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CONTAINS PULLOUTS

THE APPLICATION OF REMOTE SENSING
TO CONSERVATION EVALUATION

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Being a thesis presented by Janet E.Nichol, in accordance with the regulations governing the award of the degree of Doctor of Philosophy of the University of Aston in Birmingham.

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SUMMARY

In view of the growing need to consider the value of large areas of countryside for the purposes of wildlife conservation, it was proposed to investigate remote sensing techniques as a means of providing a suitable data base for the collection, storage and evaluation of ecological data relevant to the needs of conservation evaluation.

Two main study areas, one upland, one lowland, were chosen according to air photo availability and habitats were mapped for each area. These habitats corresponded mainly in the upland area to vegetation units, and in the lowland to land use categories. The air photos used were black and white prints at the scale of 1:10,000 and mapping categories were derived from previously defined classifications. In neither study area was it possible to identify all the a priori defined categories. An air photo study was undertaken to map vegetation according to an a priori defined classification. This study in the Moor House National Nature Reserve achieved a low level of accuracy. The need to develop classifications based on air photo interpretable criteria is therefore suggested. The parameters used for conservation evaluation - species diversity, vertical strata and local scarcity - were compared to subjective evaluations (made by a group of eminent ecologists) of the habitat types, and it was possible to suggest the relative importance of each criterion. The best indicators of conservation value were found to be local scarcity in the upland, and vertical strata in the lowland study areas.

An experiment carried out to determine the optimum grid square

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size for data collection found that data collected at square size groupings larger than the basic $\frac{1}{4}$ kilometre grid square gave, in the upland region, an acceptable level of information loss. In the lowland study area, however, the level of information loss was greater.

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CHAPTER I

CONSERVATION EVALUATION

1. The Problem.

In a densely populated country such as Britain, interested groups working in ecology and conservation have only relatively recently realised the need to identify more definite and far reaching aims than, as stated in the 1949 National Parks and Access to the Countryside Act, to "preserve and enhance the natural beauty of the countryside". The ecological movement has succeeded in replacing this one-time philosophy of 'preservation' with that of 'conservation' an essentially anthropocentric concept since its ultimate aims are the perpetuation of earth's resources for the use and enjoyment of man. It incorporates the need for a deeper scientific understanding of the environment in order to maintain it as close as possible to a state of balance.

The processes of technical production and cultivation methods introduced during the agricultural revolution have been blamed for helping to diminish the richness of the original British flora and fauna and for narrowing the range of environmental sites, both major factors contributing towards inbalance in the environment.

The problems are now recognised as being not merely ecological ones, however. Ash points out the "realisation by ecologists that they must involve planners in their ideas of 'a world in balance'", since science being 'a response to human needs, is a social phenomenon". (Ash 1972).

Accompanying changes have also taken place in the planning field in Britain during the last few years and this again is a response to unprecedented population growth accompanied by increased demands on land. In sympathy with L D Stamp's "range of environmental conditions" in Britain (Stamp,1969) is the move towards regional planning and the recent local government reorganisation. Most of Britain is now covered by Regional Development Plans and the Town and Country Planning Act of 1971 specified that one of the responsibilities of the planning authorities for the re-organised regions should be to examine and keep under review

> "(a) the principal physical and economic characteristics of the authority (including the principal purposes for which land is used" (Town and Country Planning Act, 1971).

The contribution of ecological information to the process of environmental planning would, therefore, be effective at the regional level. The aim in this context would be to protect the areas most interesting ecologically by allowing only compatible forms of land use, with necessary development taking place in the least interesting areas. However, in competition with other land uses such as those of agriculture, forestry, or urban, conservation for wildlife has distinct disadvantages in that, even should data on wildlife be available or obtainable its value as a land use is difficult, if not impossible to measure in quantitative terms. Bunce and Shaw state the situation clearly with

> "In any serious conflict of interest the paucity of ecological facts nearly always places conservation at a disadvantage compared with the alternatives for which more tangible and therefore convincing arguments can be presented. (Bunce and Shaw, 1973).

2. Evaluation of Wildlife

Thus the urgency to state their case in more concrete terms is becoming apparent among ecologists working in the field of conservation evaluation. In an attempt to do so Helliwell classes the value of wildlife to man under the following groups:- (Helliwell, 1973)

(a) Production (1) Actual meat, fish etc.
    (11) Potential - reserve of material for breeding
        - control of pest species, pollination,
        - facilities for research work and training in scientific methodology.

(b) Recreation (1) Education - to broaden one's mind
    (11) Natural history studies, photography etc..
    (111) Contribution to landscape, or character of a locality.

He defines wildlife as "all macroscopic organisms other than those which have been domesticated introduced or bred" and goes on to discuss their value in both monetary and non-monetary terms.

In spite of the fact that Helliwell has been criticised by Hooper for the allocation of numerical values to subjective judgments (Hooper 1970) it seems that adegree of consensus will be obtained only when ecologists have become confident enough to give personal opinions about values. Values must necessarily, by their very nature, be subjective and thus, are easy to criticise.

Apart from the need for a greater degree of standardisation in ecological evaluation studies, it has also been recognised that there is a need to consider, in ecological terms, the whole of the landscape, including neglected and vegetated sites within urban areas, agricultural and unenclosed land, as well as the more obvious, already protected National Parks, Areas of Outstanding Natural Beauty, Nature Reserves etc. However, this is often difficult due to the lack of the necessary information for the whole areas of countryside, or the inability to collect it efficiently.

Of the relatively few studies already undertaken for ecological evaluation by bodies such as the Nature Conservancy, Planning Authorities and Universities, the earlier ones have, on the whole, been concerned with restricted areas and particular habitat types, e.g. Tubbs and Blackwoods' survey of chalk grassland, (Tubbs and Blackwood, 1970) and all studies have been independently carried out, using different types of data and data collection techniques, different evaluation parameters and with differdnt weightings attached to each parameter. Some similar problems are apparent in the field of Landscape Evaluation. These include the difficulty of evaluating landscapes subjectively, of combining subjectively derived values and of extension of locally-designed methods to be of general regional or county value. (See Weddle, 1969).

3. Habitat Parameters used in Conservation Evaluation.

A composite list of the habitat parameters used by the existing methodologies for conservation evaluation of an area of countryside is given below:

Size
Shape
Vegetation Species Diversity
Inter-and Intra-Habitat Diversity
Faunal Species Diversity
Distance from nearest similar feature
Vertical Structure of Vegetation
Degree of Naturalness
Rarity of Individual Species and Rarity of Habitat Type.

The parameters are important individually but additionally, each may be dependent on, or be enhanced by, the value of another parameter, e.g. Faunal Species Diversity may be a function of Vegetation Species Diversity, or of Vertical Structure of the Vegetation. In considering the parameters individually, these relationships will now be described in more detail.

Size

The size of a habitat is important in determining its value for wildlife. This is due to the fact that large sites can support a greater number of each species, and also a greater number of different species (Helliwell, 1973). The number of birds occupying a wood will be limited by the number of territories which can be accommodated within the wood. However, there appears to be a size reached, varying according to the particular type of habitat, at which the number of different species will not increase significantly with further increases in size (Hopkins, 1955). Size also affects the stability of a habitat (Moore, 1962). Thus, if a habitat is reduced in size its key species become liable to extinction through inbreeding or accident.

Shape

The shape of a habitat also affects the species composition. Williamson (1967) concluded that areas of scrub, to be of maximum use to birds, should be at least one acre in extent and have an irregular outline. Elton states that the edge of a wood "is usually richer in species of plants and animals than the heart of closed scrub or wood", (Elton, 1966). On the whole this is because edges tend to harbour plants and animals of both types of habitat and an edge is often a transition between vegetation of different heights, or vertical layers. Hedges are generally classed as woodland edge and although incapable of harbouring such species as nightingale, which needs a minimum of two acres, they contain, according to the Warwickshire check list, many more species than woods (Readell, Hawkes and Cadbury, 1965). 131 species are noted as occurring in both hedges and woods, as against 48 species in woods but not hedges.

Vegetation Species Diversity.

In terms of ecological value, species diversity is important in that the presence of a large number of different plant species in a habitat will support a large number of different animal species which depend on the vegetation for their individual cover and food. Each animal has its own particular niche and food requirements which may be provided by only one, or a few plant species. Another advantage of species diversity is that high species diversity is usually related to a high degree of stability of the habitat (Westhoff 1971) but this is not always the case. Species diversity is usually measured by estimating the number of different species present, though percent cover could also be considered. A study by University College (Conservation Course,1972) (Appendix 1) of the Wye Valley and surrounding upland, concluded that "the interest of (these) upland zones may lie more in the combination of the plant associations represented, rather than in their species or structural diversity", since it was found impossible to give similar weightings to species diversity in upland and lowland land systems. This conclusion is supported by the fact that Holdgate (1971) and Helliwell (1973) also consider habitat diversity, i.e. the number of habitats on one site, to be an important factor.

Inter- and Intra-Habitat Diversity

No study has yet included this parameter, i.e. the range of different habitat types in an area and the amount of variety within a habitat. Yet these are major considerations in reserve management. Ovington (1964) stresses the fact that in woodland nature reserves it is "important to have represented as many different types of woodland as possible".
Helliwell (1973) states

> "....an area which has a wide variety of habitat types will be of greater value than an area of uniform type,

and habitats with a variety of age and structure and with only a limited amount of disturbance will be of greater individual value to wildlife conservation". As well as diversity between habitats, (inter-habitat diversity), diversity within habitats is also considered important. This can include features such as terrain variations and irregularities, relief differences, dissection by stream channels, rock outcrops, presence of boulders etc.

Faunal Species Diversity (related to Vertical Structure of Vegetation.

Because of the obvious difficulty of counting animal species in a habitat, plant species diversity and vertical structure of the vegetation are generally used to indicate this factor. Elton (1954) maintains that the structure of a habitat is often more important to animals than its species composition, and that animals often recognise their habitats structurally, by the vertical layers present. He says:

> "Many animals have vertical day and night movements ...the harvestman (Leiobunum rotundatum) spends the day on tree trunks at various heights, coming down at night to search for prey in the ground zones and field layer" (Elton 1954).

He recognises four formation types in the terrestrial system which are

1. Open ground
2. Field layer
3. Scrub layer
4. Woodland.

And in the Aquatic system, eight vertical layers but only three of which, Bottom, Water Mass and Water Surface, are associated only with the water body itself.

Distance from the Nearest Similar Feature.

It is not known how much importance should be attached to the contiguity factor in ecological surveys but it is generally agreed that contiguity does have a degree of influence on species richness. Other things being equal, the more isolated the site, the lower the number of species it will contain in relation to its size.

Moore (1962), working on heathland in Dorset, found that very small isolated areas of heath were characteristically unstable and had a poorer fauna. A distance of 5 kilometres from the main heath areas was found to be effective in preventing the occurrence of certain animal species, but with higher plants such as trees, much smaller distances seemed to be effective. It can be seen, therefore, that hedges, which provide continuity between patches of scrub or woodland, are capable of providing a link by which a species can pass from one wood to another. In a well wooded and hedged area the value of a hedge in providing continuity will be considerably lower than in an area of few hedges.

Vertical Structure of Vegetation (discussed under Animal Species Diversity, above.

Degree of Naturalness.

This is also a difficulty parameter to quantify, since virtually no natural vegetation still exists in Britain and it is not known to what extent man has influenced many of the present semi-natural communities. Consequently few studies deal with naturalness as a criterion for evaluation, although Westhoff (1971) describes four degrees of naturalness in the landscape, i.e. natural, sub-natural, semi-natural and cultivated. On the whole, naturalness is related to diversity and stability of ecosystems and its importance lies largely in these two criteria. Harrison and Warren (1970) state:

> "Communities representing earlier stages in the succession towards the climax state exhibit low species diversity, simple food chains, violent fluctuations in species numbers and are vulnerable to environmental changes".

Mutch, discussing managed systems, says:

> "...they lose diversity and inherent stability as intensity of management increases".

On the whole, therefore, the closer a system is to its natural state, the greater the number of species, and the greater the stability. A complicating factor is that the disturbance of only part of an area will increase the species diversity of the area as a whole, as colonising plants become established.

Rarity of Individual Species.

The importance of this parameter is based on the fact that the value of a species or habitat increases as its abundance decreases. According to Ratcliffe (1971) "Rarity of habitats and communities is probably of greater importance than rarity of species" and Scott (1972) states that "rare species occur in rare habitats". The majority of studies (e.g. Warwickshire County Council, 1971, Conservation Course, 1972, Scott, 1972) use rarity of habitat type rather than individual species rarity. The question of rarity is important at varying levels, i.e. local, regional, national and international, and should ideally be measured at all these levels, since national and international rarity are significant at the regional and local planning levels; moreover, within the planning process, control is often at this level. Measurement of rarity, however, is difficult if not impossible, owing to the lack of records but Helliwell's study using the Atlas of the British Flora (Helliwell, 1974) was able to consider rarity of species at the national, regional and local levels, these being defined in sizes of 10 km. grid squares.

The importance of rarity is illustrated by the consideration of lowland heath in England. Having lower species diversity than, for example, permanent pasture, it is rated higher in ecological value because of its scarcity at the national level. Dune heath in England, moreover, is rare enough to warrant consideration at the international level.

4. Need for a Methodology.

The need for a standardised methodology for use in conservation studies and land use planning is obvious. This would enable comparison between different areas so that planning for wildlife could be carried out not only locally but on a national scale. It would have to be applicable to a range of conditions, including both upland and lowland, rural and urban areas and be capable of incorporation into the planning framework. In general the value of such a methodology would increase, the more objective and accurate it became; however, it must be realised that one developed primarily for planning purposes must take into account the particular level of the planning process at which it is to be applied; this consideration will then decide the level of accuracy required, balanced against the speed and efficiency of the survey which would be conditioned by the planning budget. Experience with county planning authorities indicates that at the regional planning level the most useful methodologies are the simplest ones, often at the expense of ignoring some of the less important features, or time-consuming data collection.

The rapid collection of ecological information at the regional survey scale is now possible with the increase in the availability of aerial photographs. These are now being used by planning authorities, universities and commercial bodies, though their use is still limited by the availability of suitable and up-to-date air photo cover.

5. The Wildlife Habitat

In an attempt to simplify data collection and evaluation in ecological surveys, both by field methods and using aerial photographs, habitats have generally been used since they represent broadly homogeneous units containing similar internal conditions for wildlife.

'Habitat' is defined as "the environment in which a species exists" (Conservation Course 1972) and because animal species, to a large extent, depend for their food and cover on the structure and composition of the vegetation, vegetation is generally used as the basic mapping unit for the wildlife habitat (see Bunce and Shaw, 1973). Other non-vegetational features may be important in providing variety of food and cover in a particular habitat and may be essential for the existence of some plant and animal species, e.g. ponds, streams, rock outcrops, field boundaries. Thus a complex of additional features should be considered during the data collection stage.

6. Mapping Categories

In the absence of an adequately comprehensive classification of habitats in Britain, it is at present necessary to devise a separate classification of habitat categories for each region to be evaluated. For example, in the Merseyside planning region special consideration has to be given to a category of 'Unimproved mossland', which would not occur in most other planning regions and existing habitat classifications. Additionally, categories developed for a remote upland region would almost certainly correspond mainly to vegetation mapping categories, having gradual indistinct boundaries between one type and another which would be difficult to distinguish in the field. In a more densely settled region, however, as in lowland England, where little or no semi-natural vegetation exists, mapping categories based on habitats would be more likely to correspond to land use types, featuring distinct and concise boundaries between them. The Biological Sites Recording Scheme does provide a comprehensive method for classifying habitats, based initially on vegetation structure but this is not considered suitable or detailed enough for all levels and methods of data collection, particularly over large areas of countryside. (See Appendix I).

It is important that the mapping units chosen, of whatever type, are compatible with broader, standard classifications which have already been recognised in the appropriate fields of study, such as vegetation mapping or land use studies. This is particularly so in the absence of established habitat classifications, or those adapted to the capabilities of a data source such as aerial photographs.

7. Data Storage and Evaluation.

There are two types of areal unit for which data can be stored and evaluations made. This generally depends on the type of survey to be undertaken. Grid squares tend to be preferred for surveys of the whole landscape and discrete areas for surveys of a defined habitat type. Although there are many obvious disadvantages (Forestry Commission, 1970), grid squares are emerging as a basis for most types of planning information; they can be grouped or subdivided according to the required accuracy level; they are uniform in area and are stable reference units covering the whole country. Use of the grid square simplifies the situation when more than two different types of planning information have to be compared. Boundaries are constant and values can be combined for corresponding areas.

Evaluation of an area of countryside has usually consisted of weighting each of the parameters used (see description of parameters, above) for each habitat type, and combining the weightings for each grid square by multiplication or addition, based on the proportion of that habitat type in each square.

One of the major difficulties has been concerned with weighting the parameters relative to each other. (See Appendix I for descriptions of the major ecological evaluation surveys carried out in recent years).

There are still many questions in ecological surveying to be answered, including not only what types of data to collect, what evaluation parameters and weightings to use for each parameter, but also whether a greater degree of objectivity can be obtained at all. O'Connor questions the very basis of objecttivity in ecological surveys by saying:

> "It is not clear whether universally applicable criteria are available, or whether each land area must be treated as a special case.... Nor is it yet clear to what extent criteria derived from established ecological principles provide a better basis for value judgment than the collective views of experienced naturalists that a particular area of habitat is valuable from their point of view".

However, for a particular level of survey it should be possible at least to specify standardised survey techniques and the types of data which should be collected, within the limits of the resources and technology available for data acquisition. At the regional planning level it seems that aerial photographs are replacing ground survey methods. Although they are able to considerably reduce the time taken for ecological surveys of large areas, their cost is often prohibitive, unless they can be seen to provide a useful data source for other types of planning information as well. For the purpose of a specified type of survey, however, it is necessary to know what is the amount of useful information which can be obtained from air photos, what type of information can be collected, how much field checking will be necessary and obviously what film types scale of air photos, time of year, day etc., would be best to obtain the information required.

Thus, the mapping categories and parameters used in ecological evaluation surveys should be considered from the point of view of air photo capability, e.g. can information about size, shape, species diversity etc. related to wildlife habitats be obtained from an aerial photograph? What would be the best time of year to obtain this information and what are the best types of film emulsion and data processing and enhancement techniques to use? It is suggested that more should be known about the data collection process for surveys of large areas before refinements in data evaluation can be effected.

Chapter II will deal with Remote Sensing and its applications to ecological survey, with particular reference to vegetation mapping. Expanding on this, Chapter III describes a study undertaken in the Moor House Nature Reserve to evaluate the capabilities of aerial photography for mapping vegetation in accordance with established vegetation classifications; and Chapters IV, V and VI deal with the two main study areas, Gairloch and Merseyside. The aims are to show, at the reconnaissance scale, or at a scale suitable for county and regional planning requirements, the data collection, processing and evaluation stages of an air photo based survey of wildlife habitats in each area, and thus to assess remote sensing techniques in relation to conservation evaluation. The final Chapter will suggest a simplified methodology which could be used by planning authorities for rapid, first stage surveys in both upland and lowland areas.

CHAPTER II

REMOTE SENSING

PART I REMOTE SENSING AND AERIAL PHOTOGRAPHS

I. Introduction

Remote sensing is defined as 'the art of acquiring information about an object while at some distance from it'. There has been a remarkable increase during the last decade in its applications for the collection of information related to earth's resources. The stimulus for this growth has been the vastly increased and urgent need for knowledge about the earth's surface, the environment, and interelationships of features in the environment, which are more rapidly, and often better documented from a synoptic view. On-going research in the remote sensing field is concerned especially with dealing with the vast amounts of data accumulated, the main emphasis being on rapid, machine-assisted data extraction, data enhancement, and storage.

In Britain, the unsuitability of the weather for flying during most of the year and particularly in the winter months, is a disadvantage; April, May and June being the best. Much research still needs to be done on finding the best times of year for photographing different features or types of resources. For general vegetation surveys the question should be asked, "When do the maximum differences in tone and/or colour occur between different vegetation types, which would produce the greatest degree of contrast on a corresponding image?".

The understanding and interpretation of a remotely sensed image is aided by a small amount of experience, but is further enhanced by the understanding of certain basic principles of remote sensing which, if considered in their entirety, can fully explain the appearance of an object on an aerial photograph. There are several kinds of remote sensing devices designed for acquiring information using different parts of the electromagnetic spectrum e.g. Radar and Thermal Infra-red detectors, but since these systems are not yet operational in Britain, this account will be limited to remote sensing in the visible and near infra-red regions only (see Figure I).

2. The Electro-Magnetic Spectrum

The sun emits a continuum of wavelengths over a sizeable distribution of the spectrum, but some of the energy propogated is lost via interactions with the atmosphere, while the rest continues to the target. It can be seen from the transmission graph that the atmosphere has well defined 'windows', which will permit the passage of certain wavelengths, while others are restricted. For example, good atmospheric windows occur in the visible and near infra-red parts of the spectrum.

At each stage in the remote sensing process, energy in the form of photons generated by the sun, reacts with matter i.e. atmosphere, target (object), filter and film, and when a photon strikes matter it can be either absorbed, emitted, scattered or reflected (see Figure 2).

But because absorption, emission, scatter and reflection are

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The regions of the electromagnetic spectrum. (Subcommittee I, Photo Interpretation Committee, American Society of Photogrammetry, *Photogrammetric Engineering,* 29:761–799, 1963)

Figure 2 Diagram of energy flow (after Holz,1973)

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selective with regard to wavelength, and are specific for that kind of matter, depending on its atomic and molecular structure, it is possible to identify an object from a photograph which is sufficiently detailed.

The fact that the final recorded image is dependent on wavelength permits both prediction of the appearance of an object on a photograph, and the detection of different objects using different wavebands i.e. multispectral remote sensing which exploits unique energy signatures.

There are difficulties, however. There is never a predictable interaction between photons and matter, since scatter occurs before and after contact with the object and also at the object itself. Also, the atmosphere contributes to the total energy hitting the object, so the true reflected signal may be affected by radiation from other sources.

Scattering (see Appendix II) is performed by particles in the atmosphere, including gases, haze, fog, rain, snow, smoke etc. and its effect is to intercept and deflect light energy from its path between sun, object and camera. Scattering is selective according to wavelength and has more effect in the shorter wavelength, blue part of the spectrum; thus it is possible to photograph through some of the smaller particles such as haze by using a film sensitive to the longer wavelengths, such as infra-red film with a yellow filter to cut out blue light.

The amount of <u>reflection</u> from an object depends on the angle of incidence, on roughness, on the intensity of light energy incident on the object, and on the object's absorption characteristics with respect to wavelength i.e. spectral reflectance, which varies considerably within the visible spectrum, fresh snow being capable of 70-90% reflectance and coniferous forests as low as 3%. Furthermore, selective absorption determines colour, so that an object absorbing red and blue light will appear green.

The amount of reflectance from an object can be measured at different wavelengths, using a spectrophotometer, and it is thus possible to tell what part of the spectrum would be best for distinguishing between objects (Figure 3).

Additional factors which can affect the quality and information content of an aerial photograph are summed up by Roedel (1972). (See Appendix III).

3. The Photographic Process

On exposure to incoming radiation from an object, the sensitive silver bromide or silver halide crystals on the film absorb photons and are changed to metallic silver, one grain of silver bromide needing, on the average, four photons to become sensitised. A film made using larger crystals to catch all incoming photons would produce grainy pictures.

A filter can be used to change the spectral balance of energy reaching the film, and since it is used to exclude some of the wavelengths to which the film is sensitive, its spectral transmission must be chosen in conjunction with film sensitivity, e.g. a yellow, minus blue filter is often used with panchromatic film to minimise the effects of atmospheric haze

Figure 3 Prediction of photographic tones from spectral analysis (from Manual of Photographic Interpretation, 1960).

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Figure 4 Curve showing the spectral transmission characteristics of a 'minus blue' filter (from Manual of Photographic Interpretation, 1960).

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(Figure 4).

Densitometric analysis methods are now being used to analyse remotely sensed images according to the density of the image on the photograph compared with light reflected from the corresponding object. Eventually it may be possible to identify automatically different objects on the ground, based on their image density in different wavebands i.e. from their spectral signatures.

4. Air Photo Interpretation

Photographic interpretation is defined as "The act of examining photographic images for the purpose of identifying objects and judging their signifance", (American Society of Photogrammetry, 1960).

Image Quality

Of the many opinions as to what constitutes a good aerial photograph, four main criteria emerge. These are:-

Tone Contrast - Often seen as the most important single element, it refers to the difference in tone between objects and their background, or adjacent objects.

Image Sharpness - This accounts for the abruptness with which the tone, or colour contrast appears to take place on the photograph.

Stereoscopic Parallax - A three-dimensional image can be obtained on overlapping adjacent photographs, of an area common to both photographs, if set up under a stereoscope. The 3-D image obtained contributes greatly to the separation of objects of different height which may be similar in tone.

Resolution - This refers to the capability of the photographic system to distinguish between small objects, and is defined as the ability to render a sharply-defined image, measured in lines per millimetre. Because resolution falls off at high and low exposure levels, the washed-out appearance of broad-leaved trees on infra-red photographs is partly due to poor resolution caused by exposure levels set to record less reflective objects in the same scene e.g. shaded areas. Detection of certain objects smaller than the resolution capability of the system however, is possible due to the ability of certain very bright objects in a dark background 'contaminating' neighbouring grains of film through reflection; also, long, narrow objects such as telegraph wires may resolve since their length results in exposure to several silver bromide grains.

Fundamentals of Air Photo Interpretation

Because the vertical view presents objects in an unfamiliar aspect, attention to certain characteristics of air photos can aid in i~~n~~dentification. These characteristics are size, shape, shadow, tone and colour, texture, pattern, site and association. The first six of these criteria are obvious since they refer to the actual objects in question. In circumstances where few easily identifiable features are available, it may be possible to use knowledge of site, or association with adjacent features. For example, the interpretation of vegetation is often difficult, owing to similarity of tone, texture and pattern of different vegetation types. However, changes in vegetation type may be accompanied by changing site conditions e.g. moisture, or slope gradients, which are appropriate to each vegetation type. Similarly, identification of a particular species may be confirmed by the known presence of another species commonly associated with it. Thus, as a general rule, the photo-interpreter should proceed from known to unknown features, and from the general to the specific. Maps, literature and ground data can also be valuable aids.

5. Photogrammetry

This is defined as "The science or art of obtaining reliable measurements by means of photographs", (American Society of Photogrammetry, 1960). There are many accounts of photogrammetric techniques available, e.g. Avery T E (1968), American Society of Photogrammetry (1960). See Appendix IV

6. Film Emulsions

The most widely used type of film for aerial photography is panchromatic, of which there are several types, varying in speed, resolution and contrast. It is particularly useful in Britain, since the film has a wider exposure latitude than any other, which makes it useful for poor weather conditions. The other main types of film used are True Colour, Panchromatic Infra-red and False Colour Infra-red (or camouflage detection film). Of these four film types, the two panchromatic are single emulsion films and the true colour and false colour infra-red are multi-emulsion films i.e. consisting of more than one sensitive layer (Figure 5).

The layers in the colour film are sensitive to blue, green and red light and those in the false colour film to green, red and infra-red light. Panchromatic film, however, can be confined

Figure 5 Graphs showing the sensitivities of true colour and false colour infra-red film types (from Jones, 1971).

True colour **False Colour infra-red**

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Figure 6 Sensitivities of three types of panchromatic film (Jones, 1971).

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by filtration to specific narrow bands of the spectrum to produce multispectral photography.

Panchromatic film

This type of film is capable of registering the entire visible spectrum, 400-600m, in black and white (Figure 6), and it is agreed by most authorities that its use with a minus blue filter to reduce haze, gives the best film-filter combination for general purpose use. Panchromatic film has high resolution, though for some purposes its use is restricted by the fact that colours in nature are reproduced by a limited number of recognisable shades of grey.

Although air survey companies should be capable of specifying types of film and filter to be used, mistakes are not unknown, and thus it is useful to understand some of the uses and characteristics of different types of film with regard to specific survey requirements. Additionally, interpretation must often take these factors into account. For a fuller description of True Colour, Panchromatic Infra-red, False Colour Infra-red and multispectral photography, see Appendix V.

7. Technology for Remote Sensing Data Enhancement

None of these techniques, apart from Additive colour, are as yet operational. They are relevant because of their potential in dealing with the large amounts of data produced by remote sensors, and they are therefore described in Appendix VI.

PART II REMOTE SENSING APPLICATIONS TO VEGETATION AND ECOLOGICAL SURVEY

I. Introduction

Ecology is, by its nature, multidisciplinary, since it is based on the interelationships between organisms on the ground and their environment. Remote Sensing too, in providing a generalised view of the earth's surface, is concerned with the complex of features on the ground which make up the total environment. The uses of remote sensing techniques in ecology should therefore be considerable, but in practice, the field is little advanced in Britain. The Russian approach to remote sensing is described by Komarov (1968), the works of the C.S.I.R.O. in Australia by Christian, (1952) and the D.O.E. in Britain by Bawden, (1967). All emphasise the landscape, or land systems approach to remote sensing, an approach which is based on the interelationships of features on the ground which produce a distinctive, and often characteristic pattern on an aerial photograph (Nichol, 1974). These patterns may comprise many components within a particular land system which contribute to its distinctiveness e.g. vegetation, soil type, geology, drainage, agricultural and settlement systems, etc. and it may be difficult to isolate each component on an aerial photograph to produce a thematic map. The remainder of this chapter investigates this possibility in relation to vegetation.

As suggested in Chapter I, the evaluation of large areas of countryside for conservation is dependent on finding suitably efficient and rapid methods for the collection of ecological information. Since the basic mapping unit, the wildlife habitat, depends largely for its ecological interest on the vegetation component, then vegetation mapping must be considered one of the most important factors in ecological survey. In semi-natural environments, vegetation is often used as an indicator of other environmental features and in a more densely settled region, land use types with similar vegetational characteristics can be mapped as a single habitat category, since they are likely to have a similar wildlife value. Thus in evaluating the uses of remote sensing for ecological survey, the emphasis is on vegetation mapping.

2. The Development of Aerial Photography for Vegetation Mapping

Until very recently, few small scale botanical surveys took place in Britain. Reconnaissance and medium scale mapping of vegetation is still in its early stages, and little use has, therefore, been made of aerial photographs. This accompanies a concern in Europe for the detailed classification of vegetation and plant/habitat relationships, as opposed to an interest in overall distribution of vegetation types over large areas, as in the United States. After the development and refinement of remote sensing techniques during the second world war, the tradition in the United States, of small scale surveying, was well suited to their use, and early surveys were carried out by Burks and Wilson (1939) and Colwell (1944).

Some of the first workers in Britain to recognise the potential uses of air photos for vegetation mapping e.g. Stapledon and Davies (1936), Fenton (1951) and Taylor (1961), either did not in fact use them, or used air photos only to check or verify boundaries already distinguished by field observations. Stapledon and Davies and Tivy mentioned the differences in colour of moorland plant associations, particularly in the autumn as being useful for recognising them at a distance. Fenton foresaw the usefulness of colour aerial photography in relation to the range of colours in moorland vegetation, and Taylor's vegetation survey of Wales at a scale of 6 inches to I mile used aerial photographs to check boundaries of some of the more recognisable types, such as bracken. However, all stress the need for quantitative field data to support visual observations either in the field or from aerial photographs.

Thus, the high levels of detail required, and a strong dependence on precise definitions and classifications of plant communities in Britain has meant that vegetation mapping is still an underworked field. In order to be able to compare plant communities in different areas, and to use them as a basis for more detailed studies, it is necessary to use existing classification methods. This is the a priori approach to vegetation mapping. In a priori classifications detailed vegetation data obtained from field sampling is sorted and divided according to certain physiognomic or floristic criteria and the categories are thus derived.

In the United States, on the other hand, there has been a preference for a posteriori classifications (Kuchler,1966). Categories are derived from direct observations of plant communities in the field, or from field work and aerial photographs combined. The end result is a vegetation map free from preconceived ideas, but possibly unrelated to other areas which have been classified using either approach.

Studies of the a posteriori type are recognised in Britain as being of limited value to the ecologist. The Second Land Use Survey, for example, covering all areas of moorland and mountain pasture in England, was mapped by community and visual dominance within the community, estimated from field observations. It is recognised that units obtained in this way can be highly variable (Eddy et al 1968), since no account is taken of quantitative floristic or physiognomic factors (Shimwell 1971).

Certain notable studies of vegetation in Britain have not used aerial photographs at all, depending entirely on field quadrat data to provide the detailed information on physiognomy and floristic composition necessary in a priori classifications. Examples are Poore's study of Scottish mountain vegetation (Poore, 1955) and Ratcliffe's study of the vegetation of the Carneddau (Ratcliffe, 1954). Edgell, studying the vegetation of Cader Idris (Edgell, 1969), used aerial photographs only to locate stands after the sampling and classification stages had been completed.

3. Recent Applications

Very recently, aerial photographs have been used by several bodies in Britain for the identification and mapping of vegetation types, with field work used only to verify the initial air photo interpretation. These studies are mainly concerned with upland vegetation and the mapping of large areas of grassland, heaths and bogs.

The Dartmoor survey (Perkins 1971) was undertaken partly in order to produce a vegetation map suitable as a basis for more detailed studies. Mapping categories were chosen using an association analysis classification after field quadrat sampling; thus nine categories, based on percent cover and species presence or absence were obtained. Seven of these were easily distinguished on 1.15,000 scale colour aerial photographs, on the basis of colour, texture and topography, and a vegetation map with a high accuracy of 88.5% was produced.

Goodier and Grimes (1970), have discussed the vegetation mapping of the Rhinogau and Snowdon mountainous areas in North Wales from the point of view of air photo feasibility. For the Rhinogau Study, three different types of classification were evaluated. There were:-

1. Poore's phytosociological classification, achieved by grouping field quadrat data on the basis of physiognomy, dominance and floristic composition. (Poore, 1955).
2. The Association Analysis method, grouping on the basis of species presence or absence (Ivimey-Cook and Proctor 1966).
3. By initial photo interpretation, deriving categories on an a posteriori basis, comparable with Kuchler's Comprehensive Method (Kuchler 1966).

Although some correlations were observed between the three types of classification, differences were large enough to make direct relation between the two a priori classifications and between field data and the air photo images impracticable. This is a result of the fact that an air photo image is produced by a combination of the complex relationships on the ground between plants and features such as soils, geomorphology, drainage, etc., and may bear little relationship to the actual characteristics of the vegetation categories which are used in a priori classifications. A multidisciplinary approach is suggested (after Vink, Vestappen and Boon, 1965) in which geomorphology in particular plays an important role. For example, both a study carried out in Gairloch (Goldsmith, 1970), and the Rhinogau study noted difficulties in distinguishing moss heath communities in the highest mountains where large areas of bare rock were exposed, the main photo expression of these areas being geomorphological rather than vegetational.

It is recognised, however, that if a priori classifications are not fully suitable for relation to air photo mapped units, neither do a posteriori classifications take full advantage of the rapid mapping potential of air photos, since a considerable amount of field work is required to analyse the characteristics and vegetational composition of all the mapped units.

Goodier and Grimes, therefore, suggest that efforts should be made to develop classifications suitable for application to photo-ecology.

Clearly the development of this type of photo-ecological classification would need to take into account the abilities and limitations of different types of remote sensing systems for obtaining ecological information relevant to the requirements of the mapping project. Defining the optimum type of photography for a particular purpose would include considerations such as scale, time of day, time of year and film and filter type. However, the fact that the ecologist generally has to use any available air photo cover, limits his ability at the present time to specify particular requirements.

4. Scale

Opinions on scale vary between workers studying different resources in different areas. For example, scales of 1:100,000 and satellite imagery are frequently used in the United States and Canada for mapping forest vegetation. In Britain, the predominant growth forms are smaller, e.g. heaths and grasslands, thus necessitating larger scales of imagery. The fact that much of Britain has been covered by 1:10,000 scale Ordnance Survey photography seems to support the view (Ward et.al., 1971), that this is a good general survey scale for Britain.

The level of detail required, depending on photographic quality, generally determines scale, though the smaller the scale, the fewer the prints required so that costs and handling difficulties are kept to a minimum.Additionally the overall view is often valuable in determining the broader plant-environment relationships which may be easier to define from a single, as opposed to several photographs.

Goodier and Grimes (1970) found that panchromatic photography of the Rhinog Mountains at 1:10,000 scale was adequate for distinguishing most of the significant plant communities, and related well to the size of vegetation units. On Dartmoor, however, Jones, working with 1:10,000 scale photography concludes that scales of 1:15,000 to 1:20,000 would have been better for vegetation mapping, since less detail was required.

5. Timing

The aim in vegetation mapping should be to chose a time of year when maximum tonal differences exist between different vegetation types, and a time of day when the sun angle will best show these differences. In addition, tone, texture and stereo height, may change at different times of year. Steiner (1966), working in mountainous areas in Central Europe, found that at the end of May and early June, improved pasture could be distinguished from unimproved, using panchromatic photographs, since at this time of year, the lush green growth of the improved pasture gave it a darker tone on the photographs than the brownish tones of unimproved. Later in the year, the two types appeared similar. One problem observed in mountainous terrain was that the phenology of plants can vary significantly over short distances owing to large variations in altitude.

In Britain, Williams (1972), working in chalk grassland suggests that the best time of year for photography would be late June or early July, at the time of flowering, or maximum growth, when tone and texture differences should be at a maximum. However, workers in agriculture have found that the best time for crop species differentiation is in the early growth stages, and ecologists mapping moorland vegetation have found that the end of the growing season, when plants are dying back is the optimum time. According to Ward et.al., (1972), many species show characteristic colours at this time of year. Nardus stricta appears whitish, Tricophorum caespitosium, tawny, Eriophorum species, reddish, etc. An important observation by Goodier and Grimes (1970) is that some plant communities, e.g. bracken, will not be readily apparent either in the field or on aerial photographs outside the main growth and flowing period. Thus, the interpretation of dominance and sub-dominance in plant communities from air photos is also subject to the seasonal growth phenomenon.

Few British workers have commented on the best time of day for photographing vegetation.

6. Film Type

In spite of the growing popularity of colour film for vegetation mapping panchromatic film is still seen as having many advantages, including higher contrast and larger amounts of detail available, less variability in quality due to processing and flying conditions, and lower costs per print. Colwell (1965) states that panchromatic film with a green filter is the best combination, since panchromatic film gives maximum detail due to its high resolution. The green filter transmits green light, where foliage reflectance is highest, but cuts out blue, red and infra-red light, thereby partially excluding haze, partially excluding glare in the orange and red band, and the problems of over-and under-exposure due to the great range of infra-red film are avoided. Other workers in the United States, (Joy, Harris and Rader, 1960), (Carneggie, 1968) maintain, however, that for range resource inventories and forest type mapping, many kinds of information can be extracted from colour better than from black and white, including species composition and maturity, and terrain features such as surface roughness, and ground moisture.

Of the few stated opinions in Britain, less convincing arguments emerge in favour of the use of colour photography for vegetation mapping. Grimes and Hubbard working in coastal marshland vegetation (Grimes and Hubbard, 1971) state that no advantages are gained from using colour over panchromatic. Goldsmith (1972) however, states that of the four film types used in the Gairloch area, true colour was superior to the others mainly due to the greater ease of interpretation, but that there was only a narrow margin of superiority over panchromatic.

False colour photography is being used in an increasing number of studies, particularly those concerned with vegetation and water resources, due to the high and low levels of reflection respectively from each. It has been used very little in Britain and present evaluations of its use are based on little experience of the film type. There are many misconceptions and claims about the uses and capabilities of false colour film, mainly stemming from the fact that reflectance of infra-red radiation from plant surfaces is not fully understood. False colour film has been used in forestry and agriculture for the mapping of diseased and dying vegetation, since changes in reflectance of a dying plant occurring in the infra-red part of the spectrum may cause changes in the corresponding photographic image. Thus healthy vegetation will appear bright red on a colour infra-red photograph, while diseased, or less healthy vegetation may deviate from the red colour. Physiological disturbances to plants are generally accompanied by an increase in visible reflectance, but the change in reflectance of infra-red radiation may be quite variable.

J.E.Colwell (1974) moreover, maintains that reflectance from a vegetation canopy is a function of many factors such as leaf angle, look angle, percent of bare soil exposed, size of leaves, structure of the canopy, etc. Therefore, in diseased plants changes in reflectance may be caused by changes in the geometry and density of foliage, as much as by changes in the actual reflectance characteristics.

The uses of multispectral photography for vegetation studies are difficult to estimate, since again, little work has been carried out. Studies of agricultural land in Britain by Bell (1971) however, indicate that automatic crop identification using multispectral photography is a possibility, but that further studies, using more extensive air photo cover and specialised equipment, are needed.

As stated at the beginning of this section, vegetation is one of the most important factors in ecological survey for the purposes of conservation evaluation. The description and classification of vegetation is seen as essential in providing a scientific basis for objectively assessing the relative importance and conservation priorities of different areas. Shimwell (1971) sees one of the main applications of vegetation analysis as "to provide a scientific phytosociological, phytogeographical, and ecological basis for nature conservation."

With these considerations in mind, it was decided to attempt to establish semi-quantitatively to what extent aerial photographs could be used for the mapping of vegetation communities which had been defined by field work using a phytosociological classification. Chapter III therefore deals with a vegetation mapping project using aerial photographs and field maps of part of the Moor House National Nature Reserve in the Northern Pennines.

CHAPTER III

AERIAL PHOTOGRAPHS RELATED TO VEGETATION IN THE MOOR HOUSE NATIONAL NATURE RESERVE.

1. Introduction.

In order to provide a quantitative assessment of the capability of aerial photographs for the interpretation of a priori classified vegetation units, an area was chosen where the vegetation had been mapped in sufficient detail using a phytosociological classification. The only suitable area located proved to be the Moor House National Nature Reserve in the Northern Pennines (Figure 7).

The reserve ranges in altitude from 300 to 850 metres and comprises a steep western escarpment, a central ridge and a gently sloping eastern plateau. There is heavy rainfall, soils are waterlogged and blanket bog covers over half the area, (being predominant on the eastern plateau). Podsols, peaty podsols and rankers exist as thin soil on the fell tops along the central ridge and thin brownearths cover the isolated limestone outcrops.

The original mapping of the reserve vegetation (Eddy et al 1968) was carried out in 1960 and 1961, though fieldwork was not completed until 1967. Mapping categories were chosen according to physiognomy, floristic composition and dominance of the stands. Initial units were chosen subjectively, based on the general physiognomy of the vegetation, the main criteria being an appearance of uniformity in the field, according to all the properties, including soils, which could be observed. The units were then described according to quadrat cover values i.e. the average percentage cover of the dominant species in quadrats spaced evenly over each unit. Thirty vegetation types identified during field work were regrouped to give sixteen map units shown in Table 1.

Figure 7

Aston University

Illustration removed for copyright restrictions

2. Methods Used in the Present Study Using Aerial Photographs.

9 x 9 inch black and white air photoprints flown at a scale of 1:20,000 in October 1971 were obtained of a part of the reserve (Figure 8) along with the corresponding field maps at the 6 inch scale.

The air photos and maps were studied in order to become familiar with the vegetation types found in the area, with their site characteristics regarding drainage conditions, aspect, elevation etc. and with their corresponding air photo image. Since only a limited area had stereo cover, this area was chosen for the purposes of the study and amounted to approximately two thirds of one photographic frame, corresponding to part of the eastern plateau and central ridge.

Without further consultation of the field maps, interpretation was carried out using a stereoscope, vegetation boundaries being drawn onto a transparent photographic overlay and the units allocated to a vegetation category. Boundaries were then transferred to a 6 inch map using a Zeiss Transferscope and the resulting vegetation map can be seen as Figure 9 (pocket).

The accuracy of mapping was assessed by using a dot grid sampling system with one hundred evenly spaced dots per kilometre square, each dot representing an area of $100m^2$ on the ground. The dots were counted on the basis of being rightly or wrongly interpreted for each vegetation type mapped and, for the latter, it was recorded into which category they had been wrongly placed. The total number of points falling in each type, the total number wrongly identified as a particular type, and the percentage of correct interpretations for each type, were obtained. Separate totals were obtained for the three types comprising Blanket Bog, Fens and Flushes, and Grassland and Dry Ground vegetation respectively. (Table 1).

Figure 8 Stereo pair of black and white photographs at reduced scale showing part of the Moor House National Nature Reserve. The study area is outlined in black.

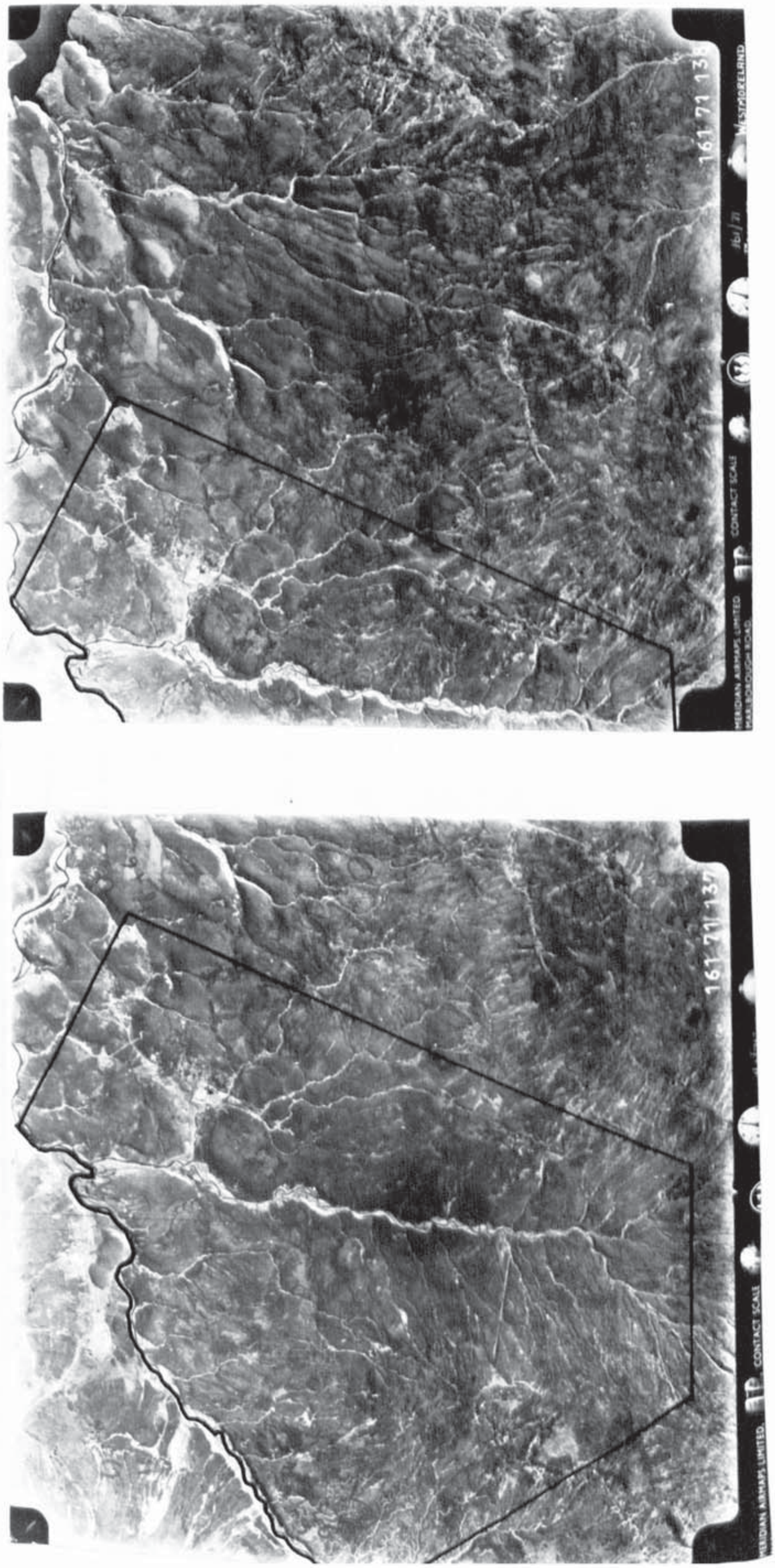

TABLE 1.

Vegetation mapping from air photos: Moor House

	Calluneto-Eriophoretum	Tricophoro-Eriophoretum	Eriophoretum	Eroding Bog	Recolonised peat complexes and peat edge vegetation	Sphagneto juncetum. effusi	Juncetum squarrosi sub-alpinum (spp poor)	Nardetum sub-alpinum (spp poor)	Festucetum	Agrosto-Festucetum	Sphagneto-Caricetum	Springs and flushes	Sandstone scree	Made ground	Peteridietum	Flushed Gleys	Points Misinterpreted	% Correct Interpretation	TOTAL POINTS
Calluneto-Eriophoretum	572	1	8	58	54	11	10	16	2	4	1	3	-	-	-	1	169	70.5%	741
Trichophoro-Eriophoretum	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	100%	5
Eriophoretum	40	-	78	11	11	2	6	6	2	1	-	-	-	-	-	-	79	49.7%	157
Eroding Bog	1	-	1	10	-	-	-	2	-	4	-	-	-	-	-	-	8	55.6%	18
Recolonized peat complexes and peat edge vegetation	62	-	8	33	149	-	-	4	-	-	-	-	-	-	-	-	107	58.3%	256
Total for blanket bog																	364	69.1%	1177
Sphagneto-Juncetum-effusi	1	-	-	1	-	4	-	-	-	-	-	-	-	-	-	-	2	66.6%	6
Total for fens and flushes																	2	66.6%	6
Juncetum squarrosi sub-alpinum (spp poor)	4	-	5	9	-	-	18	4	-	-	-	1	-	-	-	-	23	44%	41
Nardetum sub-alpinum (spp poor)	3	-	1	-	-	-	1	5	-	-	-	-	-	-	-	-	5	50%	10
Festucetum	1	-	4	3	2	-	2	5	3	-	-	-	-	-	-	1	18	15%	21
Agrosto-Festucetum	9	1	4	7	-	4	2	10	-	38	-	-	-	-	-	-	37	50.7%	75
Total for grassland and dry ground vegetation																	83	43.6%	147
OVERALL TOTAL																	448	66.3%	1330

Subsequently, based on the results obtained, some of the categories comprising similar types were amalgamated and the percent accuracy was calculated. (Table 2).

3. Mapping and Interpretation.

Ten of the sixteen categories originally mapped in the reserve were estimated to occur in the restricted area studied. The brief description of these units below, includes features related to physiognomy, situation and species composition which are thought to be capable of affecting the image of a vegetation type on an air photo. It must be realised, however, that the mapped units are amalgamations of the original thirty vegetation units distinguished in the field e.g. the Calluneto - Eriophoretum category included a typicum, a burnt facies, a Sphagnum recurvum facies and an Empetrum facies. The photographic appearance of each type is also described.

Blanket Bog Types.

1. Calluneto - Eriophoretum

This largely represents uneroded bog below 630 metres. Extensive burnt patches are in various stages of a 20 year period of succession to mature bushes, with initial recolonisation by Eriophoretum. It is found on sloping ground with few pools and an average depth of peat of 2 metres. Appearance on the air photos is very fine textured, mid-grey, with lighter burned patches of Eriophorum.

2. Tricophoro - Eriophoretum.

This type has very little extent in the reserve, as in the Pennines as a whole, being confined to almost flat and flat areas below 600 metres. These areas are very wet, frequently occurring in hollows and along streams and are often characterised by a pool and hummock topography. The air photo appearance is very light grey often with lighter blotches corresponding to hummocks.

TABLE 2 RESULTS FOR AMALGAMATED VEGETATION TYPES : MOOR HOUSE

CATEGORY	Correctly Interpreted Points	Total Points	Percent Accuracy
1 Calluneto-Eriophoretum Tricophoro-Eriophoretum Eriophoretum	704	903	77.9
2 Recolonised Peat Eroding Bog	192	274	70.1
3 Blanket Bog (Categories 1 and 2,above)	1102	1177	93.6
4 Fens and Flushes *	4	6	66.6
5 Juncetum-squarrosi sub-alpinum	18	41	43.9
6 Grassland Types +	61	106	57.5

N B * Includes Sphagneto-Juncetum effusi

+ Nardetum Nardetum subalpinum
Festucetum
Agrosto-Festucetum

3. Eriophoretum

This corresponds to high level blanket bog and is often found where Calluna has been reduced by burning and/or grazing. It has a fairly large extent in the western, higher areas as a result of both grazing and the cooler climate. In areas where grazing pressure is high, many grasses occur, and this type grades into Juncus squarrosus sub-alpinum at higher levels where peat is thinner. Appearance is very smooth textured on slopes, slightly lighter in tone and less patchy than Calluneto-Eriophoretum, and it is often dissected by channels downslope.

4. Eroding Bog.

This is described as blanket bog where more than 30% of the original surface has been removed by erosion and less than half the newly exposed surface is recolonised. It can be characterised by intensive dissection by deep gullies, or less intensive dissection by an open network of gullies. The photo interpretation of this type is aided by stereo viewing, the surrounding bog surface being at the former level of the eroded bog, and darker in tone. The larger, eroded areas appear light grey in tone and are at a lower level.

5. Recolonised Peat Complexes and Peat Edge Vegetation

These areas are varied in species composition, including rushes, grasses, Calluneto-Eriophoretum when not the original bog, and eroding peat in gullies and streams. Their justification as a separate category is that they are sub-climax bog communities. They appear very coarse textured, with very dark grey tones, sometimes interspersed with lighter, linear features parallel to the slope.

Poor Fens and Flushes.

6. Sphagneto-Juncetum effusi

Being very limited in extent, this type occurs mainly along streams and river valleys where drainage is impeded.

Its appearance is pale grey but it is distinguished mainly by its position.

Grassland and Dry Ground Vegetation.

7. Species poor Juncetum squarrosus sub-alpinum.

Always found in poorly drained conditions, on level plateaus and in valley bottoms, stands of this type also contain Nardus and Deschampsia grasses and overlap in drier areas with Nardus and Festuca grassland types. They are not strongly characterised on aerial photographs but are generally patchy, medium textured and medium grey in tone.

8. Species poor Nardetum sub-alpinum.

This type is often found on alluvial terraces or drift soils which are steeply sloping and better drained. In poorly drained areas it grades into Juncus Squarrosus communities and, elsewhere, into the two Festuca grassland types. It appears as lightish grey cone-shaped patches on upper hill slopes.

9. Festucetum.

Occurring on the tops of fells and sandstone outcrops and with a thick ground layer of mosses and liverworts, this type appears as very smooth textured, mid grey in tone but slightly darker than Nardus grassland.

10. Agrosto-Festucetum.

These are the dry, species rich grasslands. They are found mainly around limestone outcrops but also on well-drained alluvial terraces, improved meadows and colonising shingle in all large stream valleys. They appear medium to pale grey on aerial photographs and are rougher in texture than Festucetum, owing to the wide variety of species such as ferns, bushes, shrubs and tall herbs.

Although the original vegetation mapping took place several years earlier than the date of the air photo survey, it was thought unlikely that any major changes would have taken place in the reserve vegetation, except that caused by periodic burning, mainly in the lower lying areas of Calluneto-Eriophoretum moorland. Some of the originally mapped burns could be faintly distinguished as slightly lighter patches but many new burns were also evident on the photographs.

Insufficient stereo difference in some places made some aspects of interpretation more difficult, particularly in areas of eroding bog where the main identification criterion is the degree of slope at the eroding part of the bog, and the difference in level between the main part of the bog and the eroded areas. One of the main sources of error in interpretation was the highly detailed nature of the field maps, compared with the relatively small scale of the aerial photographs. The photo scale proved to be too small to determine detail along stream channels, owing mainly to the difficulty of fitting a large number of drawn boundaries into a small area, though on visual inspection, more tonal differences were evident within the stream beds than could be marked. These areas were therefore mapped as Agrosto-Festucetum since the light grey shade of this type predominated. Sphagnum-Juncus communities in the smaller streams were, therefore, lost and small areas of eroding bog were not differentiated from the larger, often adjoining areas of Recolonised Peat Complexes and Peat Edge Vegetation. It was also difficult to pick out eroding bog on the sides of deeply cut stream valleys. Nardus communities were often mapped as Agrosto-Festucetum, both being light toned but duo to the small scale, the rougher texture of Agrosto-Festucetum was difficult to detect.

Of the more widely distributed types, the Juncus Squarrosus community, containing considerable amounts of Nardus and Deschampsia, was difficult to distinguish as a separate category, its patchiness often resulting in identification as eroding bog and the boundary between the two largest blanket bog types, Calluneto-

Eriophoretum and Eriophoretum was often indistinct, the main criteria for identification being altitude and the smoother appearance of the Eriophoretum.

The number of different vegetation types included in the category of Recolonised Peat Complexes and Peat Edge Vegetation made its identification more difficult than at first seemed apparent. In spite of the fact that some of these areas stand out as being dark toned and very rough textured, the similarly dissected and rough textured nature of some of the Calluneto-Eriophoretum and Eroded Bog types caused them to be wrongly included in this category.

4. Results.

A fairly low accuracy of 66.3% of correctly interpreted points was achieved using aerial photographs for vegetation mapping. The Tricophoro-Eriophoretum category had the highest accuracy since, although limited in extent, its air photo appearance is distinctive, owing to the mottled appearance of pools and hummocks. Apart from this small area, the Calluneto-Eriophoretum category with the largest overall extent, had the highest accuracy at 70.5%. The other widespread type, Eriophoretum, had a low accuracy of 49.7% mainly caused by the misinterpretation of 40 points as Eriophoretum which were, in fact, Calluneto-Eriophoretum. Many of the points interpreted as recolonised Peat Complexes were, in fact, Eriophoretum or Eroding Bog, though the total accuracy level for Blanket Bog as a whole, is relatively high. The low level of accuracy obtained for the Grassland and Dry Ground types, i.e. 43.6% does not show any strong tendencies apart from misinterpretation as another Grassland type, due to the fact that all tend to be light coloured during October.

Because of this tendency to misinterpretation as a similar type, it was decided to amalgamate similar categories and to find the corresponding percent accuracy. As shown in Table 2 when the Blanket Bog categories are amalgamated, the accuracy level rises to 93.6% and for the three grassland categories, the accuracy rises to 57.5%.

5. Conclusions.

Some of the disadvantages relating to the photography for the mapping of vegetation have already been mentioned, i.e. scale, insufficient stereo difference and the time discrepancy between the initial mapping and flying of the aerial photography. The low accuracy level of the mapping, however, is thought to be more serious than could have been caused by these factors alone. The initial phytosociological method of classification used is based firstly on visual inspection in the field for observing uniform stands, and secondly upon percentage cover of the dominant species to confirm the initial observations. The boundary delimiting a stand which is uniform according to field survey methods may not be apparent on an aerial photograph since a change in species dominance may not be accompanied by a change in tone or texture on an aerial photograph. This may be particularly so at certain times of year. For example, the grassland categories all appear very light coloured in October, at the time of photography. In fact, much of the misidentification of the Festucetum and Agrosto-Festucetum categories was caused by being wrongly identified as Nardus. Additionally, each of these types would include varying amounts of Nardus. Almalgamation of the Grassland categories had the effect of significantly increasing the accuracy. Misinterpretation of Eriophoretum as Calluna-Eriophoretum is also thought to be due to the varying amounts of Eriophoretum colonising burned patches within the Calluneto-Eriophoretum stands. Amalgamation of these two categories with Tricophoro-Eriophoretum had the effect of greatly increasing the level of accuracy and it is thought that the high accuracy obtained for the amalgamated Blanket Bog types would be sufficient for most purposes. The fact that the mapping categories include, as well as a typicum, several facies of vegetation of different dominance could also mean that a single mapping category is represented on an aerial photograph by more than one characteristic image type. Additionally, all stands vary in species composition due to local environmental factors. For the purposes of air photo interpretation therefore, it might be preferable to amalgamate the groups in a different way, in order to reduce the effect of the two above-mentioned problems. In the present study this did to some extent increase the accuracy level for Blanket Bog and Grassland types, though limitations were imposed by the fact that it was only possible to amalgamate the initially chosen groupings. It might eventually be possible to initially define the categories taking into account similarities and differences in the air photo image related to variations in species composition within the mapping categories.

CHAPTER 1V

HABITAT SURVEYS IN THE UPLAND AND LOWLAND STUDY AREAS

1. Introduction.

Chapter I described some of the problems related to the evaluation of areas of countryside for nature conservation purposes, including the lack of standardised quantitative methods for data collection and evaluation, and the difficulties of applying similar methods to both upland and lowland regions. Chapters II and III showed the difficulties involved in using objective quantitative methods of classification when a rapid data collection system such as aerial photography was the main information source.

Because aerial photography would seem to be, at present, the only means of collecting ecological information rapidly, over large areas, it is necessary to re-examine the main criteria used in conservation evaluation (see Chapter I), in terms of air photo capability, and to assess to what extent the collection and evaluation of those criteria can be standardised to provide an objective method for ecological survey.

With these aims in mind, two extensive areas, one upland, one lowland, were chosen according to the availability of suitable air photo cover. Habitat surveys were carried out over each area and wildlife habitat maps were produced. Because of the impracticability of using a priori vegetation classifications for habitat mapping (except in small areas previously classified according to vegetation), in each case the air photos were used as the primary source of data input, with field work used to confirm and identify habitat boundaries interpreted in the laboratory.

2. The Gairloch Study Area.

This extends over approximately 112 square miles of the 130 square mile Gairloch Conservation Unit in Wester Ross, Scotland (Fig.10), and the eastern section includes the Beinn Eighe National Nature Reserve. The area is bounded by the sea in the west, by Loch Maree in the east and by Lochs Gairloch and Torridon in the north and south, thus making it a virtual peninsula. The terrain is rugged and mountainous rising from sea level to approximately 3,200 feet in the south-east, the rocks comprising mainly Cambrian quartzites and Fucoid limestone, Lewisian gneisses and schists, and Torridonian sandstone. Annual rainfall is high and conducive to bog formation over a substantial portion of the area. The main vegetation types are Calluna-Molinia with varying amounts of Tricophorum-Eriophorum in wetter areas, and at higher altitudes Empetrum nigrum and Rhacomitrium lanuginosum, often with large amounts of bare ground. Flushes, often associated with herb-rich Deschampsia - dominated grasslands, are found in small areas, mainly corresponding to the basic fucoid beds. A sizeable patch of relict pine woodland occurs on the steep, eastern slopes of the Nature Reserve. The predominant visual impression of the study area as a whole, however, is of a homogeneous expanse of moorland, with very little variety of terrain features within it. Land uses include deer and sheep management, wildlife conservation and afforestation and increasingly, tourism.

a. Photography

This area was chosen on the basis of having several different types of air photo cover. However, black and white air photos flown by the RAF in 1948 and 1950 at the scale of 1:16,500, as well as Ordnance Survey photography flown between 1963 and 1965 at the scales of 1:27,000 and 1:10,000 were

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eliminated because of their poor quality and intermittent coverage.

The remaining photography was of two types. These were firstly, 70 mm. Vinten camera multi-emulsion photography comprising panchromatic black and white, infra-red, true colour and false colour infra-red transparencies flown in September 1971 for a NERC project; secondly, 23 cm format RC8 panchromatic photography flown at the same date and as part of the same project. Both types of photography are at the scale of 1:10,000; however, the 70 mm. multi-emulsion photography is confined in its overall cover to four diagonal NW-SE transects across the conservation unit, each approximately ½ km. in width. This photography could not be used for mapping over the whole study area, and thus the habitat map was produced from the 23 cm. format panchromatic prints which were of good quality (Figs. 11-13) and which covered the entire area. A study by the Conservation Course (Warren,1974) compared the usefulness of the four 70 mm. film types for vegetation interpretation and therefore this is not done here, though the true colour transparencies were used for a separate experiment using densitometric analysis methods (Nichol,1975 Appendix VII).

b. Methods

The photographs were first examined stereoscopically in the laboratory and all significant boundaries were marked on to transparent overlays; field work was carried out by visiting as much of the area as possible. One large area was studied intensively and single visits were made to other parts. Because of inaccessibility, recording was often done using vantage points and field binoculars. Detailed subjective assessments were made within each unit delineated on the photographs, of percent cover of each of the major species,

Figure 11 Reduced panchromatic print from the Gairloch study area showing mixed Pine and Birch Woodland adjacent to Loch Maree. The major habitats are outlined in black and an explanation of the mapping symbols is given in the list on page 60 below.

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Figure 12   Aerial photographic print showing an area where elevation increases from 700 ft. altitude on the left, to 2,200 ft. on the right of the photograph. Rock type changes from Torridonian sandstone to Lewisian gneiss and the two most widespread habitat types, CT and CM, are seen to occupy lower-lying, wetter, and well-drained ground respectively.

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Figure 13 Aerial photographic print showing the light-toned appearance of mountain-top habitats, and the rapid transition from one habitat type to another with increasing altitude from the lakeshore at 1000 ft., to the mountain summit at 2,800 ft.

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height of vegetation and the amount of bare ground. The boundaries marked in the laboratory were checked, though their identification proved much more difficult in the field.

Returning to the laboratory, the habitats were categorised, partly according to the units derived by the Conservation Course (1971) from McVean and Ratcliffe's 'Plant Communities of the Scottish Highlands' (for McVean and Ratcliffe types found in the study area see Appendix VIII).

However, because a map of habitats, as opposed to vegetation was the main objective, the mapping units included types in addition to vegetation. It was possible to identify 23 different image types on the air photos, 11 of which (asterisked in the list below) correspond to McVean and Ratcliffe vegetation types.

Once the habitat types, their particular site characteristics (slope, wetness, altitude etc.), and their corresponding photo image had been defined, it was possible to extrapolate to areas which had not been visited in the field, and to confirm or alter previously marked boundaries. Boundaries were then transferred, by visual estimation on to 1:10,000 scale maps.

In addition to the habitat types, it was thought that other features characteristic of the area were important for their contribution to the ecological interest of the area as a whole. These features, in influencing diversity within and between habitats, are described as <u>Inter- and Intra Habitat Variables</u> and comprise categories 24-32 on the list below. They were mapped directly from the air photos, except for Relative Relief, which was estimated from the Ordnance Survey maps.

c. Mapping Categories

*Derived from McVean and Ratcliffe types

These are

	Category		Mapping Symbol
1.	Pinewood*		PW
2.	Birchwood*		BW
3.	Mixed Woodland		MW
4.	Bracken (*Birchwood, treeless facies)		BK
5.	Calluna-Molinia*		CM
6.	Calluna*		CA
7.	Calluna-Molinia/Tricophorum-Eriophorum*		CT
8.	Eroding Bog	*Tricophorum- Eriophorum)	TE
9.	Unpatterned Bog		UB
10.	Bog with Distinct Pools		TT
11.	Linear Patterned Bog		TH
12.	Calluna-Juniperus*		CJ
13.	Montane Heath		MH
14.	Deschampsia Grassland*		DG
15.	Rhacomitrium-Empetrum*		RE
16.	" " with Nardus		RN
17.	Coastal Grassland		CG
18.	Bare Ground		BG
19.	Scree		SC
20.	Peat Cutting		PC
21.	Improved Land		IL
22.	Sand Dunes		SD
23.	Water Surface		WS
24.	Crags and Cliffs		CR
25.	Areas with over 30% Bare Ground		RO
26.	Boulder-Strewn Areas		BS
27.	Coast Length		CL
28.	Stream Length		SL
29.	Woodland Edge		WE

30. Relative Relief	RR
31. Number of Water Bodies	WN
32. Number of Habitats	HN

Each of the habitat types, with its corresponding photographic image, is now described below:

1. Pinewood.

This type occurs mainly on the steep east-facing slopes of the Nature Reserve and has a dense understorey of dwarf shrubs and tall herbs (see Fig.14). It was easily identifiable on the black and white air photos due to its heavy texture, formed by rounded, solid crowns of varying tones, and the dark-toned understorey.

2. Birchwood.

With a patchy distribution over the area, occurring mainly in streams, valleys and sheltered coastal situations, this type generally contains some oak and willow species. It possesses a rich ground flora, including Vaccinium, Pteridium, Deschampsia, and many flowering species.It is identified on air photos by the pale understorey and light toned, delicate-textured crowns rounded in shape but with a jagged outline. Tree shadows tend to be longer and thinner than for pinewood.

3. Mixed Woodland.

Where Pine and Birch trees occur together, as on the steep slopes of the Nature Reserve, this has been classed as mixed woodland. (see Fig.15).

4. Bracken,(Birchwood, treeless facies)

This type contains up to 100% cover of bracken, but often contains other tall herbs and ferns. Within the study area it is of limited extent and is not always distinguishable on the air photos, even in September when it has a distinctive colouring. When distinguishable it appears as rough textured and medium in tone.

5. Calluna-Molinia (Fig. 16)

This is the most widespread type found in the study area. It is a bog community, covering large areas of gently sloping lower hillsides and intergrading with Tricophoro-Eriophoretum in wetter places. It has a mid-tone, textured appearance or can be an intermixture of darker and lighter areas according to the relative abundance of Calluna and Molinia, and other species such as Sphagnum and Erica. Site factors help in the identification of this type which tends to occur on freely drained slopes and does not mark the underlying rock so much as Calluna alone. Some surficial features may, therefore, show through, especially when burning has occurred.

6. Calluna.

This occurs on rather drier sites than Calluna-Molinia, often on steep slopes, at varying altitudes, and includes some Vaccinium myrtillus. There are two types of Calluna stands. Very low Calluna is evident on steep slopes at high altitudes and is dark coloured and smooth-textured on the photographs (Fig.17). Lower down on valley sides, Calluna is taller occurring in tussocks which appear smooth textured and dark, almost black in tone (Fig.18). The tussocks are often interspersed with lighter bands of grass or Tricophorum.

7. Calluna-Molinia/Tricophorum-Eriophorum.

This type is a mosaic made up of Calluna-Molinia and Tricophorum-Eriophorum, usually found lower down slopes in wetter, almost flat areas and often on Moraine. It is medium-toned but more textured than Calluna-Molinia. Smoother, lighter-toned areas correspond to patches of Tricophorum-Eriophorum in hollows. Eroded areas are often found where burning has occurred, and on the edges of channels and bogs. They appear as black linear features. (Fig. 19)

Figure 14 Pine Woodland showing a dense understorey of dwarf shrubs, tall herbs and young saplings.

Figure 15 Scattered Mixed Pine and Birch Woodland on the east-facing slopes in the Beinn Eighe Nature Reserve. The birch trees are paler in tone, smaller, and more delicately textured.

Figure 16 A large expanse of Calluna-Molinia vegetation on gently sloping valley sides. The Molinia gives the lighter toned appearance on September photography.

Figure 17 Photograph taken looking down on a stand of Calluna occupying lower mountain slopes at approximately 1,700 ft. altitude. It is identified by its smooth texture and dark colour.

Tricophorum-Eriophorum

This type is found in sizeable patches throughout the study area, but particularly in the west and north, as an extensive bog system. Its appearance, on the whole, is smooth textured and light grey in colour, though four types can be distinguished as follows:

8. Eroding Bog

This generally occurs on the steeper edges of a bog system. It is pale to mid-grey in tone, due to the eroded peat hags supporting differing amounts of Calluna which appear dark in tone. Linear, black channels at the edges of the bog, represent ridges of exposed peat, supporting dark-toned Calluna.

9. Unpatterned Bog

This type occurs as small patches of Tricophorum throughout the study area, often found in hollows or valley bottoms and adjacent to Calluna-Molinia or Calluna-Molinia/Tricophorum-Eriophorum. (Fig.20). Alternatively, it may occur as smallish patches near the edge of a large bog system. It appears light grey, with an untextured, almost completely smooth surface.

10. Bog with distinct pools.

Occurring on the mainly flat surface of a bog system, this type is characterised by a pool and Sphagnum hummock complex. It appears light grey in tone and mottled with small specks of black, corresponding to the wet pools.

11. Linear patterned bog.

This type occurs on the sloping parts of a bog complex, often towards the steeper edges of the bog. It occurs as a series of ridges at right angles to the bog slope, which may support some Calluna. This type appears light toned, with darker striped areas which are often stippled with white spots corresponding to Sphagnum hummocks.

Figure 18 Lower lying stand of Calluna occupying a well-drained site on a valley side. It is dark toned in appearance compared to the burned area in the foreground and the grassland types in the background.

Figure 19 Stand of Calluna-Molinia/Tricophorum-Eriophorum on moraine. Tricophorum and Eriophorum occupy the wet hollows in the foreground and eroded peat bogs are evident beyond.

12. Calluna-Juniperus.

This type occurs at medium to high altitudes, on level ground, between approximately 1,000 and 2,000 feet. It seldom provides complete cover, and much of the rocky morainic ground is exposed. (Fig.21). It occurs mainly within the Nature Reserve, on level plateaux below the main summits. The sparse vegetation appears very dark grey to black, contrasting highly with the light coloured Cambrian quartzite bedrock.

13. Montane Heath

Found on large expanses of flat, windswept plateaux between approximately 1,400 and 2,500 feet, the location of this type is mainly in the east of the study area. Vegetation is sparse and patchy and terrain is rough, with large amounts of bare ground (Fig.22). The main vegetation types are Rhacomitrium, Empetrum, Vaccinium, Calluna, Juniper, Arctostaphyllos and Arctous-alpina. Its appearance is patchy with light toned, nearly white areas of bare rock contrasting with the light to medium grey,smooth to medium textured vegetation. The roughness of terrain gives a coarse textured appearance overall. Some semi-circular, striped areas, representing solifluction terraces, are apparent in some areas, at relatively low altitudes.

14. Deschampsia grassland

This type generally occurs above 1,600 feet associated with base-rich fuciod beds and Torridonian sandstone ledges. It appears pale to mid-grey in tone (Fig.23) and is generally smooth textured except where interspersed with stream channels which appear as streaks in a downslope direction.

15. Rhacomitrium-Empetrum.

This type occurs at fairly high altitudes upwards, and appears fairly pale, becoming paler with increased amounts of bare rock. (Fig.24). In areas with substantial amounts of

Figure 20 Small patch of Unpatterned Bog (UB) on badly drained ground adjacent to a freshwater loch. It is characteristically pale in tone, and smooth textured.

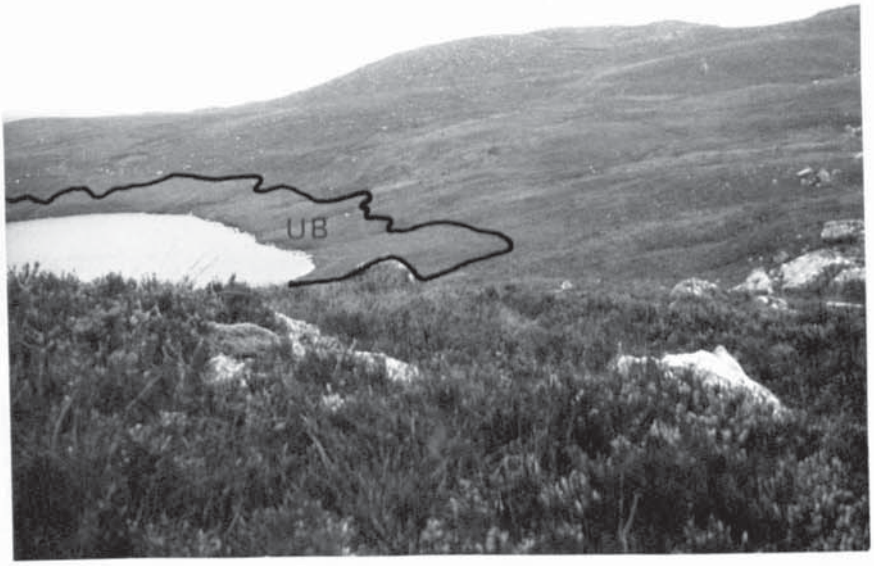

Figure 21 Calluna-Juniper heath. A low, mat-like vegetation structure characterises this type, due to the harsh climate, and large areas of bare ground are exposed.

Figure 22 A large, windswept plateau of Montane Heath habitat type at approximately 2,000 ft. altitude. Solifluction terraces occupy the middleground near the shore of the loch, but are more readily apparent on aerial photographs.

Figure 23 Deschampsia grassland (DG) occurring on base-rich fucoid limestone. In this particular locality it is highly contrasting with the darker-toned Calluna.

Empetrum the texture is fine, but elsewhere, texture is virtually absent. These areas may have very light patches, or streaks, corresponding to Nardus snow beds.

16. Rhacomitrium-Empetrum with Nardus

This mainly snow bed vegetation appears as streaks or semicircles on ridges, often occurring with Rhacomitrium-Empetrum

17. Coastal Grassland

These are smooth, closely grazed, base-rich grasslands extending up to approximately a mile inland from cliff edges. (Fig.25). They appear medium in tone and are smooth textured.

18. Bare Ground

Throughout the study area, varying amounts of bare ground with little vegetation are exposed at the surface, either as rock outcrops, or exposed plateaux or summits. (Fig.26). Photographic tone depends little on rock type and most areas appear pale grey on black and white air photos. Texture is smooth, except where loose rocks, or boulders are present.

19. Scree

This occurs at high altitudes on steep slopes, often below mountain summits and cliffs. It appears very pale or white in tone, with slightly darker streaks downslope.

20. Peat cutting

Only occurring as very localised patches in bog areas in the west of the study area, these types are identified by their regular, straight-sided outline and darker-tones, relative to the surrounding bog.

21. Improved land

This includes land which has been improved for cultivation e.g. hay meadows. It is surrounded by walls, is often ploughed and shows distinctive drainage channels. It is generally lighter in tone than the surrounding woodland and is easy to distinguish.

Figure 24 Rhacomitrium-Empetrum habitat type at an altitude of approximately 3,000 ft. The pale-toned Rhacomitrium and rock debris have a similar, light-toned appearance.

Figure 25 Base-rich coastal grassland, the smooth texture on aerial photographs a result of heavy grazing.

Figure 26 Outcrops of bare rock occurring on hill slopes contrasting highly with the dark-toned vegetation.

Figure 27 Parts of the study area have many freshwater lochs in close proximity, as shown in the photograph. On an air photograph the water surface appears dark grey or black, as opposed to the very light tone shown here.

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22. Sand dunes

Small areas of this type are located on the west coast. On air photos they appear as light streaks of bare sand, interspersed with medium to dark toned vegetation.

23. Water Surfaces (Fig. 27)

These appear as dark grey to black patches, depending on water depth and the amount of aquatic vegetation along the edge. They are often surrounded by a white, or a pale grey line, corresponding to a sandy shoreline.

d. Air Photo Interpretation

The inaccessibility of the study area, limited time available for field work and inexperience in detailed vegetation analysis made the collection of quantitative floristic data impossible. It is thought, however, that because of the distinctness of most of the mapping units and the ability to compare the findings with an existing, less detailed map (Conservation Course, op.cit.), that mapping was accomplished with reasonable accuracy. Difficulties were caused mainly by steepness of terrain in some areas, creating topographic shading on the photographs (see Fig.13), and the large amount of bare rock interspersed with some vegetation types.

The most widespread types in the study were Calluna-Molinia and Calluna-Molinia/Tricophorum-Eriophorum. Because of the sensitivity of vegetation, in an area with high rainfall and humidity, to changes in ground moisture, the degree of wetness of the site was often useful in drawing the dividing line between these types, which often corresponded to a break of slope.

The greatest difficulties were encountered in identifying Bracken, Deschampsia grassland and the mountain top communities of Rhacomitrium-Empetrum with varying amounts of Nardus and Bare Ground. Only two patches of Bracken could be distinguished using black and white air photos, since it could not be separated from other types of tall shrub understorey. Deschampsia grassland is easily overlooked, or its extent underestimated, as a result of its steeply sloping location (see D.G. on Fig.13), but identification can be aided by the use of a geology map. Rhacomitrium-Empetrum was difficult to distinguish from Rhacomitrium-Empetrum with Nardus, and Bare Ground, due to the large amount of bare ground exposed on mountain peaks, interspersed with a scanty vegetation cover, and the nearly white image of all three types (Fig.13). On the whole, accurate interpretation from black and white air photos was impossible without visiting most of the mountain peaks. It is thought that the difficulties of interpretation of the Bracken and mountain top communities would have been lessened, had total coverage of colour photography been available.

e. Data Collection and Storage

The product of the air photo interpretation stage was a map of wildlife habitats (Fig.28, pocket) at the scale of 1:25,000, obtained by reduction of the 1:10,000 scale maps using an overhead projector. In order for different types of analysis to be carried out on the data and to enable comparisons over the area as a whole, it was necessary to feed the data, comprising 32 parameters, into a computer. This was done at the 1/4 km^2 grid level. Areas of habitats were measured by planimeter, according to percent cover in each grid square. The inter- and intra-habitat variables were measured according to type of unit. An opi.someter was used for length measurements and data was stored as kilometres per grid square; areas were measured as for habitats; actual numbers of water bodies and habitats per square were counted and relative relief was estimated in feet. Grid references were used to locate squares in the computer in order to allow spatial print-outs of data.

3. The Merseyside Study Area

The lowland study area represents a sizeable portion of the Merseyside Metropolitan Planning Region, comprising most of Sefton District and coast, and small portions of Knowsley and St. Helens districts. It is irregular in outline and extends approximately 18 miles north-south by 16 miles east-west, (Fig.29). The coastline is dominated by the Ribble Estuary in the north, with large areas of saltmarsh and mudflats which gradually give way to the three to four mile wide beaches and sand dunes of Ainsdale and Formby point. South of Formby the small Alt estuary intrudes briefly into the dune frontage which ceases abruptly with spreading urban development at Blundellsands, a suburb of Liverpool. Eastwards of the extensive dune system, the land is flat and low-lying. It is mainly mossland, improved and drained to produce rich black organic soils for pasture and arable farming. Isolated patches of unimproved mossland exist mainly as, and adjacent to field boundaries, associated with drainage channels. The area as a whole is semi-rural in character with several large dormitory suburbs such as Crosby, Maghull, Rainford, Formby and Ainsdale and the seaside resort of Southport. Much of the Sefton coastal district is considered to be of outstanding value to wildlife, e.g. the Ribble estuary and the Ainsdale Sand Dunes National Nature Reserve, while there is great pressure from summer visitors from the Merseyside and Manchester conurbations.

a. Photography

Good quality, black and white air photo prints covering the whole of the Merseyside Region were available for study.

Figure 29

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The photographs were at the scale of 1:10,000 with a 9 x 9 inch format, and were flown by B.K. Surveys for the Merseyside Planning Authority in May, June and September 1974. (see Figs. 30-33).

b. Mapping and Interpretation

In the Merseyside study area, categories were chosen and mapping carried out, on the basis of interpretability on the air photos. Initially, the photographs were examined stereoscopically in the laboratory, and it was found relatively easy to identify the main land use types. Onesix-inch Ordnance Survey sheet was mapped as an experiment, and because of the complexity of land use types in the area, it was thought necessary to amalgamate some of the categories on the basis of their vegetation components i.e. their values as wildlife habitats. Certain urban land use types with a large vegetational component e.g. allotments, grounds, cemeteries, nurseries and small parks, were amalgamated as a category, and large parks were mapped according to their vegetational characteristics, as either woodland or managed grassland. The managed grassland category grouped together types such as sports pitches, park grassland, large lawns, although older residential areas with large gardens constituted a distinct category. Neglected and derelict sites such as waste ground and quarries were also categorised according to their vegetation. If they possessed over 25% scrub they were classed as scrub and otherwise, as rough grassland or, in the case of having no vegetation cover, as developed land.

The greatest difficulty was in differentiating between different types of agricultural land i.e. between permanent and temporary grassland and arable land. Plough markings were often apparent on temporary grassland but even without these, it was found impossible to differentiate between grass, crops

Figure 30 Reduced panchromatic print of part of the Merseyside study area. For explanation of the habitat types outlined see the list on p.81 below. The area shown corresponds to Ince Blundell Woods and surrounding agricultural land.

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Figure 31 Air photo print showing part of the Sefton coastline, sand dunes and Nature Reserve at Ainsdale. The dark grey to black patches represent coniferous woodland or scrub.

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Figure 32 Air photo print showing a large expanse of mudflats and saltmarsh on the south side of the Ribble Estuary and on the northern edge of Southport.

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Figure 33 Air photo print showing encroachment of the Crosby built-up area onto part of the sand dune system.

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and bare soil. Although permanent grassland is often rougher in texture than temporary grassland this is not always the case and depends on the age, form and species composition of each type, which is difficult to assess even on the ground. These three types were, therefore, grouped as agricultural land.

Freshwater marsh was impossible to identify, and mudflats could not always be identified due to the fact that some of the photography was flown at high tide. These two types, therefore, could not be mapped.

Mapping was carried out over the whole of the study area by transferring boundaries of the defined categories directly on to 6 inch maps. A lower size limit of half a hectare was specified, but all distinguishable water bodies were recorded. Field work was carried out in order to identify difficult sites, but very little was necessary, since most of the categories were well defined and had a characteristic air photo image.

As in the Gairloch study area, certain additional landscape features were considered to contribute towards the overall wildlife value and these were mapped separately from the air photos. They comprise variables 16-22 in the list below:

c. Mapping Categories

These are

	Category	Mapping Symbol
1.	Coniferous Woodland	AO
2.	Deciduous Woodland	AT
3.	Mixed Woodland	AE
4.	Sand Dunes	BB
5.	Salt Marsh	CC

6.	Freshwater Ponds and Lakes	EE	
7.	Heathland	FF	
8.	Unimproved Mossland	GG	
9.	Scrub	HH	
10.	Rough Grassland	II	
11.	Agricultural Land	JJ	Habitat Types
12.	Allotments, Cemeteries etc.	KK	
13.	Managed Grassland	LL	
14.	Developed Land	MM	
15.	" " with large gardens	MG	
16.	Hedge Length	HL	
17.	Coast Length	CL	
18.	Stream Length	SL	
19.	Woodland Edge	WE	Inter- and Intra Habitat Variables.
20.	Scrub Edge	SE	
21.	Number of Water Bodies	WN	
22.	Number of Habitats	HN	

The main features of each type and its corresponding air photo image are now briefly described below:

1. Coniferous Woodland.

This type occurs on plantations, in parks, and adjacent to the sand dune system but on the whole is not widespread as a distinct type. It is easily interpreted on air photos due to its dark grey to black tone, fine, stippled texture, and edge shadows which are long drawn out and pointed. (see Fig.31).

2. Deciduous Woodland

Most sizeable areas of this type are located in, or adjacent to, parks. They appear varied in tone, depending on the particular variation of species, and are usually mid-grey but can be lighter. They are extremely rough-textured, comprising a patchwork of rounded tree crowns with edge shadows which are rounded or oval in shape. The air photo image of this type can be seen on Fig.30.

3. Mixed Woodland

Again in, or adjacent to large parks, this type is often difficult to identify unless edge shadows can be seen. The air photo image resembles that of deciduous woodland but is interspersed with black areas corresponding to the crowns of coniferous trees.

4. Sand Dunes

Although this type comprises a large part of the study area, including a wide variety of vegetation types (Fig.34) which were mapped from the air photos (e.g. Coniferous and Deciduous Woodland, Scrub, Dune Heath, Dune Slacks, Fore Dunes, Grey Dunes etc.) it was decided, for the purpose of this survey, to consider the sand dunes as a single system under one category. Its appearance is very patchy and rough textured due to the high degree of contrast between bare sand and vegetation (Fig.35). Very light grey or white areas correspond to unfixed dune; mid-grey corresponds to fixed and grey dunes and dune slacks. Dune meadows appear smooth textured and mid-grey in tone, while dark grey to black areas represent coniferous woodland, dune heath and scrub. Dune heath is distinguished by its smooth texture, patchiness and lack of stereo height.

5. Salt Marsh (Fig. 36)

Only two areas of salt marsh are located within the study area. These are a small patch on the south side of the river Alt estuary, and an extensive salt marsh to the south of the Ribble Estuary extending as far as Southport. They are easily interpreted from their location but are characteristically mid-grey and mottled in texture, often highly dissected by winding channels of different sizes (Fig.32). The edges of the salt

<u>Figure 34</u> View of the Ainsdale Sand Dunes National Nature Reserve, illustrating the wide variety of vegetational types found in a sand dunes environment.

<u>Figure 35</u> Fixed and unfixed dunes near the Alt estuary showing the highly contrasting nature of marram grass (Ammophila), and bare sand, on black and white photographs.

marsh are often darker in tone, grading at the seaward edge into a smooth, mid-grey area of mudflats.

6. Water Bodies

These occur mainly as small ponds in agricultural land, or in parks and because they are often overhung by trees or hedgerows, they are not always visible on air photos. They are, however, distinctive features, appearing black with occasional patches of dark grey representing shallow water or vegetation, and the shoreline appears as a very light-toned surrounding margin.

7. Heathland

Found on the inland margin of the sand dunes and limited in overall extent, this type comprises mainly dwarf shrub vegetation such as Calluna, with some clumps or gorse and willow. It appears dark grey to black, and smooth - to medium - textured, depending on the height of the shrubs.

8. Unimproved Mossland

Also limited in extent, this type is found only in the east of the study area as 'island remnants' among extensive tracts of flat arable land (Fig.37). It comprises dwarf shrub species typical of acid moorland and bogs, with some birch and willow scrub. It appears extremely rough textured with patchy, medium to dark grey tones, dissected by parallel drainage channels. Darker patches correspond to scrub vegetation.

9. Scrub

This category comprises vegetated sites where over 25% of the area is occupied by scrub species such as birch, hawthorn and willow. On air photos it appears medium grey in tone, with dark grey or black stipples, streaks or patches. In fields, these darker areas, corresponding to the scrub tend to occur mainly around the edges, as infestation proceeds from the surrounding hedgerow inwards.

Figure 36 Characteristic surface of a salt marsh system, the mottled appearance on air photos being due to the patterned distribution of small pools on the surface, as seen here.

Figure 37 Unimproved mossland occurring at the junction of field boundaries in permanent pasture.

10. Rough Grassland

This category includes derelict and neglected vegetated sites, railway cuttings and other types not in agricultural use. (Fig.38). It appears medium to light grey and medium textured with some darker coloured patches, stippling and streaks.

11. Agricultural Land

This includes permanent and ley pasture, arable land and intensive horticulture. This type is smooth to medium textured, dissected by straight field boundaries, and varying in tone from black to very pale grey, often depending ontho presence or absence of crops (Fig. 39). Straight plough lines are very often present.

12. Allotments, Cemeteries etc.

This includes all categories with semi-cultivated vegetation in urban areas, such as allotments, grounds, cemeteries, large gardens and small parks, where the vegetational component was thought significant enough to constitute an important wildlife habitat. They appear on air photos as highly varied areas, comprising all tones and textures, representing a mixture of cultivated and neglected vegetation and buildings.

13. Managed Grassland

This category comprises all grassland, other than agricultural, which is regularly mapped and includes sports pitches, golf courses, park grassland, hospital and industrial lawns etc. These are extremely smooth textured, medium grey areas, often with regular markings e.g. football pitches, mowing tracks, or lighter-toned worn patches. (see areas in category LL on Fig.33).

14. Developed Land

This category includes built land and roads, i.e. residential, commercial, industrial and transportation land uses, and

Figure 38 Railway cutting approximately 3 miles from the centre of Birmingham illustrates the richness and variety of vegetation in these semi-permanent habitats.

Figure 39 Permanent pasture land with straight drainage channels as field boundaries. As well as the floristic richness of this type compared with arable land and ley pasture, overgrown drainage channels often provide even greater diversity of habitat and cover for birds and mammals. Notice the moorhen in the middleground of the photograph.

building sites, tipping sites, or disturbed land with no vegetation. These are the roughest textured areas, highly varied in tone, with the lightest tones representing straight lines of pavements, driveways and new housing estates. They are often interspersed with open spaces of smooth texture and small, dark patches corresponding to trees (see category MM on Fig.33).

15. Older residential areas with large gardens.

The criterion used to identify this category was whether at least 60% of the total area represented vegetation. These areas appear darker in colour than newer residential areas and shapes and sizes of streets and houses are more irregular. (see category MG, Fig33).

d. Data Collection and Storage

Habitats were mapped at the 1:10,000 scale on to 6 inch Ordnance Survey map overlays. (Fig.40, pocket, is an example of one of the 14, 6 inch maps covering the study area). Because of the much greater detail of the mapped units in Merseyside, compared with Gairloch, measurement of habitats by planimeter would have been too time consuming. A sampling system was therefore devised, consisting of dots spaced evenly over a 1/4 km sized grid square, since this was the size of unit decided upon for data collection. An experiment using different numbers of dots was carried out in order to find which would achieve the greatest accuracy. (see Table 3 in Appendix IX). The habitats on one 6 inch map were measured by planimeter and subsequently, using 9, 16 and 25 dots respectively. The highest accuracy was obtained using 25 dots and since the 95.4% accuracy level obtained was thought to be adequate, a larger number of dots being too time consuming, 25 dots were used. Lengths of the Inter- and Intra- Habitat variables were also measured in kilometres using an opissometer. The data for each 1/4 km^2, amounting to a total of 22 variables, was fed into a computer.

4. Parameters for Conservation Evaluation

Of the habitat parameters listed in Chapter I as being important in the assessment of conservation value, some were found to be unobtainable using air photos as the data source. Others, moreover, were unsuitable for surveying whole areas of countryside (as opposed to individual habitats), since data could not be collected and stored on a grid square basis. Each of these parameters will now be briefly considered from the viewpoint of air photo interpretation capability and storage by grid squares, in the light of the two areas studied.

Size and Shape

This is probably the easiest type of information obtainable once habitat mapping has been carried out. However, the collection of data by grid squares precludes using it in a computer-based method, since data is discrete for each areal storage unit, and no account can be taken of adjacent squares or of position within a single square. These criteria were, therefore, not included in the present study.

Vegetation Species Diversity

This parameter is not directly obtainable using air photos, due to obvious limitations of scale. It can be obtained by field sampling of a representative number of the mapped units. In the present study, information on species diversity within each habitat in both study areas was obtained from existing records, based on sampling within similar areas to find the average number of plant species in each vegetation type. (For Gairloch see McVean and Ratcliffe, 1962 and Birks, 1973, Appendix VIII). For Merseyside see South West Lancashire Data Bank: Sefton District). The values allocated and used for vegetation species diversity in each habitat type are listed in Appendix X.

Inter- and Intra- Habitat Diversity

Inter-habitat diversity is easily obtainable by counting the number of habitats in each grid square. This was done for each study area i.e. variables 32 and 22 respectively. Intra-habitat diversity, representing variety in terrain features within a habitat e.g. rock outcrops, relative relief, coast length, streams and hedgerows, could be interpreted from air photos. Variables 24-32 and 16-22 were mapped from the air photos for Gairloch and Merseyside respectively, with the exception of relative relief, which was derived from Ordnance Survey 2½ inch map contours. Measurements were obtained according to grid squares and fed into the computer.

Faunal Species Diversity

This is usually indicated by the vertical structure of the vegetation, which can be deduced from knowledge of the habitat type e.g. woodland contains four vertical layers, comprising ground, field, shrub and tree layers. Data for vertical strata, therefore, was obtained for each habitat and the values (Appendix X) were fed into the computer.

Distance from the nearest similar feature.

This information would be obtainable from air photos by process of simple measurement, if adequate cover were available. The nature of the data, however, precludes its use in this type of study based on discrete information within grid squares.

Vertical Structure of the vegetation

See under Faunal Species Diversity.

Degree of Naturalness

This parameter is difficult to estimate, since no records are available, and is usually indicated by other parameters such as species diversity. It was, therefore, not used in the present study.

Rarity of Species

This parameter, represented by rarity of habitat type, can only be estimated locally, over the study area. The total extent of each habitat type was calculated and the inverse of this was taken to represent the index of local scarcity for each habitat (Appendix X).

Grid Square Size

The size of unit for data collection is an important consideration in environmental surveying, since not only can it influence the type of data collected but also can greatly affect the time taken for the measurement of each variable within the data collection unit, time involving transfer of data to the computer, and the amount of data stored and processed by the computer. Data for this project was collected at the relatively small scale of the 1/4 km grid square, since no previous study indicated a suitable square size for either upland or lowland regions and also, since it was hoped, by amalgamating squares, to achieve some indication of a suitable square size for data collection. It was thought that the 1 km^2 level would have omitted some of the most important terrain differences in each study area and the number of squares available would not have been sufficient for experimentation.

An experiment, discussed in Chapter V, was carried out using the Ecologists Habitat Values and also the product of the Habitat Parameters (Species Diversity, Vertical Strata and Local Scarcity) to find how much accuracy of information contained in the 1/4 km squares would be lost when data was collected at levels obtained by amalgamating squares e.g. 2 x 2 squares, 3 x 3 etc. up to square size 10 x 10.

CHAPTER V

DATA EVALUATION

1. Introduction

As suggested earlier, it is the evaluation of ecological data which poses the main problems to conservationists in recommending wildlife conservation as an important factor in land use planning. Since remote sensing has been suggested as an efficient method for the collection of some types of ecological information, it is necessary to show in what ways data collected by air photo survey can be evaluated.

Using air photos as the major source of data input, it has been possible to examine two extensive areas. It is now proposed to suggest ways in which data collected over large areas can be evaluated, and to attempt to indicate from the results obtained, how some of the parameters used in conservation evaluation, such as species diversity, vertical strata, scarcity etc. can be weighted relative to each other.

2. Values Used.

Two types of evaluation were carried out. Firstly, each of the habitat types in both upland and lowland study areas was evaluated subjectively by a group of 'eminent' British ecologists to whom questionnaires were sent. The ecologists were asked to allocate values within a specified range, to each habitat type and variable, according to its 'conservation value', in the context of Britain and not of the particular local area concerned. In view of the difficulty of doing this, mainly connected with the enormous range of factors which could be taken into consideration, they were asked to complete the questionnaire in the short time space of ten to fifteen minutes. The averages and standard deviations of the values obtained for each study area are listed in Appendix X1.

The second type of evaluation obtained was 'objective' in that the values were derived quantitatively. This concerned the Parameters for Conservation Evaluation, i.e. Species Diversity, Vertical Strata and Local Scarcity described in Chapter lV. For the values obtained for each habitat type, according to these parameters, see Appendix X.

The stages of data collection, evaluation and storage involved in the present study are presented visually in the flow chart (see Fig.41 below).

3. Computer Processing.

The computer was programmed to print out a total value for each $\frac{1}{4}$ km^2 by multiplying the percent cover of each habitat type in a square by its corresponding 'Ecologists' Habitat Value'. Print outs were also obtained using the values assigned to each of the three Conservation Parameters.

Additionally, print outs were obtained for the Inter-and Intra-Habitat Variables, using both the ecologists values (in the case of Gairloch only) and discrete data.

Data storage according to grid location enabled output in map form. The range of values in most cases was divided into five levels of equal size. A density shading was allocated to each value level, ranging from very dense shading for the highest value level to very light shading (a dot)for the lowest level. The alternative was to divide the data into five groups of value with an equal number of squares in each group. However, this was thought to have the effect of 'smoothing out' the data particularly when the total range was large and to reduce the significance of the highest quality areas. A visual impression could, therefore, be quickly obtained of the spatial distribution of specified features and values within the study areas. In addition to the mapped output of data, graphs were produced in order to compare different sets of values allocated, e.g. the Species Diversity value for each square could be plotted

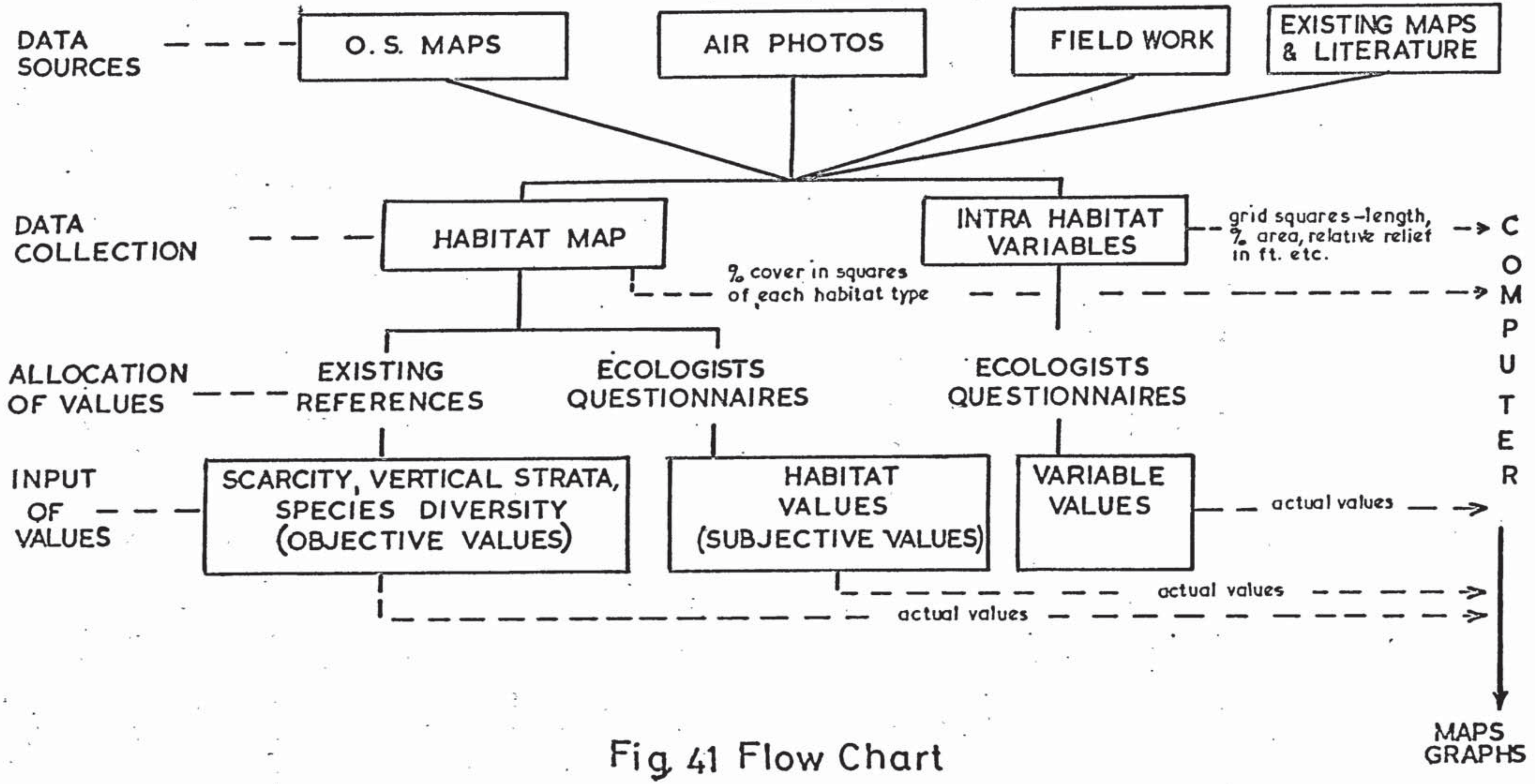

Fig 41 Flow Chart

against the 'Ecologists' Habitats' value. The visual outputs obtained were required for their ecological interest in the present study, though in fact, any combination of features could have been requested with limits specified at a certain level of occurrence.

Because the values assigned to the Inter-and Intra-Habitat Variables could not be directly compared with each other, or with the habitat values, maps based on the Variables have been produced using the discrete data. Moreover, maps have been produced for single variables only, e.g. a map showing hedge length or, in the case of Gairloch, for Variables combined according to type of data collection unit. For example, a map was produced showing Linear Features, including stream length, coast length and woodland edge length, measured in kilometres per square. Thus maps based on the Habitat Variables are not expected to bear any direct relation to those based on Ecologists Habitats, or Habitat Parameters, and are seen only as giving 'additional' value.

4. Data Output.

Seventeen maps (Fig.42: 1-17) and six graphs (Fig.44:1-6) were obtained for the Gairloch study area and nine maps (Fig.43: 1-9) and five graphs (Fig.45: 1-5) were obtained for Merseyside. These will now be described.

A. Maps of the Gairloch Study Area. (Fig.42: 1-17)

1. Ecologists' Habitats Map (Fig.42: 1)

This map shows six main areas of high quality habitat; four are located in the east of the area, corresponding to areas of Juniper heath and Montane heath, above approximately 1,300 feet altitude, and two are located in the west of the study area, corresponding to Linear Patterned Bog, and to two small patches of coastal grassland. There are also approximately six areas of secondary value, these being coastal sand dunes, woodland, inland areas of mountain top habitats and freshwater lochs. Calluna, and patches of unpatterned bog vegetation, most of these in the south and west, occur in the middle range of shading values, while the most widespread and homogeneous areas on the map, having the lowest values are represented by the Calluna-Molinia and Calluna-Molinia/Tricophorom-Eriophorum vegetation types.

2. Ecologists Variables Map (Fig.42:2)

This map is based on the Ecologists' evaluation of the nine variables mapped over the study area. These features, in addition to habitat type, are also regarded as important in contributing to the overall conservation value. The map represents total values for each square, obtained by measuring each intra-habitat variable within it and multiplying the measurement with the value allocated. Because of the difficulty of combining values for different types of feature, however, the values were adjusted to become proportional to the total range of that variable within the area by dividing by the range. In this case, therefore, the final values shown on the map must be considered in the context of the abundance of each of the variables within the study area.

The distribution shows generally higher values in the east of the study area. This is due to the predominance of areas of bare and loose rocks and boulders on and around mountain slopes, the associated crags and cliffs, a greater relative relief, a higher stream density and a larger amount of woodland edge which although low in overall amount per square, has a high value because of its scarcity in the area as a whole. The high values of patterned bog, and Montane Heath, on map 1 do not correspond to high value areas on this map.

3. Ecologists Values (Habitats+Variables) (Fig.42:3)

A map was produced using the Ecologists Habitat values with a constant, lower value, for each variable added to this score to produce a total for the square. Thus, a square would have its value increased slightly for possessing one of the variables and this increase would be the same for all of the variables, depending on the measured amount in the square. The effect of this was the equivalent of adding to the Ecologists Habitat map a constant value for each variable which occurs in the square, thus obviating the need for designating one variable higher in value than another. All the variables were thus given a value of three, which is considerably lower than the Ecologists Habitat values. Because of these lower values for the variables the map is very similar in appearance to map 1, but with fewer squares in the lowest value class and more in the middle and upper classes, giving greater uniformity. This map might be considered a more realistic representation of conservation value, since the Habitat Values were allocated independently of the particular terrain features in the area which contribute towards variety within and between the habitats.

4. Ecologists' Habitats Map (Value classes extended to 0) 42:4

This is an adaptation of map 1, with the values of the lowest shading class extended to 0. Since the lowest value in a square is 200, no squares lie within the lowest value class, which corresponds to the lowest shading onthe map. With only four levels of shading more squares occur within each. The overall appearance is similar to map 1 with the major difference being that the inland mountainous areas enter the highest value categories.

5. Vertical Strata (Fig.42:5)

Based on the number of vertical layers in the vegetation, the highest value areas represent the two types of bog, bog with distinct pools and linear patterned bog. Although only two layers are present in the bog surface vegetation, bog pools, for the purposes of their conservation value, have been allocated three layers corresponding to the bottom, the water itself and the surface. The map, therefore, shows the two areas of highest value as being the extensive bog system in the west and the wooded area in the east. The areas of lowest value correspond to the mountain top plant communities interspersed with scree and bare rock. Some squares with inland lochs also stand out as having higher value but otherwise, the rest of the map, represented mainly by dwarf shrub heath, is homogeneous. Compared with the ecologists' ratings, values are similar, except for the Rhacomitrium-Empetrum, Nardus, and Scree communities of mountain tops, which ecologists rate medium to high.

6. Local Scarcity (Fig.42:6)

The mapping of this parameter shows that the habitats with wide distribution in the study area have a proportionately low value. Because, therefore, of the homogeneity of the vegetation types within the study area, the map is influenced by the very low values of the widely distributed types. Conversely, there are also types within the area with extremely small distribution and correspondingly very high values, creating a wide total range. All squares with any degree of shading (i.e. above the lowest value class) therefore, largely represent small distributions and this causes the great majority of the map to correspond to the lowest value category. The shaded squares in the west of the area correspond to woodland, sand dunes, coastal grassland and peat cutting and those in the east to woodland, bare rock and bracken. Most of these, namely woodland, coastal grassland and sand dunes, were rated high by the ecologists.

7. Local Scarcity (Equal no. of squares at each level) 42:7

With an equal number of squares included in each level of values corresponding to a shading density, e.g. a fifth of the squares have the highest value, this map could be considered more useful in representing local scarcity than map 6, since the greater breakdown allows more comparisons between types within the study area. Montane heath, bog, Rhacomitrium heath, Calluna-Juniper, Improved land and Calluna, have now entered the highest two value categories, while the only type consistently in the lowest category is Calluna-Molinia. These values correspond very closely with values allocated by the ecologists to these types, though bare rock, peat cutting and bracken are anomalies, having high scarcity values and low values allocated by the ecologists.

8. Species Diversity (Fig.42:8)

The values were obtained for the average number of species in each plant community corresponding to a habitat type. The lowest values correspond to areas of bare rock, scree and water surface in the centre and south east of the area, while the highest values correspond to patterned bog, improved land, sand dunes, coastal grassland and Calluna in the west, and to mixed and deciduous woodland, Bracken, Montane Heath and Juniper in the east. The high values in the centre of the map represent mountain slope vegetation such as Deschampsia and Nardus grasslands, some patches of patterned bog, and Calluna. The remaining large part of the map corresponds mainly to the second lowest category, representing Calluna-Molinia, Rhacomitrium-Empetrum and Calluna-Molinia/Tricophorum-Eriophorum habitat types. In comparison with map 1, the major differences are the low rating for water surfaces, Rhacomitrium-Empetrum and Nardus communities and a high rating for Calluna and Improved land on the present map.

9. Product of Habitat Parameters (Diversity, Strata, Rarity Map) (42:9

This map is very similar to map 1 with patterned bog, Montane heath, Pine woodland, Calluna-Juniper, sand dunes, freshwater lochs and mountain top communities having similarly high values. However, because the two areas of sand dunes stand out as having considerably higher values than the rest of the area, the range of values is increased, thus lowering the values on the rest of the map in comparison with map 1.

10. Relative Relief (Fig.42:10)

This map was produced in order to illustrate the distribution of a single variable which has been measured over the study area. It is based on the difference in altitude between the lowest and the highest points in each $\frac{1}{4}$ km square. The gentler relief features in the west of the study area contrasted with the highly varied relief of the mountainous areas in the east are readily apparent.

11. Linear Features (Fig.42:11)

Again, map production was based on the actual measured data collected for each feature, rather than on subjectively assigned values. The variables included were stream length, coast length and woodland edge length. The distribution is seen to be very even over the study area.

12. Rocks and Boulders (Fig.42:12)

Comprising variables 25, 26 and 27, areas with over 30% in rock outcrops, boulder strewn areas and crags and cliffs, this map closely resembles map 10, Relative Relief. The entire eastern section of the map scores high or medium values due to the presence of rocky outcrops, crags and cliffs at higher levels and boulders on the lower slopes, while in the west, values are lower, corresponding to the gentler relief features of the weathered Lewisian Gneiss bedrock.

Text cut off in original

13. Number of Water Bodies (Fig 42:13)

Based on the number of water bodies present in each square the map shows highest values in the centre of the study area.

14. Number of Habitats (Inter-Habitat Diversity) 42:14.

Because the largest number of habitats occurring in any one square is five, the five levels of shading represent one to five habitats per square respectively. The distribution of shading appears to be fairly even, with a slight increase of inter-habitat diversity in areas with steep altitudinal gradients and also in some areas of bog, represented by the four different types of bog habitat as well as the small patches of peat cutting.

15. Number of Habitats with over 12% cover in a Square. 42:15

Maps were produced based only on habitats having a reasonable percentage cover of a square and for this the 12% and 20% levels were specified. Similar distributions remain as in map 14 though the higher the specified percentage, the lower the values and associated shading levels.

16. Number of Habitats with over 20% cover of the Square.

See under 15. above.

17. High Value Habitats (Fig 42:17)

It was thought that for some purposes it might be useful to obtain a rapid print-out of squares containing high quality habitats, as opposed to squares where the overall value was high. High value was defined as having a score of 5.5 or over, based on the ecologists' ratings. (Appendix X1). Thus, because no square possessed more than two high value habitats only three levels of shading appeared on the map, these representing squares with 0, 1 or 2 high value habitats. The overall distribution remains similar to map 1 though water surfaces, because of their small size, tend to be better represented on this map.

B. Graphs of the Gairloch Study Area (Fig.44:1-6)

1. Vertical Strata v Ecologists Habitats 44:1

A correlation coefficient of 0.238 for this graph shows a high correlation, with less than 0.001% probability that the relationship between the two sets of data could have occurred by chance. The main anomalies are in the Rhacomitrium-Empetrum, Coastal grassland and Montane Heath communities, all with high Ecologists Habitat values but with a low vegetation structure. Apart from these types, however, the Vertical Strata parameter gives a reasonably good indication of conservation value in an upland area, particularly if the habitat types above approximately 1,700 feet are excluded.

2. Local Scarcity v Ecologists Habitats (Fig.44:2)

With a correlation coefficient of 0.47 the data on the graph are highly correlated, showing that on the whole the habitats with a low extent in the study area have been rated high by the ecologists. If local scarcity (within the study area) bears a good relationship to rarity of habitat type in the national context, this could indicate that rarity is one of the important factors taken into consideration by ecologists in judging conservation value. Local scarcity, moreover, seems to be a good indicator of conservation value within the study area.

3. Species Diversity v Ecologists Habitats (Fig.44:3)

These two sets of data also show a very high correlation, with a correlation coefficient of 0.467, suggesting that species diversity is a good indicator of conservation value in an upland area.

4. Ecologists Variables v Ecologists Habitats (Fig.44:4)

The correlation coefficient of 0.0157 shows that there is a poor correlation between the two sets of data, indicating that the variables, including environmental and terrain features which contribute towards the overall diversity of an area are not necessarily located in the areas possessing high ecological interest according to the ecologists' evaluations. These results suggest, therefore, that these additional features should be taken into account in assessing conservation value locally.

5. Total Variables v Ecologists Habitats (Fig.44:5)

This graph is similar to graph 4 except that actual data for the Variables were used rather than the subjectively assigned values. Again, the correlation coefficient of 0.022 shows a poor correlation.

6. Habitat Parameters (Diversity x Strata x Rarity) v Ecologists Habitats (Fig.44:6)

This graph shows a very high correlation between the two data sets with a correlation coefficient of 0.41. Thus the squares with the highest values for Species Diversity, Vertical Strata and Local Scarcity combined also tend to have high values according to the Ecologists Values. There is a closer grouping at the lower end of the graph, since the widely distributed types e.g. Calluna-Molinia tend to have low values according to both sets of data.

C. Maps of the Merseyside Study Area (Fig.43:1-9)

1. Ecologists Habitats Map 43:1

This map shows one very large area in the highest value category, occurring along almost the entire length of the coastline and extending up to five, $\frac{1}{4}$ km squares eastwards, inland. This corresponds to the sand dune system which accounts for most of this high value coastline and also, to the large salt marsh in the north of the area. Apart from this major area of high value, the only others consist of single squares containing large amounts of scrub, unimproved mossland, or deciduous woodland. There are four areas of secondary quality;

the two major ones corresponding to Ince-Blundell woods which comprises mixed, deciduous and coniferous woodland, and a sizeable area mainly to the west and south of Woodvale Airport and inland of the sand dune system, of high quality rough grassland with adjacent heathland. A large area of scrub to the west of Maghull and an area of unimproved mossland and woodland to the west of Rainford constitute the other areas of secondary quality. The lowest quality category is represented by built-up areas, i.e. the northern edge of Crosby (part of the Liverpool conurbation), Maghull, Formby and Southport in the north. Developed land with gardens, along with Allotments, Cemeteries etc. Managed Grassland and Agricultural land occupy the second lowest category. Therefore, the overall distribution tends to be concentric, with the built areas of developed land in the lowest category surrounded by the second lowest category of semi-rural environments represented by sports pitches, allotments etc. These are surrounded by the most widespread type, namely, agricultural land, also in the second lowest category and finally, by the highest value, semi-natural habitats, particularly in the west.

2. <u>Ecologists Values (Habitats + Variables)</u> (Fig.43:2)

Like the Gairloch map of Ecologists Values, each of the Variables is given the same value which is low, relative to the Ecologists Habitat Values. The final form of the map is thus more influenced by the Ecologists Habitat Values than by the Variables. The shading is more evenly distributed than on map 1, with higher values in the east of the study area. Because of the nature of the Variables, however, the Developed areas remain low in value and the main increases occur in agricultural areas, owing to the presence of streams and drainage ditches, hedges and pools. This map could be thought the best indicator of overall conservation value, since it is a combination of values assigned to habitat types, with additional points scored for features of ecological interest in the countryside, which have been measured.

3. Vertical Strata (Fig.43:3)

This map shows a more even distribution of values since the sand dunes with four vertical layers become of secondary importance to salt marsh, which has five (due to the presence of pools among the salt marsh vegetation). Apart from this, the map is similar in appearance to map 1 since the areas of woodland have high values while Unimproved Mossland and Scrub have high to medium values. Agricultural land, with two vertical layers, again appears in the second lowest category but a major difference in the lowest category is a reduction in the total area of Developed Land due to the influence of adjoining Developed Land with gardens, which has three vertical layers.

4. Local Scarcity. (Fig.43:4)

Like the Local Scarcity map for Gairloch, very little shading appears on this map, since by definition, the scarcest types are small in area, thus having disproportionately high values compared to the other types. The habitat types which feature on this map are Salt Marsh, Unimproved mossland, Allotments and cemeteries, Heathland and Water surfaces.

5. Species Diversity (Fig.43:5)

The map again appears very similar to map 1, since again the sand dunes have the highest value, with 200 species and Developed Land the lowest value. Ince Blundell Woods and the Rough Grassland near Woodvale Airport have retained their position in the second highest category, though Unimproved Mossland has fallen to the second lowest, to join the remaining areas of Agricultural land.

6. Product of Habitat Parameters (Diversity,Strata,Rarity)43:6

This map is very similar in appearance to map 1, with low, medium and high values for the major areas of developed land, agricultural land, and sand dunes respectively. The major differences are the Ribble Estuary Salt Marsh which has entered the second lowest category and a slight increase in the lowest category areas, probably due to the inclusion of developed land with gardens along with developed land.

7. Hedge Length (Fig.43: 7)

This map is very different from map 1 since the areas with most hedges are mainly agricultural. These are mainly in the south of the area, with field boundaries in the north consisting largely of drainage ditches.

8. Number of Habitats (Inter - Habitat Diversity) 43:8

This map appears very different from map 1, since the largest number of habitats in such a semi-rural area tend to occur in squares represented by developed land, or near to developed land. Within built-up areas, for example, there may exist areas of managed grassland, allotments and cemeteries, rough grassland, water surfaces and small patches of woodland as well as different types of residential areas i.e. with and without large gardens, all in close proximity. The agricultural and sand dune habitat types have the largest continuous distribution within the area and, therefore, squares representing these categories are low in value according to Inter-Habitat Diversity.

9. High Value Habitats (Fig.43:9)

These include Mixed and Deciduous Woodland, Sand Dunes, Salt Marsh, Water bodies, Heathland, Unimproved Mossland and Scrub. This map was thought to be particularly meaningful in the Merseyside area, since the habitats may be quite small and thus very little represented in the overall value of a square. It would, therefore, be particularly difficult to locate the smaller, high quality habitats. Compared to map 1, sand dunes and agricultural areas are now in low value categories. The three highest quality areas are Ince Blundell Woods, with two types of woodland, and water surfaces; the Woodvale area with Heath, Scrub and Sand Dunes and part of Southport, with water, woodland and Sand Dunes in close proximity.

D. Graphs of the Merseyside Study Area. (Fig. 45: 1-5)

1. Vertical Strata v Ecologists Habitats (Fig.45:1)

The very high correlation coefficient of 0.956, associated with this graph demonstrates that, almost without exception, squares with high vertical strata values, also have high values according to the Ecologists Habitat ratings. Exceptions such as coniferous woodland are minimised by their low proportions, compared to other types, in any square. These results would seem to imply that, in a lowland area, the Vertical Strata Parameter can give a good indication of conservation value.

2. Local Scarcity v Ecologists Habitats (Fig.45:2)

The data on this graph are again highly correlated, the correlation coefficient of 0.251 suggesting less than 0.001% probability that the relationship between the two sets of data occurred by chance. The correlation is not, however, as good as graph 1, and scatter on the graph is correspondingly wider. This is due largely to the high Ecologists values for the Sand dunes which are not scarce within the Merseyside region, and also to low value habitats such as Allotments, Cemeteries etc., which are low in distribution, giving them a high scarcity value.

3. Species Diversity v Ecologists Habitats (Fig. 45:3)

The data are extremely highly correlated, with a correlation coefficient of 0.851. The main anomalies are Unimproved mossland, Heathland and Salt Marsh, all having relatively few species but with high Ecologists values. Agricultural land, on the other hand, is relatively high in species compared to its low ecological value, though on the whole, the Species Diversity

Parameter seems to be a good indicator, in a lowland area, of conservation value.

4. Total Variables v Ecologists Habitats (Fig.45:4)

This graph does not show a good correlation, suggesting that the Variables, i.e. Hedge, Coast and Stream length, Woodland and Scrub Edge, Water Bodies and Number of Habitats per square, do not reflect the distribution of Ecologists Values. This has already been discussed under Map 2.

5. Habitat Parameters (Diversity x Strata x Rarity) v. Ecologists Habitats (Fig. 45:5

This graph shows a high correlation between the two sets of data with a correlation coefficient of 0.38. The distribution of values for the Habitat Parameters is, therefore, a good indication of the distribution of Ecologists Habitat values, though in this study area it is not as highly correlated as Vertical Strata and Species Diversity.

E. Grid Square Size.

Chapter lV described an experiment carried out using the Ecologists Habitat Values and also the combined Habitat Parameters of each study area, in order to assess to what extent the original information contained in the $\frac{1}{4}$ km squares would be retained using a coarser grid. This was done by grouping the small squares into larger sizes i.e. square size 2 x 2 to square size 10 x 10.

For each level of square groupings the average values for the large squares were found and the Standard Deviation of the small squares within the large squares was calculated. This was then divided by the degrees of freedom, i.e. $\sqrt{\frac{\sigma}{n}}$ and values were given for the 68.3%, 85% and 95% confidence levels respectively, e.g.

$$95\% \text{ level} = \bar{x} \pm 1.96\sqrt{\frac{\sigma}{n}}$$

The resulting figure is equivalent to the overall difference in values obtained when data is collected at the level of the large squares, rather than at the more detailed level of the small squares. It represents the amount of information which might be lost at the level of the large squares.

For example, for the Habitat Parameters in the Gairloch area, at the 2 x 2 square level, the values of the large squares could be expected to lie within + or - 223 value units of the small squares, with a confidence level of 68.3%, or 1 Standard Deviation. This corresponds to an uncertainty in the order of approximately 5.1% of the total Range, and to 9.6% of the Mean of the Habitat Parameters (see Tables 4 a & b). The uncertainty increases at the 85% confidence level to 7.3% and 13.8% respectively, and also as the square groupings become larger.

Expressed as a percentage of the total range, the results can be compared with the five shading levels on the corresponding maps which are also based on the total range of values. For the above example again, it could also be said that the uncertainty of 5.1% at the 68.3% confidence level was of the order of approximately ¼ of one shading level (each of the five shading levels contains 20% of the total range of values). An uncertainty of 5.1% means that a maximum of approximately 20 different classes in the data can be distinguished and this falls to 10 different classes (9.9% uncertainty) at the 95% confidence level. It cannot be stated how much of the original information has been lost, since this depends on the type of information required but certainly, while the broad class groupings remain, the detailed information within them has been lost.

Expressed as a percentage of the mean, the values for the large squares could be expected to represent an uncertainty of 9.6% of the mean of the small squares.

GRID SQUARE SIZE

Degree of uncertainly at each square size level given as percentage of total range of values and of mean values for three confidence levels.

Table 4 (a.) Gairloch Area

	Ecologists Habitat Values Mean = 332 Range = 500						Values for Habitat Parameters Mean = 2,330 Range = 4,400					
Confidence level	68.3%		85%		95%		68.3%		85%		95%	
Square Size	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
2	18.1	12.0	26.0	17.2	35.5	24.0	9.6	5.1	13.8	7.3	18.7	9.9
3	21.4	14.2	30.7	20.4	41.9	23.8	10.3	5.5	14.9	7.9	20.3	10.7
4	25.6	17.0	36.7	24.4	50.3	33.3	12.4	6.5	17.8	9.4	24.2	14.8
5	25.6	18.7	36.7	24.4	50.3	33.3	12.7	6.7	18.3	9.7	24.8	13.2
6	27.4	18.2	39.4	26.3	53.6	35.7	13.0	6.9	18.7	9.9	25.6	13.5
7	27.1	18.2	39.1	26.3	53.0	35.7	13.2	7.0	19.0	10.1	25.9	13.7
8.	28.3	18.9	40.7	27.0	55.4	37.0	13.4	7.1	19.3	10.3	26.3	13.9
9	28.9	19.2	41.6	27.8	56.6	36.5	12.3	6.5	17.7	9.3	24.1	13.5
10	28.3	18.9	40 7	27.0	55.4	37.0	13.4	7.1	19.3	10.2	26.2	13.8

Table 4 (b.) Merseyside Area

	Ecologists Habitat Values Mean = 2340 Range = 3730						Values for Habitat Parameters Mean = 8160 Range = 20,000					
Confidence level	68.3%		85%		95%		68.3%		85%		95%	
Square Size	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
2	16.5	10.4	23.8	14.9	32.4	20.3	28.1	11.5	40.5	16.6	55.2	22.5
3	22.8	14.3	32.9	20.6	44.7	28.1	40.5	15.2	53.6	21.9	72.9	29.8
4	24.2	15.2	34.8	21.8	47.4	29.8	41.0	16.7	59.0	24.1	80.3	32.8
5	30.0	18.9	43.2	27.1	59.9	36.9	51.6	21.0	74.4	30.4	101.2	41.3
6	29.4	18.4	42.3	26.6	57.6	37.4	49.2	20.1	70.9	28.9	96.5	39.4
7	30.8	19.3	44.4	27.8	60.5	37.9	56.5	23.3	81.4	33.2	110.8	45.4
8	32.0	20.1	46.1	28.9	62.7	39.4	57.9	23.6	83.3	34.0	113.1	46.3
9	33.0	20.7	47.5	29.8	60.5	37.9	56.1	22.9	80.8	33.0	110.0	44.8
10	33.7	21.1	48.5	30.5	66.1	41.5	59.6	24.3	85.9	35.1	116.8	47.6

Discussion of the Results.

Unless otherwise stated, discussion will refer to the 85% confidence levels, since this is thought to be the lowest acceptable level.

Both Gairloch and Merseyside study areas show a reasonably large degree of uncertainty according to Ecologists Habitat Values, even at the square size 2 level, with an uncertainty of 26% and 23.8% of the mean respectively. The percentage uncertainty in the range of values corresponds on the computer maps to an uncertainty of between half and one shading level in both cases.

The mean values for the Habitat Parameters on the other hand, differ widely between the two areas, with a much lower degree of uncertainty for Gairloch and a much higher degree of uncertainty for Merseyside. The values for the large squares at square size two, for example, can be expected to represent an uncertainty of 13.8% and 40.5% respectively of the mean. The Habitat Parameters are probably a better indication of environmental pattern than the Ecologists Habitat Values, so that in Gairloch, for example, the large size of the habitats, and the lack of a significant difference in Vertical Strata, Species Diversity and Local Scarcity over large expanses of the area creates a greater degree of homogeneity within the larger square groupings. Conversely, in a densely settled region, the human influence on land use and thus on habitats, increases the complexity of the area, thus making reliable data collection at the large square level impossible. Taking the Habitat Parameter Values for Gairloch, at the 95% confidence level the values for the large squares can be expected to represent an uncertainty from 9.9% to 13.8% of the total range, for square sizes 2 to 10 respectively. The degree of uncertainty represents from just below, to just above half a shading level on the maps, and it is thought that in some circumstances, the loss of detail, even at the 10 x 10 square size might not be too great to preclude data collection at this level only. None of the square size levels for Merseyside are thought to be sufficiently representative of the $\frac{1}{4}$ km square values, to suggest the use of a coarser grid.

Initially, this experiment was designed to test whether amalgamation of the $\frac{1}{4}$ km square into large square sizes would give similar indications of the values in the original $\frac{1}{4}$ km. squares than smaller sized square groupings. If this were the case, it could have been suggested that data be collected at the largest square size possible, balanced against information loss.

In regions where the main environmental features corresponded approximately to a constant size (i.e. a regular size pattern of the dominant environmental features) this may have been the case when a square size was reached which just exceeded the size of these features. Internal homogeneity would have been lost as the size was exceeded and the values of the large squares would no longer approximate to such an extent those of the small squares. However, it is thought that not enough squares were available in either study area to be able to compare a large enough range of square size levels. Some trends were evident in the data, such as the reduction in the uncertainty of the large square values, at square sizes 6 and 9 of the Gairloch area Habitat Parameters. However, in order to make definite recommendations it would be necessary to analyse larger areas and to compare results between similar types of area.

Additionally, using this method of data storage, it was impossible to compensate for the fact that the amalgamated square groupings must tend to fall across boundaries between homogeneous areas, i.e. the computer cannot work with unevenly shaped areas within a data set. It is thought that, should 'homogeneous areas' first be defined, possibly using aerial photographs, and the analysis be carried out only within each of these areas, then a much greater level of accuracy could be shown to be obtainable from larger, as opposed to smaller square sizes. This could be a useful observation for future work, provided that care is taken when deciding the types and detail of data required.

CHAPTER VI

ANALYSIS OF RESULTS

1. Data Collection using Aerial Photographs

Some of the advantages and limitations of using air photos for the collection of ecological information over extensive areas of countryside have already been discussed in previous chapters. Goodier and Grimes' observations in the field of vegetation mapping, (Goodier and Grimes, op.cit.) stressing the need for the development of air photo-ecology are seen as even more relevant for the mapping of wildlife habitats when features other than vegetation are also important. The use of air photos for vegetation mapping in the Moor House National Nature Reserve indicated that categories derived from existing vegetation classifications based on criteria such as physiognomy, dominance and floristic composition may be misinterpreted on an air photo due to the relative colour, tone and percent cover of several of the major species in a stand, any of which may vary at different times of year.

Limitations of using air photos in the upland and lowland habitat mapping surveys undertaken, although possibly specific to the black and white air photos used, were mainly concerned with the inability to identify a priori defined categories. These were, in the Gairloch study area, mountain top communities, where large amounts of bare rock were interspersed with a scanty vegetation cover, and bracken, (though in the case of bracken its restricted occurrence made realistic assessment impossible); and in the Merseyside area mudflats and freshwater marsh were categories which could not be mapped due to the fact that on some of the photography, flown at high tide, mudflats were invisible; moreover, freshwater marsh could not be identified. Additionally, none of the three major agricultural land categories could reliably be identified in all parts of the area, though some such as very rough textured grassland, surrounded by drainage ditches, and with grazing animals, could be reliably interpreted as permanent pasture. In many other cases the distinctions were too slight, as were those between ley pasture and arable land, and especially so early in the growing season where the percentage leaf area to bare soil was low.

Although more work needs to be done, it is thought that some of the problems of air photo interpretation in the lowland area could have been overcome using false colour photography taken shortly before the period of maximum crop growth, i.e. in early June. At this time of year, the relative lushness of the temporary grassland and its corresponding bright red or magenta image would be expected to contrast with the mixture of growing and dead grasses and other species in permanent pasture, which are represented by a paler red, or pink tone on the air photos. Additionally, arable land and temporary grassland would be easier to separate, since the distinctive colour differences on false colour photography between crops and bare soil would be evident in arable land early in the season, and fields of bare soil in particular would be easy to distinguish from pasture. For habitat mapping purposes, however, the distinction between arable and ley grassland is not considered to be of great importance, since both are temporary habitats, offering only short term cover for wildlife. Freshwater marsh could also be more easily identified using false colour photography, since water is non-reflective in the near infra-red part of the spectrum, giving water surfaces and marshy ground a black, or dark-toned appearance. Since most available aerial photography at the present time is black and white, it would seem advisable to map these different agricultural types as one category, unless detailed field work or agricultural census information is available to confirm air photo observations.

In an upland area, although environmental boundaries are more easily visible on an air photo than in the field, these boundaries do not necessarily conform to previously defined vegetation units since geomorphological, or other terrain features may have more influence than vegetation on the photographic appearance. Evidently for the mapping of habitats some method is needed whereby some of the established vegetation categories, e.g. grasses, can be amalgamated, or grouped in different ways according to percentage cover of the dominant species, this percentage to be defined according to the corresponding air photo image at a specific time of year. Additionally, it would seem of little value to expend large amounts of time and resources attempting to establish the presence of, for example, small amounts of Nardus or Empetrum, interspersed with block scree or mountain top detritus if, for the purposes of conservation evaluation, geomorphological features such as crags and cliffs and the mountain top environment itself were the predominant features of interest. Another useful distinction in upland areas is the one recognised in Stapledon and Davies' Grassland Survey of England and Wales (Stapledon 1936), and by the First Land Use Survey (Stamp, 1962). This is the distinction between heather moorland and heather fell, the latter incorporating heather moorland which is rocky and steep, often strewn with large boulders and in places showing small precipices of bare rock. In the present survey these terrain features were mapped as Intra-Habitat Variables, distinct from the habitats themselves, though the photo-ecological approach to habitat mapping would overcome the distinction.

For the purposes of mapping in both upland and lowland areas, it is thought that smaller scales of imagery would have been preferable, and particularly so in the Gairloch study area where in some homogeneous areas of moorland only two or three boundaries occurred on one air photo, at the 1:10,000 scale. It is thought that good quality air photos at the scale of 1:15,000 in Merseyside and 1:20,000 in Gairloch would have yielded similar amounts of information, with the advantage of handling smaller numbers of prints.

Finally, the limitations involved in using the parameters for conservation evaluation (which were not used in the present study), namely Size, Shape and Distance from the nearest similar feature, apply only at the regional reconnaissance level when considering areas of countryside, as opposed to individual habitats. More detailed local surveys of individual habitats could usefully take account of these parameters using measurements from air photos.

2. Methods of Evaluation Used

The major distinction between the types of evaluation used was that between 'subjective' and 'objective' methods. The Ecologists' Habitat Values, allocated by 'eminent' ecologists, each with particular specialisations in the field of ecology were accordingly expected to show some degree of variability. The Standard Deviations ratioed to the values given (Appendix XI) show slightly less variability in values allocated to the lowland habitats, and particularly those with the greatest degree of human influence. This could be due to the fact that it is more difficult to differentiate between several types of semi-natural environment than between environments with distinct degrees of human influence. The Ecologists' Habitat Values, however, although based on varying opinions, are thought to be no less valuable than the 'objective' measured criteria of the Habitat Parameters, whose status in conservation evaluation can be decided using only subjective criteria. For this reason the former have been used as indicators of conservation value in order to permit the weighting of the Habitat Parameters relative to each other, and to act as a basis for comparison of the Inter-and Intra - Habitat Variables. According to the correlation coefficients of each of the Habitat Parameters with the Ecologists Habitats, the Parameters can be ranked in the order shown in Table 5 below.

Table 5

Ranking of Parameters for Conservation Evaluation

Gairloch		Merseyside	
Parameter	Correlation * Coefficient	Parameter	Correlation* Coefficient
1. Local Scarcity	0.47	1. Vertical Strata	0.96
2. Species Diversity	0.46	2. Species Diversity	0.85
3. Product of Parameters	0.41	3. Product of Parameters	0.38
4. Vertical Strata	0.24	4. Local Scarcity	0.25

*Refers to correlation with Ecologists' Habitat Values

Because all the parameters in both study areas are highly significant when correlated with the Ecologists' Habitat Values with, in all cases, less than 0.001% probability that the relationship occurred by chance, it could be suggested that Rarity, Species Diversity and Vertical Strata were important factors taken into consideration by the ecologists in carrying out the evaluations, in the national, rather than the local context. Some were more highly correlated than others, however, and the order of the three parameters was reversed between the two study areas. It can thus be suggested that in an upland area of the size studied or larger, Local Scarcity is the best single parameter indicating high conservation value, followed very closely by Species Diversity.

The parameter Local Scarcity, based on representation within the particular study area, is influenced by the extent to which the study areas are typical of upland and lowland areas in Britain. It is thought that the Merseyside area is the least representative due to the large amount of coastline and the associated Sand Dune and Salt Marsh habitats which, although widespread within the study area, could be considered rare in the national context. This could therefore explain the low correlation coefficient for Local Scarcity in the Merseyside region, as opposed to its high correlation for Gairloch, where, with the exception of Montane Heath, all of the high value habitats (see Figure 42, Map 17 for Gairloch) are relatively scarce, not only within the study area but within upland areas generally in Britain.

In both study areas Species Diversity is highly correlated with the Ecologists Habitat Values. It is more highly correlated in Merseyside than in Gairloch, possibly due to the fact that some of the high value habitats in an upland region are located in exposed and marginal situations which allow fewer species to survive than in more protected areas at lower altitudes.

The Vertical Strata Parameter is probably less indicative of conservation value in an upland region where many of the high value habitats, e.g. mountain top communities, Montane Heath, Calluna-Juniper, are of low physiognomy, again due to exposure. On the other hand in a lowland region the lowest conservation values have, on the whole, been given to habitats low in Vertical Strata, such as Developed land, Managed Grassland and Agricultural land. The intermediate types, in terms of Vertical Strata, Allotments, Cemeteries etc., Rough Grassland, and Scrub, are similarly intermediate in Ecologists Habitat Values, and according to the ecologists the high value habitats such as Mixed and Deciduous woodland and Salt Marsh are also high in Vertical Strata.

In the Gairloch area the Product of the Parameters was almost as highly correlated with the Ecologists Habitat Values as any of the parameters singly, suggesting that in an upland area a good indicator of conservation value could be obtained by multiplying the measurements for the Habitat Parameters. In the Merseyside area the Product of

Parameters was not as good an indicator of conservation value as Vertical Strata or Species Diversity. It is suggested, therefore, that in an upland region Local Scarcity, Species Diversity and the combined Parameters are good indicators of conservation value, and that in a lowland area Vertical Strata and Species Diversity are the best indicators.

The Ecologists Variables had correlation coefficients of 0.02 and 0.07 respectively for Gairloch and Merseyside, showing that the high value habitats were not necessarily accompanied by the environmental and terrain features which contribute towards diversity in the area. However, these variables may be of high ecological interest. Hedgerows in the Merseyside study area, for example, lie mainly within agricultural land which has been rated low for conservation purposes. In the Gairloch study area some areas of low value Calluna-Molinia/Tricophorum-Eriophorum habitat types are interspersed with large numbers of small lochs and pools which would contribute to the overall diversity of the area and provide an important habitat for certain types of waterfowl, and for animal species requiring areas of water within the moorland habitat. It is suggested, therefore, that in assessing overall conservation value the Inter- and Intra-Habitat Variables be taken into consideration in addition to data related to the habitat types. It was thought that since the majority of the variables are extremely local, or small and patchy, occurring alongside and within the main habitat types, the additional values given should be considerably lower than the habitat values. (See Figure 42, Map 3, Gairloch, and Figure 43, Map 2, Merseyside, of Ecologists Values). The difficulty of combining the values allocated by the ecologists to the variables could not be overcome. For example, how many kilometres of stream length are equal in value to two kilometres coast length, or six water bodies? The method adopted was, therefore, to allocate the same value to each variable. The difficulty will remain until further research allows a greater degree of objectivity in evaluating the importance of such features. In terms of the present study, maps 3 and 2, the Ecologists Values maps, for Gairloch and Merseyside respectively, are suggested as being the best overall indicators of conservation value.

3. Comparisons Between Upland and Lowland

The significant differences between upland and lowland environments, including the greater degree of uniformity and lack of diversity in upland vegetation, inhibits attempts to use similarly weighted evaluation parameters for each type of region. It is suggested that in upland environments, other factors such as the intra-habitat variables are more important contributors to conservation value than in lowland areas. In uplands terrain is more irregular and interest is created as much by features such as rocks, boulders, surface irregularities, slopes, and changes in altitude, as by the number of species, or vertical layers in the vegetation, which tend to be relatively low, or less highly correlated with conservation value. In a lowland region, however, it is important not to disregard the variables such as hedge, coast, stream and woodland edge length, and water bodies, all of which may represent isolated islands of semi-natural habitats within intensively managed areas, and which, for this reason, are additionally important.

Larger data collection units are thought to be appropriate for upland environments, in accordance with the greater extent of the main habitat types and environmental variations. The grid square size experiment showed that, for the Gairloch Habitat Parameters, the uncertainty which could be expected in the measurements obtained at square size nine was not significantly greater than at square size two, (an uncertainty of 9.3%, as opposed to 7.3% of the range of values at the 85% confidence level) whereas in Merseyside the uncertainty was approximately doubled, from 16.6% to 33%. While the levels of uncertainty for Gairloch might, for some purposes, be considered acceptable, those for Merseyside would probably not.

The value of the types of evaluation described in this study are thought to be greater in upland regions than in lowland, since the initial apparent uniformity of upland regions inhibits attempts to differentiate distinctive areas within them for purposes of evaluation. Ecological information processed and output in map form according to kilometre squares can therefore greatly aid such attempts. The more readily definable land use types in a lowland region, on the other hand, do not pose such difficulties, and the value of these methods must lie partly in the ability to compare within the basic grid square framework other types of planning information with the ecological data.

Applications to Other Areas

The applications of the methods of data collection, processing and evaluation used in this study to wider areas depend, as has been stated in the discussion of vegetation classifications (Chapter II), on the existence of standardised mapping units suited to air photo interpretation. No such classification of habitats is at present available, though an on-going survey to produce a National Vegetation Classification based on phytosociological criteria, at the 1:25,000 scale (Nature Conservancy Council, in preparation) would seem to have potentials in this context, enabling a greater degree of objectivity to be obtained from comparisons of mapped units in different areas. In the absence, at present, of this type of classification, the most suitable method would be to adopt categories specified for previous studies of similar types of terrain, e.g. McVean and Ratcliffes' classification of Plant Communities of the Scottish Highlands.

The weightings of the parameters suggested for upland and lowland regions respectively must necessarily depend for their usefulness on the types of mapping categories to which they are applied, and in any particular study they are necessarily influenced by the representativeness of the study area in which they are used. Having considered these limitations it is possible to suggest a simple method, using Remote Sensing techniques, for the collection and evaluation of data over extensive areas of both upland and lowland for conservation purposes. This method will now be described in Chapter VII:

CHAPTER VII

A SIMPLE METHOD FOR CONSERVATION EVALUATION USING REMOTE SENSING

1. Introduction

Methods for carrying out a particular project are necessarily limited by the current state of knowledge in the field concerned, and by instruments and techniques available.

This study has examined the techniques of remote sensing in relation to the major problems and the present state of knowledge in the field of conservation evaluation. Limitations have been seen to be imposed by three main factors. These are, firstly, the difficulty of obtaining suitable remote sensing imagery; secondly, the problem of identifying mapping units suited to air photo interpretation; and thirdly, evaluation for conservation purposes of the data collected.

In view of the growing need to consider wildlife conservation as a relevant factor in land use planning, however, some attempt must be made to devise a sufficiently standardised method which can be used for rapidly evaluating at a generalised level extensive areas of countryside. This could then provide the necessary information base for more detailed surveys as, for example, in local plans, or in the designation of areas as nature reserves. Based on the findings of this study, it is now possible to suggest a standardised method,based partly on objective criteria, which can be used for the rapid collection and evaluation of ecological data for the purposes of conservation.

2. Data Collection

Aerial Photography

Air photo survey work must often make use of existing photography, or if special photography can be flown, the choice of scale, or type of film may depend on other types of data collection surveys to be undertaken using the same photography.

The optimum scale of photography in an upland area is thought to be 1:20,000 but 1:15,000 or 1:10,000 would probably be more suitable if the photography is to be used for more detailed studies at a later stage as, for example, in differentiating types of bog, contouring, and studies of burning and grazing. In a lowland area a scale of 1:10,000 or at least 1:15,000 would be required due to the greater amount of ground detail present. However, in areas incorporating both upland and lowland types of environment, 1:10,000 or 1:15,000 would probably be necessary.

It is always useful to have more than one type of photography available, since features which cannot be distinguished on one film type may be readily identifiable on another. In an upland region, panchromatic and true colour photography are suggested as the best two types and the best combination. It is easier to obtain good quality photographs using panchromatic film, and most of the major vegetation communities and terrain features can be distinguished on the basis of pattern, grey tone, texture and site. For the more difficult features such as rock and scree communities, bracken, and Deschampsia grassland, colour photography would introduce a wider range of tones and thus facilitate interpretation. Moreover, the realistic nature of colour compared to false colour photography would help to verify the boundaries of most of the mapping categories, particularly if flown in late August or in September, at the time of maximum colour differences in the vegetation.

The best types of photography to use in a lowland region are thought to be panchromatic, and false colour infra-red. Most types of habitat can be distinguished using panchromatic photography, and its realistic image and good quality would enable this to be used for the majority of the mapping. On the other hand the inability to distinguish freshwater marsh and permanent pasture are thought to be serious inadequacies when dealing with wildlife habitats, and false colour infra-red is thought to be the best film type for obtaining this information. Mudflats would be an additional category obtainable if photography were flown at low tide.

Mapping Categories

These should preferably conform to an existing classification for a similar area, for which field descriptive and quantitative data is available. In the absence of any such classification, mapping units could be derived from an a posteriori method, using the air photos as the primary source of information. Homogeneous units would be delineated, followed by field work involving visiting a specified proportion (e.g. 5%) of each delineated type, in order to verify the boundaries mapped. Subsequent laboratory work would then involve re-grouping the units delineated on the air photos according to the field information obtained, and any remaining unclassified areas could then be verified by subsequent field visits. These methods (see Kuchler 1967), would apply principally to natural environments since most lowland land use types are readily identifiable, though in a lowland area it might be necessary to carry out field surveys in order to check the accuracy of interpretation of categories such as fresh water marsh, small ponds, scrub and rough grassland.

Size of Unit for Data Collection

As stated in Chapter I of this study, if the information is to be used as part of an overall planning strategy, combined with other types of information, and to be stored by computer, discrete habitat areas are thought to be inefficient for the collection of habitat information over extensive areas of countryside. The efficiency of data collection by grid squares is influenced by the size of square used in relation to the number and size of habitat types within the study area. Based on the results of an experiment described in Chapter V and shown in Table 4, in view of the generalisations involved in grid square data, it can be suggested that in a lowland region data collection at the $\frac{1}{4}$ kilometre square level would be necessary in order to retain the required level of accuracy. In an upland region the larger size of the habitats would enable data to be collected at the level of the 1 or 5 kilometre square without a serious loss of accuracy. It is also suggested that the 10 kilometre square level would be feasible for some regional reconnaissance survey purposes.

Measurement of areas must necessarily involve a degree of error, whether using a planimeter or a dot grid sampling system. However, the greater length of time taken using a planimeter must be balanced against the loss of accuracy involved when a dot grid is used. It is thought that compared with planimetred measurements (Appendix IX), the 95.4% accuracy obtained using 25 dots for the $\frac{1}{4}$kilometre grid square (Appendix IX) would for most purposes be acceptable, and the 91.2% accuracy obtained using 100 dots for the 1 kilometre grid square (Nash, 1975) would also be acceptable. In this study measurement by planimeter of 23 habitats in 960, $\frac{1}{4}$ kilometre squares for the upland study area involved approximately 35 man-days and for the lowland study area, dot grid sampling of 15 habitats in 628, $\frac{1}{4}$ kilometre squares involved approximately 6 man-days.

3. Data Evaluation

The parameters for conservation evaluation, Local Scarcity, Species Diversity, Vertical Strata, and Inter- and Intra- Habitat Diversity have been found to be the most useful in this type of study, since data can be stored on a grid square basis, by computer, and can easily be obtained from air photos, or in the case of Species Diversity, from existing records for air photo-derived habitat categories.

It has been found (Chapter VI of this study) that in an upland region, characterised mainly by semi-natural habitats, Local Scarcity, Species Diversity, and the Product of the Habitat parameters (Diversity, Strata and Scarcity), had similar high correlation coefficients when correlated with conservation values subjectively allocated by a group of ecologists. In a densely settled lowland region, on the other hand, the parameters, Vertical Strata and Species Diversity were both very highly correlated with conservation values (see Table 5). A method for the objective evaluation of habitats could therefore be based on the allocation of equal weightings to each of these, for each type of region respectively. The Inter- and Intra-Habitat variables are also thought to be important, and probably more so in a semi-natural, as opposed to a cultivated or semi-rural landscape. Thus, it is suggested that equal weightings be attached to each variable within each region, though these should be lower than the weightings attached to the parameters, and slightly lower in a lowland than in an upland region. Therefore, weightings could be allocated as follows:-

Upland		Lowland	
Local Scarcity	3	Vertical Strata	5
Species Diversity	3	Species Diversity	5
Product of Parameters	3	Each of Variables	1
Each of Variables	2		

Total for each square = Conservation Value

In order for the weightings to take effect, the values for the habitat types according to each parameter would be scaled in order to obtain a mean value equal to the weighting. The formula for the conservation value of a habitat in an upland, or semi-natural environment could therefore be suggested as follows:-

$$\text{Conservation value of habitat } x = \frac{LSx}{\frac{\overline{LS}}{3}} + \frac{SDx}{\frac{\overline{SD}}{3}} + \frac{PPx}{\frac{\overline{PP}}{3}}$$

where LS = Local Scarcity
SD = Species Diversity
PP = Product of Parameters
$\overline{LS}$ = Mean of Local Scarcity values for all habitat types
LSx = Local Scarcity Value for habitat x

The formula for the conservation value of a single grid square would be as follows

$$\text{Conservation value} = \%\text{ cover }(xI) + \%\text{ cover }(x2)\text{.....etc. to }xn$$
$$+ 2\,v_I + 2\,v_2\text{ ....etc. to }2vn$$

where v = variables
x_1 = conservation value of habitat x_1 (as above)

In the formula the measurement obtained for each variable within a square would be multiplied by its value (2), thus although all of the variables are given the same value, some allowance is still made for its extent, or magnitude, within each square. The same formula could be applied to lowland regions, using the weightings suggested.

The parameters which cannot be used in this type of study, namely size, shape, and distance from the nearest similar feature, obviously contribute to the inadequacies of the method suggested, though they could be used at a more detailed level for the evaluation of individual habitats with discrete boundaries. These suggestions, moreover, are based on the results of one study, and should be treated as a guideline for ecological surveys for application at the generalised level, rather than as a defined methodology.

CHAPTER VIII

CONCLUSIONS

The present study was undertaken using remote sensing for the collection and evaluation of data for conservation purposes over large areas of countryside. From experience gained, it is thought that remote sensing is the most practical and efficient method for acquiring the generalised type of information needed at the regional survey level. The use of remote sensing allows large, often inaccessible areas of countryside, to be surveyed over a relatively short time period, and boundaries difficult to distinguish in the field may be easily seen on an air photo. In an easily accessible lowland region the use of air photos for ecological surveys can greatly reduce the time involved, even should some field work be necessary.

The two major problems encountered in using remote sensing, however, were firstly the lack of classifications of vegetation types or habitats suitable for air photo interpretation, and secondly the difficulty of obtaining suitable types of remote sensing imagery.

As demonstrated by the Moor House vegetation mapping experiment, and also in both the Gairloch and Merseyside study areas, it was impossible to reliably identify on the air photos used all the a priori defined vegetation and habitat categories.

In the case of vegetation mapping, this is probably to a large extent due to the criteria on which the initial classification is based. These criteria, including physiognomy, dominance and species composition, are derived from detailed field investigations and, apart from physiognomy, may bear little relationship to the image of the particular plant community on an air photo, especially since the image can vary at different times of year. Bracken, for example, which may be dominant in species composition in a plant community, may not actually appear above ground at certain times of year, and thus would not be identified on an air photo. Other plant types which are dominant, or sub-dominant, in a community may be small in structure and physiognomy, and the air photo image may comprise other species larger in size and lower in species composition. Certain types, such as mountain top communities and grasslands, may resemble each other at certain times of year, and in some habitat types geomorphological and terrain features may be more apparent than the associated vegetation on a corresponding air photo image.

In view of these difficulties there is an obvious need for the development of classifications suited to air photo interpretation based on the appearance of plant communities and habitats at different times of year in relation to their air photo image, and also in relation to the needs of the survey. It would, for example, be superfluous to attempt to distinguish between two plant communities of similar appearance if they had identical requirements and values for conservation and management purposes. A classification of habitats suited to the purposes of air photo interpretation could possibly be obtained by grouping some of the a priori defined categories on the basis of per cent cover of each type related to air photo appearance. Or alternatively, additional categories could be introduced on the basis of vegetation combined with geomorphological and terrain features such as rocks and rocky outcrops, mountain top detritus and scree, or the occurrence of small pools.

In the Gairloch study area the main difficulty was in the interpretation of mountain top habitats in some cases where it was found impossible to distinguish between areas of bare ground and the very pale toned Rhacomitum-Empetrum and Nardus communities which often provide only a sparse cover. However, because these environments are often inaccessible on foot, and because of the time involved in visiting large numbers of mountain tops, now frequently under great pressure from recreational and other types of development, e.g. the Cairngorms, some attempts should be made to comprehensively survey these areas, using a suitably devised classification. It is suggested that true colour aerial photography might offer a better opportunity for differentiating between vegetation and bare rock, and also between different types of Arctic-Alpine vegetation communities and geomorphological features on mountain tops, since on black and white photographs their generally light toned appearance limits the ability to differentiate between the narrow range of shades of grey. Warren, working in the Gairloch study area with the multi-emulsion photography mentioned in Chapter IV, found that true colour was preferable to panchromatic for distinguishing between vegetation and scree. From a total of 10, 10 and 4 points were allocated for this ability, to each film type respectively. For distinguishing between bare ground and vegetation, 9 points were allocated to true colour, and 6 to panchromatic (Warren, 1971).

In general, however, before attempts can be made to develop classifications suited to air photo interpretation, more must be known about the different types of remote sensing imagery and combinations of imagery which could best be used in different types of environment. The National Vegetation Survey, when completed, might provide a standardised basis for deriving habitats suitable for air photo interpretation.

In a lowland area the inability to distinguish freshwater marsh, and to separate the agricultural land types, arable, ley pasture and permanent pasture, was thought to be a serious limitation of the photography used. In a semi-rural lowland region wetlands may be isolated remnants of semi-natural vegetation and an important habitat for fauna; marshy areas and small ponds in a cultivated landscape may be surrounded by semi-natural vegetation left as unsuitable for ploughing. Permanent pasture, as opposed to arable land and ley pasture, is often very important for wildlife and may be very rich floristically due to the length of time it has remained unchanged. It is thought that false colour infra-red photography would be more successful for identifying both freshwater marsh and permanent pasture if, in the latter case, some criterionwere adopted for defining the age, related to the air photo appearance of permanent pasture. As well as the type of photography, scale is also important, and again this must be related to the purposes for which the data is required. Scales of 1:15,000 or 1:20,000 are suggested for upland areas and 1:10,000 or 1:15,000 for lowland. For an intermediate type of region, incorporating both upland and lowland environments, 1:15,000 would probably be most useful, since sufficient detail would still be available to record the greater amount of complexity in a more densely settled region, while retaining the advantage of dealing with a smaller number of prints and obtaining an overall view. The uses of smaller scales, however, may be restricted by the need to carry out subsequent, more detailed surveys of, for example, burning and grazing, classifying different types of bog, and in a lowland region, for recording and classifying important features such as hedges, road verges and railway cuttings.

The attempt to standardise units of data collection from air photos might be assisted by techniques of remote sensing data enhancement such as densitometry and spectral signature analysis (see Chapter II, part I). Multispectral photography might eventually be used to automatically identify vegetation or terrain types on the basis of spectral signature in different wavebands. In ecological studies these techniques could be used to specify the levels at which the image spectral differences between one vegetation or habitat type and another shall be seen as large enough to necessitate inclusion in different mapping categories, and ultimately to identify these. The difficulty of drawing objective boundaries in semi-natural environments where gradations from one type to another may be obscure could possibly be overcome by edge enhancement techniques, using digital outputs of spectral data. An experiment undertaken using a microdensitometer in the Gairloch study area is described in Appendix VII. Because the techniques are not yet sufficiently developed, it was possible in this experiment to record only relative variations in image density representing terrain variations in one local area. For this reason, the experiment was an attempt to use densitometric techniques as a means of indicating relative variations in terrain, or terrain diversity, within an area. The objective use of these techniques, however, requires purpose flown photography with the appropriate types of data collected at the time of the flight. In this, as in all aspects of remote sensing related to ecological studies, more work needs to be carried out using different types of remote sensing imagery. Of the parameters for conservation evaluation mentioned in Chapter I which have been considered in past studies, some were found to be more suitable than others for use with air photos. Moreover, with the additional limitations imposed by the collection and storage of data on a grid square basis, the parameters which could be used in this type of study were found to be Plant Species Diversity, Vertical Structure of the Vegetation, Local Scarcity and Inter- and Intra-Habitat Diversity, which includes both local terrain and vegetational features, as well as the number of habitats within an area. The parameter Local Scarcity was used to replace Rarity, since until considerably larger areas have been surveyed it will not be possible, in the national context, to give a reliable estimate of a particular plant community.

Although at the present time little is known about the optimum size of unit for data collection, it has been possible by grouping data collected for the smallest size of grid square, namely a $\frac{1}{4}$ kilometre square, into larger square units, to calculate the amount of accuracy lost at each level, in terms of the total amount of data for both upland and lowland study areas. With each increase in square size, the degree of uncertainty obtained for the data collected also increased and for the lowland study area the decrease in accuracy at all larger square sizes was thought to be unacceptable for most survey purposes. In the upland study area, however, results were obtained for square sizes as large as 9 x 9 and 10 x 10 which were thought to be acceptable for some purposes. Square size 10 x 10 would correspond to the 5 kilometre grid size which is thought to be the largest feasible mapping scale for extensive surveys of remote areas, particularly when time and other resources are limited. It is thought that the prior definition of homogeneous units as, for example, from small scale air photos or from satellite imagery, would enable the size of data collection unit to be considerably larger, with a smaller amount of accuracy lost.

The methods of data storage and output used in this study are considered to be flexible and open-ended. With data stored by computer, according to grid location, it is possible to add additional information, either ecological or other types of planning data, and to print out totals in visual form for the combinations specified.

Evaluation of the data collected may also demand flexibility. For example, the data storage and output methods used allow print outs of the locations of high value habitats, as well as of high value squares, or print outs can be obtained with an equal number of squares in each value class rather than those showing classes of equal value.

Largely due to inadequacies of the data collection process, conservation evaluation of large areas of countryside is seen, at the present time, as an exercise which is subjective. Standardised methods of evaluation can only be adopted for small areas where intensive field studies can provide exact, quantitative information about species number, species composition, etc., or for individual habitats when parameters such as size, shape and species composition can be thoroughly examined (see a study by Helliwell, 1974). For studies of large areas, however, until the data collection process can become more objective, attempts to standardise techniques of data evaluation will be inadequate.

In the present study the best method for obtaining habitat values was considered to be through consultation of authorities in the field of ecology and conservation. The fairly large variability in the values obtained must reflect the past and present reluctance of ecologists to make value judgements, and this lack of agreement is almost certainly a result of the non-existence of any definite guidelines suggesting the importance of different criteria for conservation evaluation. In attempting to provide an indication of the relative importance of different parameters used in conservation evaluation, a comparison of the evaluations according to each parameter with the ecologists' values showed that, in an upland area, the order in descending importance of Local Scarcity, Species Diversity, the Product of Parameters, and Vertical Strata, was obtained. In the lowland region the parameters arranged in order of descending importance were Vertical Strata, Species Diversity, Product of Parameters and Local Scarcity.

It was possible, for the purposes of conservation, to suggest a method for the rapid collection, storage and evaluation of ecological data in extensive areas of both upland and lowland environments. The usefulness of the method is subject to the limitations of the study itself which are in turn restricted by present technology and air photo availability in the field of remote sensing, as well as by the lack of suitable classifications of habitats and the lack of standardised criteria for evaluation in the field of ecology. However, the urgency at the present time to attach objectively defined conservation values to the whole of the countryside, as opposed to already designated sites, necessitates the development of a standardised method which is based on specified criteria. This will then enable comparisons with other areas in which data have been collected and evaluated in a similar way, and also enable values for conservation to be compared quantitatively with other types of planning use. The method suggested would be suitable for use by planning authorities or other bodies responsible for land use planning and management, though the need for further research is recognised in both remote sensing data collection and in the field of conservation evaluation.

ABSTRACT

This study examines the present and potential usefulness of remote sensing techniques for the collection of ecological data relevant to the needs of conservation evaluation over large areas of countryside.

Parameters for conservation evaluation are examined in relation to air photo capability and in relation to methods of data storage.

Two areas, one upland, one lowland, were chosen according to air photo availability, and wildlife habitat maps were produced, with mapping units derived from previously defined classifications. It was thus possible to evaluate the usefulness of air photos in relation to existing vegetation classifications in these two study areas, and also in relation to a detailed vegetation map of part of the Moor House National Nature Reserve. Types and scales of remote sensing imagery could be recommended for further studies of a similar nature.

An experiment was carried out in order to indicate the optimum size of data collection unit in relation to the level of accuracy obtained for varying square sizes, in both upland and lowland study areas.

The habitats in each study area were evaluated for conservation purposes by a group of eminent ecologists, and by comparing the values obtained with those for the conservation parameters, Species Diversity, Vertical Strata, and Local Scarcity, it was possible to indicate the relative importance of each parameter in each study area.

Finally, based on the results of the present study, a method was suggested, using remote sensing as the primary source of information, for conservation evaluation over large areas of countryside.

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APPENDIX I

EXISTING TECHNIQUES FOR ECOLOGICAL EVALUATION

1. Ecological Appraisal of West Sussex: West Sussex County Council 1973

This study is an example of an extremely simple method. Aerial photographs at a scale of 1:12,000 were used for habitat mapping and the habitats were weighted by a member of the Nature Conservancy on a scale of from 0 to 10 in terms of wildlife value, i.e.

High Grade Habitats		Other Habitats	
Woodland	10	Parkland	8
Scrub	10	Orchard	6
Heath	10	Plantation	6
Unsown Grassland	10	Improved Grassland	3
Tidal Mudflats	10	Arable	2
Sand Dunes, Sand	10	Developed Areas	0
Freshwater marsh	10		
Saltings	10		
Freshwater	10		

The proportion of each habitat type in each km^2 was estimated using a sampling system comprising 16 equally spaced dots, each representing 6.25% of the area of the km^2. A score for each habitat in a square was then obtained by multiplying the number of dots falling on it by its weight, and the scores were added together to give a total score for each square. Additional points per km^2 were allocated for large areas of over $\frac{1}{2}$ km^2 of high grade habitat,hedges represented by the number of fields and for the presence of nature reserves, SSSIs and reserves owned by the Sussex Trust for Nature Conservation.

2. The Assessment of Ecological Value: A new approach and field Evaluation: Conservation Course, University College 1972

This study was carried out in part of the Wye valley and surrounding upland. Data was collected in the field and assessment was based on the parameters of Extent, Rarity, Plant Species Diversity and Animal Species Diversity (related to vertical layers of the vegetation). Calculating an Index of Ecological Value for each km^2, the study concluded that different parameters, and different weightings of the parameters should be used for evaluation of upland and lowland areas respectively. A second conclusion reached was that in studies of this type there was a need for some basis for overall comparison of results, such as sites already designated, or evaluated by a different method. The use of aerial photographs was recommended for future studies of this type.

3. Criteria for the Selection of Nature Reserves: D.A. Ratcliffe. Advancement of Science, 27.

The processes of selection of Nature Reserves are outlined as comprising 1. field survey, 2. the application of agreed standards of judgment to the data collected and 3. the final choice of some of the highest quality sites. The judgment and selection of sites is based on

Extent
Diversity
Naturalness
Rarity
Fragility
Representativeness
Research and Educational Value
Recorded History
Potential Value

4. An Ecological Evaluation for Planning Purposes: East Hampshire AONB Report, 1968, Hampshire County Council.

The study was undertaken as part of a general resources survey for planning purposes, which at the time was a new approach in rural planning. Most of the data was collected by field survey methods, though air photos were used to determine boundaries between different ecological zones, for inaccessible areas and for the location of agricultural land and hedgerows.

The wildlife value of the area was divided into five categories based on the parameters of habitat diversity and rarity of the ecological zones, in the context of Southern England.

The 28 ecological zones mapped fell into one of three broad categories.

(a) A complex of habitats comprising a particular type of agricultural land

(b) Commercial woodland

(c) Unsown vegetation

Evaluation of the zones was based on subjective criteria. Because of their rarity in lowland England, <u>unsown vegetation</u> and <u>commercial</u> woodlands were given high and fairly high values respectively. The evaluation of agricultural land was based on habitat diversity, reflected by the presence and amounts of the following features

1. Permanent pastures and long term leys
2. Hedgerows and hedgerow timber
3. Boundary banks, roadside cuttings, banks and roadside verges
4. Park timber and orchards
5. Ponds, ditches, streams and other water courses
6. Fragments of unsown vegetation smaller than $\frac{1}{2}$ km^2 (the minimum size limit for an ecological zone).

For each agricultural zone the above features 1-6 were given scorings as follows

0 = none, or virtually none present

1 = present (not conspicuous)

2 = numerous

3 = abundant

Thus the five categories of wildlife value comprised

Categories I and II Unsown Vegetation
II and III Commercial Woodland

Agricultural land fell into Categories II, III, IV and V according to score.

5. A Quantitative Survey of Chalk Grassland in England
J.W. Blackwood and C.R. Tubbs, 1970, Biological Conservation
Vol. 3 (From a survey carried out in 1966).

The aims of the survey were to demonstrate the practicability of carrying out rapid and extensive quantitative habitat surveys and secondly to obtain data about the amount and distribution of chalk grassland as a basis for further study. Mapping was carried out by field survey and the criteria for inclusion were strictly defined.

The habitat was defined as "unsown grassland on soils of which the parent material was chalk". Other refinements, largely subjective, were made, e.g. former use of herbicides meant exclusion as did sites less than 2 hectares and sites with over 50% scrub. Areas were estimated by using a transparent grid superimposed on survey maps.

The data obtained was on a county basis and included

Acreage of chalk grassland
Acreage of land on chalk
Chalk grassland percentage
Number of fragments (by size categories).

6. A Method for the survey and classification of marginal land
in agricultural landscapes. M. Kent (1972), M.Sc. Thesis,
University College, London

Marginal land, for the purposes of this study, is defined as "land not, or only marginally, involved in agricultural production, and lying outside areas of settlement". The methodology developed had two basic phases; firstly, data collection and secondly organisation of the data into a meaningful form, preferably of use to the planner, or decision maker.

Data was collected from maps and by field survey for all marginal sites within one region, and the following site characteristics were recorded

1. Area
2. Shape
3. Measure of habitat type (using Elton's system of habitats and formation types)
4. Vegetation species diversity - number of species counted for each type of habitat
5. Quality of surrounding agricultural land
6. Access quality and access distance
7. Distance from nearest similar feature
8. Present use of site
9. Landscape quality
10. Ownership

The data was then classified on the basis of site similarity for management purposes, using cluster analysis, the main divisions of the data being based on habitat types.

7. <u>An Ecological Survey and Evaluation: C.L. Scott (1972) M.Sc. Thesis, University College, London</u>

The aims of the survey are seen as

1. ease of assimilation into the planning process
2. accuracy and objectivity to enable comparison between different areas
3. simplicity, for understanding by both ecologists and laymen
4. provision for use at different levels of the planning process

Aerial photographs and field surveys were used for data collection on habitat types on a 200 metre^2 grid basis, and the evaluation parameters used were

- Vegetational Species Diversity - number found by field samples
- Vertical Structure
- Size (including shape)
- Scarcity

The scorings for vertical structure were as follows

			Score
		Edge	10
	High Canopy (Trees)		
15'		Edge	8
	Low Canopy (Scrub)		7
6'		Edge	6
	High Field layer		5
3'		Edge	4
	Low Field layer		3
6"		Edge	2
	Ground zone		

<u>Scarcity</u> was measured at the local level by giving a value inverse to the amount of the habitat within the test area. Arbitrary values of 10 were given for each of National and Regional scarcity. Measurements of <u>size</u> took account of percent cover in each square and the total size of the habitat, e.g.

$STH_1 \times C_1 + STH_2 \times C_2$

STH = Total Size of Habitat

C = % cover in 200m^2

Species Diversity values were calculated by multiplying the number of species found in a particular habitat type by the percent cover of that type in each 200m square.

Total values for each 200m square were then calculated by multiplying together the scores for each parameter. Scores for discrete areas were also obtained by adding all the squares touched by the area.

8. Conservation of the New Forest: Forestry Commission et at (1970)

Data was collected using maps, ground knowledge and field survey and aerial photographs, and after trying the division of the area into a grid based on 500 sq. metres, discrete areas were adopted for greater precision, which proved too complex when comparing different types of information.

The study used subjectively chosen categories of unenclosed common land, enclosed private land, and forestry commission enclosures. The categories were then evaluated subjectively according to three grades of value based mainly on habitat and species diversity and according to local knowledge of the area.

9. A Plan for the Chilterns: Joint Study Group, 1971, Report of the Chilterns Standing Conference

Habitats were mapped at the 1:25,000 scale. These included

Woodland (deciduous, coniferous, mixed, coppice with standards)
Scrub
Grassland (chalk downland, acid grassland)
Heath (dry, wet)
Wetland (marsh, water meadows)
Open water
Agricultural land
Built-up areas

The habitats were evaluated subjectively based on the fact that "a sound local knowlege is needed". Areas were marked 'important', 'very important', and 'worth preserving', arbitrarily using weighting factors such as the importance of beechwoods and chalk grassland in the Chilterns and the scarcity within the Chilterns of other habitats.

10. The Value of Vegetation for Conservation: Four land areas in Britain. D.R. Helliwell, 1974. Journal Environmental Management Volume 2

This is the first study to compare one region with another, rather than one part of a region with other parts of the same region, and is of great value in that it specifies the use of defined weightings which can be applied to any area in Britain, based, as they are, on rarity of the actual species in the study area. One area had already been mapped by the Nature Conservancy using colour and black and white air photos, and the other three were sampled in a random fashion on the ground.

The Atlas of the British Flora was used to compare the frequency of plant species in each km^2 in the study area with its occurrence in the region and in Britain. A total score for each species was obtained based on its local, regional and national rarity. Using a constant index for conservation value, the scores for all the species are summed to give a total score for the study area. Using this method for four study areas it was possible to compare, with some degree of objectivity, the total value for conservation of the plants in each region.

11. Coventry - Solihull - Warwickshire: A Strategy for the Sub-Region, Warwickshire County Council (1971), Supplementary Report 5 - Countryside

The basis of this report was the work of Helliwell, with values based entirely on rarity and species diversity. In the absence of a scientific classification of habitats, land use categories previously defined for a landscape study were used. Categories were amalgamated wherever their habitats were sufficiently similar to support the same, or comparable species. On this basis the habitats used were:

Farmland
Woodland
Developed land
Parkland
Heathland
Unused land
Water

Scarcity indices were based on total extent within the region. Diversity indices were based on a consensus of opinion within the Nature Conservancy, and combined values were found by multiplying them together. These final values were then compared with distributions from the Atlas of British Birds (1970), since birds are known to respond quickly to changes in the environment. The number and scarcity of birds within each 10 km square showed a reasonable correlation with the wildlife values arrived at.

Biological Sites Recording Scheme, S.P.N.R. Conservation Liaison Committee, Tech. Publ. No. 1, 1969

This scheme is not a study of a particular area, but is a methodology devised to enable habitats to be classified objectively according to specifically defined criteria. The scheme originated from the lack of a standard method for collecting reliable information on the extent, distribution, quality and management of habitats in the county. A method is described for collecting habitat information about sites. This would include:

1. Variety of habitat present
2. Species associated with habitats (frequency and extent)

The habitat classification used considers both vegetation, and the physical characteristics of the environment, such as soil acidity and drainage regime. Habitats are defined according to vegetation structure and species composition, with structure comprising the first level of the hierarchy, and each habitat can be modified by designations Alpine, Brackish, Maritime, Intertidal and Peat. Data is collected on record cards for easy transfer to 80 - column punch cards.

APPENDIX II

Scattering

Rayleigh Scatter

This is performed by atmospheric molecules and extremely small particles smaller than the e-m radiation. This shortwave radiation is scattered more than long; blue light being scattered four times more than red light, changing its direction, but not its colour or energy. Because it affects the shorter wavelengths, Rayleigh scatter is more obvious on clear days when there are fewer particles of dust and water vapour which affects both short and long wavelengths. It is also more evident later in the day, with a longer atmospheric path of the sun's rays. So many of the blue wavelengths may be scattered that the sun often has a reddish appearance.

Mie Scatter

This is caused by small droplets and particles with similar wavelengths to e-m radiation. The total amount of scatter is greater than Rayleigh scatter, affects longer wavelengths and is selective according to wavelength, blue light still being affected more than red, however.

Raman Scatter

This is insignificant compared with the total amount of scatter. Occurring in the visible and ultra-violet parts of the spectrum, it involves a change in energy, and, therefore, in wavelength, of the photons received.

Non-selective scattering

This type scatters all wavelengths and is accomplished by particles several times the size of the e-m radiation, e.g. fog, mist, rain or smoke. Water droplets in clouds, and smoke particles scatter all wavelengths equally well, hence the generally white appearance of clouds and smoke.

APPENDIX III

Factors affecting quality and information content of an aerial photograph (After Roedel 1972)

a) Incident sunlight/skylight

b) Primary attenuation of sunlight by atmosphere

c) Spectral absorption and reflection of the ground subject

d) Intensity of ground subject reflection

e) Secondary attenuation of ground reflected light by atmosphere

f) Spectral transmittance of the optical system

g) Spectral sensitivity of film emulsion

h) Quality control of film processing system

APPENDIX IV

PHOTOGRAMMETRY

For photogrammetric mapping purposes vertical aerial photographs tend to be preferred to oblique photography. Most measurements are carried out using adjacent, overlapping photographs under a stereoscope, which produces a 3-dimensional image. Measurement of objects imaged on the photograph depends on knowledge of the scale, which is a function of the focal length of the camera, and the flying height above ground level of the plane. The most popular focal length is 6 inches and so to produce a scale of 1:10,000, the plane would have to fly at a height of 5,000 feet above ground level. The difficulty of doing this consistently in rugged and mountainous terrain, however, produces inconsistencies in scale. Distortion of objects on the photograph can also be caused by tip and tilt of the plane, i.e. nose and tail, or either wing up or down respectively, though the amount of tip and tilt can be calculated, and distortions rectified. Most photographs are automatically rectified to remove geometrical distortions, and electronically dodged to lighten areas of shadow or darken areas of high reflectance or glare.

The height of objects on the ground can be obtained by measuring the parallactic displacement of objects caused by the fact that the camera has looked at them from a slightly different angle on each photograph. Contours can be plotted by obtaining a series of measurements and joining up points with similar height above datum. Alternatively, contouring can be carried out using a plotting machine such as the Wild A7 stereo-plotter, relatively rapidly, and with a high degree of accuracy. For example, using photographs at a scale of 1:3000 a 6ft. contour interval can be achieved.

APPENDIX V

FILM EMULSIONS

True Colour Film

True colour film has three sensitive emulsion layers using the colorants, Cyan, Magenta and Yellow, which are sensitive to red, green and blue light respectively (Figure 5). A yellow filter is placed between the blue and green sensitive layers, since they are also sensitive to blue light. Its resulting sensitivity is thus approximately 0.4 - 0.7 microns. Using these three primary colours it is possible to produce all colours perceived by the human eye, though there is no process to accurately do this. Colour film is used with a Wratten 1A filter to cut out short wavelengths, absorb blue light and haze, and thus correct the colour balance at low altitudes.

Panchromatic Infra-red film

This film has a sensitivity to all parts of the visible spectrum except between approximately 0.5 and 0.52 microns. It extends into the near infra-red as far as 0.9 microns and its use with an 88A filter cuts off light below 0.70 microns. As a result, the overall sensitivity covers parts of the red and near infra-red portions of the spectrum. It is thus not affected by atmospheric haze, although most investigators agree that the usefulness of this film is limited by the 'washed out' appearance of the image, the loss of clarity being partly due to the fact that most aerial cameras are set with the focal plane appropriate for panchromatic film, infra-red film needing 0.5% greater focal plane. A second difficulty is in obtaining the correct exposure, since the filter used excludes most of the visible light and infra-red film tends to be underexposed.

False Colour Infra-red Film

Similar to true colour film in that it has three sensitive layers, False Colour Film has the blue layer replaced by an infra-red sensitive layer. Cyan-, yellow-and magenta-forming layers are sensitive to infra-red, green and red radiation respectively. All emulsions of the film are sensitive to visible radiation below 500 microns, but these wavelengths are eliminated by the use of a yellow, minus blue filter. Objects reflecting only infra-red energy will form a red image, those reflecting only red energy will form a green image and those reflecting energy in the green part of the spectrum will form a blue image.

Multispectral Photography

Because of its sensitivity to all of the visible wavelengths panchromatic film is well suited for use with different filters in multispectral photography. This is a process which uses several sensors to record e-m energy from a scene, each in a different restricted spectral band. For example, if two objects such as grass and trees reflect similar amounts of energy in the green band and differ in the red band, then in order to distinguish between them it would be necessary to use a film-filter combination sensitive to red, but not necessarily to green light. A popular choice of film-filter combination to obtain multispectral photography using panchromatic film is:

Panchromatic	film	with a	47B	filter	(0.40 to 0.48 microns)
"	"	"	61	"	(0.47 to 0.61 ")
"	"	"	25A	"	(0.58 to 0.72 ")
"	"	"	88A	"	(0.70 to 0.90 ")

Multispectral photography is carried out using either a multi-lens camera or two or more cameras bore-sighted together, though neither device is as yet readily obtainable, and work in multispectral photography is still very much of a research nature.

APPENDIX VI

Technology for Remote Sensing Data Enhancement

Densitometric Analysis

This involves measuring photographic density of very small portions of a photograph, e.g. 1 million bits per photograph, in one or several spectral bands, using a scanning microdensitometer. If certain physical conditions of the system are known, the density can be converted to a spectral signature (Preston, 1974). This signature can be used in automated systems to identify the object on the photograph according to the difference in density in each band, or the spectral signature. Unique spectral signatures are not known for most environmental parameters, owing to dynamic variables in the environment, or to instrumentation errors.

There are certain highly specific requirements necessary for the scientific evaluation of aerial photographs using densitometry, and these requirements should be observed for most photographic missions if meaningful conclusions are to be drawn from the imagery obtained. The criteria needed are:

1. Film characteristics
    - a) D log E curve for the film gamma
    - b) Spectral sensitivity curve
2. Filter transmission
3. Lens characteristics
    - a) Light distribution at the film plane
    - b) Spectral transmission
    - c) Focal length
    - d) Field of view and correspondent image field size
    - e) Aperture
    - f) Shutter type and speed

4. Environmental conditions
    - a) Sun altitude and incidence relative to flight line
    - b) Meteorological conditions at time of flight

5. Calibration control

either a) Ground control panels of known spectral reflection properties to be included in at least the first and last frames

or b) Measurements by a telespectroradiometer at several points during the flight, these to include the downward solar flux distribution at the aircraft level

6. Spectroradiometer measurements of spectral reflectance of vegetation in selected test areas in the flight line. Correlations can then be applied to the densitometric data obtained from the photography, allowing a greater degree of confidence in classifying objects and extending signatures to areas beyond those used.

Digitisation Techniques

These computerised techniques convert the photographic densities obtained from each band to a computerised numerical value. The spectral signatures from each point are classified as belonging to an already defined group of objects. Thus, each ground resolution element can be allocated to a particular ground cover type based on similarity of spectral signature. A computer symbol, or digit can be used for each of these types, and a print out of estimated ground cover types can be obtained in map form.

Image Enhancement

There are three main techniques which can be used to aid interpretation of an image. These are:

Density slicing - This involves the measurement of photographic density by an image processor capable of recording a large number of grey tones, to which a range of colours is allocated, and the enhanced image can be displayed on a video screen.

Edge enhancement - This involves machine measurement of the overall range of photographic density within image components of a size designed as constituting an edge. The size is specified according to the type of edge being investigated, since a field boundary edge, for example, may be narrower than the boundary between two natural vegetation units. Where the range of photographic density between one image component and the next is greater than a specified level, these components constitute an edge.

Additive colour techniques - These are used for the enhancement of multispectral photography, from which positive transparencies have been produced for the image representing each band. These are then projected, each with a different coloured light, to be superimposed on one another. By using blue, green and red lights, a true colour rendition can be obtained and if a fourth infra-red image is used, a false colour image results. A special additive viewer gives control over brightness and colour saturation, though the basic effect can be achieved using a lantern slide projector.

APPENDIX VII

COLLECTION AND PROCESSING OF REMOTE SENSING DATA RELATED TO WILDLIFE CONSERVATION IN NATURAL ENVIRONMENTS

INTRODUCTION

There is a growing need, in many countries of the world, for rural planning of a comprehensive nature, involving the rapid collection and evaluation of thematic information relevant for wildlife conservation. Environmental planning, in this context, aims at protection of the most ecologically interesting areas by allowing only compatible forms of land use, with more intensive development of the least interesting areas.

This study describes the collection, processing and evaluation of remote sensing data related to wildlife habitats in the Gairloch Conservation Unit, Wester Ross, Scotland (Figure 1), by both manual and machine-assisted methods.

Figure 1. Study Area

Aston University

Illustration removed for copyright restrictions

I GROUND TRUTH DATA COLLECTION

METHODS USED

The film types used were black and white panchromatic prints and true color transparencies, both at a scale of 1:10,000.

The collection of environmental data relating to the area's ecological interest was done thematically, using the panchromatic photography, since adequate coverage of the color photography was not available. Data was obtained for the whole area and was fed into a computer on a $\frac{1}{4}$ km^2 grid basis. The data collected included

A. HABITAT TYPE

Type of wildlife habitat (based mainly on vegetation mapping categories, but including such environmental features as bare rock, scree, water surface, etc.)

B. INTRA-HABITAT FEATURES

1. Stream length (kms per $\frac{1}{4}$ km^2)
2. Coast length (kms per $\frac{1}{4}$ km^2)
3. Woodland edge (kms per $\frac{1}{4}$ km^2)
4. Relative Relief (difference in altitude within $\frac{1}{4}$km^2)
5. Boulder-strewn terrain (% within $\frac{1}{4}$km^2)
6. Rocky outcrops (areas having over 33% surface in rocky outcrops (% within $\frac{1}{4}$km^2)
7. Crags (% within $\frac{1}{4}$km^2)
8. Number of water surfaces (per $\frac{1}{4}$km^2)
9. Number of habitats (per $\frac{1}{4}$km^2)

EVALUATION

Both the habitat types and the Intra-Habitat features were given a value based on questionnaires sent to a group of eminent ecologists, and a print-out of the total value for each square was obtained.

II

This type of rapid survey which is, in ecological terms, both small scale and generalised, cannot include some of the important factors in ecological evaluation, such as species rarity and species diversity; however, at this scale of survey, variety of terrain and diversity in and between habitats become important, and are readily identified on aerial photographs.

MICRODENSITOMETER ANALYSIS

METHODS USED

To obtain a more objective measure of terrain diversity both within and between habitats, a scanning microdensitometer was used with 38 randomly selected frames of the true color transparencies (Figure 2) in order to measure variations in photographic density. The area of each frame corresponded to $\frac{1}{2}\text{km}^2$. It was assumed that photographic density would correspond to variations in conditions on the ground i.e. terrain diversity.

Figure 2, Black and White print from colour transparency.

Aston University

Illustration removed for copyright restrictions

The initial survey using the panchromatic photography provided ground truth information and values were calculated, as above, for areas corresponding to each of the 38 frames selected. These more conventional assessments of ecological value could then be compared with the values obtained using the scanning microdensitometer i.e. qualitative measurements of different terrain features compared with generalised measurements of variations in photographic density, this also representing terrain variation.

Four parallel scan lines a frame were obtained for the 38 frames and slit width was adjusted to 800 , representing 8 meters on the ground at 1:10,000 scale. Graphs were drawn for each scan line (Figure 3).

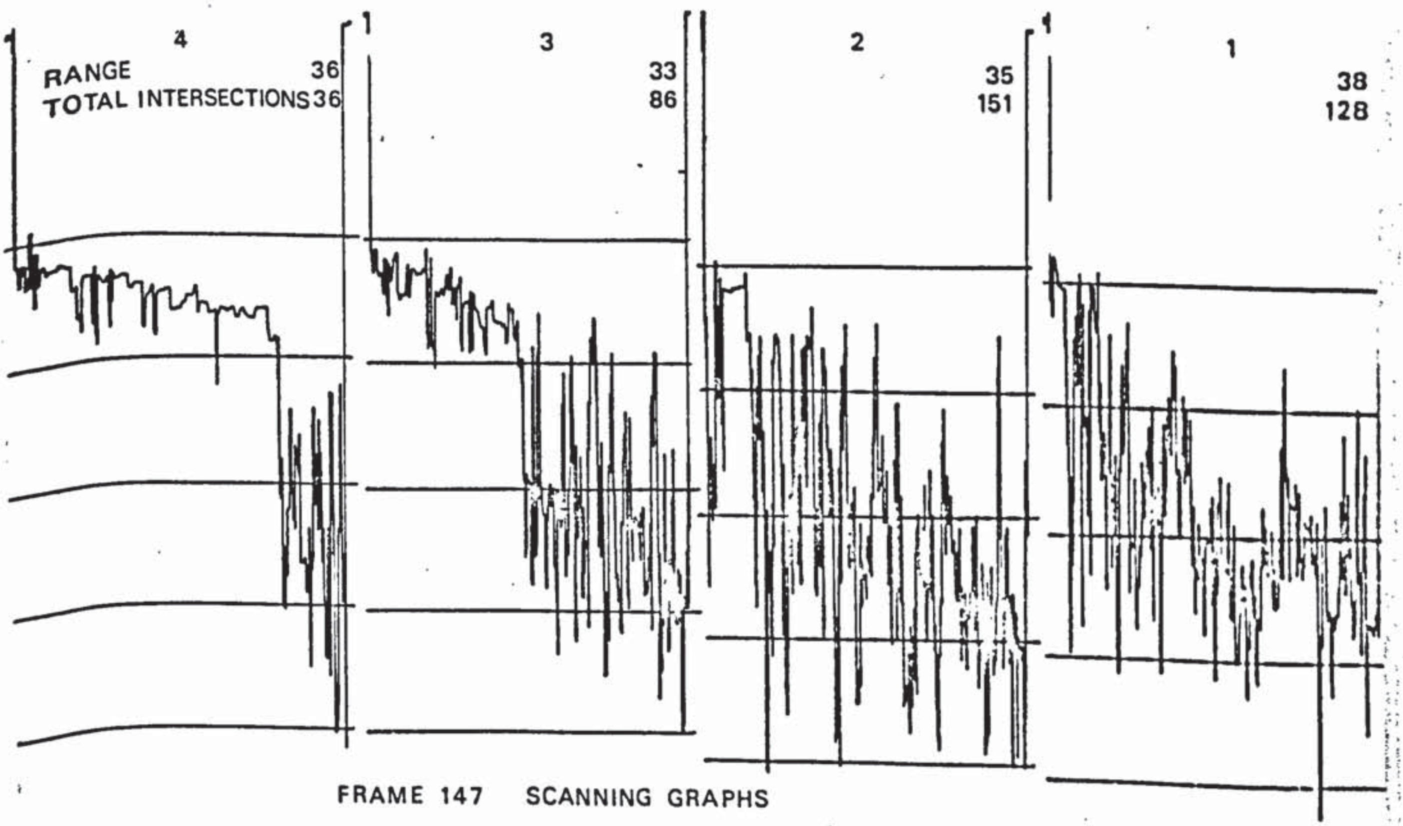


Figure 3. Frame 147 Scanning Graphs

Processing of the scanning graphs involved consideration of the total number of intersections of the graph with class boundaries which were fixed according to the average range of all the graphs and of each individual graph. Graphs having the greatest number of intersections indicated frames with the highest amount of variation in photographic density. Scanning graph data was then correlated with scores for the areas of frames evaluated according to Intra-Habitat variables.

RESULTS

The table below shows the results for the first five out of 38 frames.

TABLE 1

FRAME	GRAPH TOTAL INTERSECTIONS	INTRA HABITAT-VARIABLES
1	610	1188
2	563	919
3	500	858
4	616	2151
5	579	1027
etc to 38		

CORRELATION COEFFICIENT = 0.606

From statistical tables the correlation coefficient 0.606 has approximately 1 chance in 1000 of being not significant, i.e. there are 1000 to 1 chances that the data are significantly correlated.

CONCLUSIONS

The results show that the variations in photographic density on the sample frames shown by fluctuations of the corresponding scanning graphs correlate well with values assigned to measured variations within and between habitats on the ground, i.e. Intra-Habitat diversity (variables B 1-9).

SUMMARY

Among the inadequacies of this, and similar surveys, are:-

1. Some variations on the ground may not be fully represented in variations in photographic tone, e.g. shadow due to sun angle and sloping terrain.
2. The impossibility of measuring (e.g. in B. 1-9) all the terrain variations.
3. The difficulty of accurately combining values for e.g. stream length with those for relative relief, however, in terms of environmental planning, it is being realised that this kind of effort must be made, for the purpose of making comparisons and decisions between different areas.
4. Lack of knowledge of atmospheric and film processing criteria for the particular mission prohibits absolute comparisons between ground and remotely-sensed data.

APPENDIX

Scores for all measured variables were divided into classes ranging from 1 to 10, the size of a class being based on the range of scores in that category, i.e. highest to lowest.

e.g. Relative Relief Category

Highest = 500(m) Lowest = 0 in any area corresponding to a frame

Scores of 0 - 49 = 1
50 - 99 = 2
450 - 500 = 10

APPENDIX VIII

Data used for mapping categories

Mapping categories, according to Conservation Course (1971) derived from 'Plant Communities of the Scottish Highlands' (McVean and Ratcliffe, 1962)

Mapping categories comprise the following types:

Category	Types included
Pinewood	Pinetum Hylocomieto - Vaccinetum Pinetum Vaccineto Callunetum
Birchwood	Betuletum Oxaleto - Vaccinetum either birch or rowan dominant
Bracken Grassland	Birchwood, fern-rich, treeless facies
Calluna	Vaccineto - Callunetum Molinieto - Callunetum
Calluna Molinia	Molinieto - Callunetum Tricophoreto - Callunetum Molinia - Myrica nodum
Calluna-Molinia/Tricophorum-Eriophorum	Molinieto - Callunetum Tricophorum - Eriophorum Calluneto - Eriophoretum
Tricophorum-Eriophorum	Tricophoreto-Eriphoretum typicum Molinieto-Callunetum Molinia-Myrica nodum
Calluna-Juniperus	Juniperetum nanae Western Calluna-Arctostaphyllos Arctoeto-Callunetum Molinieto-Callunetum Vaccineto-Callunetum
Deschampsia caespitosa	Alchemilla-Agrosto-Festucetum Thalictrum-Ctenidium provisional nodum Deschampsieto-caespitosae alpinum Tall herb nodum Deschampsieto Rhytidiadelphetum Triquetrosum Philonoto-Saxifragetum stellaris
Rhacomitrium-Empetrum	Rhacomitreto-Empetrum Cariceto-Rhacomitretum lanuginosae The cusion herb facies of the preceding type Nardus-Tricophorum nodum

Category	Types included
Rhacomitrium-Empetrum with Nardus	Nardus-Tricophorum nodum Nardus-Rhacomitrium nodum Cladineto-Callunetum Cariceto-Rhacomitretum lanuginosae

Field sampling methods used (after McVean and Ratcliffe)

Square plots were marked out, slightly larger than the recognised minimal area, (Poore, 1955). A standard plot size of 4 square metres was used, but where appropriate, sizes of 1, 2 and 16 metres were used. Species occurring in each plot (including bryophytes) were then listed, along with criteria such as altitude, aspect, slope, percent cover and height. Species Diversity values for the Habitat mapping units were taken as the average number of species in each of the McVean and Ratcliffe vegetation types making up the Habitat mapping unit, e.g. Montane Heath was given the average of the number of species occurring in Juniperus nanae and Arctostaphyllos-Calluna types.

Eroding bog was counted as Calluna-Molinia
Unpatterned bog was counted as Tricophorum-Eriophorum
Bog with distinct pools was counted as Tricophorum-Eriophorum
Linear patterned bog was counted as " "
Improved land was counted as Spp. poor Agrostis-Festuca
The categories, Bare Ground, Scree, Peat Cutting, Coastal Grassland, Sand Dunes and Water Surface did not occur in McVean and Ratcliffe vegetation types, and the number of species in each of these was taken from Birks (1973).

Criteria used (after Birks) for evaluations of Species Diversity

Sand Dunes — Plot Size $4m^2$. No. of stands = 2
Fore dunes av. no. of spp. = 18
Grey dunes " " " " = 26

Coastal Grassland — Plot size $4m^2$. No. of stands = 5
Molinio-Arrenatheretea
Average no. of spp. per stand = 29.4

Water Surface No. of lochs sampled = 11
Average No. of spp. = 14.7

Peat Cutting Allocated same score as eroding peat

Bare Ground Plot size = $\frac{1}{2}$ and 1 square metre
No. of stands = 7

Sampled communities on igneous rocks, on blocks, and irrigated rock slabs

Average no. of spp. = 16

Scree Communities Plot size = $4m^2$ No. of stands = 4

Sampled scree and gravel communities of the Alpine and Sub. Alpine zones.

Average no. of spp. = 14

MERSEYSIDE

Data from South-West Lancashire Data Bank, Merseyside Museum.
Agricultural land value taken as average of Rough Grassland and Managed Grassland.

* No values obtainable therefore values allocated based on estimations from values for other habitats.

APPENDIX IX

COMPARISON OF AREAS (PERCENTAGES) OBTAINED FROM SAMPLE POINTS AND MEASURED AREAS

TABLE 3.

	9 dots per $\frac{1}{4}$ km^2	16 dots per $\frac{1}{4}$ km^2	25 dots per $\frac{1}{4}$ km^2	Measured	Difference from measured areas		
					9 dots	16 dots	25 dots
A2	-	0.2	0.2	0.2	-0.2	0	0
H	12.2	11.7	12.5	12.5	-0.3	-0.8	0
I	0.5	0.4	0.5	0.6	-0.1	-0.2	-0.1
J	62	58.2	59.0	57.8	+4.2	+0.4	+1.2
K	1.7	1.3	1.6	3.4	-1.7	-2.1	-1.8
L	4.4	5.1	5.0	5.4	-1.0	-0.3	-0.4
M	17.5	20.5	18.7	17.6	-0.1	+2.9	+1.1
Mg	1.7	2.4	2.5	2.5	-0.8	-0.1	0
			PERCENT	ERROR	8.4%	6.8%	4.6%

APPENDIX X

VALUES FOR THE HABITAT PARAMETERS, SPECIES DIVERSITY VERTICAL STRATA AND LOCAL SCARCITY

GAIRLOCH

	Habitats	Local Scarcity	Vertical Strata	Species Diversity
1	Pinewood	1.9	4	18
2	Birchwood	1.65	4	28
3	Mixed woodland	0.55	4	23
4	Bracken	5.6	2	25
5	Calluna-Molinia	0.01	2	18
6	Calluna	0.18	2	33
7	Calluna-Molinia/Tricophorum-Eriophorum	0.02	2	21
8	Eroding Bog	0.92	2	18
9	Unpatterned Bog	0.21	2	23
10	Bog with distinct pools	0.74	5	23
11	Unpatterned Bog	0.52	5	23
12	Calluna-Juniperus	0.41	2	24
13	Montane Heath	0.15	2	24
14	Deschampsia Grassland	0.24	2	29
15	Rhacomitrium-Empetrum	0.22	1	20
16	Rhacomitrium-Empetrum with Nardus	0.38	1	20
17	Coastal Grassland	2.17	1	29
18	Bare ground	4.26	1	16
19	Scree	0.73	1	14
20	Peat Cutting	8.84	2	18
21	Improved land	0.43	2	25
22	Sand dunes	1.78	2	22
23	Water Surface	0.26	3	15

MERSEYSIDE

	Habitats	Local Scarcity	Vertical Strata	Species Diversity
1	Coniferous woodland	25.6	4	30
2	Deciduous woodland	3.8	4	150
3	Mixed woodland	25.0	4	150
4	Sand dunes	0.5	4	200
5	Salt marsh	4.0	5	50
6	Water bodies	22.2	3	130
7	Heathland	24.4	2	50
8	Unimproved Mossland	9.6	3	20
9	Scrub	2.3	3	50
10	Rough Grassland	2.4	2	150
11	Agricultural land	0.2	2	77
12	Allotments, Cemeteries, etc.	7.2	3	40*
13	Managed grassland	1.8	2	5
14	Developed land	0.3	0	1*
15	Residential areas with gardens	1.3	3	20*

*No data available. Values derived from other similar types and subjective opinion.

SOURCES

Vertical Structure of the Vegetation, after Elton, 1966

Species Diversity: GAIRLOCH, after McVean and Ratcliffe, 1962

APPENDIX XI

RESULTS OF EVALUATION OF HABITATS AND INTER-AND INTRA-HABITAT VARIABLES, ACCORDING TO THEIR CONSERVATION VALUE

Evaluation was carried out by questionnaire to ten 'eminent' British ecologists. Average values (maximum 8.0) and Standard Deviations are given in the tables below.

GAIRLOCH

Habitats	Average of Ecologists' Values	Standard Deviation	Ratio
1 Pinewood	7.0	4.25	16.5
2 Birchwood	5.7	4.48	12.7
3 Mixed woodland	5.9	5.05	11.8
4 Bracken	1.6	3.79	4.2
5 Calluna-Molinia	2.4	4.52	5.3
6 Calluna	3.9	7.13	5.5
7 Calluna-Molinia/Tricophorum-Eriophorum	3.0	5.48	5.4
8 Eroding Bog	1.0	6.90	1.4
9 Unpatterned Bog	4.0	6.90	5.8
10 Bog with distinct pools	4.0	6.6	6.1
11 Linear Patterned Bog	7.0	6.6	10.6
12 Calluna-Juniperus	6.6	4.0	16.5
13 Montane Heath	6.5	4.74	13.8
14 Deschampsia Grassland	3.5	7.6	4.6
15 Rhacomitrium-Empetrum	5.5	4.9	11.2
16 Rhacomitrium-Empetrum with Nardus	4.7	2.8	16.7
17 Coastal Grassland	7.1	4.11	17.3
18 Bare Ground	2.8	6.45	4.4
19 Scree	3.8	5.6	6.8

GAIRLOCH

Habitats	Average of Ecologists' Values	Standard Deviation	Ratio
20 Peat Cutting	2.3	5.1	6.8
21 Improved land	2.0	4.24	4.8
22 Sand dunes	6.0	4.58	13.0
23 Water Surface	6.0	1.68	35.0

Variables	Ecologists' Values
24 Crags and cliffs	5.7
25 Areas over 30% bare ground	3.1
26 Boulder strewn areas	4.0
27 Coast length	6.0
28 Stream length	5.5
29 Woodland edge	7.0
30 Relative Relief	4.1
31 Number of Water Bodies	6.0
32 Number of Habitats	6.0

MERSEYSIDE

Questionnaire to five 'eminent' ecologists: maximum value = 50

Habitats	Average of Ecologists' Values	Standard Deviation	Ratio
1 Coniferous woodland	20	2.45	8.16
2 Deciduous woodland	43	3.03	14.19
3 Mixed woodland	39	3.0	13.0
4 Sand dunes	41	5.0	8.2
5 Salt marsh	41	3.46	11.8
6 Water bodies	42	3.08	13.6
7 Heathland	41	5.38	7.6

	Habitats	Average of Ecologists' Values	Standard Deviation	Ratio
8	Unimproved mossland	42	3.0	14.0
9	Scrub	36	2.64	13.6
10	Rough grassland	28	3.03	9.2
11	Agricultural land	20	3.46	6.3
12	Allotments, Cemeteries, etc.,	26	4.36	6.0
13	Managed grassland	16	2.97	5.38
14	Developed land	9	0.89	10.1
15	Residential areas and large gardens	23	4.15	5.5

	Variables	Ecologists' Values
16	Hedge length	42
17	Coast length	
18	Stream length	42
19	Woodland edge	42
20	Scrub edge	
21	Number of water bodies	
22	Number of Habitats	

APPENDIX XII QUESTIONNAIRES TO ECOLOGISTS

THE UNIVERSITY
OF ASTON
IN BIRMINGHAM

Gosta Green, Birmingham B4 7ET / Tel 021-359 3611 Ex 221

Department of Civil Engineering
Head of Department
Professor [illegible] M Holmes, BSc, PhD, D[illegible] CEng FICE FIStructE FIMunE
Professor of Civil Engineering
K I Majid BSc, PhD, CEng FICE, FIStructE

27 November 1974

Dear

I am working in conjunction with the Nature Conservancy in Edinburgh on the development of a methodology for the rapid evaluation of habitats according to their 'conservation value'. For this I am using aerial photography of the Gairloch Conservation Unit.

I am interested to know how an informed group of Ecologists, Biologists and Botanists would rate independently the habitats and features on the enclosed list, using the ratings as follows:-

VH	Very High
H	High
M	Medium
L	Low

or a designation such as L-M. The ratings should be done rapidly, and should be based on the 'Conservation Value' of the habitats and features on the list in the context of Britain, and not of North West Scotland.

I realise the difficulties involved in doing this, mainly connected with the vast range of factors which should be considered. However, this is the only way of getting this kind of information. If any use is made of the results, no reference will be made to the names of people filling in the questionnaire. I should be extremely grateful if you would complete the enclosed. It is not intended you should spend more than approximately 10-15 minutes on it.

Thanking you,

Yours sincerely

RATINGS FOR CONSERVATION EVALUATION OF BRITISH UPLAND HABITATS

PINEWOOD	
BIRCHWOOD	
MIXED PINE/BIRCH	
BRACKEN	
CALLUNA/MOLINIA	
TRICOPHORUM/ERIOPHORUM (patterned bog)	
" / " (unpatterned bog)	
CALLUNA/JUNIPERUS	
DESCHAMPSIA GRASSLAND	
RHACOMITRIUM/EMPETRUM	
" / " /NARDUS	
BARE ROCK	
SCREE	
PEAT CUTTING	
IMPROVED LAND	
BASE-RICH GRASSLAND (incl. hay meadows)	
COASTAL GRASSLAND	
SAND DUNES	
MONTANE HEATH (often windswept; incl. Rhacom., Empet., Vacc., Nardus, Calluna, Juniper)	
COASTAL TYPES (e.g. cliffs, stacks)	
STREAMS (length in km^2)	
EDGES (length in km^2)	
CRAGS	
Areas interspersed with OVER 30% BARE ROCK.	
WATER SURFACE (Area & Number in km^2)	
RELATIVE RELIEF (in km^2)	
BOULDER-STREWN AREAS	

Symbols:

VH	Very High
H	High
M	Medium
L	Low

CALLUNA:

[illegible]

THE UNIVERSITY
OF ASTON
IN BIRMINGHAM

Gosta Green, Birmingham B4 7ET/Tel: 021.359 3611 Ex 221

Department of Civil Engineering

Head of Department
Professor M Holmes BSc PhD DSc, CEng, FICE, FIStructE, FIMunE.
Professor of Civil Engineering
K I Majid BSc, PhD, CEng FICE, FIStructE

March 1975

Dear

I am working in conjunction with the Nature Conservancy in Edinburgh on the development of a methodology for the rapid evaluation of habitats according to their 'conservation value'. For this I am using aerial photography of Merseyside and Gairloch, Wester Ross.

I am interested to know how an informed group of Ecologists, Biologists and Botanists would rate independently the habitats and features on the enclosed list, using the ratings: 1 = very low to 10 = very high.

The ratings should be done rapidly, and should be based on the 'Conservation Value' of the habitats and features on the list in the context of Britain, and not of North West England.

I realise the difficulties involved in doing this, mainly connected with the vast range of factors which should be considered. However, this is the only way of getting this kind of information. If any use is made of the results, no reference will be made to the names of people filling in the questionnaire. I should be extremely grateful if you would complete the enclosed. It is not intended you should spend more than approximately 10-15 minutes on it.

Thanking you,

Yours sincerely

RATINGS FOR CONSERVATION EVALUATION OF BRITISH LOWLAND HABITATS

CONIFEROUS WOODLAND	
DECIDUOUS WOODLAND	
MIXED WOODLAND	
SAND DUNES	
SALT MARSH	
MUDFLATS	
FRESHWATER MARSH	
FRESHWATER PONDS AND LAKES	
HEATHLAND	
MOSSLAND (UNIMPROVED)	
SCRUB (BIRCH, HAWTHORN, etc)	
ROUGH GRASSLAND (incl. derelict and neglected sites not in agricultural use)	
AGRICULTURAL LAND (incl. arable, ley and permanent pasture)	
ARABLE LAND	
LEY PASTURE	
PERMANENT PASTURE	
ALLOTMENTS, SMALL PARKS AND LANDSCAPED GARDENS	
MANAGED GRASSLAND (incl. sports pitches, golf courses, park grassland, hospital & industrial lawns, etc)	
DEVELOPED LAND (incl. built land, building sites, tipping sites and non-vegetated disturbed land)	
HOUSE GARDENS (generally in older residential areas of towns)	
STREAMS	
WOODLAND EDGE (incl. hedgerows)	
WATER EDGE	

COMPUTER-DRAWN MAPS

FIGURE 42:1-17, GAIRLOCH MAPS

FIGURE 43:1-9, MERSEYSIDE MAPS

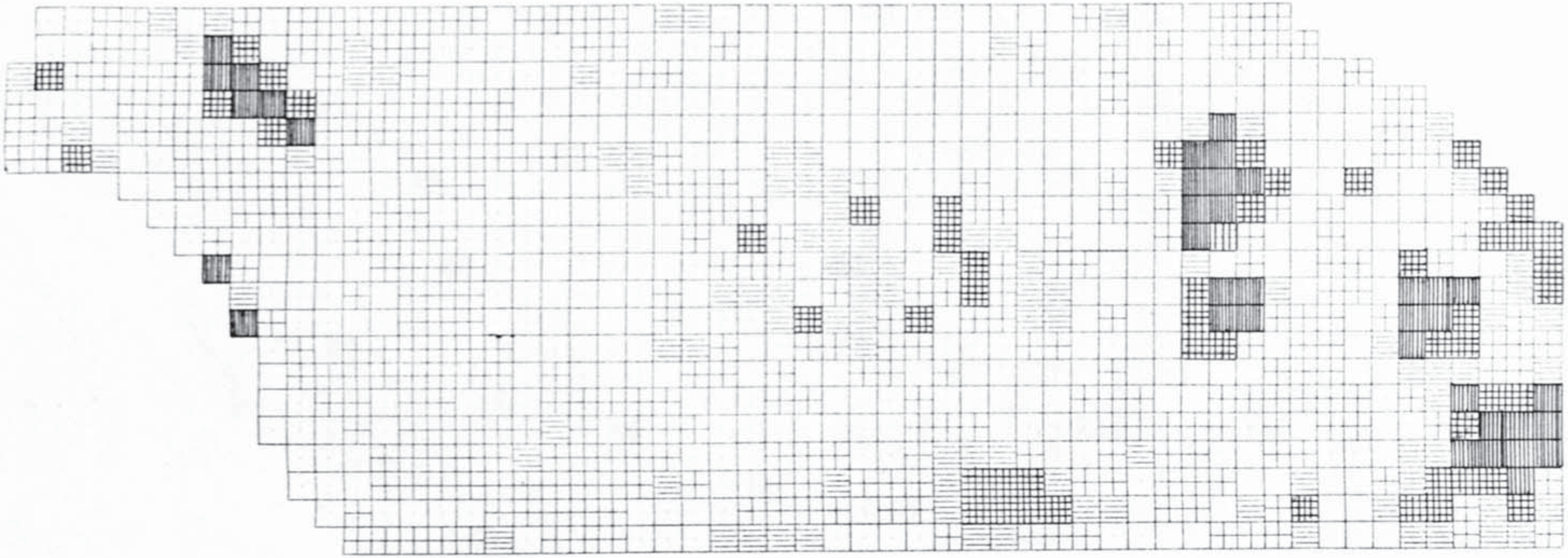
KEY (VALUES DIVIDED INTO 5 EQUAL VALUE CLASSES)

▥	5 (HIGHEST)
▦	4
▤	3
⊞	2
⊡	1

Fig. 42:1

GAIRLOCH AREA DATA

ECOLOGIST'S HABITATS



The UNIVERSITY of ASTON
in BIRMINGHAM.
LIBRARY.

Fig 42:2

GAIRLOCH AREA DATA

ECOLOGIST'S VARIABLES

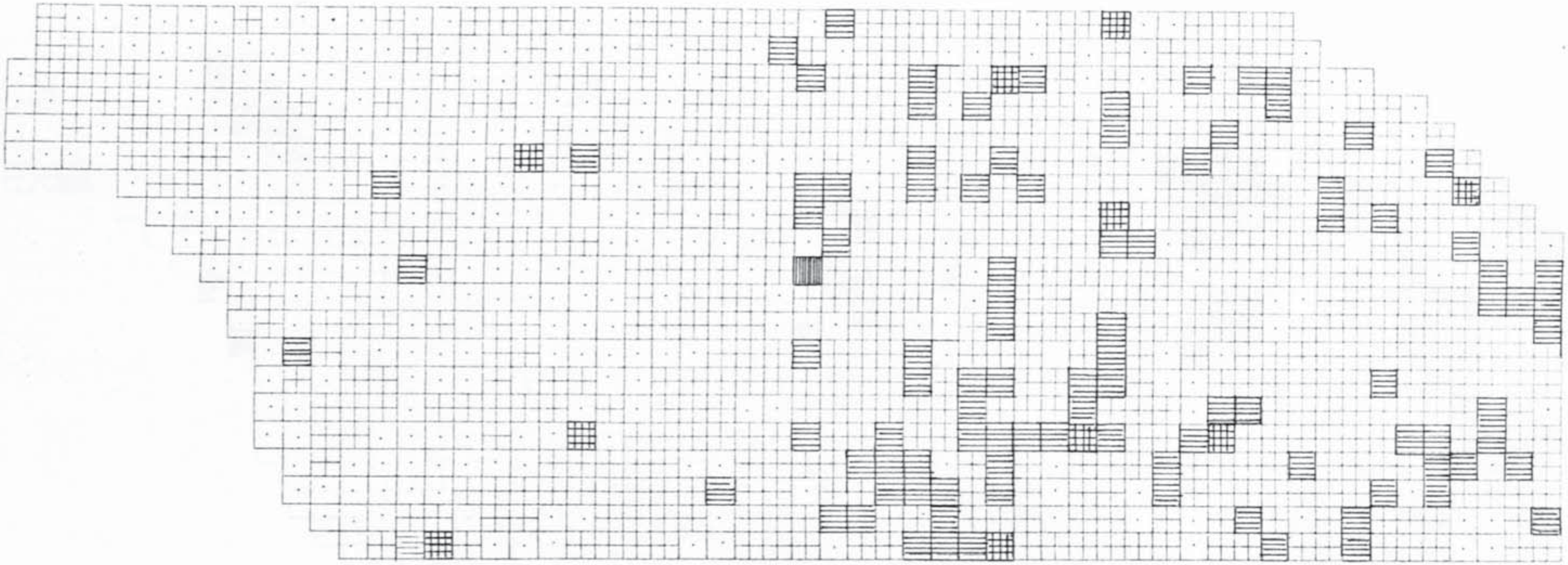


Fig. 4.2:3

GAIRLOCH AREA DATA

ECOLOGIST'S VALUES

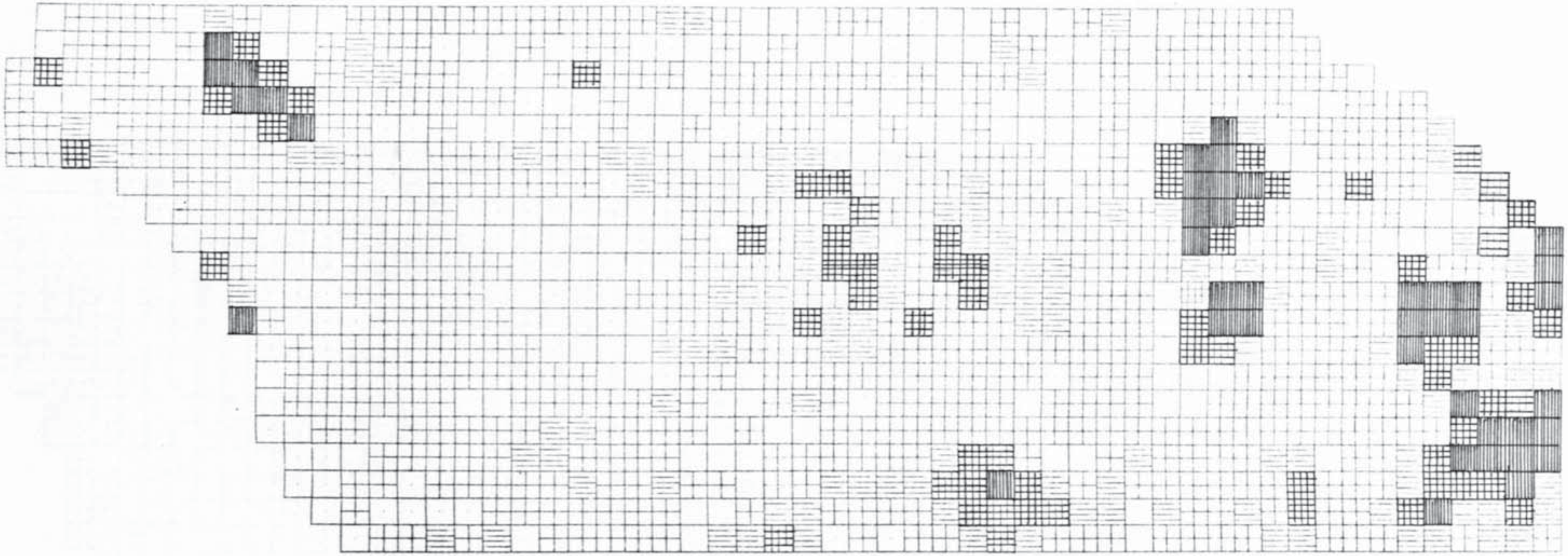


Fig 42:4

GAIRLOCH AREA DATA ECOLOGIST'S-HABITATS

VALUES EXTENDED TO 0

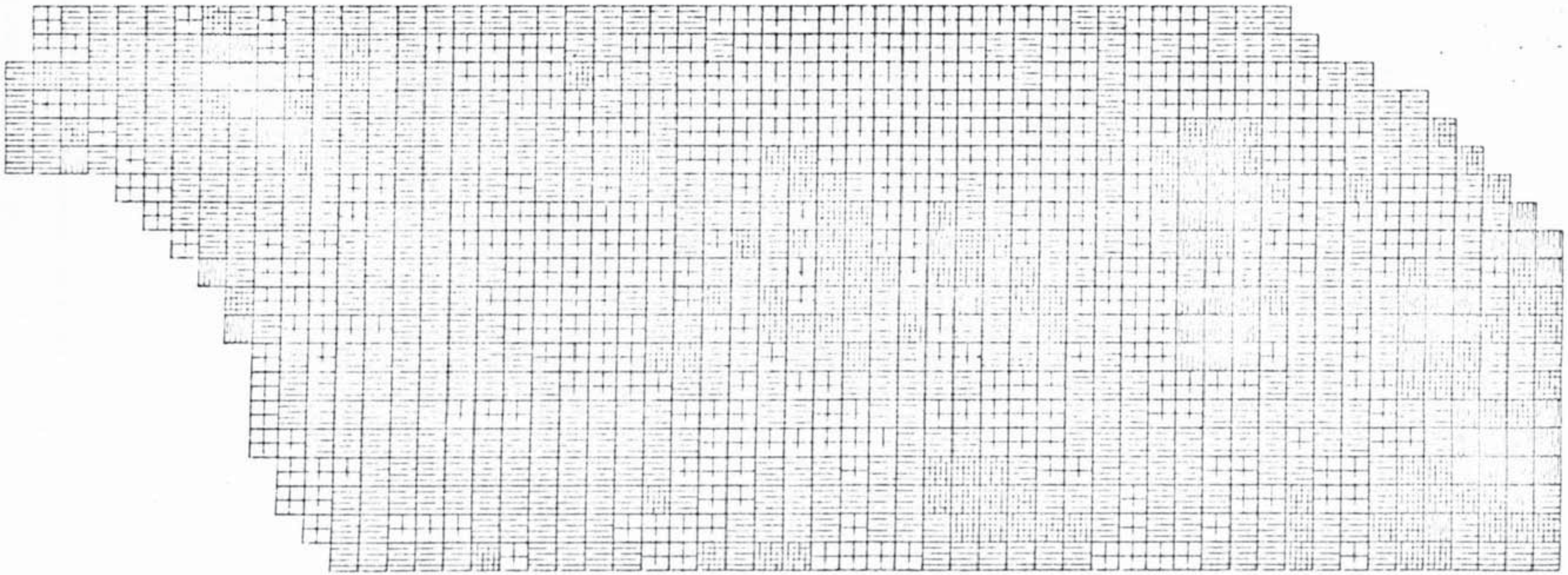


Fig. 42:5

GAIRLOCH AREA DATA

VERTICAL STRATA

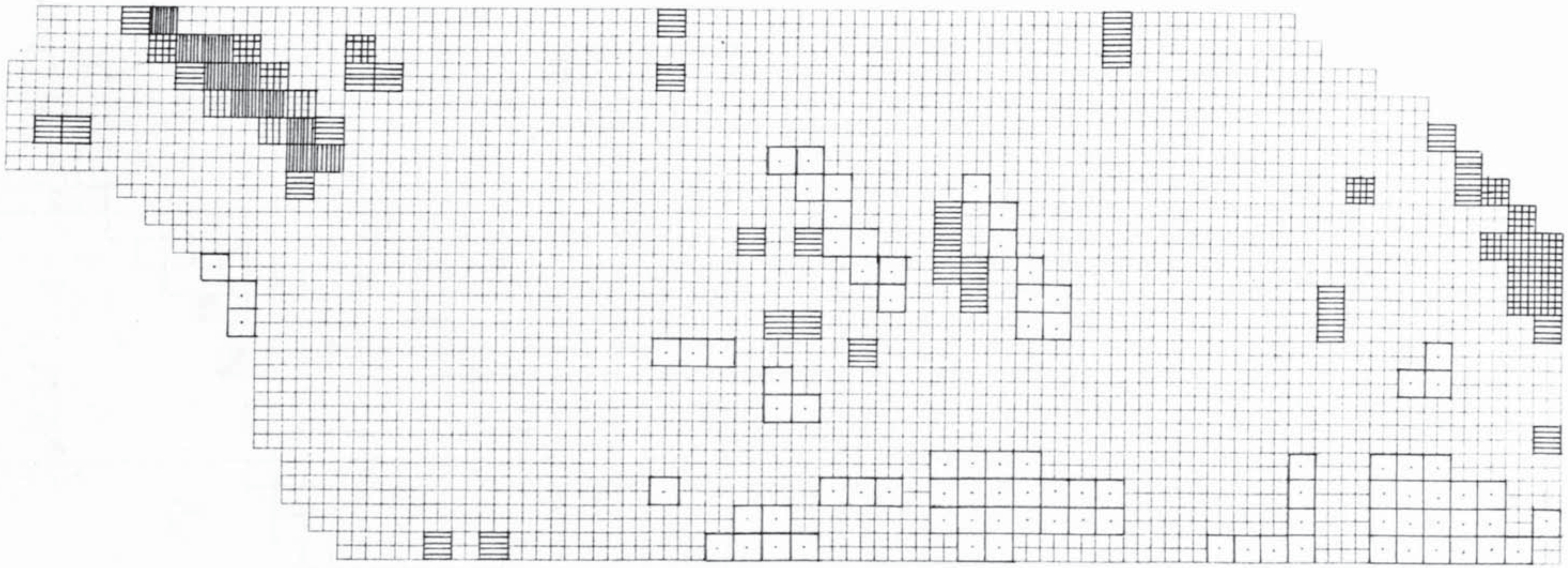


Fig 42:6
GAIRLOCH AREA DATA

LOCAL SCARCITY

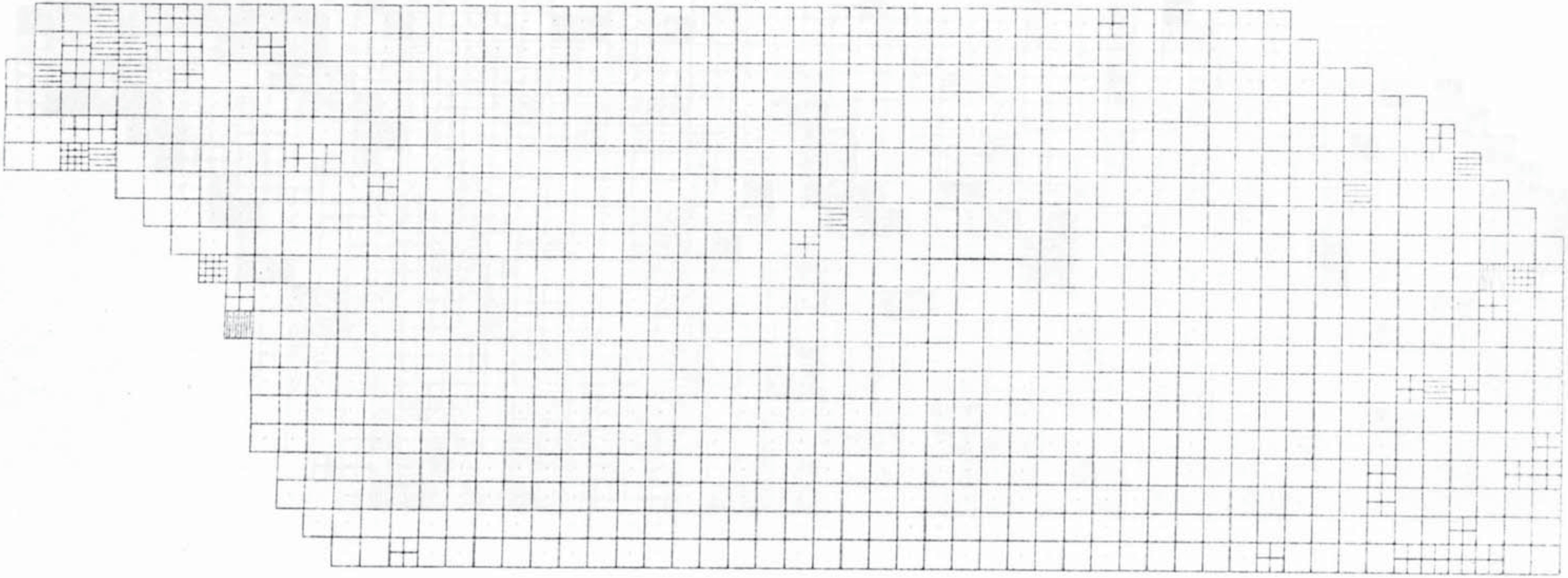


Fig 42:7
GAIRLOCH AREA DATA

LOCAL SCARCITY

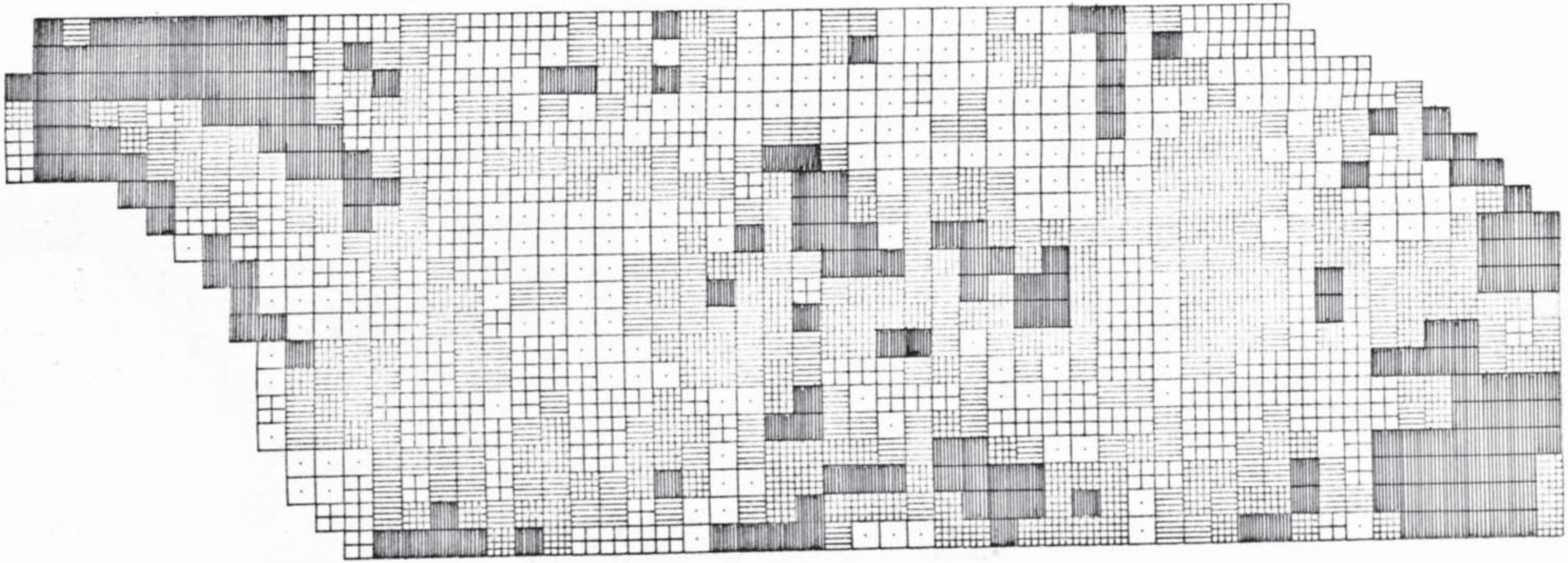


Fig 42:8
GAIRLOCH AREA DATA

SPECIES DIVERSITY

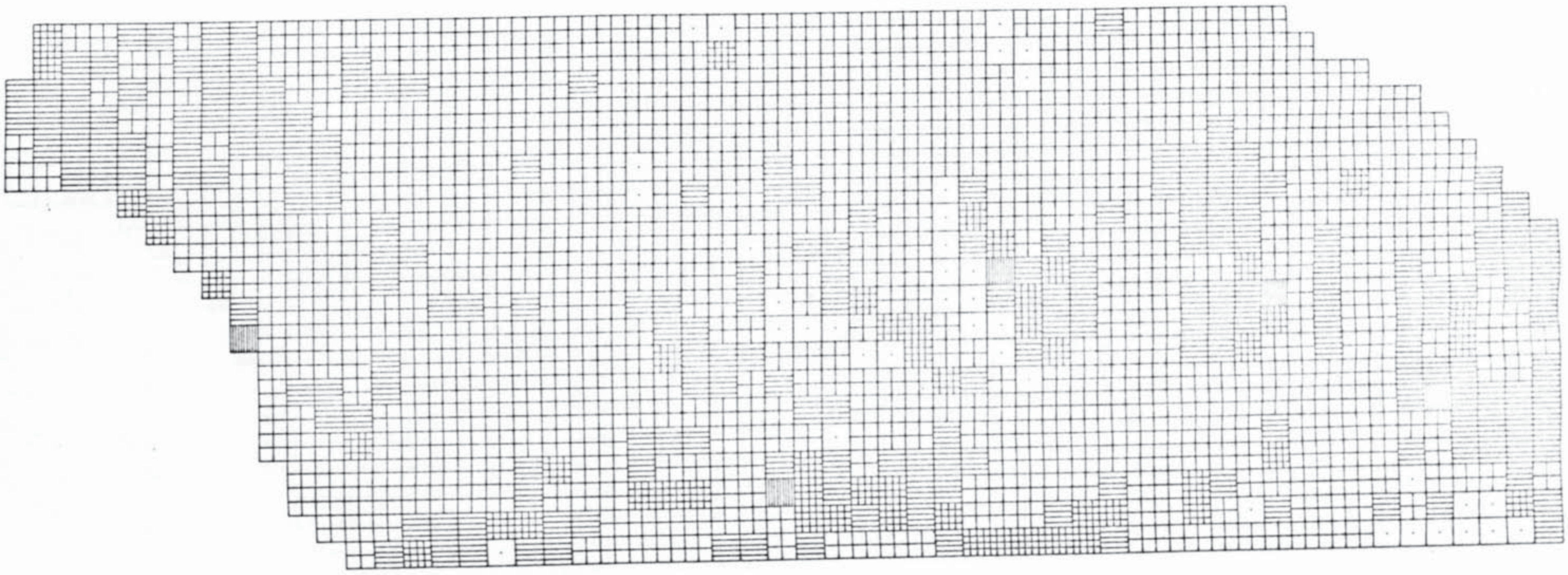


Fig 42:9
GAIRLOCH AREA DATA

DIVERSITY, STRATA, RARITY

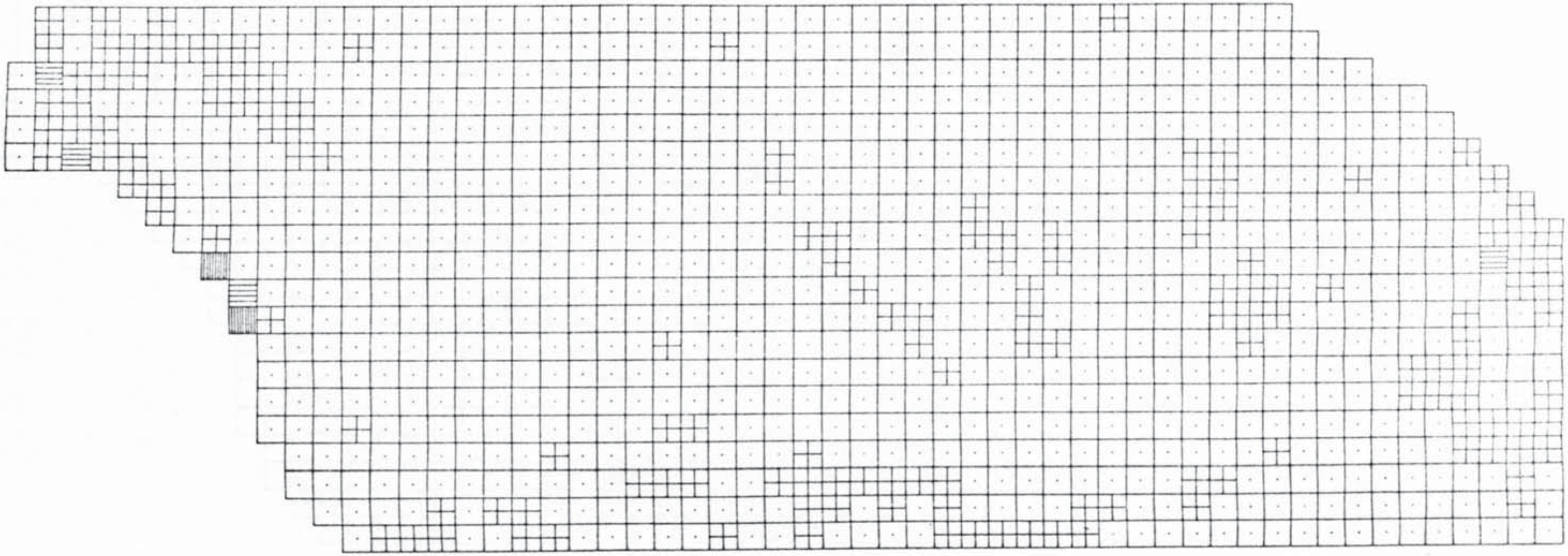


Fig 42:10
GAIRLOCH AREA DATA

RELATIVE RELIEF

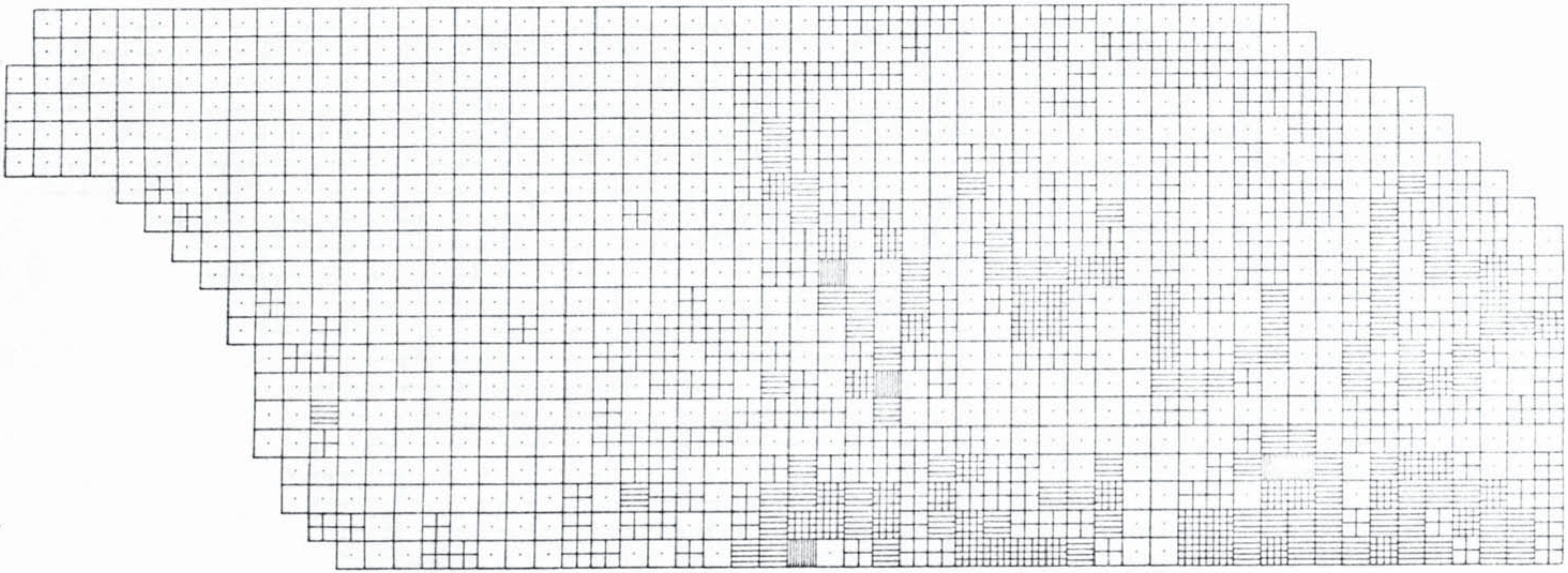


Fig 42:11
GAIRLOCH AREA DATA LINEAR FEATURES

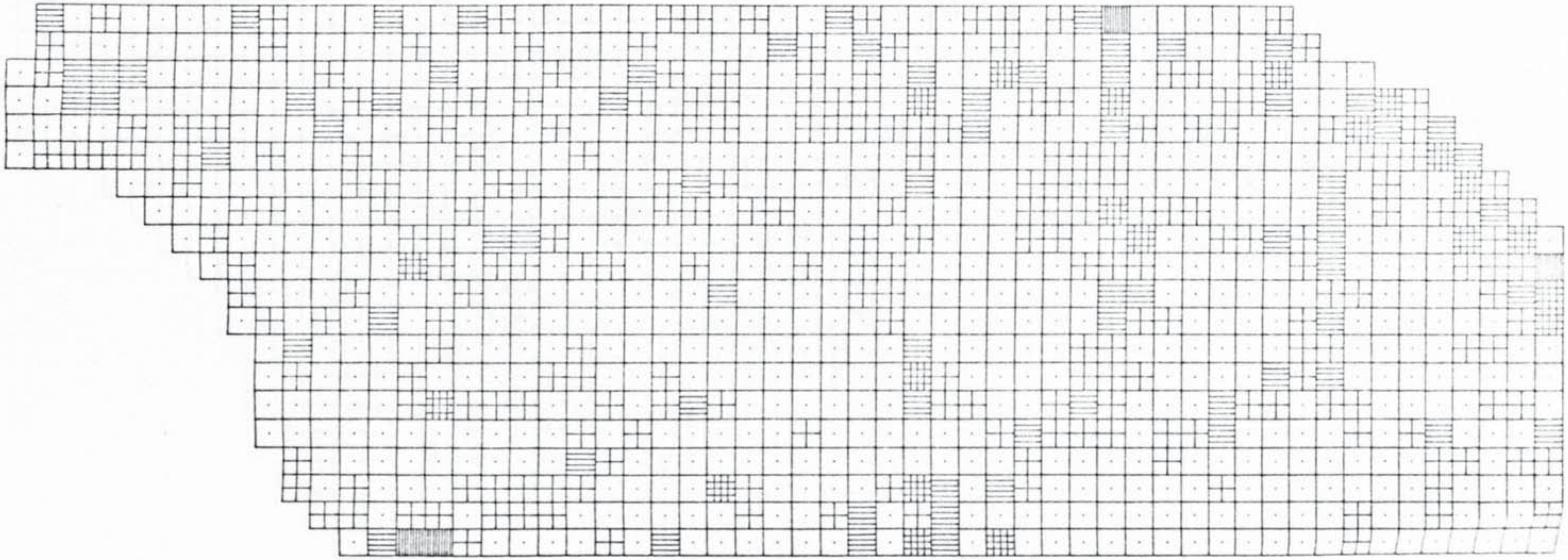


Fig 42:12
GAIRLOCH AREA DATA

ROCKS AND BOULDERS

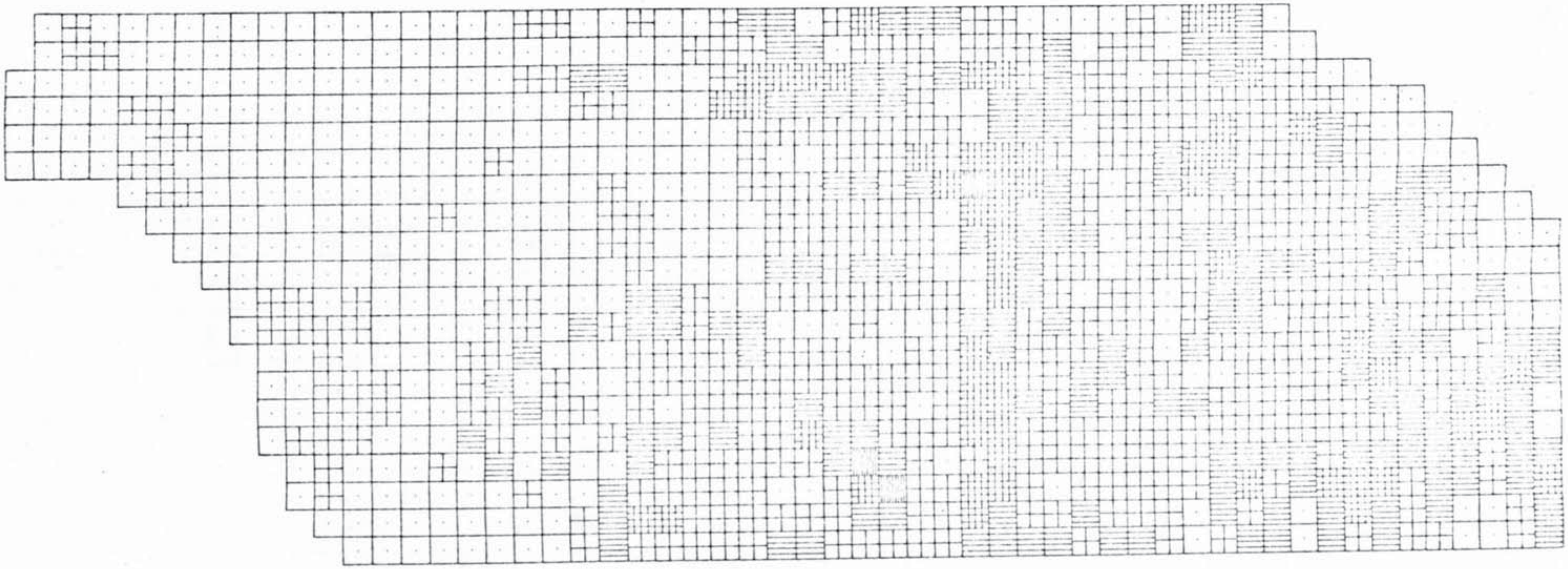


Fig 42:13
GAIRLOCH AREA DATA

NO. OF WATER BODIES

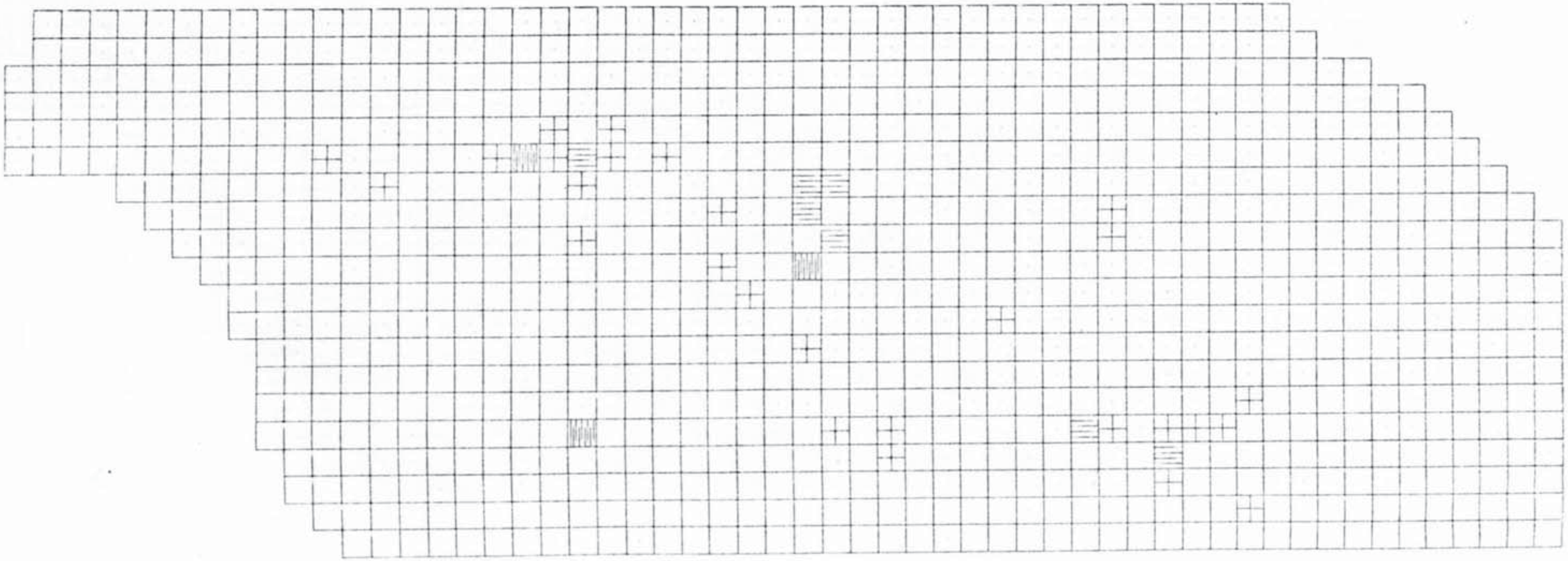


Fig 42:14
GAIRLOCH AREA DATA

NO. OF HABITATS

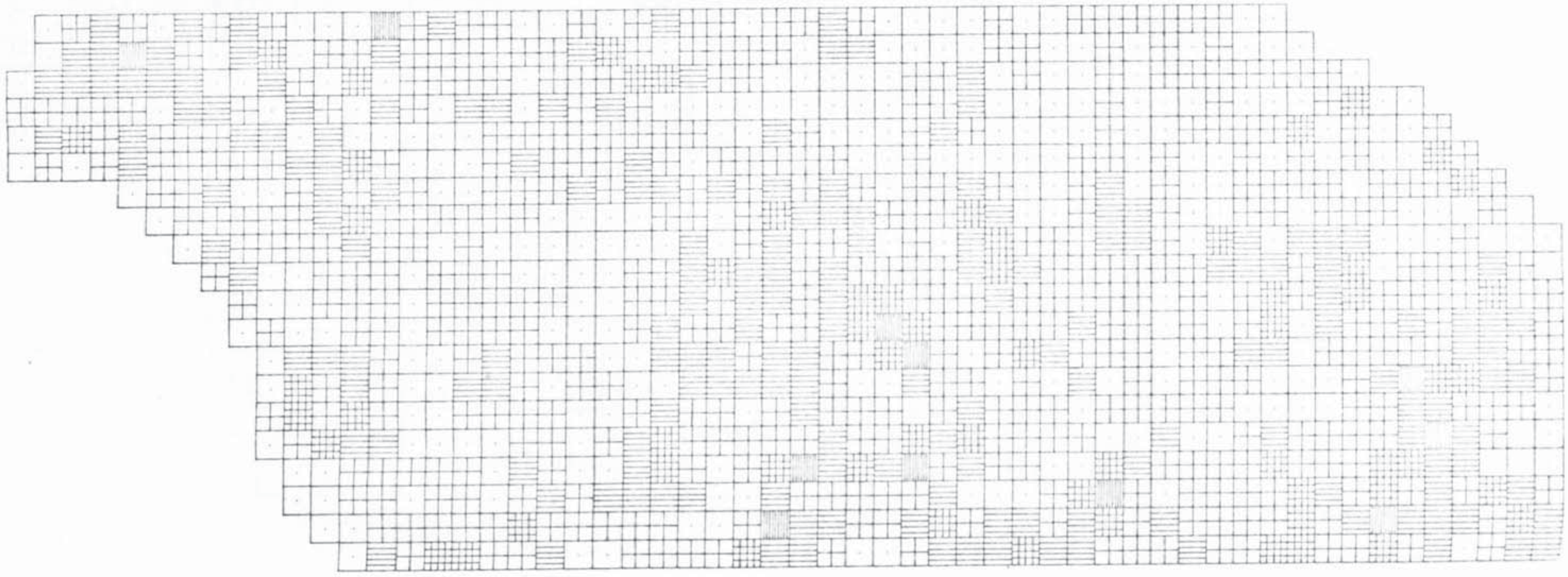


Fig 42:15

GAIRLOCH AREA DATA NO. OF HABS. OVER 12.0%

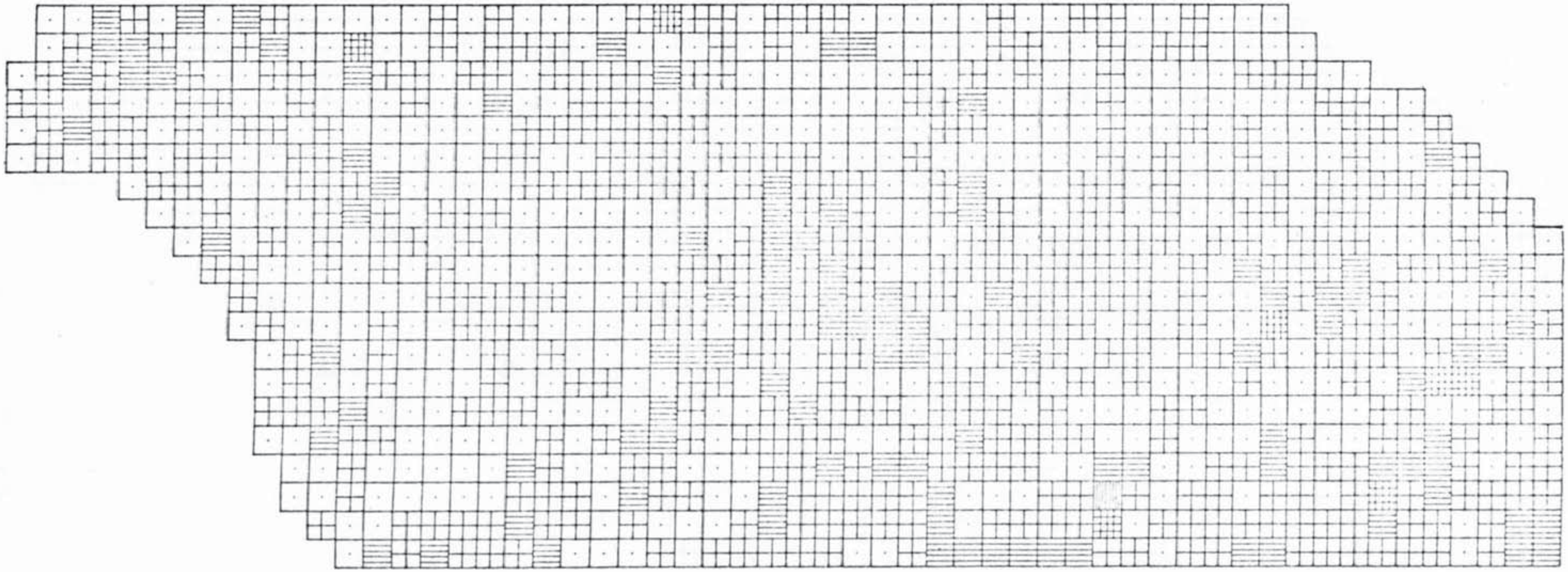


Fig 42:16
GAIRLOCH AREA DATA

NO. OF HABS. OVER 20.0%

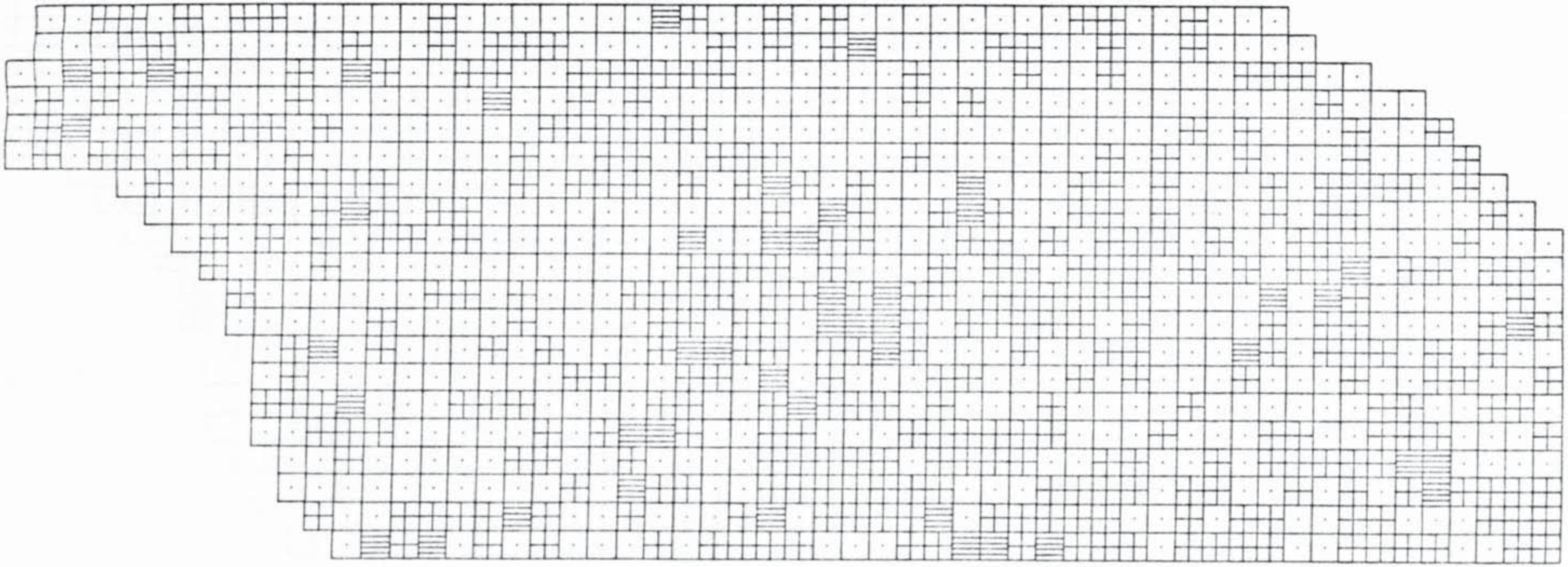


Fig 42:17
GAIRLOCH AREA DATA HIGH VALUE HABITATS

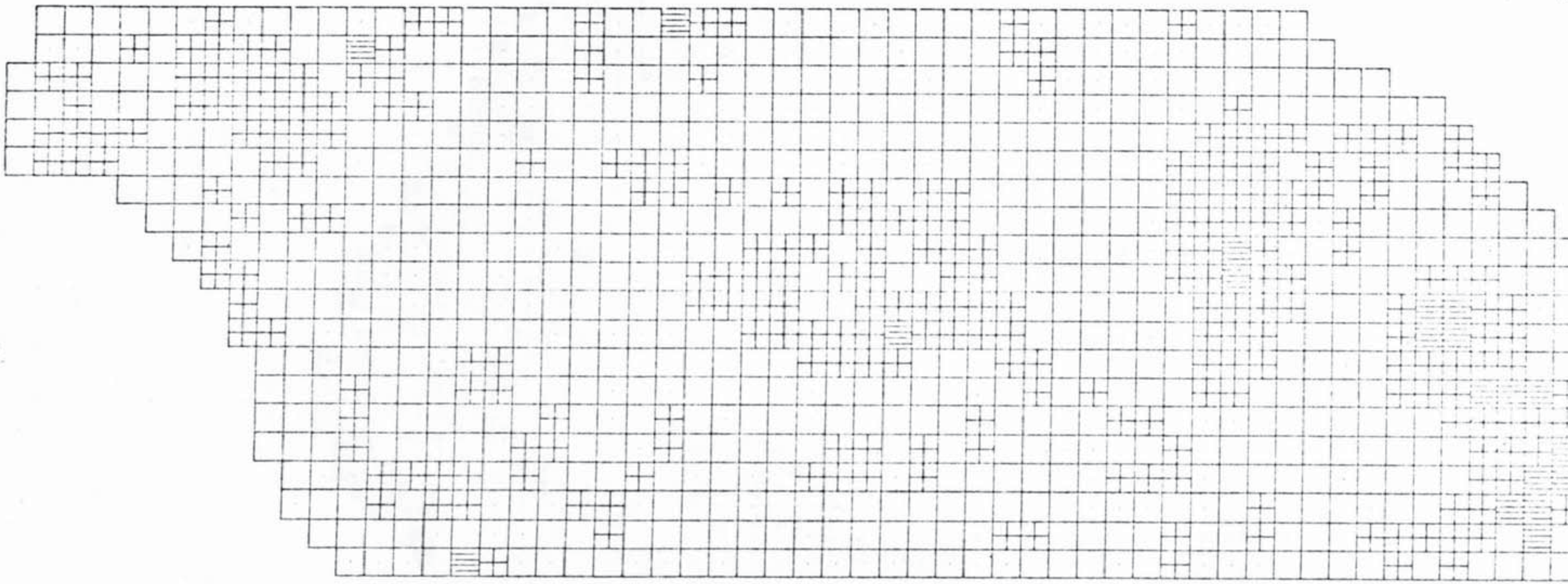


Fig 43:1
MERSEYSIDE AREA DATA ECOLOGIST'S HABITATS

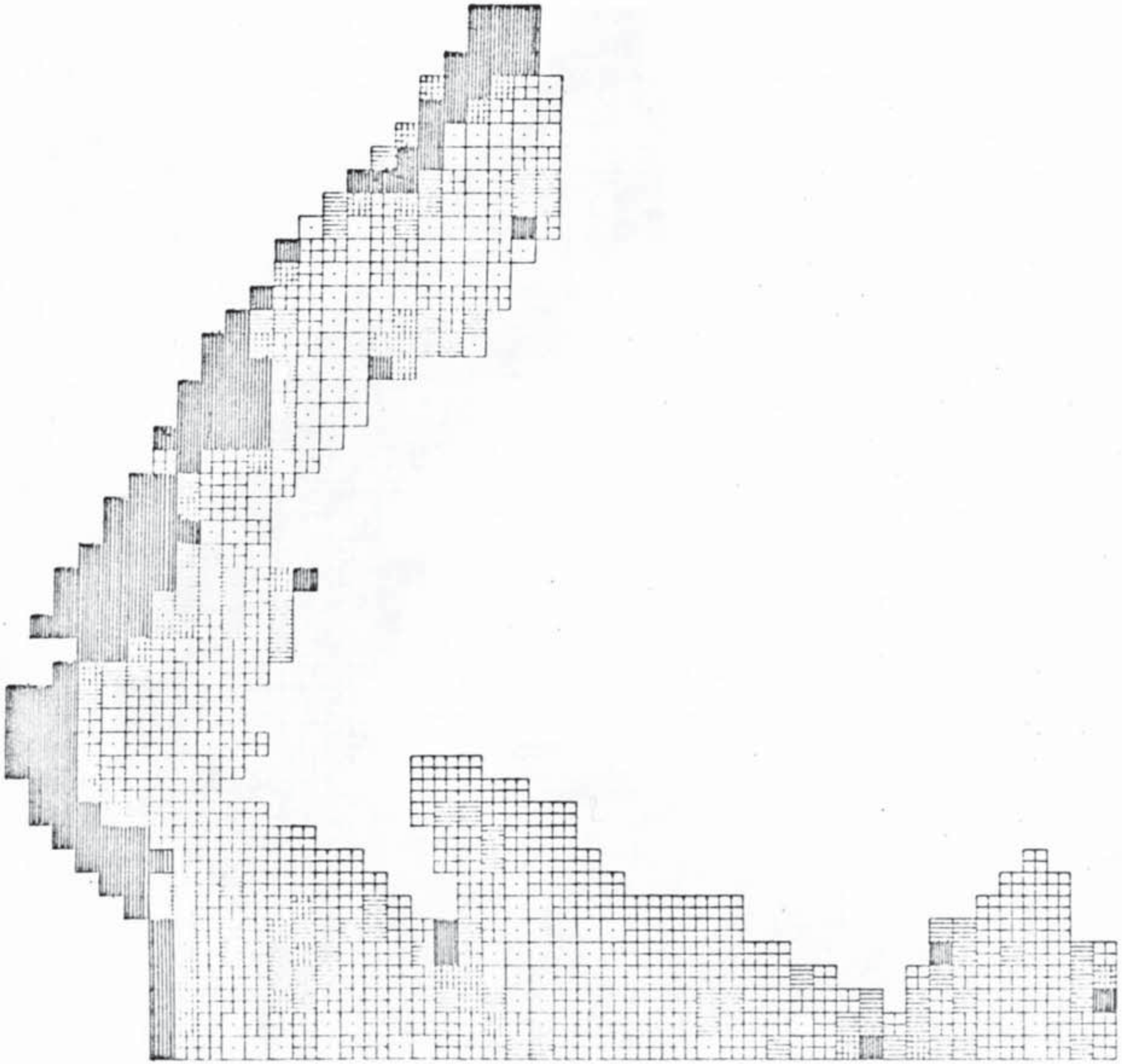


Fig 43:2
MERSEYSIDE AREA DATA ECOLOGIST'S VALUES

Fig 43:3
MERSEYSIDE AREA DATA VERTICAL STRATA

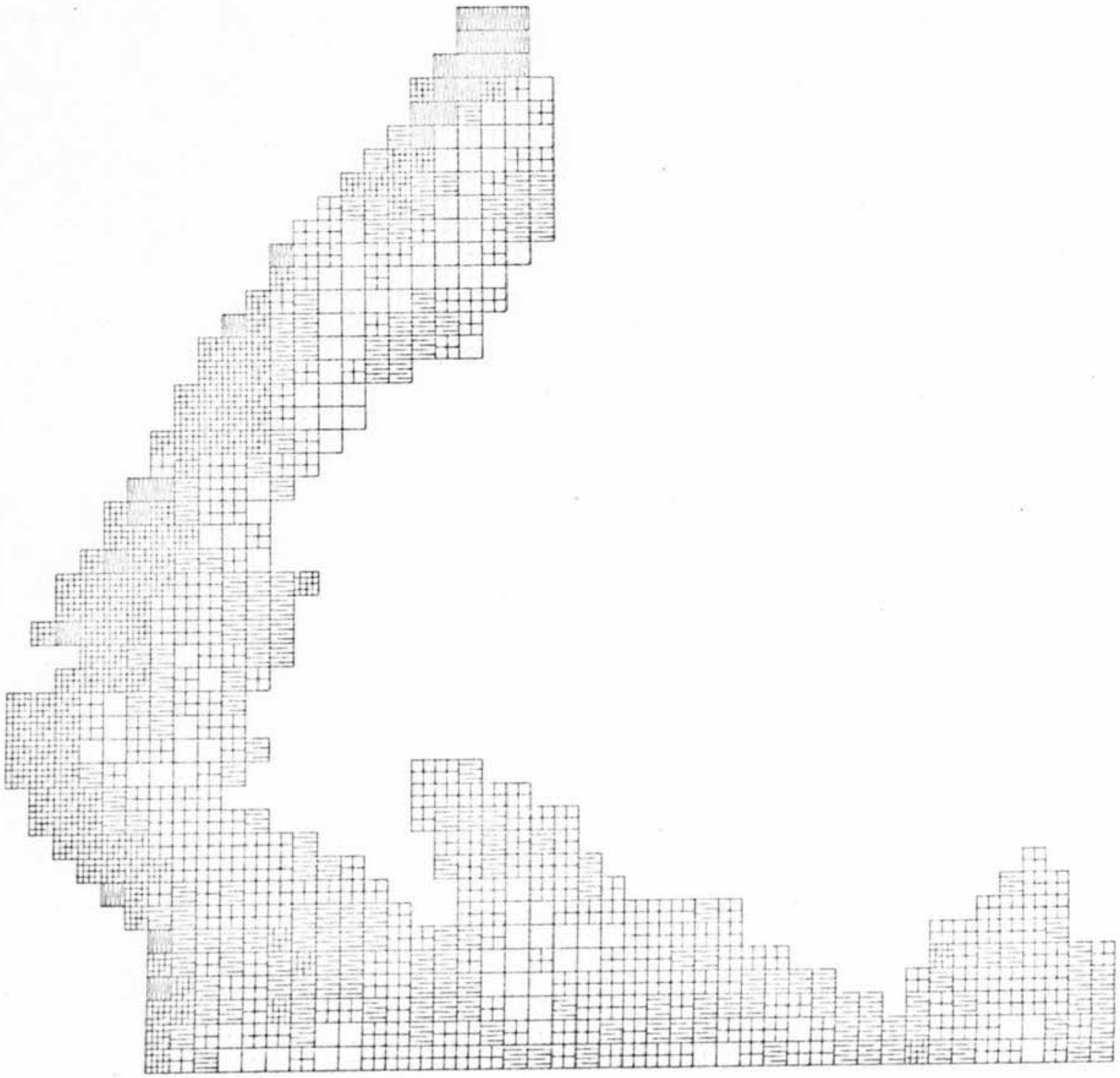


Fig 43:4
MERSEYSIDE AREA DATA LOCAL SCARCITY

Fig 43:5

MERSEYSIDE AREA DATA SPECIES DIVERSITY

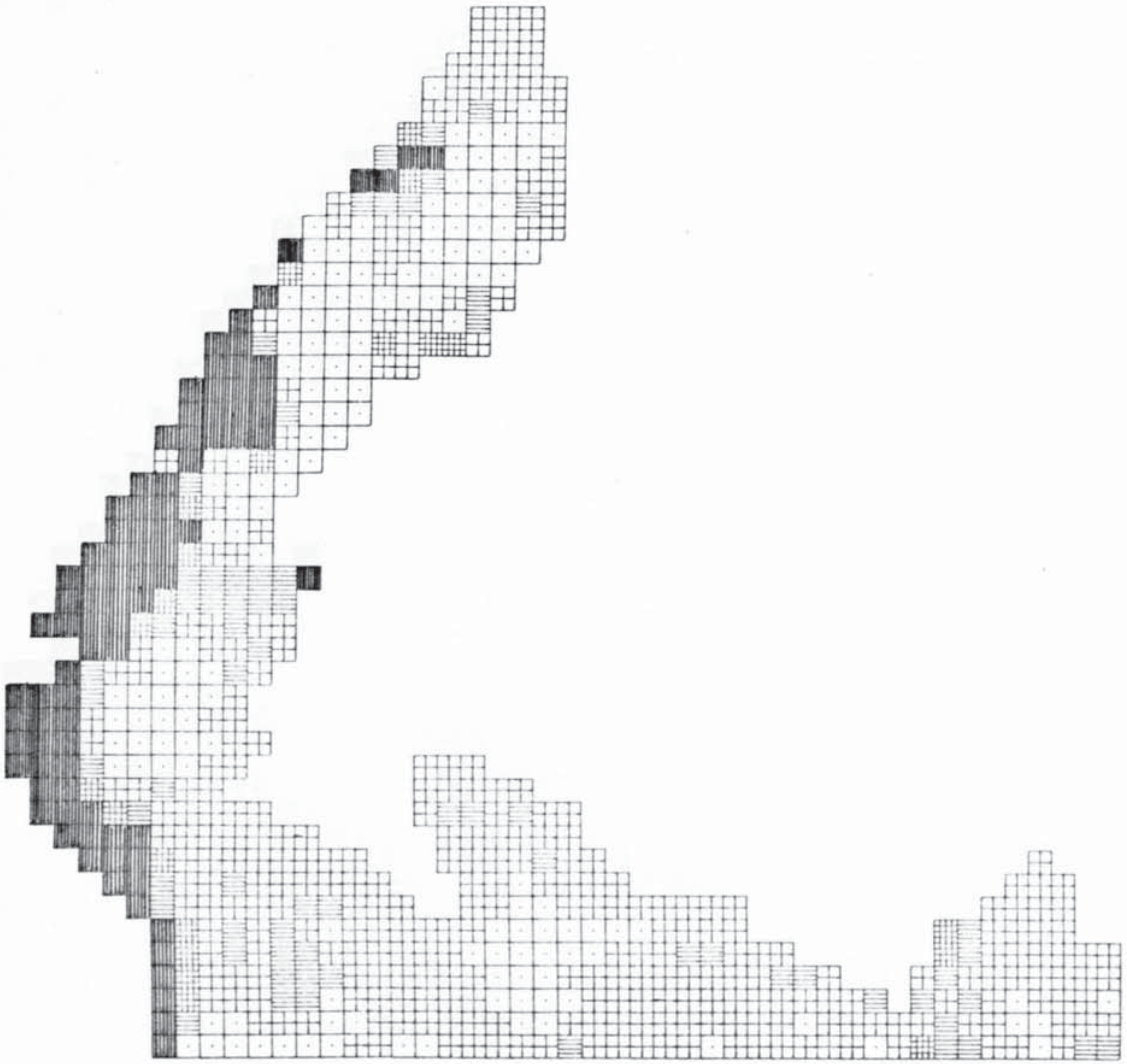


Fig 43:6
MERSEYSIDE AREA DATA DIVERSITY, STRATA, RARITY

Fig 43:7
MERSEYSIDE AREA DATA

HEDGE LENGTH

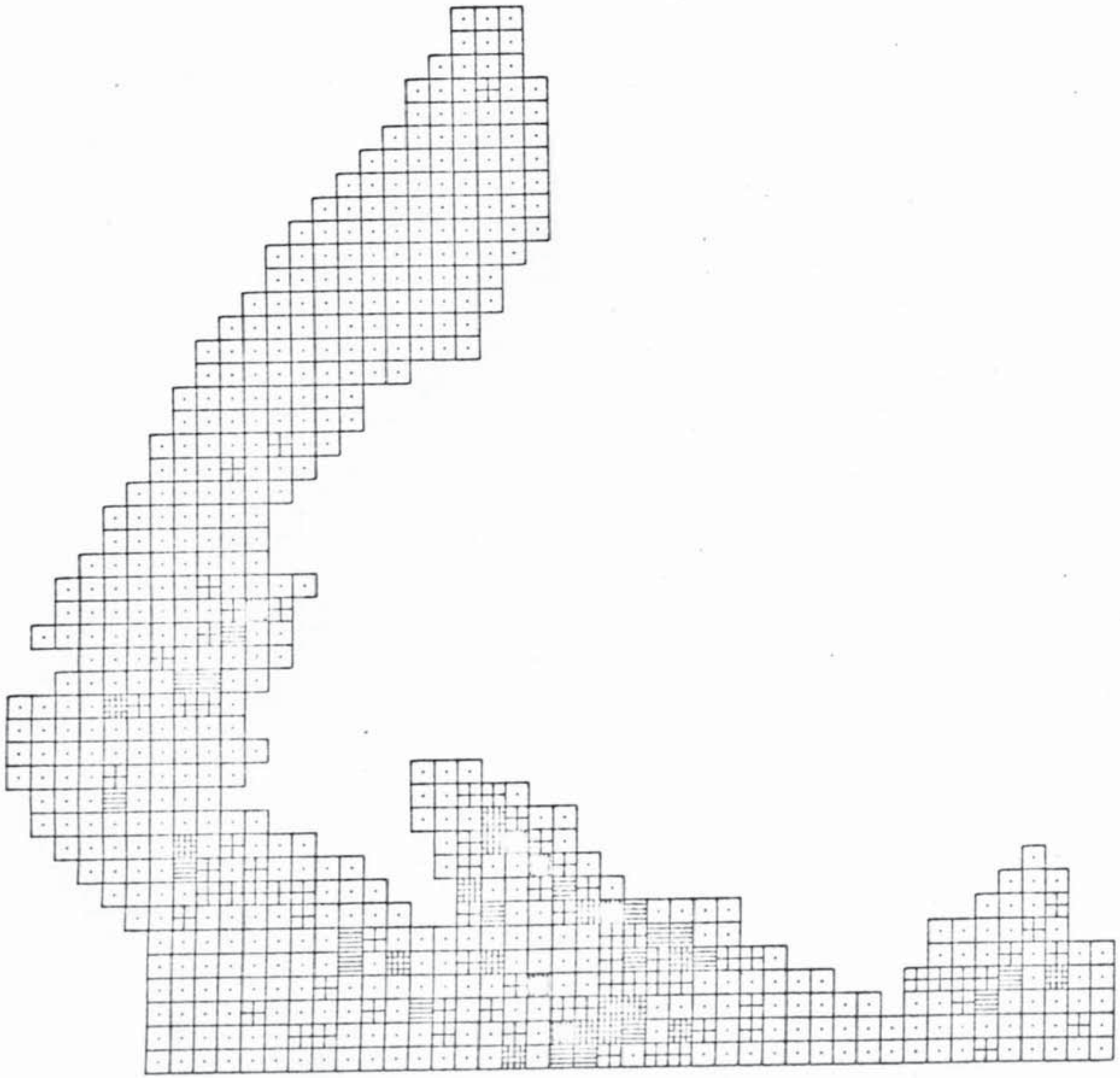


Fig 43:8
MERSEYSIDE AREA DATA

NO. OF HABITATS

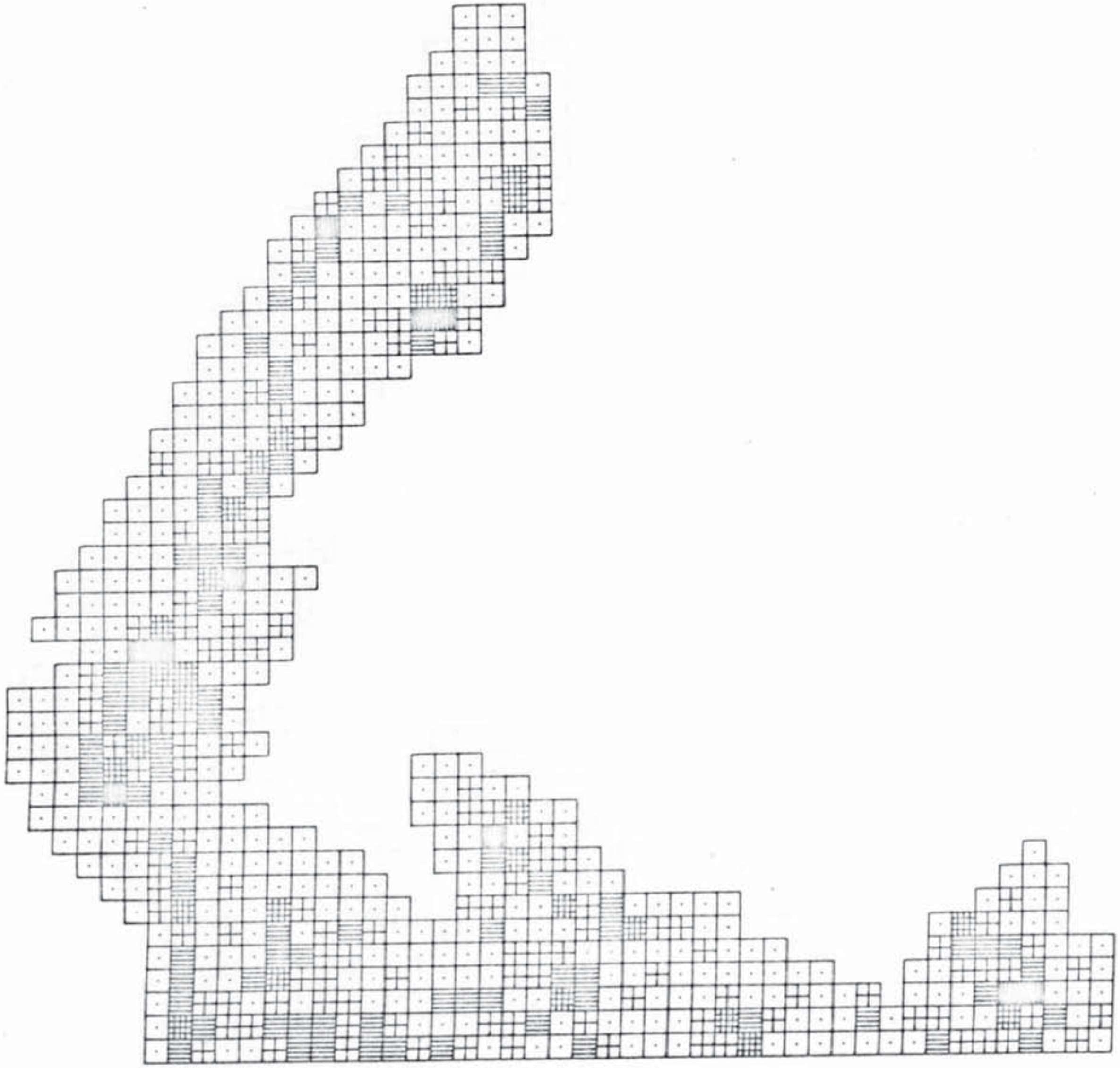
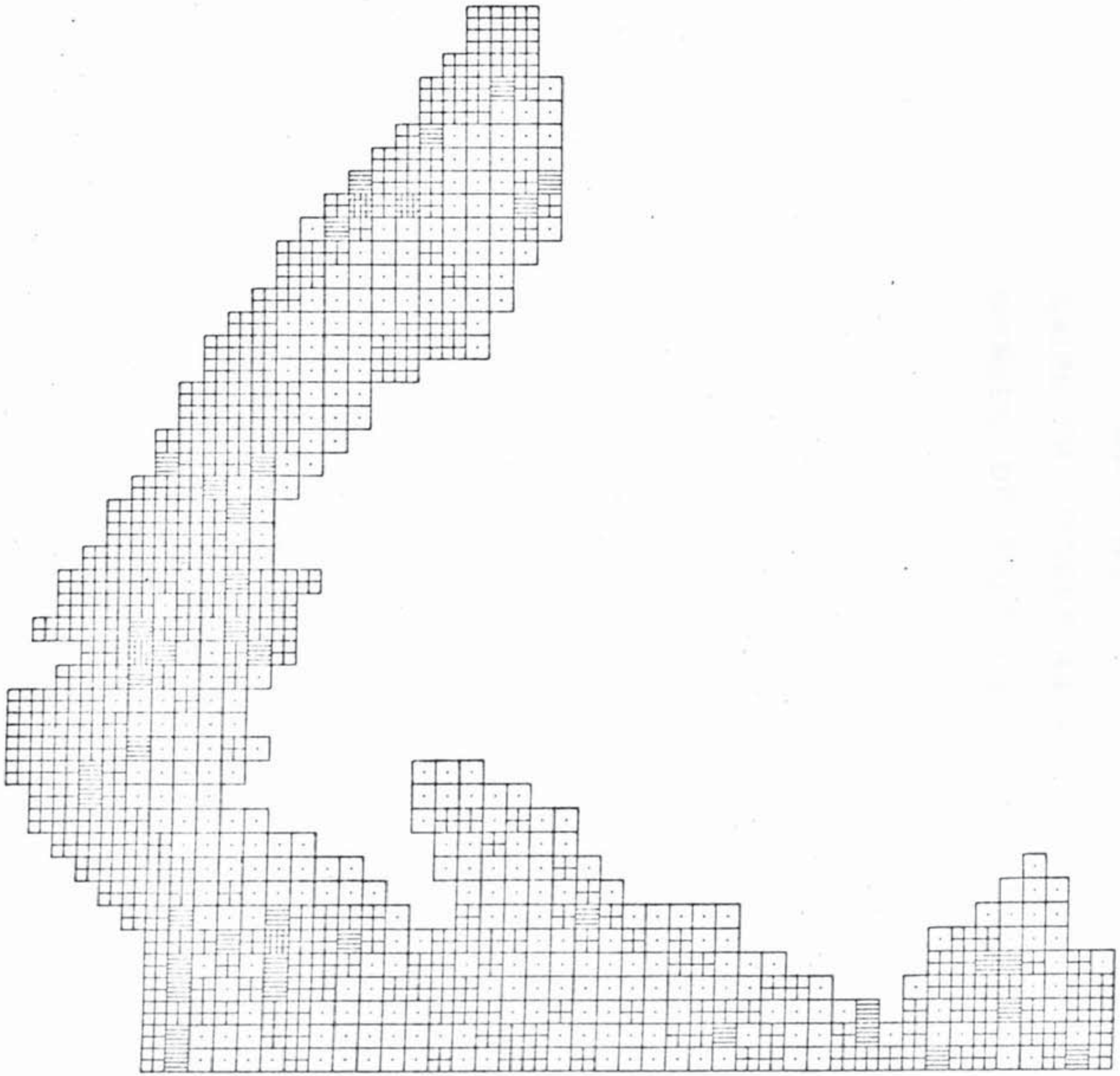


Fig 43:9
MERSEYSIDE AREA DATA HIGH VALUE HABITATS



COMPUTER DRAWN

GRAPHS

GAIRLOCH, FIGURE 44, 1-6

MERSEYSIDE, FIGURE 45, 1-5

Fig. 44:1
GAIRLOCH AREA DATA

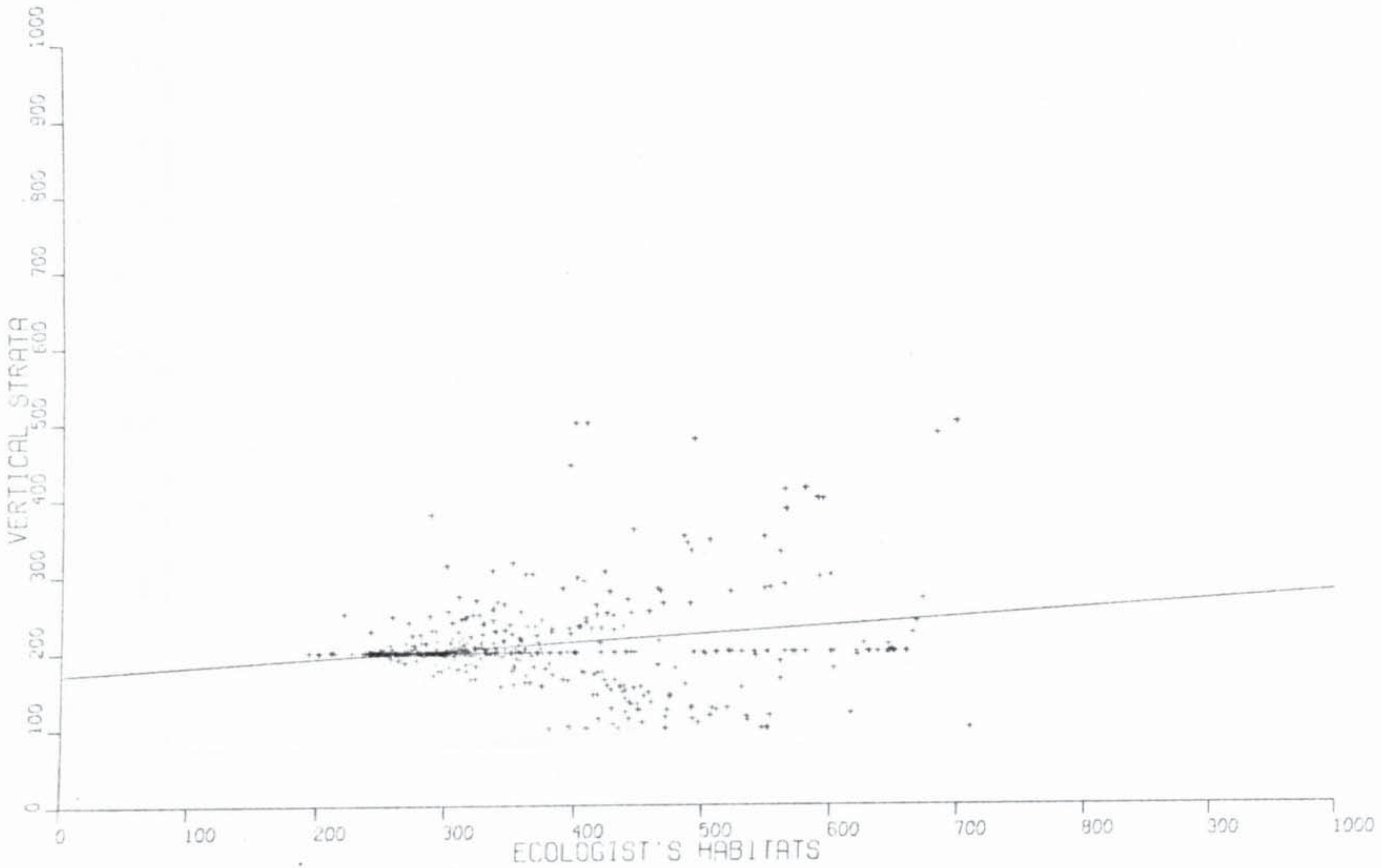


Fig. 44:2
GAIRLOCH AREA DATA

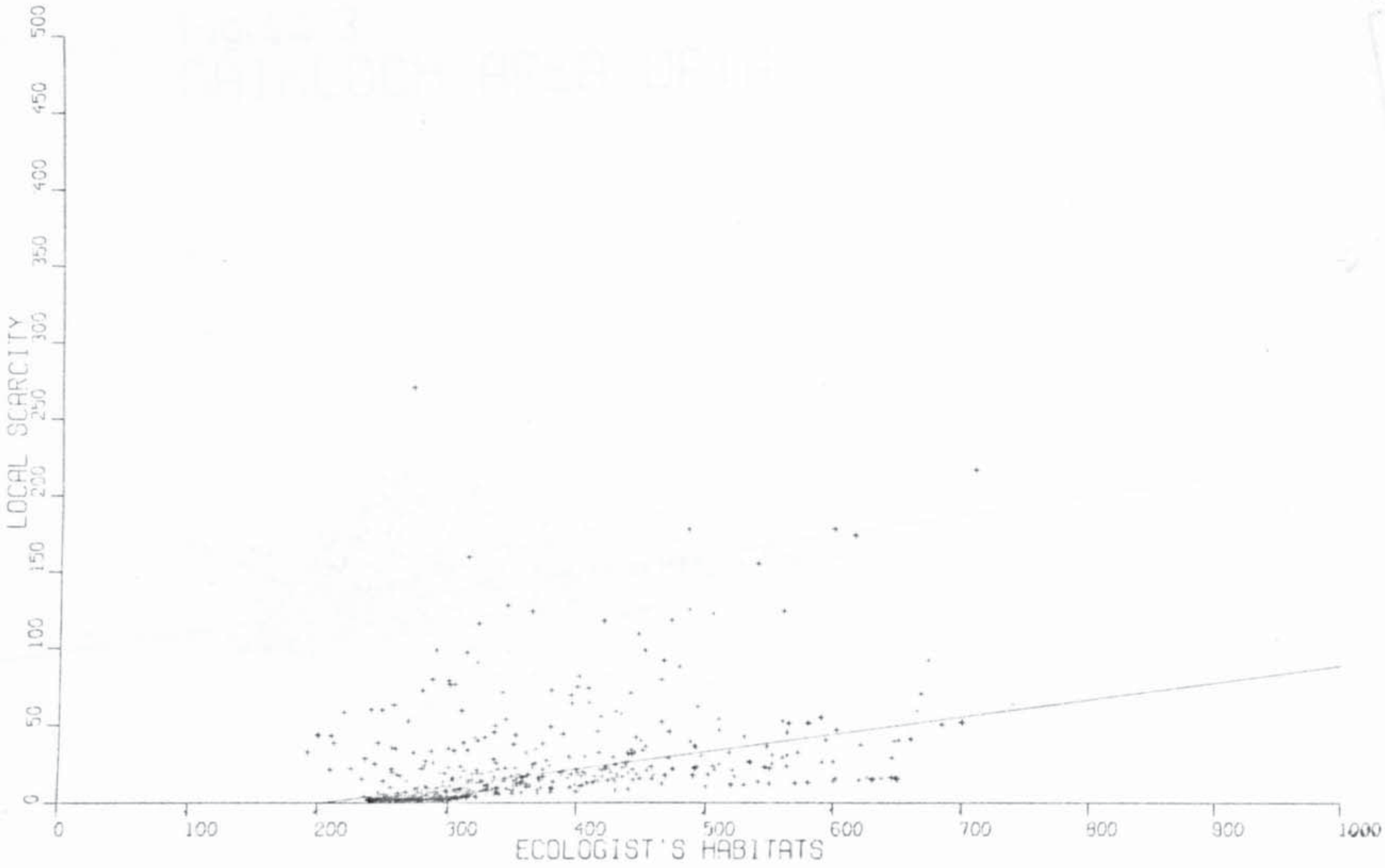


Fig 44:3
GAIRLOCH AREA DATA

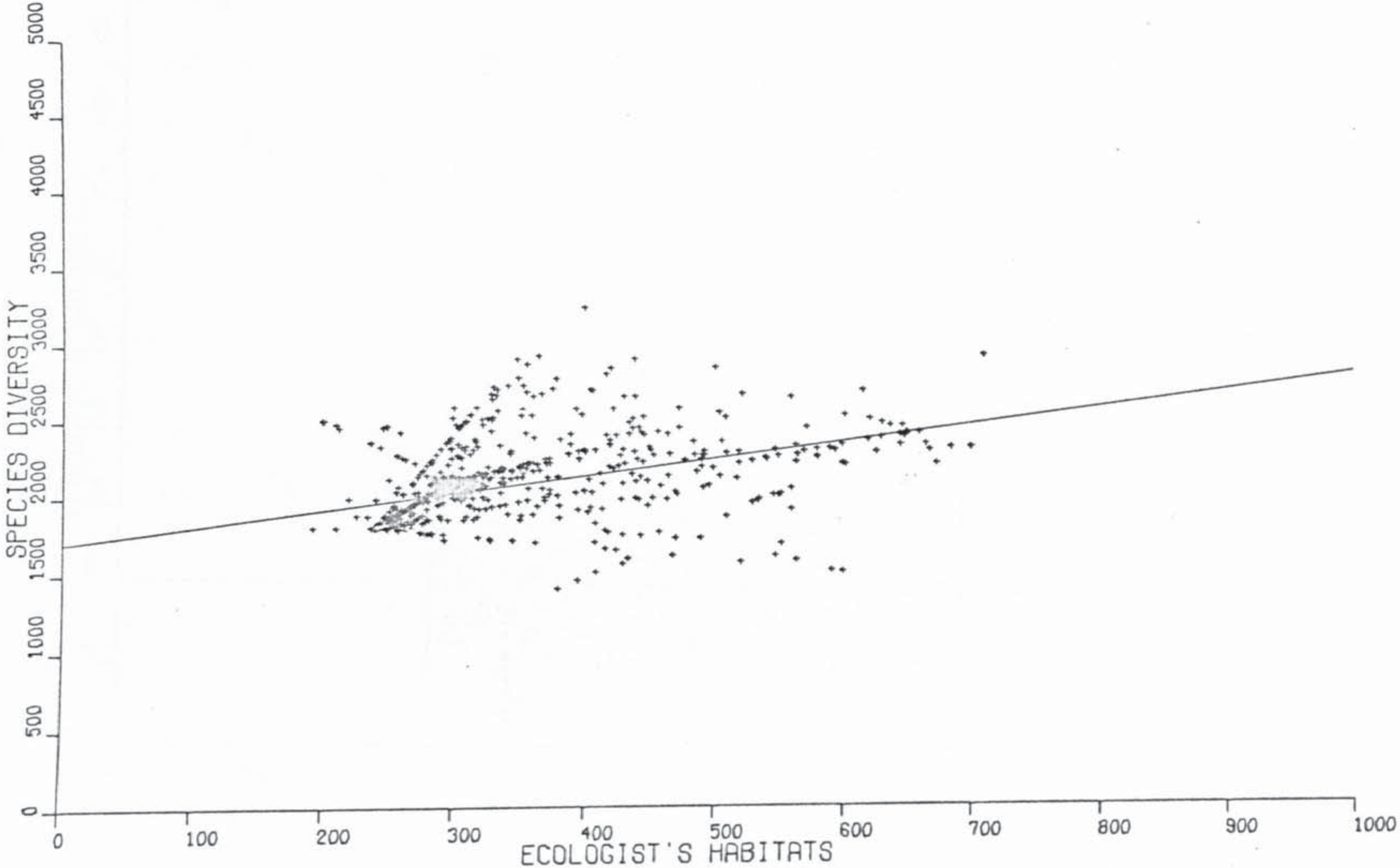


Fig. 44:4
GAIRLOCH AREA DATA

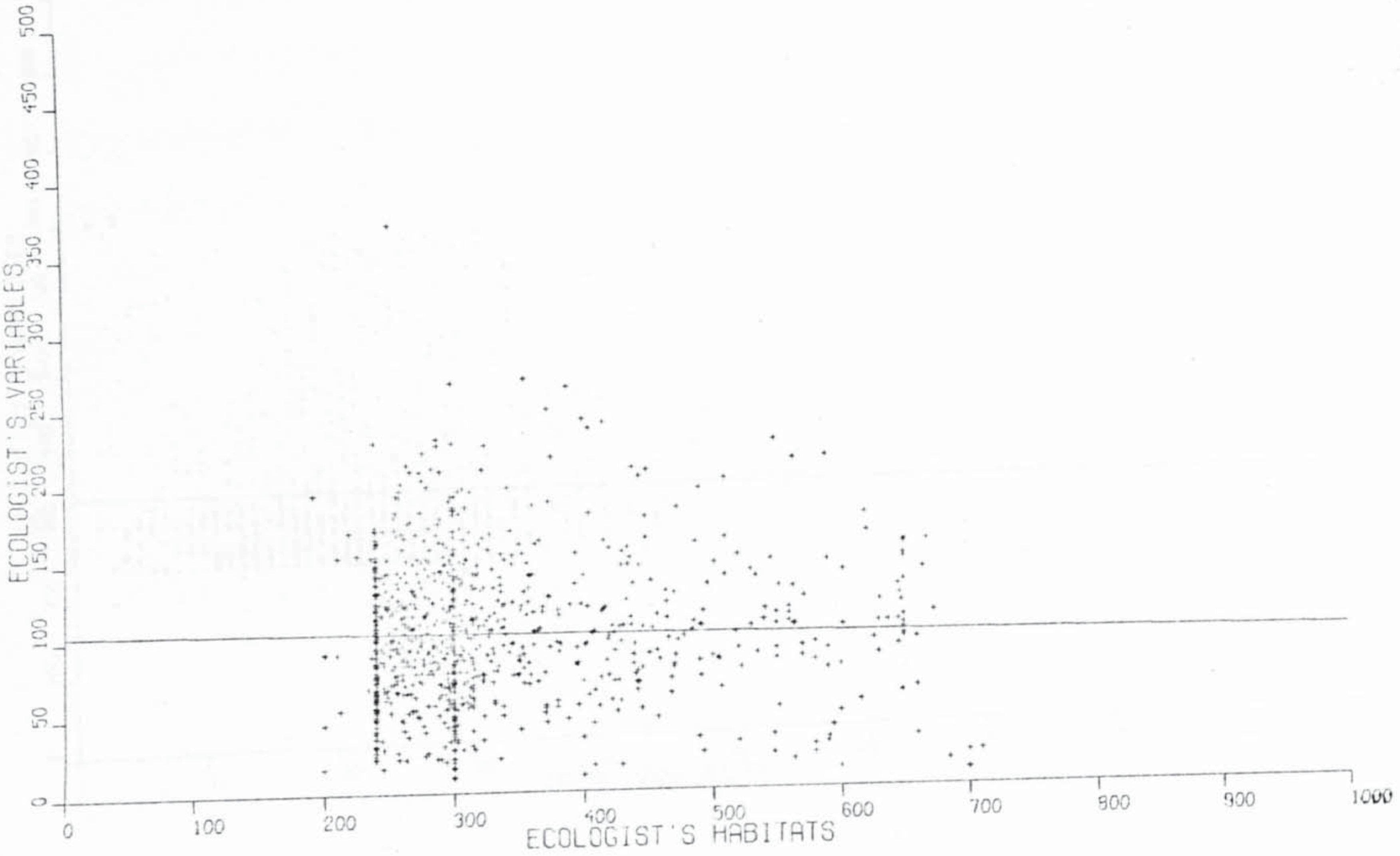


Fig. 44:5
GAIRLOCH AREA DATA

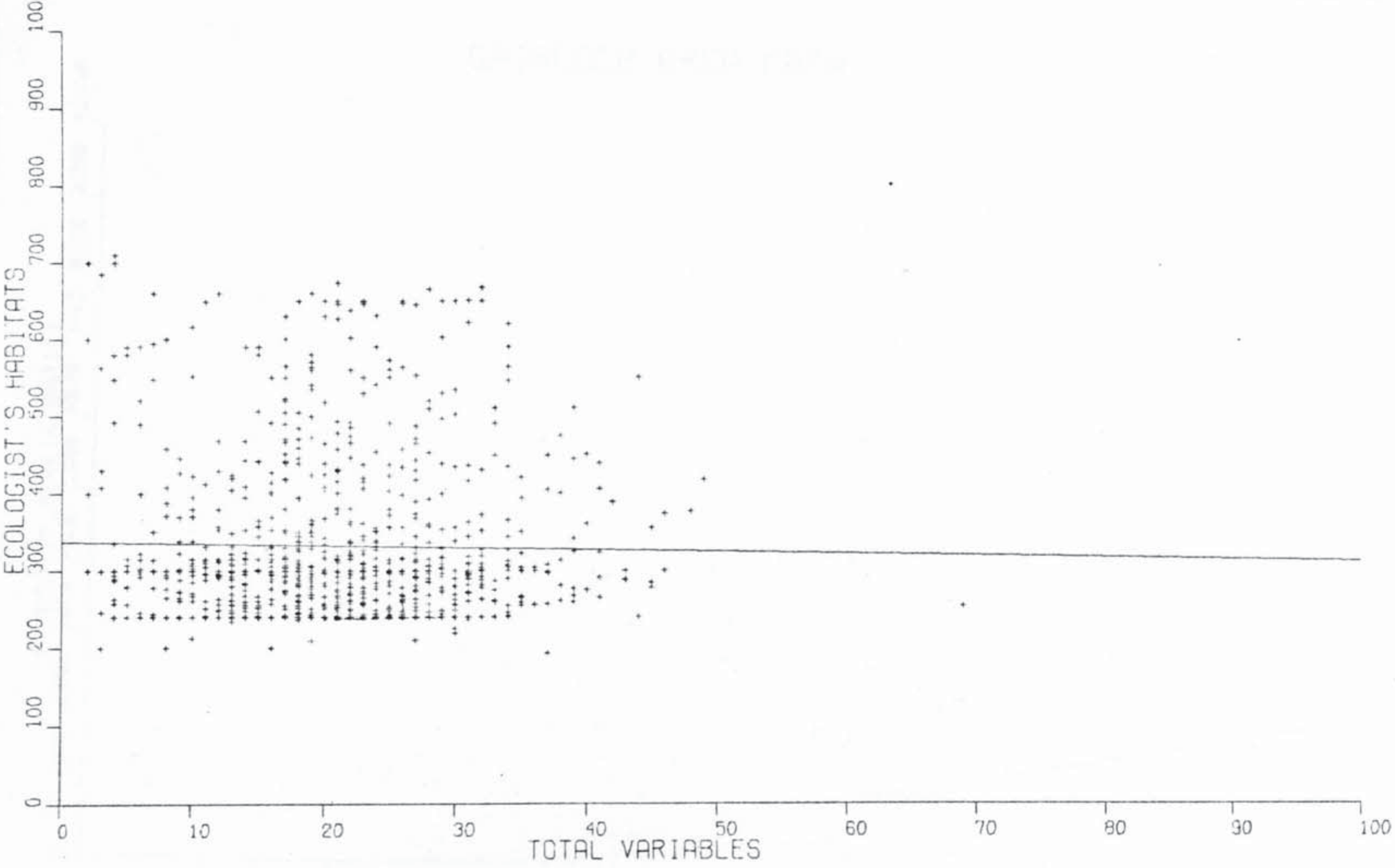


Fig .44:6

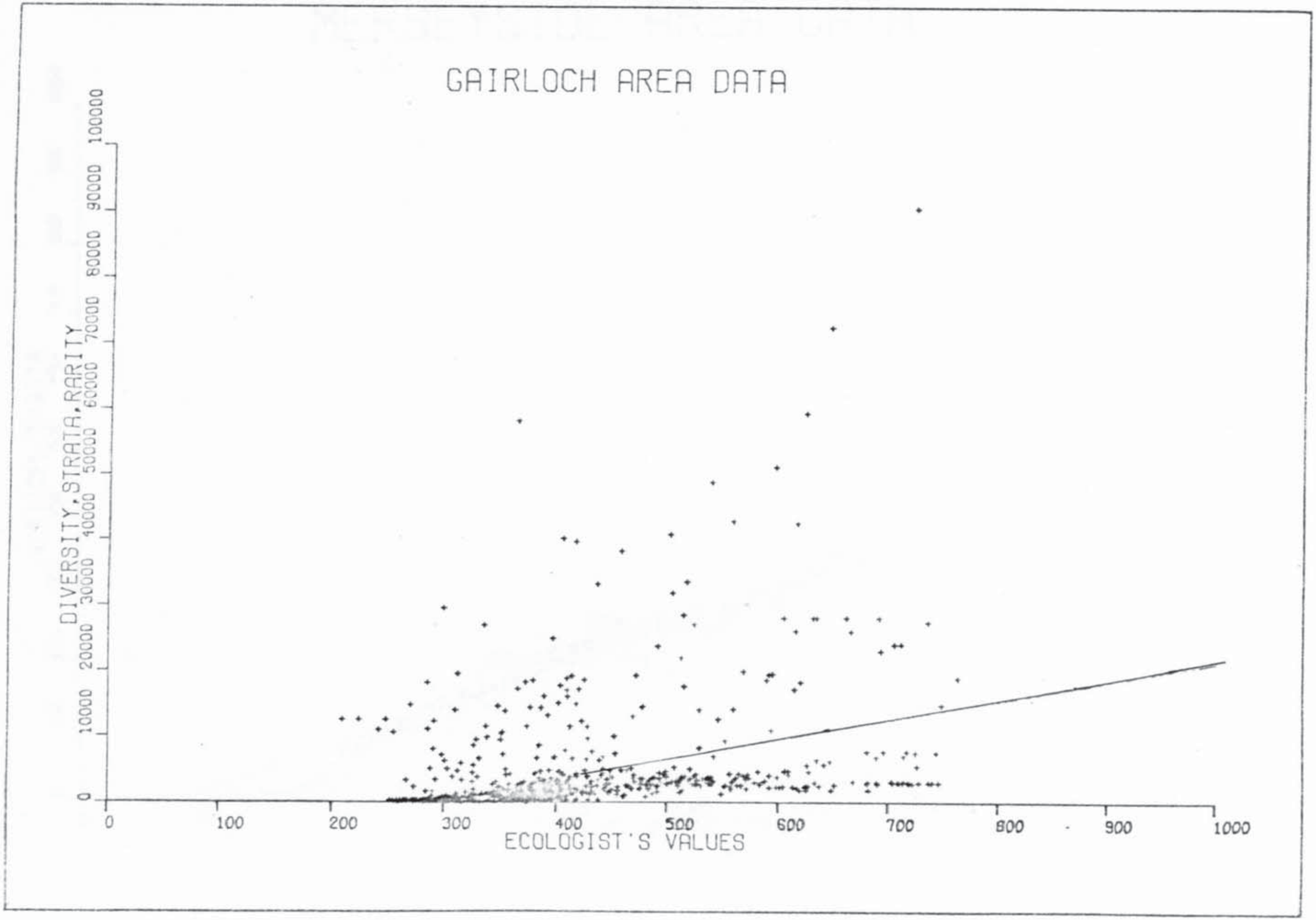

GAIRLOCH AREA DATA
DIVERSITY,STRATA,RARITY
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000
0
100
200
300
400
500
600
700
800
900
1000
ECOLOGIST'S VALUES

Fig. 45:1
MERSEYSIDE AREA DATA

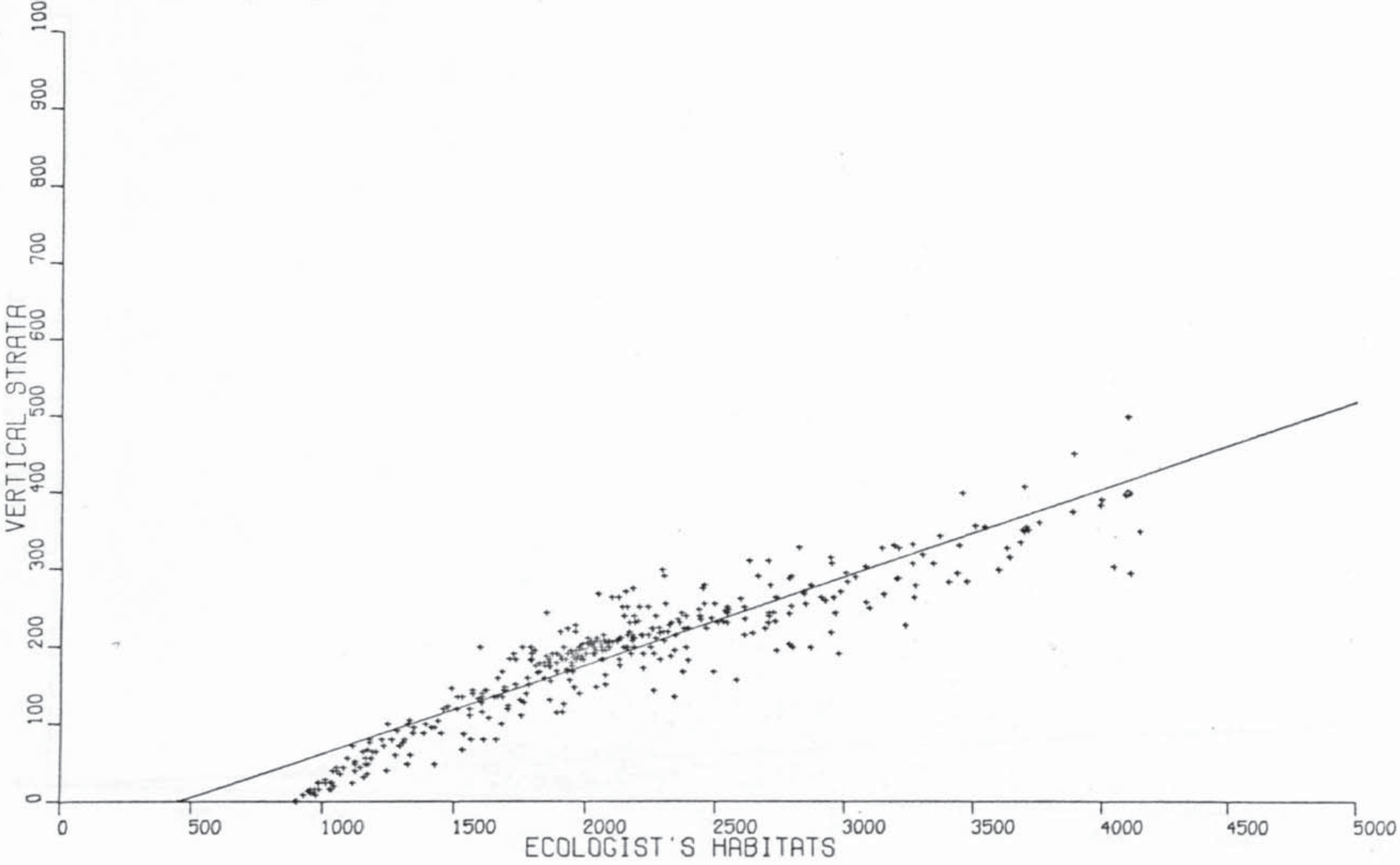


Fig. 45:2
MERSEYSIDE AREA DATA

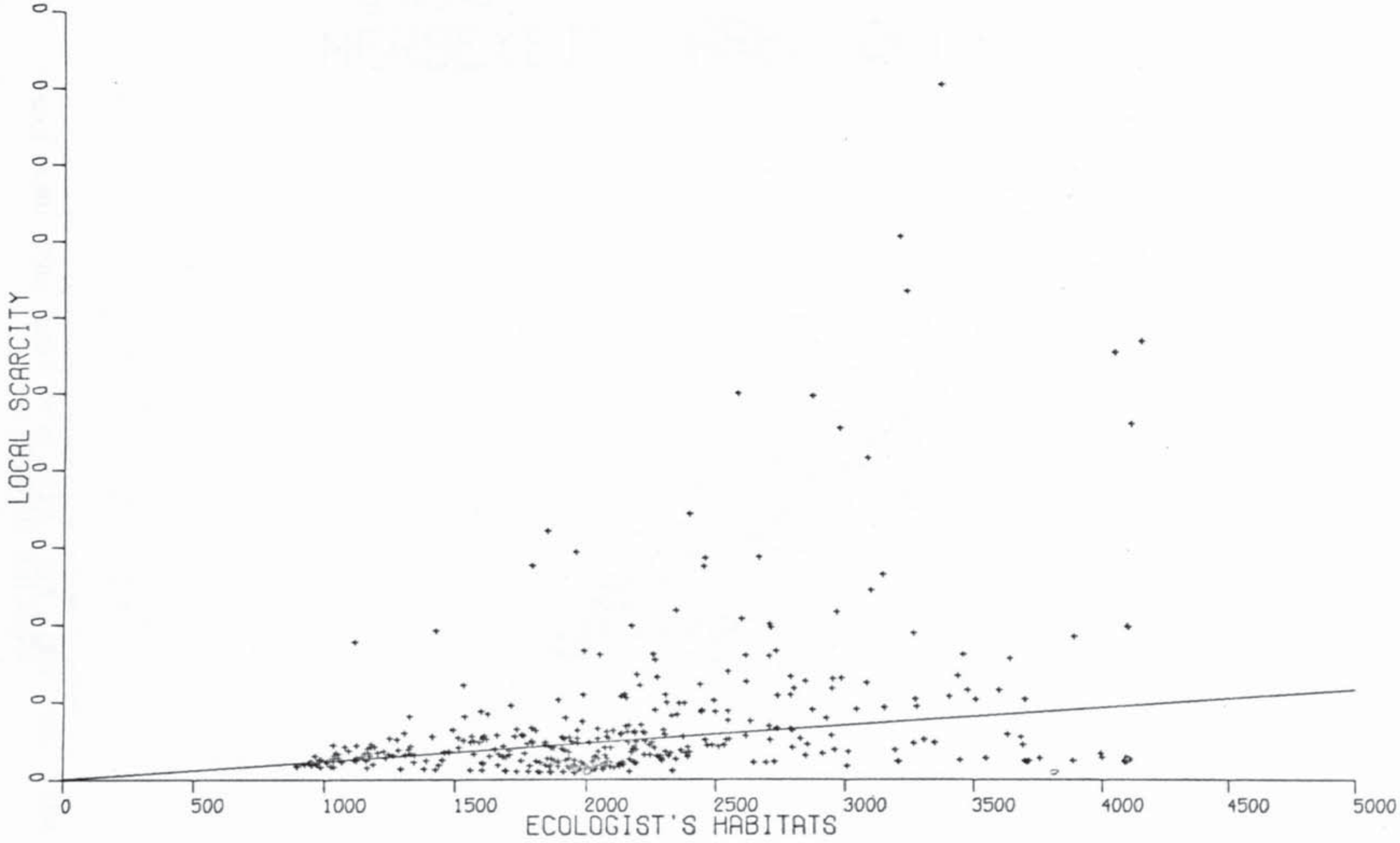


Fig. 45:3
MERSEYSIDE AREA DATA

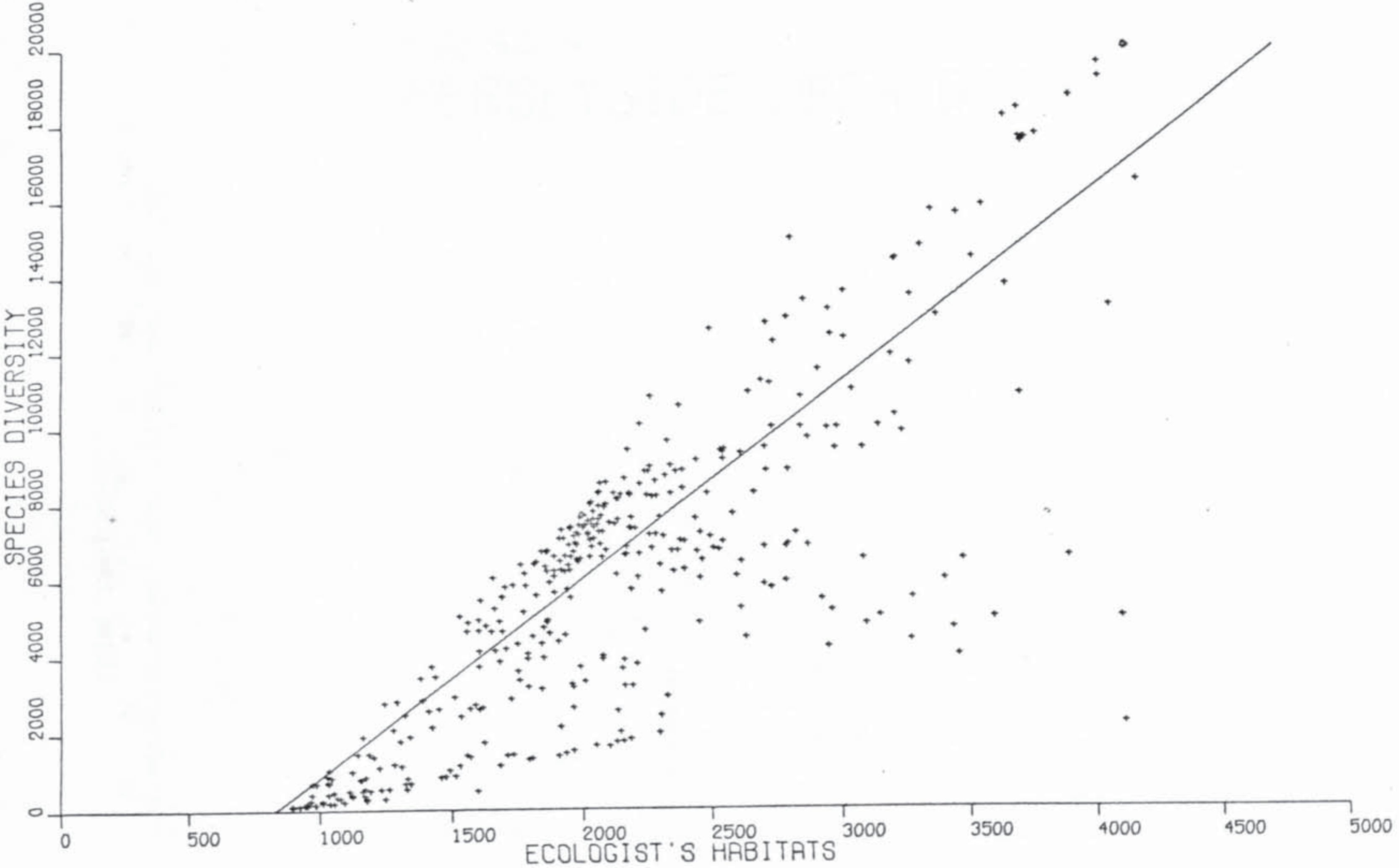


Fig. 45:4

MERSEYSIDE AREA DATA

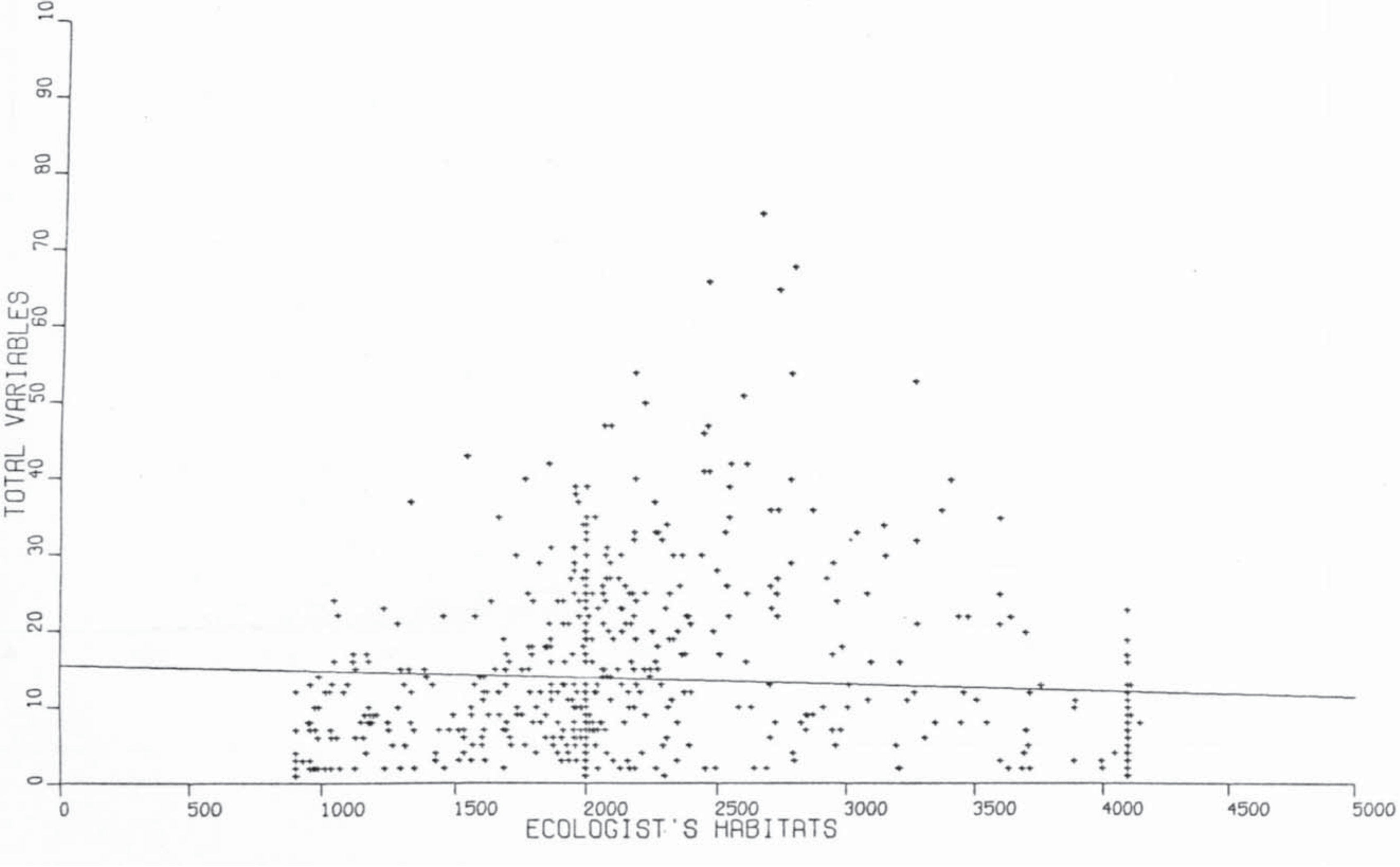
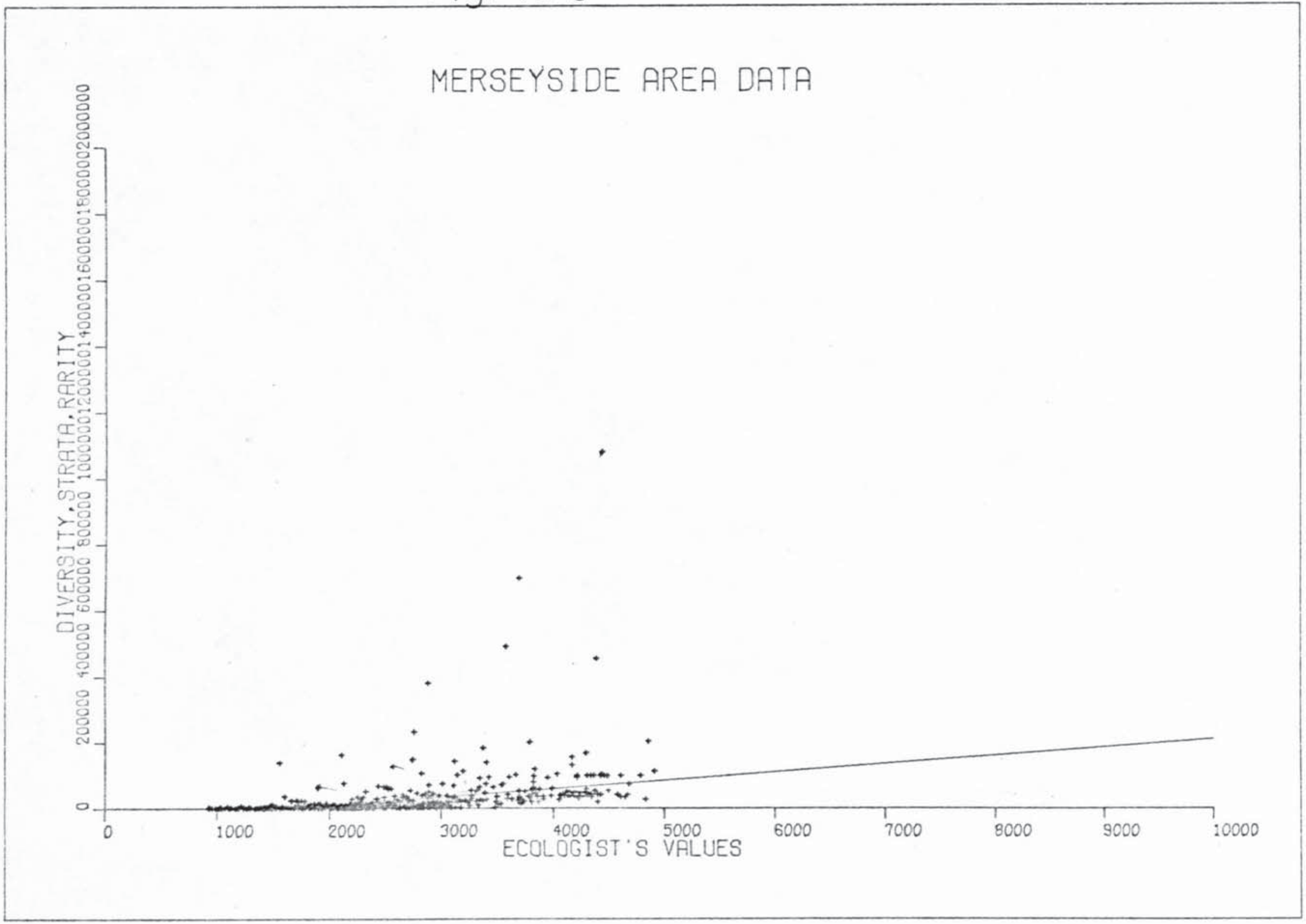


Fig. 45:5



MERSEYSIDE AREA DATA