, habitat units/edge	0.93	√
1981 vegetated land, habitat units/index	0.95	√
1984 developed land, habitat units/edge	0.68	√
1984 developed land, habitat units/index	0.67	√
1984 vegetated land, habitat units/edge	0.91	√
1984 vegetated land, habitat units/index	0.92	√

Appendix 3

The Mann-Whitney U Test

The Mann-Whitney U Test was used to determine whether there was any difference in the levels of patchiness recorded in the different land use types in 1981 and 1984. It is a non-parametric test therefore no assumptions need to be made about the characteristics of the population concerned. It has nearly 95 per cent of the power of the parametric Students 't' test. It can be used with unpaired data. It is based on calculating whether the difference in the mean of two independent samples is statistically significant, that is, the samples come from different populations.

For samples sizes above 9 the following formula is used

$$U = n_1 n_2 + 0.5 n_1 (n_1 + 1) - R_1$$

where U = the Mann-Whitney statistic
n_1 = the size of the smallest sample
n_2 = the size of the largest sample
R_1 = the sum of the ranks values of n_1.

In order to reject the null hypothesis and conclude that there was a significant difference between the two populations in question, the calculated U value had to be equal or less than the critical value of 72. This is the critical U value for a one-tailed test at 95 per cent confidence level for a sample size (n_1) of 15.

Table A. 3.1 The values of U calculated for the habitat patchiness analysis

Sample Populations	U value for habitat units	U value for habitat index	Statistical significance $\alpha = 0.5$ Habitat units	 Habitat index
1981 developed and vegetation samples	79	108	X	X
1984 developed and vegetation samples	78	99	X	X
1981 and 1984 developed land samples	110.5	54	X	√
1981 and 1984 vegetation land samples	112	86	X	X

Appendix 4

The Krustal-Wallis analysis of variance test

To determine whether the predicted bird species numbers from the two Woolhouse models (1983) and the Luniak model (1983) differed significantly, the analysis of variance statistical test was conducted. The test is non-parametric. It can be used to calculate whether a number of independently derived samples are in fact samples from the same population. This is done by comparing the means of each sample with the means of the other samples in the test.

The following formula is used.

$$H = \frac{12}{N(N+1)} \sum^{k} \frac{R^2}{n} - 3(N+1)$$

where H = the analysis of variance statistic
R = sum of the ranks in each sample
n = number of values in each sample
N = total number of values
k = number of samples

H_0 = There is no significant difference between the numbers of bird species predicted with the 3 models.

H_1 = There is a significant difference between the numbers of bird species predicted using the 3 models.

The level of rejection was $\alpha = 0.05$.

The figures analysed for the test were based on those figures quoted in Table 9.2.

Table A 4.1 The relationship between woodland area and the number of bird species

Woodland Area (ha)	Eq ii	R	Eq iii	R	Graph vi	R
41.2	32.2	**19**	37.34	**23**	33	**21**
40.2	32.1	**18**	37.55	**24**	32.5	**20**
14.4	25.66	**10**	26.16	**11**	28	**13**
7.0	21.59	3	20.39	**2**	20	**1**
21.4	27.84	**12**	30.05	**14**	31	**16**
8.93	22.8	**5**	22.19	**4**	23	**7**
9.78	23.33	**8**	22.9	**6**	24.5	**9**
31.18	30.35	**15**	34.25	**22**	32	**17**
		ΣR 90		**ΣR 106**		**ΣR 104**

$$H = \frac{12}{24(24+1)} \quad \frac{90^2}{8} + \frac{106^2}{8} + \frac{104^2}{8} \quad - \quad 3(24+1)$$

$$H = 0.38$$

The calculated value of H (0.38) is less than the critical value of H (5.99) at a 95 per cent probability level. The null hypothesis cannot therefore be rejected. The test indicates that there is no significant difference between the values predicted from the 3 models in question.

Appendix 5

The Mann-Whitney U Test

Of the common bird species identified as likely to breed in Saltwells Local Nature Reserve, a number of these have not been found nesting in the area. As the amount of suitable habitat in the reserve, for each species was calculated, the Mann-Whitney U test was carried out to see whether there was a significant difference between the area of suitable habitat available to the breeding and non-breeding species.

The following formula was used

$$U = n_1 n_2 + 1/2 n_1 (n_1 + 1) - R1$$

where U = the Mann-Whitney statistic

n_1 = the size of the smallest sample

n_2 = the size of the largest sample

R_1 = the sum of the ranks of n_1

As the sample size is above 20, it is not possible to use the U statistic. The U statistic needs to be converted into a z score. z scores are based on the normal distribution. As the size of the sample increases, i.e. above 20, the sampling distribution of U approaches the normal distribution.

$$z = \frac{U - 1/2\, n_1 n_2}{\frac{(n_1)(n_2)(n_1 + n_2 + 1)}{12}}$$

H_0 = The total area of suitable habitat for breeding and non-breeding birds forms part of the same distribution and the differences between the two are the result of chance variations.

H_1 = The amount of suitable habitat area available to breeding birds was significantly higher.

Table A 5.1 The relationship between the amount of suitable habitat available to breeding and non-breeding bird species

Breeding Species			Non-breeding species		
Species	Area (ha)	R	Species	Area (ha)	R
Blue Tit	31.39	52.5	Collared Dove	38.81	56
Chaffinch	31.39	52.5	Turtle Dove	24.18	46
Great Tit	31.39	52.5	Sparrow Hawk	21.65	45
Robin	31.39	52.5	Kestrel	21.44	42.5
Song Thrush	31.39	52.5	Tree Sparrow	21.44	42.5
Wren	31.39	52.5	Hawfinch	21.43	39.5
Mistle Thrush	28.66	48	Tawny Owl	21.43	39.5
Tree Creeper	28.66	48	Coal Tit	21.43	39.5
Woodpigeon	28.66	48	Longtailed Tit	17.65	35.5
Nuthatch	21.66	44	Willow Tit	16.96	33
Great Spotted Woodpecker	21.43	39.5	Lesser Whitethroat	16.12	28
Linnet	18.38	37	Nightingale	16.12	28
Whitethroat	17.65	35.5	Cuckoo	15.93	26
Blackbird	16.96	33	Pheasant	14.5	24
Redpoll	16.96	33	Redstart	14.22	22
Greenfinch	16.78	30.5	Tree Pipet	14.22	22
Bullfinch	16.78	30.5	Woodcock	11.75	20
Jay	16.12	28	Sedge Warbler	10.05	19
Wood Warbler	14.43	25	Grasshopper Warbler	8.06	17
Magpie	14.22	22	Little Owl	7.41	15.5
Dunnock	9.96	18	Yellow Hammer	7.41	15.5
Spotted Flycatcher	7.22	11.5	Goldfinch	7.22	11.5
Stock Dove	7.22	11.5	Green Woodpecker	7.22	11.5
Blackcap	7.0	6	Jackdaw	7.22	11.5
Chiffchaff	7.0	6	Lesser Spotted Woodpecker	7.22	11.5
Willow Warbler	1.03	1.0	Marsh Tit	7.19	8
			Garden Warbler	7.0	6
	$n^1 = 26$	$\Sigma R_1=871$	Meadow Pipet	5.76	4
			Yellow Wagtail	5.34	3
			Nightjar	2.92	2
				$n_2=30$	$\Sigma R_2=725$

U = 260

z = 2.13

A one-tailed test was carried out. The rejection level was α= 0.05. For a one-tailed test, at the 0.05 rejection level, the critical probability associted with z= 2.13 is 0.018. This indicates that it is 0.018 probability of the difference between the area totals of breeding and non-breeding species being due to chance. As the rejection level was set at 0.05 probability, the null hypothesis can be rejected and the difference is considered significant.

Appendix 6

The Mann-Whitney U Test

The aim of this test was to determine whether a significant difference existed between the area of suitable habitats for breeding and non-breeding woodland birds. On this occasion, the areas of suitable habitat available were adjusted to take into account any complex habitat requirements identified for certain bird species.

The formulas used are the same as those quoted in Appendix 5. The rejection level was set at $\alpha = 0.05$.

H_0 = There is no significant difference between the adjusted amount of suitable habitat area available to breeding and non-breeding bird species.

H_1 = There is a significant difference between the adjusted amount of habitat area available to the breeding and non-breeding bird species, i.e. the breeding bird species have a greater amount of suitable habitat available to them.

Table A 6.1 The relationship between the adjusted amount of suitable habitat available to breeding and non-breeding bird species

Breeding Species Species	Area (ha)	R	Non-breeding species Species	Area (ha)	R
Blue Tit	31.39	53.5	Collared Dove	19.08	42
Chaffinch	31.39	53.5	Turtle Dove	12.09	28
Great Tit	31.39	53.5	Sparrow Hawk	10.83	27
Robin	31.39	53.5	Kestrel	21.44	47.5
Song Thrush	31.39	53.5	Tree Sparrow	21.44	47.5
Wren	31.39	53.5	Hawfinch	21.43	44.5
Mistle Thrush	25.04	49.5	Tawny Owl	21.43	44.5
Tree Creeper	25.04	49.5	Coal Tit	21.43	44.5
Woodpigeon	14.33	29	Longtailed Tit	17.65	39.5
Nuthatch	18.04	41	Willow Tit	8.43	21
Great Spotted Woodpecker	21.43	44.5	Lesser Whitethroat	16.12	33.5
Linnet	9.19	22	Nightingale	16.12	33.5
Whitethroat	17.65	39.5	Cuckoo	15.93	31
Blackbird	16.96	37.5	Pheasant	10.74	26
Redpoll	16.95	37.5	Redstart	10.61	25
Greenfinch	16.78	36	Tree Pipet	7.11	18.5
Bullfinch	16.12	33.5	Woodcock	5.88	14
Jay	16.12	33.5	Sedge Warbler	10.05	24
Wood Warbler	14.43	30	Grasshopper Warbler	4.03	11
Magpie	7.11	18.5	Little Owl	3.71	9.5
Dunnock	9.96	23	Yellow Hammer	3.71	9.5
Spotted Flycatcher	3.61	5.5	Goldfinch	3.61	5.5
Stock Dove	3.61	5.5	Green Woodpecker	3.61	5.5
Blackcap	7.0	16	Jackdaw	3.61	5.5
Chiffchaff	7.0	16	Lesser Spotted Woodpecker	3.61	5.5
Willow Warbler	1.03	1.0	Marsh Tit	7.19	20
			Garden Warbler	7.0	16
	$n^1 = 26$	$\Sigma R_1=889.5$	Meadow Pipet	5.76	13
			Yellow Wagtail	5.34	12
			Nightjar	2.92	2
				$n_2=30$	$\Sigma R_2=706.5$

$U = 241.5$

$z = 2.44$

For a one-tailed test at the 0.05 rejection level, the critical probability associated with $z = 2.44$ is 0.016. As this probability is below the 0.05 level selected, the null hypothesis can be rejected. The difference between the amount of area available to the breeding and non-breeding birds is significant.

Appendix 7

The Chi^2 test

This test was conducted to investigate whether the difference between the numbers of breeding bird species with complex habitat requirements was significantly different to the numbers with simple habitat requirements.

The Chi^2 test is a method for comparing nominal data. It is a simple test which works by testing the distribution actually desired in the field against a theoretical distribution determined by the null hypothesis. It is not a very powerful statistical test and tends to be used when there are no other suitable alternatives. In this instance, this was the only testwhich was suitable for the data in question. The rejection level was set at $\alpha = 0.05$.

The Chi^2 formula is simple

$$X^2 = \sum \frac{(O - E)^2}{E}$$

where X^2 = Chi^2

O = observed frequencies

E = expected frequencies

H_0 = There is no relationship between the likelihood of a bird species breeding and the complexity of its habitat requirements.

H_1 = There is a significant difference between the numbers of breeding bird species with complex habitat requirements and the numbers breeding with non-complex habitat requirements.

Table A7.1 The Chi^2 test

	Breeding species		Non-breeding species		
	O	E	O	E	
Complex habitats	8	10.68	15	12.32	$\Sigma r = 23$
Non-complex habitats	18	15.32	15	17.68	$\Sigma r = 33$
	$\Sigma k = 26$	$\Sigma k = 30$			$N = 56$

$$X^2 = \frac{(8 - 10.68)^2}{10.68} + \frac{(18 - 15.32)^2}{15.32} + \frac{(15 - 12.32)^2}{12.32} + \frac{(15 - 17.68)^2}{17.68}$$

$$X^2 = 2.13$$

The critical value of X^2, at one degree of freedom $\{(r-1)(k-1)\}$ and at the 0.05 probability level, is 3.84. As the calculated X^2 value (2.13) is less than the critical value (3.84), the null hypothesis cannot be rejected.

This test thus suggests that there is an equal probability of bird species with complex or non-complex habitats breeding in Saltwells Local Nature Reserve.

Appendix 8

The Mann-Whitney U Test

The amount of suitable habitat available to each common woodland species was adjusted to take into account competition for that particular habitat. The total area of each habitat type in the Reserve was divided equally between all the species likely to use that habitat.

The Mann-Whitney equation used is listed in Appendix 5. The rejection level was set at $\alpha = 0.05$.

H_0 = There is no significant difference between the amount of suitable habitat area available (after competition) to breeding and non-breeding bird species.

H_1 = There is a significant increase in the amount of suitable habitat area available (after competition) to breeding bird species in comparison to the non-breeding bird species.

Table A 8.1 The relationship between the amount of suitable habitat available to breeding and non-breeding bird species after habitat competition

Breeding Species

Species	Area (ha)	R
Blue Tit	1.54	48.5
Chaffinch	1.54	48.5
Great Tit	1.54	48.5
Robin	1.54	48.5
Song Thrush	1.54	48.5
Wren	1.54	48.5
Mistle Thrush	1.63	53
Tree Creeper	1.63	53
Woodpigeon	1.63	53
Nuthatch	1.42	45
Great Spotted Woodpecker	1.04	39.5
Linnet	0.98	35.5
Whitethroat	0.72	27.5
Blackbird	0.72	27.5
Redpoll	0.71	27.5
Greenfinch	0.67	22.5
Bullfinch	0.67	22.5
Jay	0.82	33
Wood Warbler	0.8	31
Magpie	0.5	8
Dunnock	0.59	12.5
Spotted Flycatcher	0.59	12.5
Stock Dove	0.22	3.5
Blackcap	0.22	3.5
Chiffchaff	0.6	1.0
Willow Warbler	0.22	3.5

$n^1 = 26$ $\Sigma R_1 = 804$

Non-breeding species

Species	Area (ha)	R
Collared Dove	2.13	56
Turtle Dove	1.35	43
Sparrow Hawk	1.41	44
Kestrel	1.04	39.5
Tree Sparrow	1.04	39.5
Hawfinch	1.04	39.5
Tawny Owl	1.04	39.5
Coal Tit	1.04	39.5
Longtailed Tit	1.7	55
Willow Tit	0.98	35.5
Lesser Whitethroat	0.71	25.5
Nightingale	0.67	22.5
Cuckoo	0.67	22.5
Pheasant	0.66	20
Redstart	0.84	34
Tree Pipet	0.8	31
Woodcock	0.8	31
Sedge Warbler	0.65	19
Grasshopper Warbler	0.53	9
Little Owl	0.63	18
Yellow Hammer	0.6	16.5
Goldfinch	0.6	16.5
Green Woodpecker	0.59	12.5
Jackdaw	0.59	12.5
Lesser Spotted Woodpecker	0.59	12.5
Marsh Tit	0.59	12.5
Garden Warbler	0.22	3.5
Meadow Pipet	0.77	29
Yellow Wagtail	0.46	7
Nightjar	0.23	6

$n_2 = 30$ $\Sigma R_2 = 792$

U = 327

z = 1.03

For a one-tailed test the critical probability of z = 1.03 is 0.159. As this probability level is above the rejection probability level of 0.05, the null hypothesis cannot be rejected. This z value indicates that the differences in the 2 sample sets could have occurred by chance 15 times out of every 100 occasions.

Appendix 9

The Mann-Whitney U Test

This test was conducted to determine whether the species with the largest number of individual suitable habitat units were more likely to breed. The null hypothesis is stated in Chapter 9, section 9.7.4.

Table A 9.1 The relationship between the number of habitat units available and the likelihood of the bird species breeding

	Breeding Species		Non-breeding species		
Species	Number of habitat units	R	Species	Number of habitat units	R
Blue Tit	137	47.5	Collared Dove	220	55
Chaffinch	137	47.5	Turtle Dove	218	54
Great Tit	137	47.5	Sparrow Hawk	89	26
Robin	137	47.5	Kestrel	26	9.5
Song Thrush	137	47.5	Tree Sparrow	26	9.5
Wren	137	47.5	Hawfinch	25	6.5
Mistle Thrush	111	35	Tawny Owl	25	6.5
Tree Creeper	111	35	Coal Tit	25	6.5
Woodpigeon	111	35	Longtailed Tit	143	51.5
Nuthatch	90	27	Willow Tit	133	43
Great Spotted			Lesser Whitethroat	86	20.5
Woodpecker	25	6.5	Nightingale	86	20.5
Linnet	227	56	Cuckoo	77	15
Whitethroat	143	51.5	Pheasant	115	38.5
Blackbird	133	43	Redstart	107	32
Redpoll	133	43	Tree Pipet	107	32
Greenfinch	124	40	Woodcock	146	53
Bullfinch	86	20.5	Sedge Warbler	115	38.5
Jay	86	20.5	Grasshopper Warbler	132	41
Wood Warbler	4	1.0	Little Owl	95	29.5
Magpie	107	32	Yellow Hammer	95	29.5
Dunnock	112	37	Goldfinch	86	20.5
Spotted Flycatcher	86	20.5	Green Woodpecker	86	20.5
Stock Dove	86	20.5	Jackdaw	86	20.5
Blackcap	21	3	Lesser Spotted		
Chiffchaff	21	3	Woodpecker	86	20.5
Willow Warbler	56	13	Marsh Tit	30	11
			Garden Warbler	21	3
	$n^1 = 26$	$\Sigma R_1=828$	Meadow Pipet	62	14
			Yellow Wagtail	45	12
			Nightjar	92	28
				$n_2=30$	$\Sigma R_2=768$

U = 303

z = 1.43

For a two-tailed test with a z-value of 1.43, the critical probability is 0.162. As this probability figure is greater than the 0.05 rejection level, the null hypothesis cannot be rejected.

Appendix 10

The Mann-Whitney U Test

As there is no relationship between the number of suitable habitat units available and the breeding of bird species, this test was conducted to investigate whether the average size of unit habitat area available to each species has any influence on the breeding of that species. The same conditions apply as in Appendix 9. The null hypothesis is listed in Chapter Nine, section 9.7.4.

Table A 10.1 The relationship between the likelihood of bird species breeding in the average size of suitable habitat unit

Breeding Species			Non-breeding species		
Species	Area (ha)	R	Species	Area (ha)	R
Blue Tit	0.229	37.5	Collared Dove	0.176	29
Chaffinch	0.229	37.5	Turtle Dove	0.111	17
Great Tit	0.229	37.5	Sparrow Hawk	0.243	43
Robin	0.229	37.5	Kestrel	0.825	50.5
Song Thrush	0.229	37.5	Tree Sparrow	0.825	50.5
Wren	0.229	37.5	Hawfinch	0.857	53.5
Mistle Thrush	0.258	45	Tawny Owl	0.857	53.5
Tree Creeper	0.258	45	Coal Tit	0.857	53.5
Woodpigeon	0.258	45	Longtailed Tit	0.123	19.5
Nuthatch	0.241	42	Willow Tit	0.128	23
			Lesser Whitethroat	0.187	31.5
Great Spotted Woodpecker	0.857	53.5	Nightingale	0.187	31.5
Linnet	0.081	7.0	Cuckoo	0.207	34
Whitethroat	0.123	19.5	Pheasant	0.126	21
Blackbird	0.128	23	Redstart	0.133	26
Redpoll	0.128	23	Tree Pipet	0.133	26
Greenfinch	0.135	28	Woodcock	0.080	6
Bullfinch	0.187	31.5	Sedge Warbler	0.087	14
Jay	3.608	56	Grasshopper Warbler	0.061	3
Wood Warbler	0.133	26	Little Owl	0.078	4.5
Magpie	0.089	15	Yellow Hammer	0.078	4.5
Dunnock	0.084	10.5	Goldfinch	0.084	10.5
Spotted Flycatcher	0.084	10.5	Green Woodpecker	0.084	10.5
Stock Dove	0.333	48	Jackdaw	0.084	10.5
Blackcap	0.333	48			
Chiffchaff	0.018	1	Lesser Spotted Woodpecker	0.084	10.5
Willow Warbler			Marsh Tit	0.239	41
			Garden Warbler	0.333	48
$n^1 = 26$		$\Sigma R_1 = 834$	Meadow Pipet	0.093	16
			Yellow Wagtail	0.119	18
			Nightjar	0.032	2

$n_2 = 30$ $\Sigma R_2 = 762$

U = 297 z = 1.52

Again the critical probability for this z value is larger (0.134) than the rejection level (0.5), therefore the null hypothesis cannot be rejected.

Appendix 11

The Mann-Whitney U Test

This test was conducted to investigate whether the average number of units per suitable habitat type had any influence on the breeding of bird species. The null hypothesis is recorded in section 9.7.4 of Chapter Nine. The same conditions apply as in Appendix 9.

Table A 11.1 The relationship between the average number of units per habitat and the likelihood of the bird species breeding

Breeding Species

Species	Average number of units per habitat type	R
Blue Tit	27.4	37.5
Chaffinch	27.4	37.5
Great Tit	27.4	37.5
Robin	27.4	37.5
Song Thrush	27.4	37.5
Wren	27.4	37.5
Mistle Thrush	18.5	14
Tree Creeper	18.5	14
Woodpigeon	18.5	14
Nuthatch	18	12
Great Spotted Woodpecker	21.4	23
Linnet	37.3	53
Whitethroat	21.5	27.5
Blackbird	21.5	27.5
Redpoll	12.5	5.5
Greenfinch	25.2	34
Bullfinch	23.8	32.5
Jay	33.3	51
Wood Warbler	33.3	51
Magpie	41.3	55
Dunnock	28.6	43.5
Spotted Flycatcher	28.6	43.5
Stock Dove	4.0	1.0
Blackcap	21	20
Chiffchaff	21	20
Willow Warbler	13	8

$n^1 = 26$ $\Sigma R_1 = 775$

Non-breeding species

Species	Average number of units per habitat type	R
Collared Dove	27.5	41
Turtle Dove	31.1	48
Sparrow Hawk	22.3	31
Kestrel	8.7	2.5
Tree Sparrow	8.7	2.5
Hawfinch	21.4	23
Tawny Owl	21.4	23
Coal Tit	48.7	56
Longtailed Tit	28.8	46
Willow Tit	33	49
Lesser Whitethroat	19	16.5
Nightingale	19	16.5
Cuckoo	21.5	27.5
Pheasant	21.5	27.5
Redstart	21.5	27.5
Tree Pipet	21.5	27.5
Woodcock	15	9.5
Sedge Warbler	12.5	5.5
Grasshopper Warbler	12.5	5.5
Little Owl	12.5	5.5
Yellow Hammer	23.8	32.5
Goldfinch	33.3	51
Green Woodpecker	28.6	43.5
Jackdaw	28.6	43.5
Lesser Spotted Woodpecker	38.5	54
Marsh Tit	16.4	11
Garden Warbler	21	20
Meadow Pipet	20.7	18
Yellow Wagtail	15	9.5
Nightjar	30.6	47

$n_2 = 30$ $\Sigma R_2 = 821$

$U = 356$ $z = 0.55$

The null hypothesis cannot be rejected as the probability level (0.617) associated with $z = 0.55$ exceeds the level of rejection (0.05).

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