


Institute of Terrestrial Ecology

Annual Report 1994–95

Centre for Ecology and Hydrology

Natural Environment Research Council

The ITE mission

The Institute of Terrestrial Ecology will develop long-term, multidisciplinary research and exploit new technology to advance the science of terrestrial ecology, leading to a better understanding and quantification of the physical, chemical and biological processes of the land.

Priority is placed on developing and applying knowledge in the following areas:

- the factors which determine the *composition*, *structure*, and *processes* of terrestrial ecosystems, and the *characteristics* of individual plant and animal species
- the dynamics of *interactions* between atmospheric processes, terrestrial ecosystems, soil properties and surface water quality
- the development of a sound scientific basis for *monitoring*, *modelling* and *predicting* environmental trends to assess past, present and future effects of natural and man-made change
- the securing, expansion and dissemination of ecological data to further scientific research and provide the basis for impartial advice on environmental protection, conservation, and the sustainable use of natural resources to governments and industry.

The Institute will provide training of the highest quality, attract commissioned projects, and contribute to international programmes.

ITE will promote the use of research facilities and data to enhance national prosperity and quality of life.

Report of the Institute of Terrestrial Ecology 1994–1995

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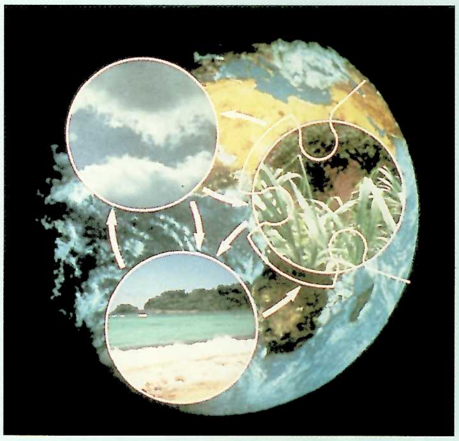


Biodiversity

(Photo J Grace)

Understanding and protection of biodiversity

- Studying spatial and temporal patterns of distribution of biota and measuring change in UK and world biodiversity.
- Characterisation of the essential elements representing the diversity of life forms, their genetic variation, evolution and phylogeny; development and use of new techniques in molecular biology for quantifying genetic variation and studying gene flow and speciation in populations.
- Establishing the factors controlling the origins, maintenance and loss of biological diversity and how changes affect ecosystem processes; empirical studies and mathematical modelling of factors influencing distribution and abundance of organisms and community assembly.

(NERC priorities 1995)

Introduction

Although long recognised by ecologists, there has been an increased awareness of man's impact on the natural environment in recent years, leading to unprecedented action by governments worldwide.

At the 1992 United Nations Conference on Environment and Development in Rio de Janeiro, the Convention on Biological Diversity was signed by 153 countries, including the UK and the European Community, to 'develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity ...'. First coined by the eminent sociobiologist E O Wilson as a shorthand for biological diversity, biodiversity represents the 'total sum of life's variety on earth expressed at the genetic, species and ecosystem level'. Intimately linked with this concept is that of sustainability.

Whilst natural phenomena affect species or habitats, it is generally accepted that the most deleterious and rapid impacts come from anthropogenic causes, usually development or changes in land use, eg deforestation for agriculture and loss of wetlands. Indirect effects, such as pollution and man-induced climate change, are also important, particularly at the genetic and species level.

The core strategic programme in ITE has focused on the three main themes in the NERC biodiversity programme.

Spatial and temporal patterns of distribution of biodiversity

- To develop techniques for recording (eg remote sensing) and integrating (eg geographical information systems (GIS)) environmental variables and species/habitat distributions.
- To integrate data including land cover, climate and topographic features to predict species distribution, abundance and community structure.
- To relate the dynamics of metapopulations and communities to landscape structure, including linear and fragmented features.
- To elucidate the factors and processes (including the performance of the individual) that determine the distribution and abundance of organisms.

Factors controlling biodiversity, relationship with community assembly and function

- To investigate mechanisms underlying pattern and process in biotic communities, including the development of models to describe species assembly, plant/animal interactions, co-evolutionary host/ parasite systems.
- To characterise successional processes and develop predictive mechanistic models.
- To determine the relationship between community structure and function.

Characterisation of genetic variation, gene flow and speciation

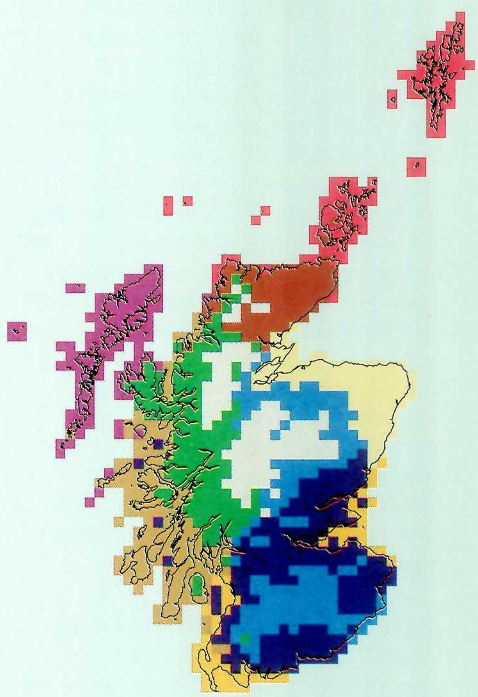
- To quantify genetic variation in natural populations of selected plants and animals and its consequences.
- To investigate mechanisms of population differentiation and speciation.
- To develop and apply genetic markers to studies of breeding biology, dispersal, gene flow and population structure.

ITE's research programmes on large-scale processes are also developing to cover international aspects of biodiversity, and the three articles presented illustrate the breadth of our commissioned research in this area. The first describes the biological databases that are available in a European context. Clearly, before biodiversity can be protected we need to know what is where and the trends in species abundance and habitat distribution. The European Biotopes Inventory was developed through a research programme for the Commission of the European Communities. The project has now become the core of the European Environment Agency's Topic Centre for Nature Conservation. Staff in the Environmental Information Centre at ITE Monks Wood are playing a key role in the operation of this Topic Centre.

The second paper describes a joint project between ITE and the Institute of Environment and Natural Resources at Makerere University, Uganda. The objectives are to develop methods and to train personnel in Uganda in the use of remote sensing and computer technologies (especially GIS and databases) for inventory and land cover classification. Such techniques are essential when dealing with large and complex biomes.

The third paper describes how information on population processes can be used, not only to protect species, but also to manage them in a sustainable manner. The ecology of the saker falcon was little known, yet the species is much valued as a hunting animal in the Middle East. The paper describes how cropping can alter the age structure of populations but will not necessarily result in population decline. The study makes good use of modern techniques, such as radiotelemetry and satellite tracking.

B W Staines



Biogeographical zones of Scotland

Biodiversity databases – the European context

Biodiversity conservation has emerged in recent years as a political goal embraced by governments across the globe, demonstrated by the United Nations Conference on Environment and Development in Rio de Janeiro, at which 150 heads of state or governments signed the Convention on Biological Diversity Since Rio, several signatories have developed Action Plans so as to implement the Convention A common theme to these Plans has been the essential requirement for reliable information on biodiversity The key elements of biodiversity conservation have been identified as

- audit of existing resources,
- establishment of conservation targets and priorities,
- implementation of action plans to achieve these targets,
- monitoring the success of the Action Plans

These procedures depend on the quality of the information which is available on the status and trends of the components of biodiversity, ie species of fauna and flora, and the habitats which support them

Biodiversity may be considered at a range of spatial scales in practice, these are usually local, regional, national, continental and global The question of scale clearly influences the approach which should be adopted for the conservation of biodiversity For example, at a national level, it is appropriate to devote considerable resources to protecting populations of species which are at their range edges, although they are common elsewhere examples might be the Dartford warbler (*Sylvia undata*) or lizard orchid (*Himantoglossum hircinum*), rare in Britain but widespread in continental Europe Biodiversity may also be defined at the genetic, species or ecosystem level For example, at the genetic rather than species level, the argument could be advanced that nationally rare species such as those mentioned above carry globally rare genotypes

At the UK national level, Government followed up the signature of the Convention by the publication of the UK Action Plan (Department of Environment 1994) ITE is involved in a number of activities which have been initiated so as to implement that Plan For example, ITE is represented on the Biodiversity Action Plan data subgroup, which is establishing information standards for national audit and monitoring At the European level, ITE is involved in biodiversity research in two ways through its role as a member of the CONNECT network of conservation research organisations, and through its membership of the consortium which forms the European Topic Centre for Nature Conservation, under contract to the European Environment Agency

The European Community itself (now European Union (EU)), as well as individual governments of the Member States, is a signatory to the Biodiversity Convention The need to collect data of relevance to biodiversity at the European Community level was recognised in the mid-1980s during the formulation of a series of Community Directives on the environment This was one of the factors which led to the establishment of the experimental CORINE programme (COoRdination of INformation on the Environment) which ran from 1985 to 1990 CORINE resulted in the establishment of a consistent methodological framework for the collection and recording of European environmental information, which led on to the creation of a geographical information system (GIS) covering the EU territories This GIS included basic data layers (coastlines, boundaries, settlements, etc), and thematic data, including biotopes, air emissions and land cover The Biotopes project, co-ordinated by ITE since 1985, has resulted in an inventory of over 7000 sites of European importance for nature conservation (Moss & Wyatt 1994)

The principle of CORINE was considerably extended on the formation of the European Environment Agency (EEA), established in Copenhagen in 1993 after a long gestation period The aim of the EEA, which is an agency independent of the European Commission, is to provide the Commission and Member States with the information needed effectively to monitor and develop environmental policies It aims to do so by encouraging Member States to adopt accurate and comparable methods for collecting and reporting environmental data The EEA will not be a policy-making body or an environmental regulator, but it will provide information and advice to inform policy, will help the Commission assess the impact of EU legislation, and provide information to the Commission about compliance with legislation in each of the Member States

The EEA will have a small central staff, and will rely for much of its work on two networks

- **National Focal Points** in each Member State, who will have access to the information required by the EEA held in National Reference Centres, and
- **European Topic Centres** (ETCs), which will be contracted to provide the scientific expertise required to fulfil the EEA's work programmes

The first five ETCs were selected at the end of 1994, covering nature conservation, inland and marine waters, air quality and air emissions Further ETCs are being established in 1995 The strong emphasis placed on biodiversity issues in the work programme of the European Topic Centre for Nature Conservation sets this ETC as a flagship for the EEA's programme, because of the high public profile and urgent needs of biodiversity conservation

The ETC for Nature Conservation is based at the Museum National d'Histoire Naturelle in Paris, and consists of a consortium including ITE and several other members of the European Conservation Research Network (CONNECT), the European Centre for Nature Conservation (The Netherlands) and its partners, and several institutes in mediterranean countries The ETC has three major projects for 1995

- **General approach to nature protection**
  Identify information needs and relevant existing information
  Survey national and international databases on species, habitats and designated areas, and identify gaps in the data
  Formulate proposals for further data collection and the development of database tools
- **State and trends of biodiversity in Europe**
  Establish a conceptual framework for biodiversity assessment at the European scale
  Develop a map of biogeographic regions, and test assessment

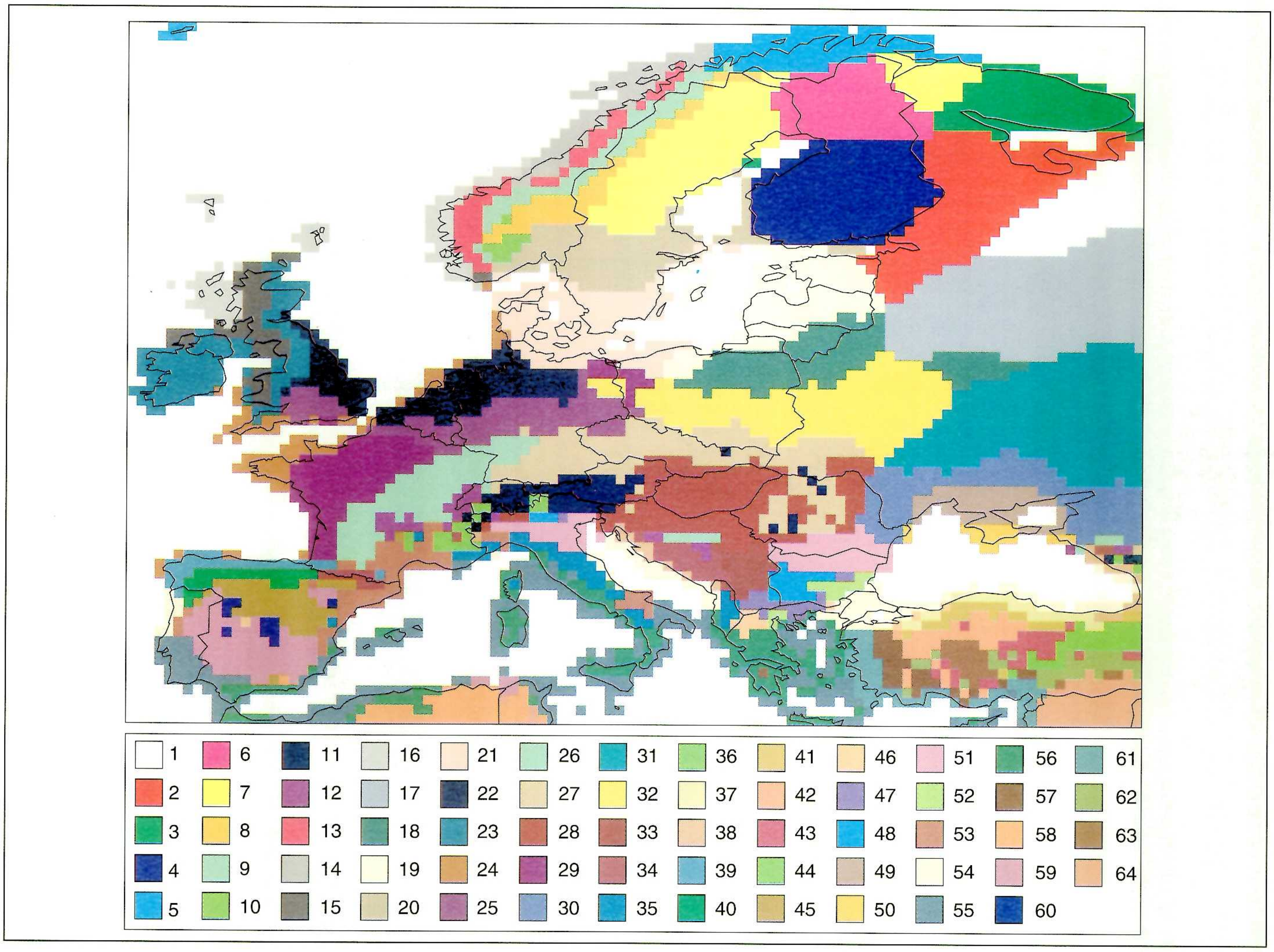


Figure 23. The distribution of the 64 classes of the baseline classification derives from statistical analysis of climate and altitude data. These can be grouped hierarchically to form 10 classes as follows: Boreal-continental (1–4), Northern Baltic (6–7), Boreal (5, 8, 9, 13, 14), Oceanic (15, 16, 23), Sub-continental (19–22, 24, 25, 29), Continental (17, 18, 31, 32), Alpine (10–12, 26, 27, 34, 36–41), Baltic/Black sea (28, 30, 49–52), Mediterranean inland (42–45, 47, 48, 57–64), Mediterranean coastal (35, 46, 53–56, 61)

methods by pilot studies in these regions
Survey indicators of status and change for species and habitats
Review and exploit the CORINE habitat classification
Survey activities in species nomenclature
Develop a standardised methodology for monitoring sites of European importance
Develop criteria for identifying ecological corridors and buffer zones

- **Support for the Natura 2000 network of sites designated under EU legislation**

  Maintain the CORINE Biotopes database
  Initiate creation of the Natura 2000 network database
  Assess the possibility for integration of all relevant information in a common Europe-wide nature protection database system or network

ITE is responsible for two of the above subprojects which develop the earlier CORINE experience: maintenance of the CORINE Biotopes database; and the review of the CORINE habitat classification, which was developed for site description for the Biotopes project and later adopted to define habitats to be protected under the Habitats Directive. ITE also provides expert scientific advice on the west Atlantic biogeographic region for the biodiversity subprojects of the ETC.

ITE has also provided a pan-European classification based on climate, altitude and location data for 0.5 x 0.5 degree cells (Figure 23). This classification, originally developed as part of NERC's TIGER IV programme on "landscape dynamics and climate change", used baseline data provided by the Climate research unit in Norwich. The 64 classes are being linked by the ISEGI institute of Lisbon, using other criteria such as the potential natural vegetation, to develop a map of the biogeographic regions of Europe. These regions will form the basis for the assessment of the state and trends of biodiversity in Europe, which should provide a more efficient statistical stratification than the traditional use of national or regional boundaries.

Work on this ambitious series of projects, many of which will review the current state of knowledge and indicate possible ways forward, is due for completion by the end of 1995. A schematic outline of the future overall database system is shown in Figure 24.

D Moss and C E Davies

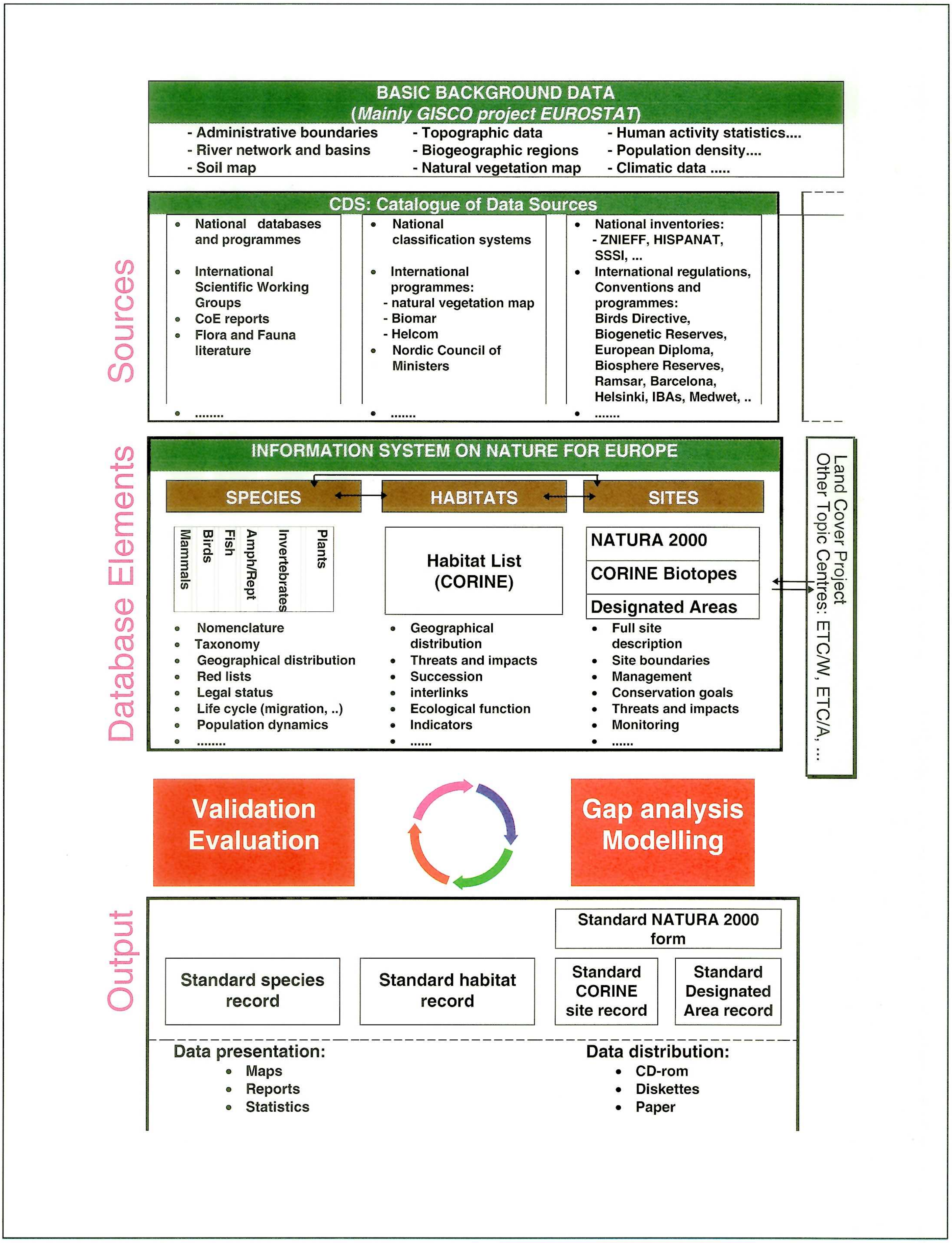


Figure 24. Framework for an information system on nature in Europe (source: European Topic Centre for Nature Conservation)

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Remote sensing of biodiversity in the Sango Bay area of Uganda

(This work was partly funded by the Department of the Environment's Darwin Initiative for the Survival of Species)

Mapping and the recording of biodiversity

Sango Bay comprises some 30 km × 100 km of swamps, grasslands, cultivation and forests which border Lake Victoria in Uganda. The extensive wetlands, with a local climate strongly influenced by proximity to the Lake, support a wide variety of plant and animal species. ITE was commissioned to:

- undertake the mapping of Sango Bay by analysis of satellite data, for monitoring and management of biodiversity,
- evaluate the operation and cost-effectiveness of satellite-based mapping for the conservation of biodiversity more generally in Uganda,
- undertake these exercises with substantial Ugandan collaboration, to enable capacity building through the transfer of technology for subsequent local development of biodiversity conservation objectives using remotely sensed data.

Landsat Thematic Mapper (TM) digital data were used for the land cover mapping. The best-quality and most recent Landsat TM imagery data available at the commencement of the study were 1989 and 1990 scenes, and 1984 data filled, as far as possible, gaps caused by the cloud cover (installation in 1995 of a new ground receiving station for satellite data in East Africa ensures that future acquisitions will be more readily available). The project installed two Personal Computers running the TNTmips geographical information system (GIS) and image analysis software, with identical systems in Kampala and the UK to ensure interchange of images and so that the methods and results produced were directly comparable. UK- and Uganda-based training programmes gave project personnel the expertise needed to undertake image analyses and field surveys with full GIS integration.

The four quarter scenes of TM data were georeferenced to Universal Transverse Mercator (UTM) Projection. About 400 field sites were visited to collect reference data. They formed the basis of an extrapolation using a Maximum Likelihood Classifier to classify the ground coverage, for each pixel of the images, according to spectral reflectances recorded in red, near infrared and middle infrared bands. Minor misclassifications were corrected by 'contextual' methods (Groom *et al.* 1995), which selectively filtered out 'noise' in the output maps, identifying those pixels 'out of context' (eg urban pixels in swamp areas). Spectrally different subclasses of similar cover types were merged to give 14 final output classes (Table 1). The four land cover maps (one per scene) were merged to produce the Land Cover Map of Sango Bay (Figures 25 & 26).

A validation survey visited 240 sample sites selected (for logistical and safety reasons) to fall within 1000 m of roads and access tracks. At each site, a global positioning system (GPS) was used to record UTM co-ordinates, combined with field records of vegetation cover type, vegetation structure, and species dominance (Plate 14). In the laboratory, the co-ordinates were entered (via a FoxPro database) into the TNTmips GIS for analysis. Scoring recorded presence/absence of the field cover type, at the appropriate UTM locations on the map. Because the map has residual geometric displacements of perhaps two pixels and GPS positions incorporate similar inaccuracies, presence was also checked within the immediate vicinity using 120 m GIS-generated buffer zones. Results reveal that 62% of points gave the expected cover type at exactly that UTM position on the map, and that about 86% of points recorded the expected cover type within 120 m.

A subsequent more detailed vegetation survey aimed to relate details of species composition to the mapped cover

Table 1. The land cover classes mapped in the Sango Bay area

Water and swamps	Water Papyrus Tall grassy swamps
Dry grasslands	Medium-height grass Short grass
Degraded woody vegetation	Scrub bush and thicket Degraded forest
Semi-natural woody vegetation	Swamp forest Riverine woodland Forest
Intensive land usage	Eucalyptus plantation Tea plantation Cultivated land Urban, villages, bare

classes. Five survey sites per semi-natural class were pre-defined within 1 km of roads, using a buffer zone constructed in the TNTmips vector GIS. At each survey point, plant species were recorded within a 20 m × 50 m quadrat; the information included percentage cover of dominant species. A walking search added any plant species within 100 m, and then any further plant species within 200 m. The surveys identified those cover types with highest plant biodiversity.

In parallel with the Darwin Initiative (DI) study of Sango Bay, and closely integrated with it, is the Global Environment Facility (GEF) project, covering the same area. The GEF survey selected a series of sampling

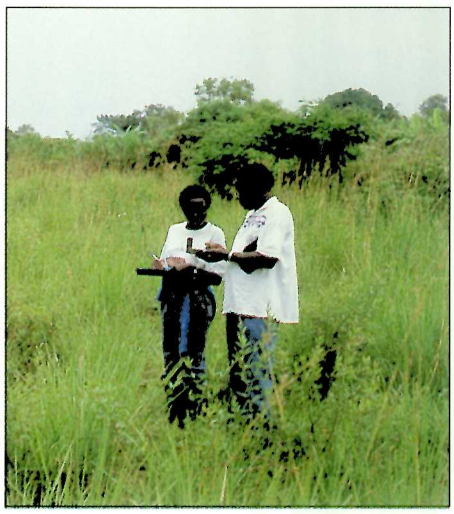

Plate 14. Pep Ipulet and Sam Mugisha, on a field validation survey, using a global positioning system to record UTM co-ordinates, combined with field records of vegetation cover type, vegetation structure, and species dominance

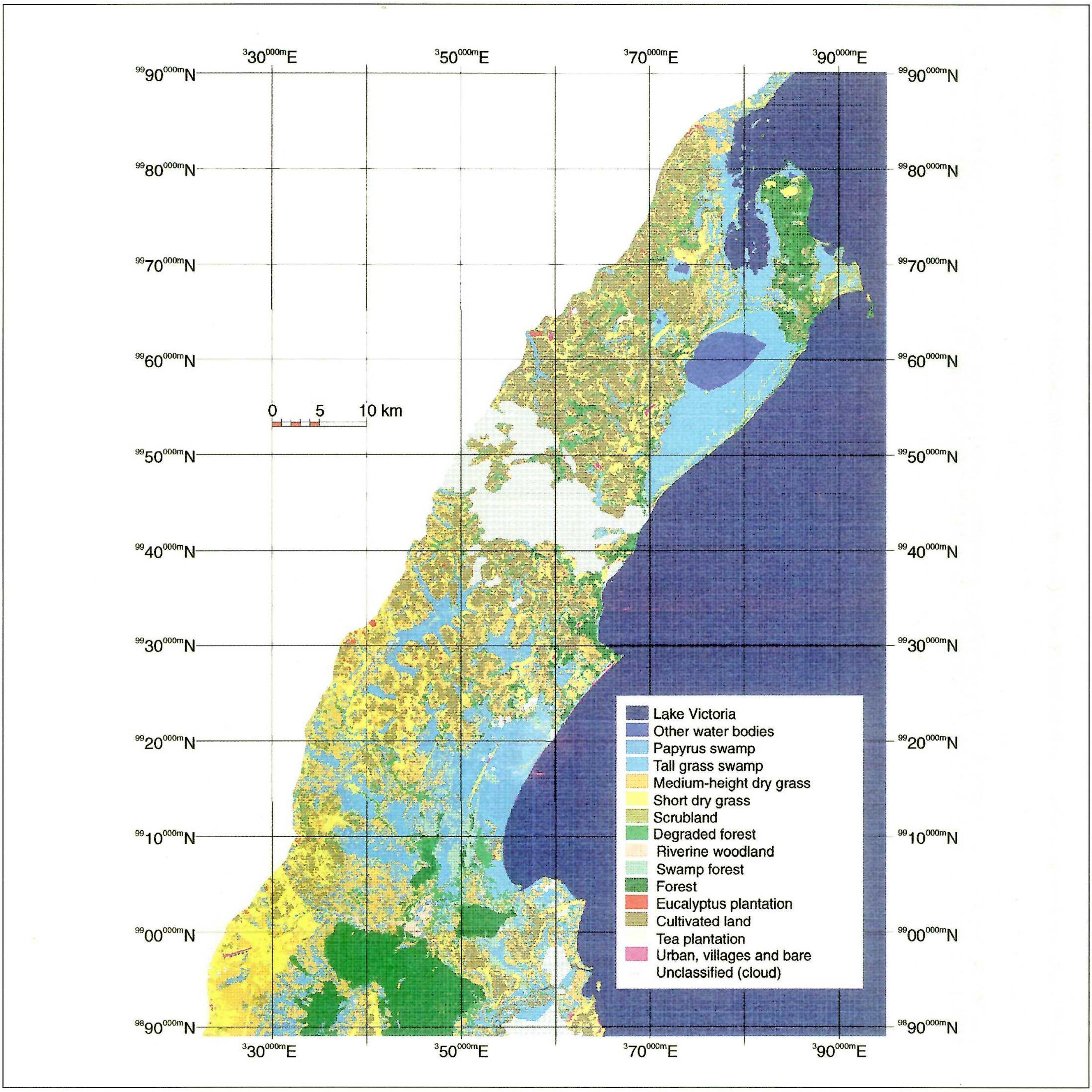

Figure 25. The Land Cover Map of Sango Bay

sites, which collectively covered wetlands, seasonal wetlands and drylands, such that all of the major land cover types were sampled: it must be emphasised that this selection pre-dated the existence of the Land Cover Map of Sango Bay, so it was necessarily based upon field assessments. The sites were chosen to complement the previous and ongoing work of others in the area. The Ugandan Forest Department had collected data on small mammals, understorey birds, trees, and key lepidopteran taxa from several sites in the main Sango Bay forests. The Wetlands Inventory Team of the Ugandan Department of Environment is collecting data on the major water flora and fauna, including fish and birds. The water birds were recorded in a series of sites in the Sango Bay area as part of a study by the Makerere University Institute of Environment and Natural Resources. The DI project included additional surveys of wetland plants and of fish species diversity. Table 2 gives a summary of the survey results.

Biodiversity and conservation assessments

It was not the aim of the Darwin Initiative project to determine conservation policy, but rather to provide objective data and advice from which policy-makers can assess the options and determine optimal strategies which balance the conservation and the socio-economic needs.

In Sango Bay, conservation potential might be predicted directly from land use: intensively used land is unlikely to

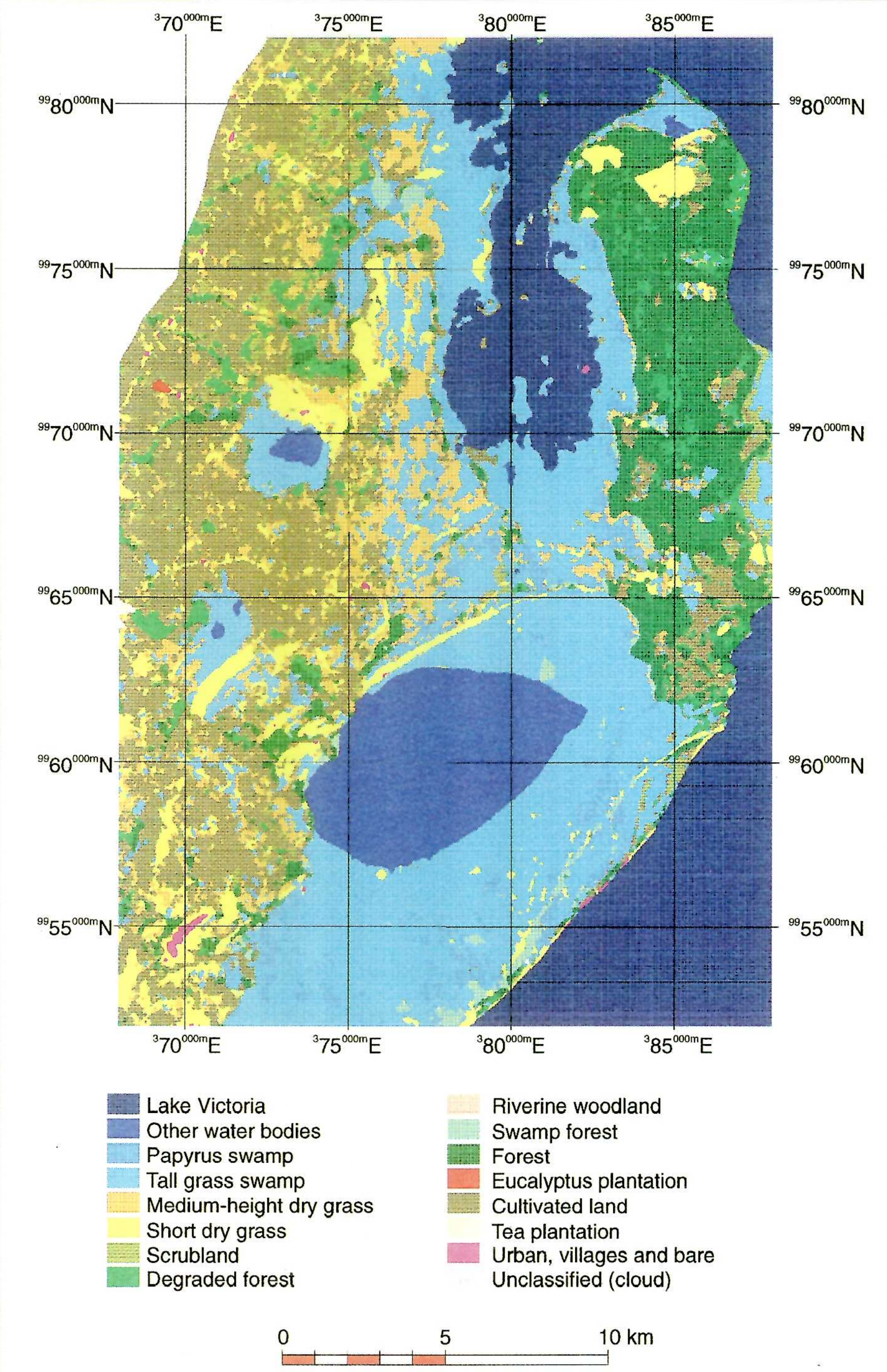

Figure 26. A detailed extract of the Land Cover Map of Sango Bay showing the Lake Nabugabo area to the north of the study site

offer important biodiversity areas. Using the simplicity of vector GIS, it is possible to split Sango Bay into broad categories of use, with simplified and generalised polygon outlines. The 25 m raster map of 14 classes was resampled to 100 m pixels, filtered to remove all the fine 'speckle'; the 14 water/land cover classes were renumbered in the GIS, initially to give intensity levels from '3 – high intensity use', through '2 – semi-natural', to '1 – natural areas'. The highly generalised map of 'intensity' was converted to vector and the serrated outlines of the 100 m raster were removed using the GIS. The results (Figure 27) showed that much of the western part of Sango Bay was under intensive use, with just pockets of 'natural' land, mostly wetlands, associated with the river valleys. Natural areas lie mostly on the eastern side of the study area, nearer the Lake shore. Much of the intensive use is surrounded by a 'protective' buffer of semi-natural land.

The 'intensity' map has been further simplified to highlight areas of high and low conservation potential. The 'semi-natural' areas have been aggregated with the 'intensive' areas to give just two classes, and smaller areas, likely to be less diverse, have been removed for demonstration purposes (Figure 28).

The assessment of biodiversity and conservation potential has been further refined by combining the generalised, but spatially near-complete, information provided by the vegetation map with the detailed, albeit sample-based, species data from field surveys. We must emphasise that the methods used here rely upon numerous assumptions about map accuracy and the representativeness of the sample data. In practice, it is, of course, recognised that the maps incorporate errors. The cover types show within-class variations which would ideally be better understood and mapped; the field data have recorded only a very small part of Sango Bay for a limited period of time; many biological groups have not been covered; and there are probably hundreds of important species yet to be recorded and related to habitat and vegetation cover in Sango Bay. Furthermore, the analyses applied here are very simple in approach; more sophisticated analyses are planned but will not be available for some time. Nonetheless, the technique gives a useful insight into possible methodologies for biodiversity assessment and produces a preliminary map of biodiversity distributions for Sango Bay.

Data for each biological group were tabulated to facilitate comparisons. Wetland and dryland sites were

Table 2. The number of species recorded in Global Environment Fund surveys of Sango Bay (by June 1995)

Group	Species recorded	% of Uganda's total
Flowering plants	1000	20
Dragonflies	72	34
Butterflies	257	29
Fish	48	15
Amphibians	32	33
Reptiles	15	13
Birds	387	39
Mammals	68	20

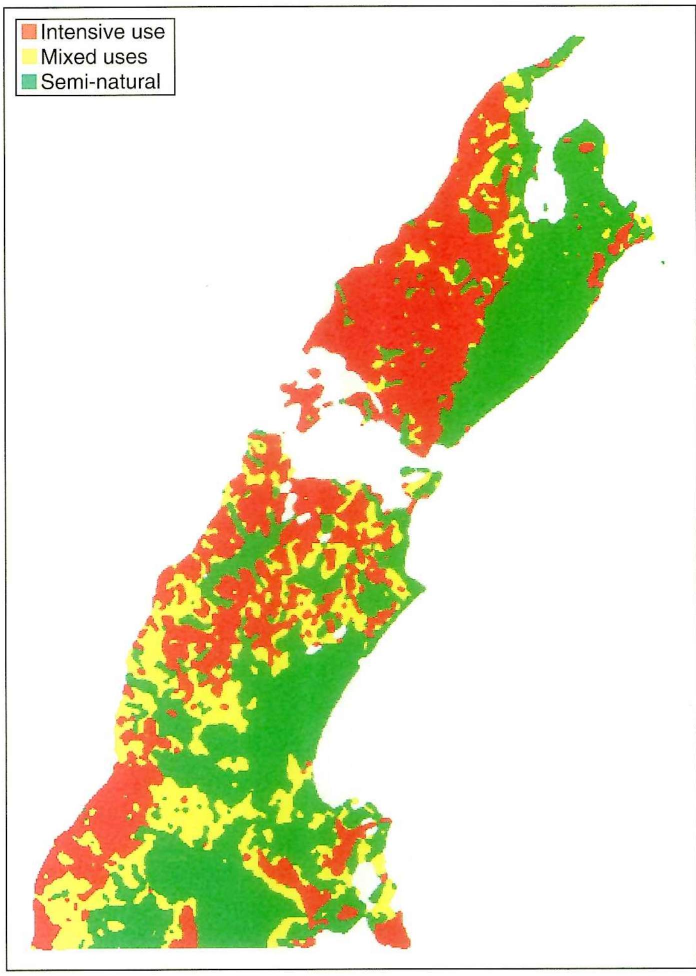

Figure 27. A generalised vector map showing land use intensity based upon classes identified in the Land Cover Map of Sango Bay

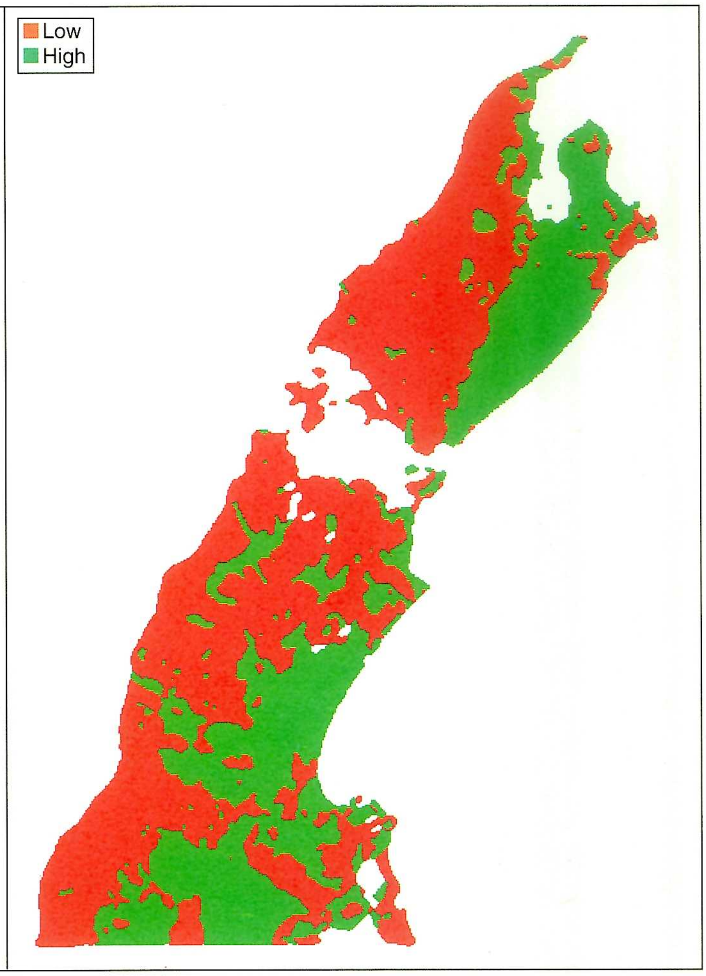

Figure 28. A map showing areas of high and low conservation potential, based upon a generalisation of the semi-natural areas of the 'intensity' map (Figure 27)

evaluated separately, the seasonally wet sites being included with the drylands. Two independent measures of biodiversity value were used.

Species richness – the total number of species for each site

Although the amount of effort was unequal between sites, the differences were not considered to have been so large as to affect the results greatly. The site with the most species was given a score of 5, the next 4, and so on.

Species uniqueness – based upon the number of sites at which each species occurred

A species found at only one site scored 3 for that site; species found at two sites scored 2 for both sites; species found at three sites scored 1 per site. The total scores for each site were then ranked; the top site scored 5, the next 4, and so on.

These data were used to categorise sites as follows.

Sites/scores	Biodiversity rating
Dryland sites	
Scoring 25 and above	Very high
Scoring from 15 to 20	High
Scoring from 10 to 15	Medium
Other more-or-less natural sites	Low
Wetland sites	
Scoring 20 and above	High
Scoring from 10 to 15	Medium

This information was then transferred to the Land Cover Map, reallocating cover to biodiversity scores and thus producing the preliminary Biodiversity Map of the Sango Bay area (Figure 29).

In the second half of 1995, discussions with local officials, elected representatives and others in the region will be incorporated into the planning of a proposal to identify nature reserves, buffer zones, multiple use areas (where predominantly traditional practices will occur), and the remainder (which would be subject only to the land use restrictions required by district authorities and national legislation). The final step will be to seek funding to implement the proposal.

Wider uses within and beyond Uganda

Information about land cover and land use is fundamental for:

- taking stock
- monitoring change
- understanding environmental relationships
- modelling and predicting future change
- landscape planning and management
- assessing successes and failures of management policy

Ecologists in Uganda need to improve their understanding of the factors controlling the numbers and distributions of plants and animals, and how these organisms might respond to conservation management or, conversely, to intensification of land use. It is important

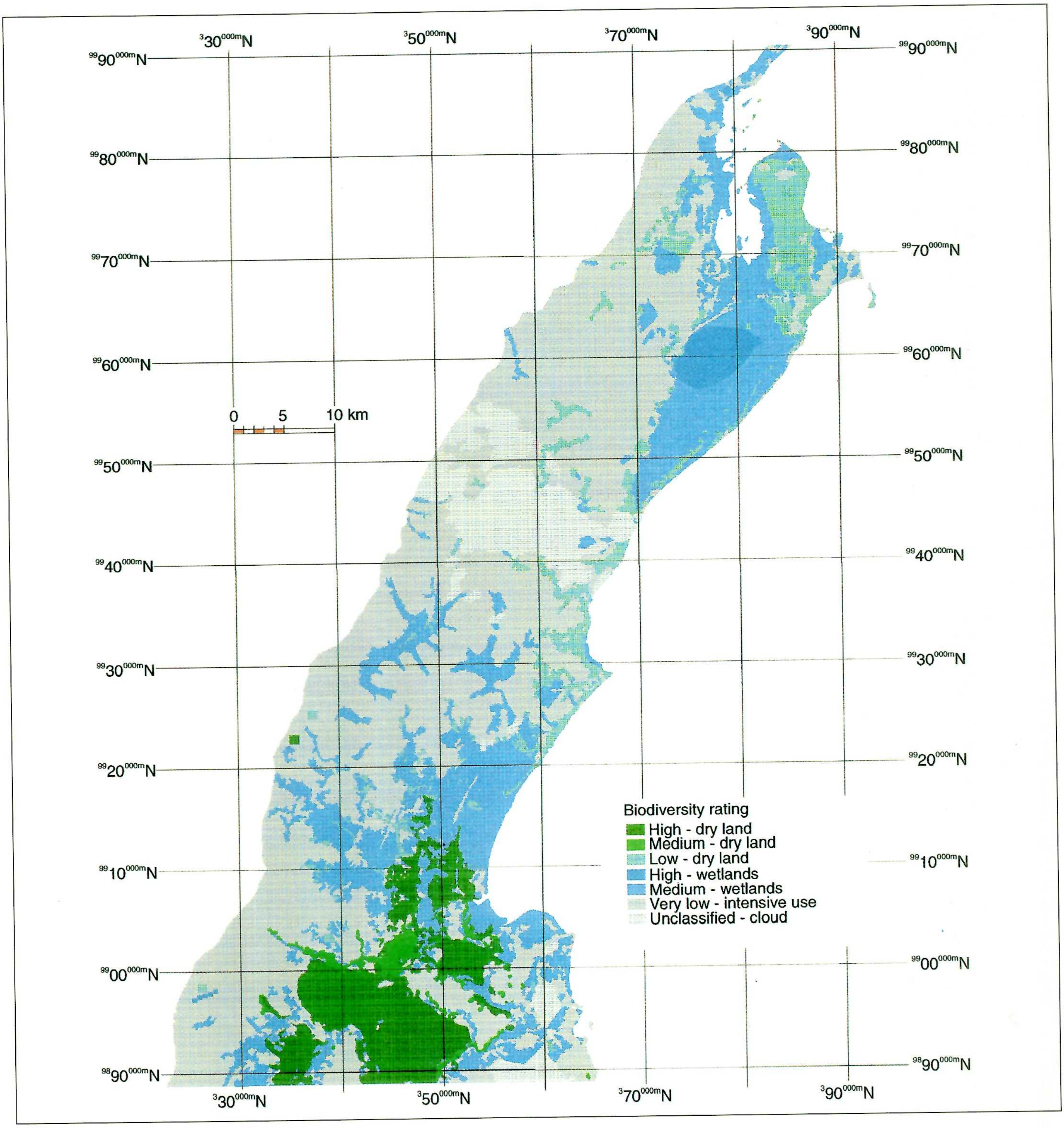

Figure 29. A preliminary Biodiversity Map of the Sango Bay Area, derived by integration of the land cover information (Figure 25) and biodiversity scores for the different cover types

to understand the effects of landscape pattern, the importance of patch size, habitat continuity and the significance, if any, of habitat fragmentation and isolation. There is a need to see if different species require mosaics of particular habitats or adjacency of particular habitats (eg grassland for feeding and forests for nesting sites). Only with this understanding can long-term conservation policies be guaranteed success.

There are also wider uses of land cover maps. Just two years after its launch, the Land Cover Map of Great Britain has some 150 users of the data, for example in biological conservation, public health, monitoring of pollution effects, environmental impact assessments, landscape policy and planning. There are many good reasons for believing that Uganda might also use similar products to improve its planning of land use, development and sustainable management.

Just as mapping in the Sango Bay area was previously limited to topographic maps with very generalised information on vegetation cover, so elsewhere in Uganda there is the need for more detailed information. Indeed, this is true throughout most of the world, whether in developed or developing countries. ITE has shown satellite mapping techniques to be successful and cost-effective in such diverse landscapes as the intensively used and managed landscape of temperate Britain and the largely natural wetlands of tropical Africa. The combination of increased power and refinements of GIS, the easy access to such facilities through PC-based systems and workstations, and the increasing availability of imagery at varying resolutions, means that the opportunities are excellent for ongoing use and development of such techniques.

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Acknowledgments

This report draws upon additional data collected under the GEF project, and from surveys of the Ugandan Forest Department, the Wetlands Inventory Team of the Ugandan Department of Environment, and other projects of the Makerere University Institute of Environment and Natural Resources. Dr R E Bailey of Kings College London and Mr R Ogotu-Ohwayo of the Ugandan Fisheries Research Institute undertook the fish surveys. We are grateful to the many other individuals who have contributed assistance, data, information and advice.

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Plate 15. A trained saker falcon, tagged for tracking by satellite, ready for release in the United Arab Emirates

Demography of saker falcons

(This work was funded by the National Avian Research Centre, Abu Dhabi, United Arab Emirates, and NERC)

The saker (*Falco cherrug*) is the world's second largest falcon. However, its ecology is far less known than that of the larger gyrfalcon (*F. rusticolus*) and the smaller peregrine (*F. peregrinus*). Whereas peregrines can be studied throughout the world, and gyrfalcons in all high latitudes, sakers breed mainly in areas previously restricted for western ecologists, from Hungary east to Manchuria, and from Afganistan north into Siberia. Even the extension of saker wintering areas, into north-east Africa and the Indian peninsula, is not well defined.

Lack of information about sakers is serious, because they are a wildlife resource of considerable value. For centuries they have been trapped on autumn migration, and trained for Arab falconry. Traditionally, their owners hunted desert hares and migratory birds, counting the houbara bustard (*Undulata macqueenii*) as the ultimate quarry, and then released the falcons in spring (Plate 15). Oil wealth has raised the value of a saker to about $5,000, though a well-proven falcon can realise much more. Veterinarians in the Middle East have estimated that more than 2000 sakers are obtained annually (Riddle & Remple 1994), which indicates an annual value for the resource alone of at least $10 million.

In 1992, ITE proposed to the newly formed National Avian Research Centre (NARC), in Abu Dhabi, that it would be wise to assess the saker's status and the sustainability of trapping for falconry. The proposal was:

- to construct a harvest sustainability model for saker populations,
- to estimate population size and harvest rates throughout their distribution,
- to collect tissue samples to study contaminants, pathogens and genetics, and
- to investigate how released falcons could best contribute to wild stocks.

Before committing itself to funding a project that could gather all the necessary data, NARC commissioned a two-year pilot study, mainly to test whether techniques pioneered on sedentary raptors in western countries could also be applied to a migratory falcon in less accessible areas. The first study areas were to be in Kazakhstan (Figure 30), which spreads across the centre of the saker's global distribution.

Towards a sustainability model

Techniques to construct a raptor population model rapidly have already been developed to study the resilience of goshawk (*Accipiter gentilis*) populations (Kenward 1993), and are now also being used for the common buzzard (*Buteo buteo*). The approach determines the survival and productivity of birds in different age classes by using radio-tags, which improves on results produced by ringing. For example, ringing during

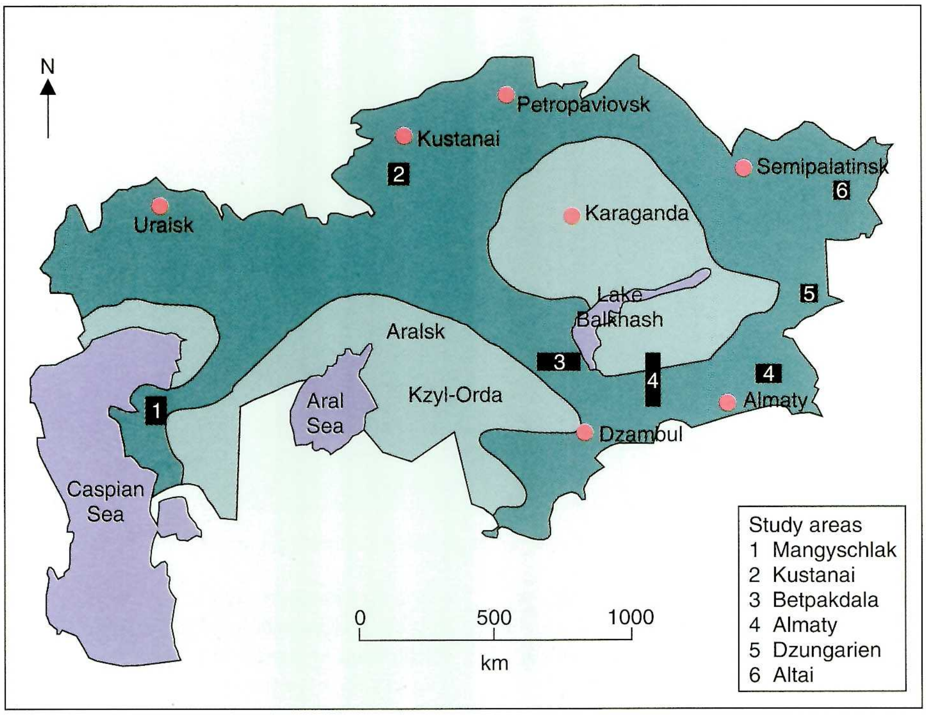

Figure 30. The areas used to study saker falcons in Kazakhstan. The dark green areas show breeding habitat

30–50 years had suggested that 60–70% of goshawks and 50–60% of buzzards died in their first year, whereas radio-tagging for five years recorded first-year mortality of 35% for female goshawks, 50% for males, and 30% for buzzards. The low first-year mortality means that more of these raptors survive to breed than had been imagined, and that there are many non-breeding adults in a stable population. There were as many breeders as non-breeders among the adult female goshawks.

When a model of population structure and production is available, one can ask 'what if' questions. To estimate sustainability, the question is 'what if n% of the young are removed'. Some removal of young may be compensated by a reduction in numbers of non-breeding adults, without reduction in the number of breeding pairs; the model can estimate this proportion. If survivors can begin breeding earlier in life, more young may be removed without reduction in numbers breeding; the model can estimate this figure, too, if there are data on minimum breeding age. Whereas no goshawks bred in their first year in the stable population, in growing populations or where many adults were killed there was up to 35% first-year breeding: in this case, the model indicated that goshawks might sustain 50% removal of young each year.

To record survival and breeding with radio-tags, it must be possible to detect birds in their breeding areas. With reliable tags that transmit for several years, that is practical for sedentary species: about 20 buzzards tagged as young in Dorset are now being tracked into their fourth year of life. A first question for sakers was whether similar backpack-tags could record them returning to natal areas after migration. A first group of 40 sakers were therefore radio-tagged before fledging in 1993 (Plate 16), monitored to dispersal, and sought again in natal areas the following spring. Four young left the cohort before dispersal, two being killed by eagle owls (*Bubo bubo*), and another five were reported trapped on migration. However, signals from at least five were recorded in natal areas the following spring, and another three may have been heard but poor weather prevented confirmation. Their visits were brief, lasting three weeks at most, but showed that young sakers are philopatric, so that survival data can be recorded in natal areas.

When recording survival, it is important to check that the radios themselves have no adverse effect. With a total of 74 young falcons radio-tagged during 1993–94, survival between leaving the nest and dispersal was 90%, the same as for similar-aged goshawks and buzzards. Five of the 74 radio-tagged young have been trapped during autumn migration, a similar proportion to the five trapped from 59 marked only with rings, so survival to their first autumn seems similar for falcons with and without radios.

It seems, therefore, that the 22 g radios, at 2–3% of saker bodymass and lasting three years, can be used to record survival rates of falcons up to three years old. By that age, a general rate for adults should apply; this fact can be confirmed by records of adult turnover

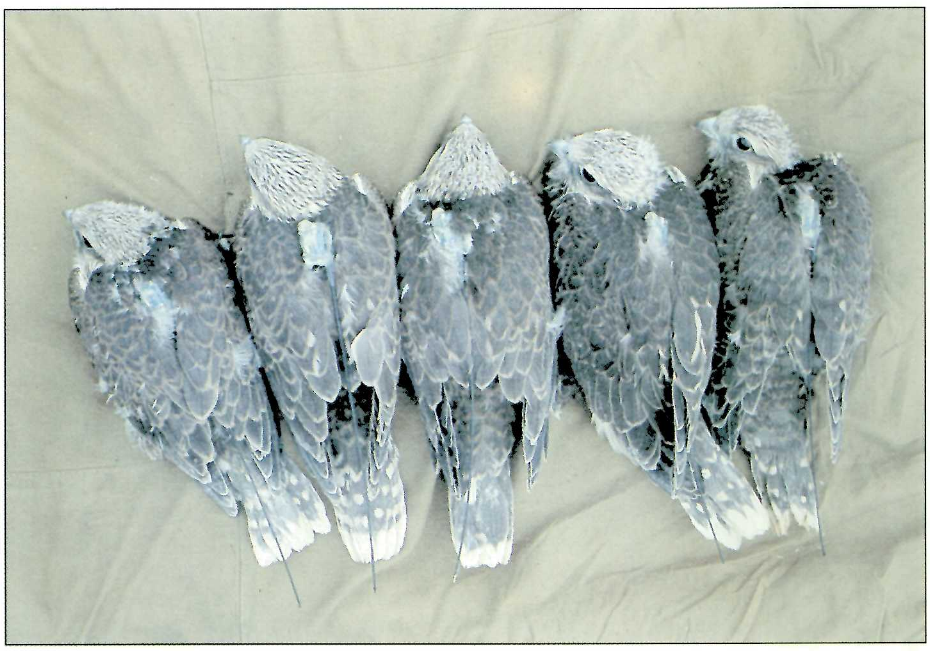

Plate 16. A brood of five young saker falcons marked with radio-tags

at nests. As tagged falcons mature, they will provide age-specific breeding data. The first two years of study have indicated the likely range of overall productivity: breeding was good in 1993, with sakers producing 2.8 young per breeding pair, whereas poor weather and other adverse factors reduced their success to 1.9 per pair in 1994. The production per successful nest each year, of 4.1 and 3.3 young respectively, shows that sakers can be prolific breeders. Broods of 4–5 young are common. This evidence suggests that saker populations may sustain a harvest of young at least as high as for goshawks.

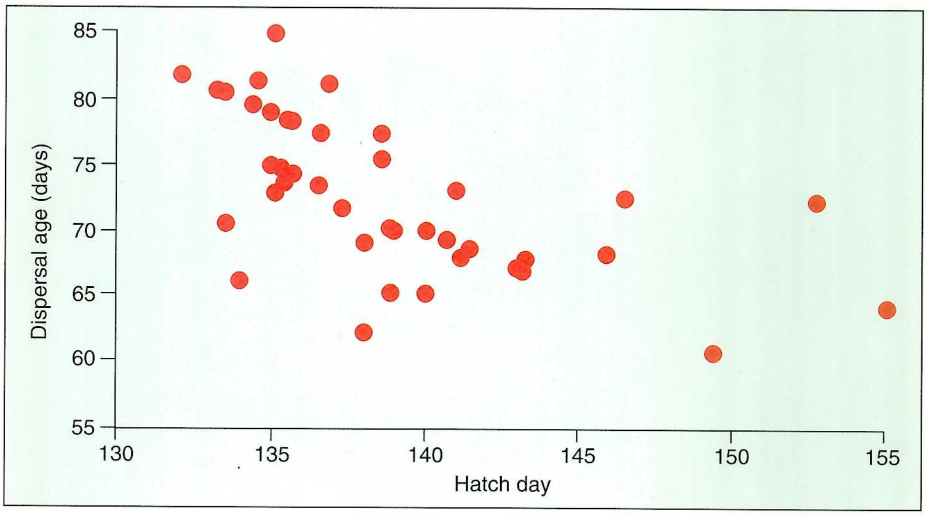

Figure 31. Young sakers which hatched late in the season dispersed younger than early broods

Population sizes and harvests

Thanks to competent Kazakh co-workers, study areas could be established rapidly in north and south Kazakhstan. In the south, Ralf Pfeffer had worked for ten years on cliff-nesting sakers, towards a thesis with the Academy of Sciences. In the north, Dr Yevgeny Bragin had completed a doctorate on the imperial eagles (*Aquila heliaca*) that built most of the tree nests used by sakers there. Expeditions were made to establish areas in other parts of Kazakhstan (see Figure 30) to record breeding success, to mark young, and to start gathering data for density estimates. One method of estimating population size estimates density in suitable habitats, and then multiplies density by area of habitat. Saker breeding was very patchy, however, reaching 26 pairs per 1000 km` locally, but with 0.8–3.0 pairs per 1000 km^2 over much larger areas. It may, therefore, be more accurate to estimate population sizes by correlating density with habitats defined from satellite data, and then using satellite-based maps to estimate numbers over wide areas.

A third method for estimating population sizes depends on marking, trapping, and identifying natal areas of unmarked birds from biomarkers. The marking and trapping alone give harvest estimates. Young falcons were marked both with conventional rings, and with implanted microtransponders. Microtransponders are used routinely to mark all falcons referred to the major veterinary hospitals in the Middle East, and thus recorded birds from the study population even when rings had been removed. In the first year, ring and transponder records showed that at least 23% of young female falcons had been trapped. If biomarkers could be used to identify how many falcons at a hospital came from Kazkahstan, for example, then dividing this number by the harvest rate (0.23) would indicate the total number of young produced there, and dividing that total by the productivity per breeding pair would estimate the number of breeding pairs.

Tissue samples

Blood samples taken from all young falcons, and clutches of abandoned eggs, showed levels of organochlorine pesticides and polychlorinated biphenyls (PCBs) well below 0.1 ppm in wet weight. Saker falcons in Kazakhstan were, therefore, not at risk from the toxins that have been so damaging, for instance, to peregrine falcon populations. Moreover, levels of heavy metals in feather samples were so much lower than those seen normally in Europe that these elements might serve as useful biomarkers to distinguish central Asian falcons from more western populations. Blood stored for genetic analyses residues may in due course provide even more valuable biomarkers for population studies.

Released falcons

If falcons were being harvested close to the limit of sustainability, then the survival of those released after training could be important for maintaining populations. The survival of such released falcons proved difficult to measure. Falcons did not remain at study sites in the United Arab Emirates, but tended to leave shortly after release on long journeys, with initial flights typically downwind. The tail-mounted radio-tags on seven of ten falcons were out of range by the second day after release. These abrupt, long movements were similar to those of young falcons leaving natal areas; a marked tendency for those that hatched late to disperse young indicated the strong pressure on young sakers to disperse (Figure 31).

Three of the released falcons were also marked with tags for tracking by satellite (Plate 1), and a single satellite location suggested that one may have travelled to north-east Kenya, 2000 km south-west of the release site. It remains unclear whether this was a rogue location, or a result of releasing in April when the bird's next movement might have been to a southerly wintering ground, or a normal movement to an area where there have been no ornithologists to record wintering sakers. It is clear, however, that much more work is needed to determine how falcon releases can best contribute to wild stocks.

The future

Work on saker falcons is unfinished. It seems that radio-tagging can be used to build a population model from which to estimate potential harvest rates. Data for the sustainability model would come from a southern study area where pressure from trapping has apparently already reduced the breeding age of falcons: females at three of 17 pairs were in first-year plumage. Actual harvest rates can be measured by ringing and using microtransponders.

Density data can be gathered to build a habitat-based model for estimating population sizes across the saker's global distribution, and the resulting estimates could be checked by independent mark/trap data if suitable biomarkers could be found The techniques are available, and it now remains to be seen whether the resource use will be put on a sound scientific basis to prevent damage by over-exploitation

R E Kenward

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Waste management, bioremediation and land restoration

- Monitoring the response of groundwater systems to pollution from agricultural and waste disposal activities and industrial contamination; analysing the processes that control migration of groundwater through porous and fractured rock and the transport of contaminants within these media to provide a basis for the design and operation of facilities for the safe disposal of wastes.
- Contaminated land assessment and remediation. Studies of the geotechnical properties of rocks, including the application of geophysical survey methods to contaminated land and pollution studies, the evaluation of landfill sites and derelict land, and groundwater assessment.
- Multidisciplinary research to underpin the development and improvement of biological treatment technologies for the removal of pollution from water, streams and soils, and the reclamation of degraded and polluted land.

(NERC priorities 1995)

Introduction

ITE has long played a role in assessing the environmental impacts of waste management processes. This has included studies of the transport of pollutants from solid waste disposal sites, contaminated land and incinerators. Research on large-scale restoration of contaminated and degraded sites has increased recently both in the UK and overseas. Bioremediation of contaminated sites has also grown in importance, with current research focused on oil spill remediation.

An illustration of research on waste management risk assessment is a study for the Department of the Environment which utilised chemical analytical expertise within ITE to study leachate from landfill sites. These leachates are complex mixtures of chemicals disposed to the sites in the past or generated by chemical processes within the sites themselves. Many chemicals long since banned for use in agriculture or industry leach from such sites and form a source for potential contamination of organisms. Whilst the initial results presented in this section suggest little wide-scale risk to wildlife, some areas are giving cause for concern and the studies will continue. Staff at several ITE Stations are modelling the movement of specific chemicals in soil and wildlife, backing up the more applied studies of disposal sites. ITE's extensive interest and expertise in the effects of pollutants on wildlife complement these studies, and allow us to extend risk assessments to the many modern and historical waste disposal sites in the UK.

The investigation of the fate of chemicals in soil and groundwater has, in the past, been largely the responsibility of physical scientists in the areas of geology and hydrology. An increasing public and political interest has raised the profile of such studies from the biological viewpoint. ITE has responded with increased co-operative research with other NERC institutes – both in the United Kingdom and abroad. We have developed projects with geologists in looking at effects on wildlife of mine wastes from gold extraction in Africa and southern Asia. Biomarker techniques have shown contamination of organisms in soil and surface waters. These studies will be expanded to other regions in the coming year.

ITE has a strong record of research in habitat management for conservation. With the greater availability of land not required for agriculture and strong pressures not only to conserve but also to increase biologically diverse habitats, this expertise is facing the challenge of restoration and recreation of species-rich assemblages. ITE has taken the lead in the re-creation of species-rich grassland for many years; the wildflower mixtures industry derives principally from ITE research. Scientifically, interest has extended from the vegetation structure of such habitats to the functioning of re-created ecosystems at all levels. This practical work is being supported by customers, such as the Ministry of Agriculture, Fisheries and Food, to extend areas of biological interest in wetland and heathland. The scientific and theoretical underpinning of habitat re-creation is also being addressed. An example of co-operation with civil engineering to save and extend biodiverse downland habitat threatened by road development shows that scientists and industry can work together with good results for wildlife.

Expertise on restoration continues to be applied in the area of tropical forestry, and an update of research in technology transfer and training in the Tropical Forest Section at ITE Edinburgh is presented here. Native tree species can be rapidly brought into cultivation through cloning, which has many benefits for tree production in tropical countries; it enables the direct capture and utilisation of superior genotypes, which can be rapidly bulked up; and it circumvents the problems of erratic seed supply and poor storage that are common to many tropical trees. ITE has adopted a 'low-tech' approach to cloning, through the use of simple methods of vegetative propagation which have been applied to more than 200 tropical timber and non-timber tree species from different environments and families. In parallel with conducting research, an important function is to improve the skills of local staff. This training is accomplished through, for example, short 'in-country' technical training courses run by ITE staff in collaboration with local organisations. Staff are well equipped to provide this training because, having worked extensively in developing countries, they understand the need to work at the appropriate level of technology, whilst having the necessary breadth of experience and research background with which to develop new techniques.

ITE intends to develop research on risk assessments for the waste management cycle – this includes hazard identification, flux processes, dose./response and exposure assessment. ITE is investing in molecular soil microbiology and developing a network of collaborators in the soil bioremediation field. Collaborative work with the Institute of Virology and Environmental Microbiology has started on the application of molecular genetics to biodegradation processes of xenobiotics in the rhizosphere of soils. Research on reclamation will be expanded to develop techniques for ecosystem restoration rather than just revegetation of sites, both in the UK and overseas.

S Dobson

Persistent organic contaminants and metals in landfill leachates and gas condensates: risks to wildlife

(This work was funded by the Department of the Environment)

Chemicals released as a result of human activity persist in the environment for various periods of time. Experience suggests that those persistent chemicals that are also soluble in animal fats accumulate in wildlife food chains. They contaminate top predators, such as fish and birds of prey, that are important to people either as food or as indicators of the well-being of the ecosystem. Some of these chemicals, such as certain organochlorine pesticides (eg DDT and its breakdown product DDE), and polychlorinated biphenyls (PCBs) have persisted in wildlife populations for 10–20 years after production has ceased. However, concentrations of even the most persistent chemicals might be expected to decline in wildlife once inputs to the environment from production or use have stopped.

Changes of this kind are being looked for in the ITE predatory bird monitoring scheme. Results from the scheme over the past 30 years have shown that, initially, following a mixture of voluntary action by industry and regulatory action by governments, a fairly rapid decline in average levels of contamination in predatory birds occurred. For certain chemicals (eg HEOD residues derived from the cyclodiene group of insecticides), the decline appears to be continuing.

For other chemicals, for example PCBs, an initial decline seems now to be slackening off, and there is even evidence for some increases of concentrations in some species. No real trend over time in residues is apparent in still other species. Another feature of the PCB levels found in bird livers is that the data on residues is skewed to the left so that many birds contain less than one part per million of PCB per gram of liver (wet wt) and high residues are only found in a relatively few individuals (Figure 32). Taken together, these findings and characteristics of the data could be interpreted as evidence for continuing inputs of PCBs, particularly because the data distribution may not be consistent with the view that PCB levels in the environment are heading towards equilibrium (where concentrations in individuals might be expected to be normally distributed around the mean). If these unidentified sources are either point sources (such as landfill sites) or stochastic events (such as spills and fires), it could explain why some individuals have residue levels that are several orders of magnitude higher than those in other individual birds.

Partly to explore these ideas further, and to fill a gap in knowledge about the concentrations of persistent chemicals present in landfills, ITE conducted a study of metals and priority organochlorine compounds in landfill leachates and gas condensates, in conjunction with a number of other research groups commissioned to undertake work by the Technical Wastes Policy Division of the Department of the Environment.

Main aim

One of the major disposal options for solid waste in the UK is disposal in landfill. Landfilling operations lead to potentially polluting material being deposited in the landfill, with new compounds generated as a result of biochemical and chemical processes in the landfill. Since the introduction of landfill technology, there has been concern regarding the transfer of chemicals from the landfill site to the surrounding environment. Thus, the main aim of this work was to determine whether the chemicals deposited or generated in landfills pose a threat to wildlife.

Approach

Leachate samples were obtained from 30 landfill sites in the UK, with landfill gas condensate sampled from six of these sites. Each landfill received primarily domestic waste. The samples were centrifuged to remove fine particulate material present in some samples and analysed for a wide range of organic compounds, including pesticides and industrial products and by-products. Gas chromatography was used to analyse organochlorine compounds, including pesticides and PCBs. Inductively coupled plasma mass spectrometry (ICP–MS) was used to analyse elements present in the sample. ICP–MS was operated in scanning mode to give qualitative data on elements present, rather than quantitative data on the concentrations of specific elements. Selected chemicals determined in the leachate/condensate samples were also analysed in wildlife samples which had been received at Monks Wood, either as part of the wildlife morbidity and mortality incident investigation schemes or as part of the predatory bird monitoring scheme. Additional information on levels in wildlife was obtained from the scientific literature.

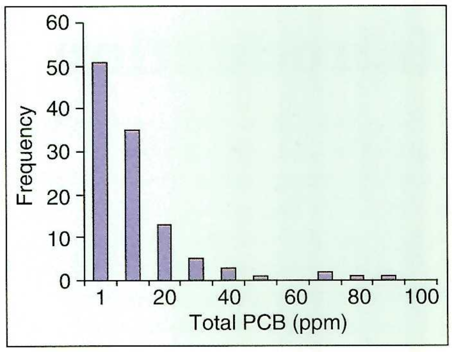

Figure 32. The residue data show a marked skew to the left, with many residues being less than 1 ppm. The figures for total PCB are the maximum value in each class

Main findings

Few of the persistent organochlorine chemicals were present at concentrations above the limits of detection in either leachate or gas condensate. The most frequently detected organochlorine in the 30 leachate samples was HEOD. This residue is derived from aldrin and dieldrin, although these insecticides should not have been used in the UK since the early 1980s. HEOD was detected in 22 leachates, at concentrations ranging from 0.01 to 0.48 mg l^{-1}. Lindane was detected in five leachates, at concentrations ranging from 0.02 to 0.05 mg l^{-1}. The insecticide DDT was not found, although two leachates contained the metabolite DDE.

The leachates were complex organic mixtures with unidentified material found in many samples; preliminary mass spectrometry suggested the compounds present included organic acids, terpene-like compounds and substances such as undecane (a known narcotic). PCBs were detected in 27 leachates, with concentrations of total PCBs ranging from 0.01 to 17.11 mg l^{-1}. The profile of PCB congeners present in the leachate samples was markedly different to the condensate profile. The more volatile congeners, nos 8,18 and 52, were only detected in the condensates, whereas the less volatile congeners, nos 101, 118, 138,

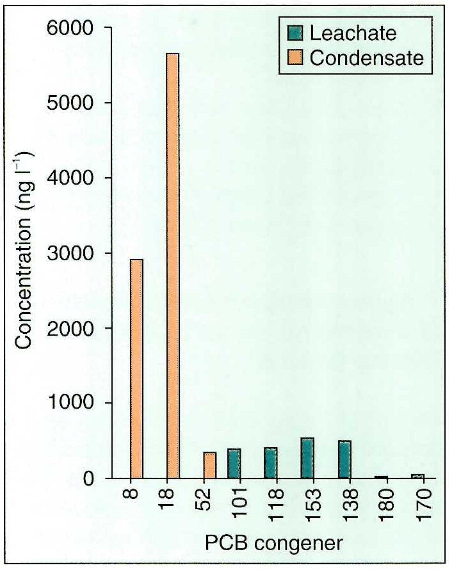

Figure 33. Mean concentrations of individual PCB congeners (where detected) in landfill leachate and gas condensate samples

153, 170 and 180, were only detected in the leachates. This finding suggests that the physico-chemical properties of a chemical play a major role in determining its fate within the landfill. The distribution of PCB congeners between landfill leachate and condensate is shown in Figure 33.

In contrast with studies on leachate from industrial landfills, little evidence was found that would support the view that leachates from domestic landfills contain substantial concentrations of either mercury, cadmium, or lead. Trace levels of lead, mercury and cadmium were found in these leachates. The leachates also contained a wide range of other metals, including tungsten, zirconium and, occasionally, bismuth. The pattern of metal residues found in the leachates bore more resemblance to a biological sample than a geological sample, possibly because of the active microflora involved in the landfill processes.

Condensates contained less metals than the leachates, although chromium, manganese, strontium and lead were present. Most striking was the presence of antimony, a potentially toxic metal. It has been suggested that this might be derived from the plastic pipes used to collect landfill gas at some sites.

There was no simple relationship between the phase of the landfill process, determined by the fatty and acetic acid content of the leachate, and the presence of persistent organochlorines or metals in leachate or condensate.

Many of the organochlorine compounds and metals found in leachates and condensates have also been found in wildlife. This raises the possibility that landfill can act as a source of these chemicals. In order to assess the hazard of landfill leachate to wildlife, it would be necessary to know the following:

i. the identity of compounds contained in the leachate;
ii. the partitioning of these compounds between the water and solid phases;
iii. the physical characteristics of the leachate;
iv. the characteristics of the compound, including physical/chemical properties, environmental fate and toxicity;
v. the underlying geology;
vi. the integrity of the landfill structure.

Information was not available on the rates at which material in leachate or gas might be transferred from the landfill to the wider environment, or on the total volumes of material involved. The absence of this information made it impossible to assess the contribution landfill is actually making to the residues of metals and persistent organochlorine compounds found in wildlife. Impacts on aquatic life or soil organisms are dependent on the degree to which the chemical complex in landfill modifies reproduction or survival in such species. In turn, this would depend on the attenuation of the materials in water bodies or soils, and on atmospheric transfer processes. Compounds detected in these leachates are known to be toxic to wildlife. HEOD is toxic to both terrestrial and aquatic organisms, and PCBs have been implicated in effects on the reproductive and immune systems.

There is limited evidence for local impacts. This suggests birds can become either contaminated or poisoned through feeding at landfill sites. For example, herring gulls (*Larus argentatus*) that fed for part of their time on refuse (possibly at landfills) were reported to contain high concentrations of PCBs. However, these gulls also fed on offal discarded from local fishing boats, which could have been contaminated with small amounts of PCBs. Gull deaths were reported following feeding at the base of an active landfill in Wales. The deaths were associated with the consumption of invertebrates containing up to 80 ppm Cd, although little Cd was found in the gull tissues.

In general, the concentrations of metals in both leachates and condensates seemed too low for domestic landfill to act as a substantial source of these contaminants to wildlife, except in situations where raw leachate was managing to enter the open environment, or where wildlife gained access to contaminated food during filling operations. This study produced no evidence to suggest that compounds found in leachates or in landfill gas pose an overall threat to wildlife populations, although it did suggest that landfills could be a source of contamination (eg with PCBs or HEOD) if material in the landfill were to leave the site.

H M Malcolm, J Wright, D Osborn and C Wyatt

Species translocation and habitat restoration – a case study in ecological engineering

(This work was funded by Mott MacDonald Civil Ltd)

The growing urgency of the need to conserve wildlife has resulted in an increasing use of species translocations and introductions for a variety of objectives, including:

- establishing new populations, or supplementing declining populations, of rare or threatened species (eg the Species Recovery Programme of English Nature);
- increasing the biodiversity of communities with currently low conservation value (eg agriculturally improved grassland and forestry plantations);
- creating or restoring plant and animal communities on sites degraded by human activity (eg by construction, quarrying, pipelaying or mining projects); or
- relocating communities to new sites to prevent their destruction by these human activities.

Here we describe a large project in which techniques have beeen developed to prevent – and mitigate – the loss of semi-natural habitat during the construction of a section of the M3 Motorway between Bar End and Compton near Winchester, Hampshire

Plate 17. The motorway works and restoration area

(Plate 17). The basic criterion was to establish appropriate and self-sustaining plant and animal communities on two areas around the Arethusa Clump and on the restored A33, in all some 7 hectares (see also Morris *et al.* 1994). Only part of this programme is described here – that carried out on the 1.49 ha area known as Arethusa A.

Two distinct methodologies were used to establish a semi-natural community: habitat translocation and sowing of seed.

Habitat translocation involves the wholesale lifting of a community as turves, followed by its establishment on a new site. Such relocation of a community should be purely for rescue purposes, to avoid its destruction in the construction process. The complex attributes of the original community are maintained, including the soil structure, established plants – representing the full complement of species (including lower plants), the seedbank, and the soil and above-ground invertebrate fauna. However, past habitat translocations have encountered problems (Exton *et al.* 1991). Species may be lost during the lifting and transportation of turves – especially above-ground invertebrates. If the turves are shallow, deep-rooted plant species and elements of the seedbank and soil fauna will be lost. Further species disappear during establishment of the turves because of inappropriate environmental conditions – the soil may be too thin, the conditions (eg hydrology) of the receptor site may be different from the original donor site, or the management may be different.

Seed sowing is used to create a completely new community of conservation value. It does not give the 'instant community' of habitat translocations, but, by selecting the appropriate species and careful site preparation and management, a particular target community can be created much more rapidly than by allowing natural succession to take place (Stevenson, Bullock & Ward 1995). However, animal and plant species typical of the community which are not seeded in (including the lower plants), or which do not establish well, must colonise to achieve a fully functioning community. This colonisation may be impossible when the area is not adjacent to a source habitat. There are also suggestions that, if seed is not derived from local plant populations ('local provenance'), introducing non-local races may have negative effects on the ecology and conservation genetics of pre-existing local populations.

Techniques have been developed to overcome the potential problems listed above and applied on a larger scale than attempted previously:

- macroturfing improves the transfer of an intact soil structure and species complement;
- local seed collection avoids the problems of species provenance;
- the planting of pot-grown plants allows the establishment of poor germinators;
- site preparation techniques can improve establishment of turves and sown plants; and
- appropriate management directs community development.

Translocation and establishment of communities on to Arethusa Clump Area A

The initial stages involved drawing up a detailed plan (Figure 34) for optimal use of available turf and seed resources. We aimed to achieve a varied, species-rich chalk grassland which would eventually contain a rich downland invertebrate fauna. The design would also yield valuable data which would allow modification of the methods to be used later in the works and also in future habitat reconstruction/creation work.

Some areas of species-rich downland turf were identified in an area known as the Dongas, which would be lost during the construction of the motorway. It was decided that this turf, and some of lesser quality, should be used as a basis for the revegetation of Arethusa A. The areas which could not be turfed would be sown with appropriate downland seed mixes. Following tests for soil nutrients, the nutrient-rich topsoil was removed to expose the thin nutrient-poor soil which favours the development of herb-rich downland vegetation.

Turf translocation

The main turf translocations were accomplished using specially developed 'ecological' macroturfing equipment (Plate 18). The turves cut by this equipment measure 2.4 m × 1.2 m and can be more than 30 cm thick; they are thus less prone to either frost or dessication problems. All but the most deep-rooted plants survive, including the orchid species which are often at risk during grassland translocations. Weed problems through soil disturbance are minimised and the soil structure remains intact. Burrowing invertebrates also transfer successfully.

Some 3000 m^2 of downland turf were lifted from the motorway route in the Dongas during December 1992, moved 1.6 km and positioned in Arethusa A according to the design in Figure 34.

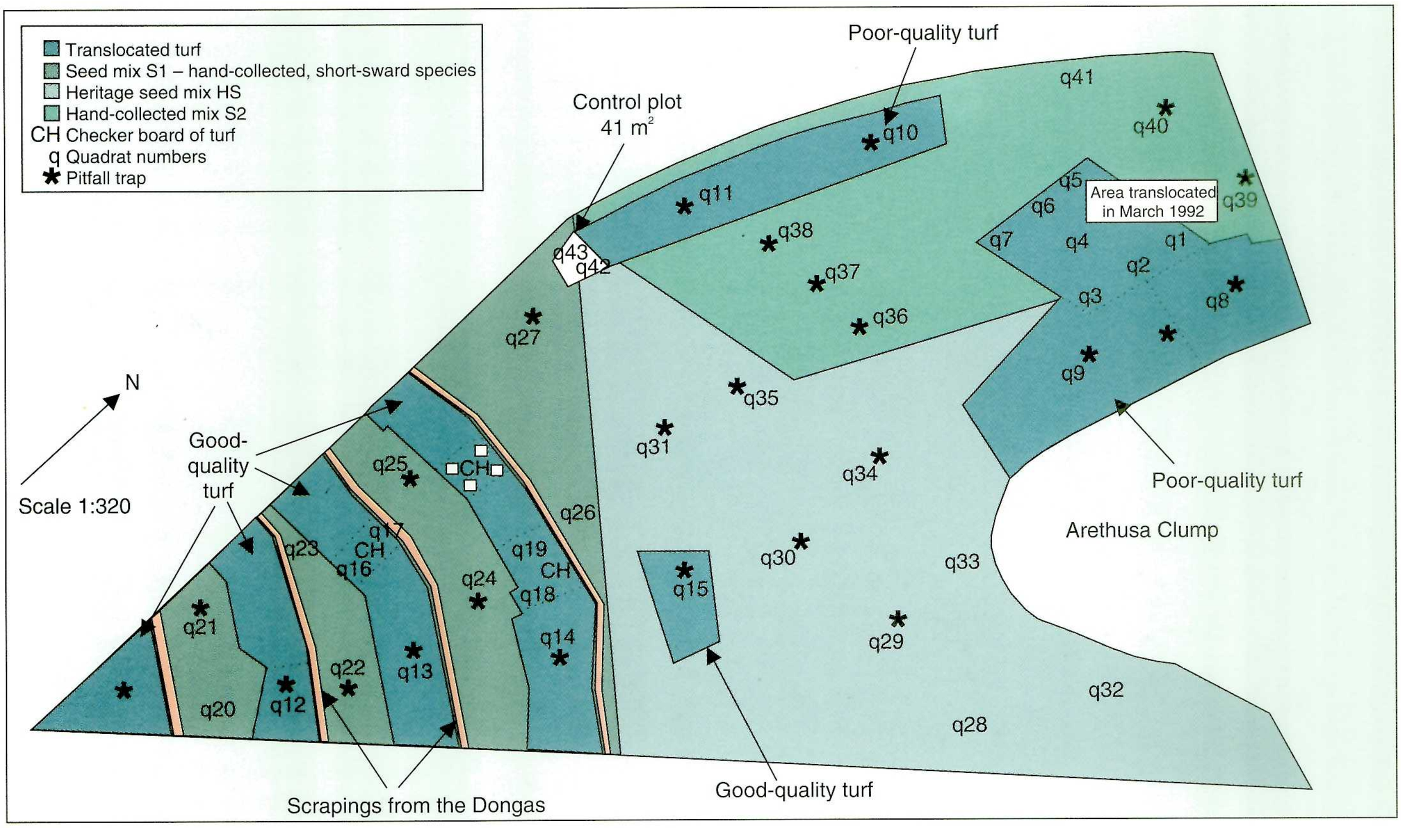

Figure 34. A map of Arethusa A showing the design of the restoration programme, including the positions of the relocated turves, the sown areas, and the position of sampling points (pitfalls and quadrats) for monitoring

Seeding

As far as possible, seed of local provenance was collected from appropriate, species-rich downland sites in the vicinity of Winchester during the summer prior to each phase of restoration. Great care was taken on all these sites to cause as little impact as possible on the resident flora and fauna. Collection in the first two years was mostly by mechanical suction equipment, with hand-collecting to supplement selected target species, especially those not commercially available. Any shortfall in quantities needed for each seeding was made up using commercial downland seed of known south of England origin.

Three different seed mixes (S1, S2, HS) were made up and sown in late March 1993 according to the designs in Figure 34. To enhance the diversity of the seeded area, 31 000 pot-grown plants of eight species of downland plant which do not establish reliably from seed were grown from local source material and planted after main seed germination. Eventually, some 104 300 plants will be grown from local source material and planted into the three restoration areas.

Monitoring

The progress of all the reconstructed downland areas is being monitored in order to assess the success of the work and to give feedback to 'fine-tune' the management. On the Arethusa downland areas, monitoring is taking place over a ten-year period in the summers of years 1–4, 6, 8 and 10, and comprises a comprehensive range of fixed botanical quadrats to assess the progress of the developing sward. Corresponding detailed monitoring of several invertebrate groups, such as butterflies, Coleoptera, Araneae, Hemiptera and Formicidae, is assessing the development of the downland fauna.

Plate 18. Macroturfing machinery in action

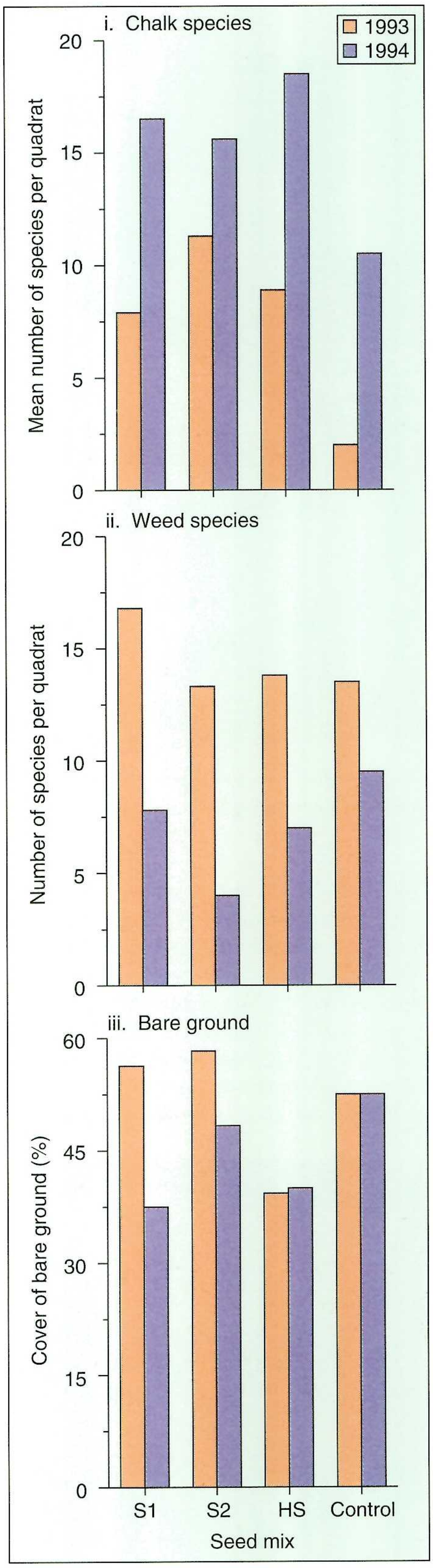

Figure 35. Vegetation development between 1993 and 1994 on the sown areas on Arethusa A compared to the unsown, control, plots. The changes in the numbers of chalk grassland flowering plant species and in the undesirable (weed) species are shown, along with changes in vegetation cover

Early results

Two years of monitoring have been completed at Arethusa A. The results so far are encouraging (Ward & Stevenson 1994): on the turves, there are large numbers of chalk grassland species of flowering plants, and these have increased from 56 to 58 over the two years. Other, undesirable (weed, species are present but these have decreased in number over the two years, such that the total plant species number has dropped from 112 to 98.

The progress of the sown areas towards typical downland vegetation has been very good (Figure 35), with increases in downland species, deceases in numbers of weeds, and a gradual increase in vegetation cover. Almost all the 58 species sown were recorded, if in low numbers. Only six sown species were not recorded, although some of these take many years to establish – for example, the pyramidal orchid (*Anacamptis pyramidalis*) may take up to five years to appear.

Invertebrate colonisation of the whole site appears to be progressing well (Snazell, Rispin & Thomas 1995). It is gratifying to see that the deep-burrowing spider *Atypus affinis* is still present in the translocated turf, as is the Notable A species *Xysticus acerbus*. In all groups, the high numbers of primary colonisers present in the first year have dropped as the sward has started to close and the numbers of ground-living species have increased. This development is best exemplified by the spiders. In 1993 the linyphiids, typical primary colonisers, represented 81.1% of the population. By 1994 this figure had dropped to 36.9%. Correspondingly, the *Pardosa* wolf spiders have risen from 2.8% to 34.9%. The Chalkhill blue butterfly (*Lysandra corridon*), central to concerns at the Public Inquiry, occurred at very high densities on Arethusa A in 1993. Although numbers were down in 1994, the colony this year was still four times as dense as that on St Catherine's Hill.

The future

In this project, techniques such as macroturfing, local seed collection and planting plug plants grown from local source material were used to overcome the potential problems involved in establishing species-rich grassland. Following the initial translocation or introduction procedures, establishing the appropriate management is essential to the development of the target community. The detailed programme of monitoring is also vitally important to determine the ultimate outcome of our programmes and to assess the techniques, in order to refine them for use in future projects.

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Technology transfer in tropical forest regeneration

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Much of the work of ITE's Tropical Forests Section is aimed at assisting developing countries to develop sustainable utilisation of their forests, through the regeneration of forests and replanting of domesticated trees. There are four main lines to this work:

- genetic improvement (collection, selection, propagation and planting);

Plate 19. Staff of Faculdade de Ciencias Agrarios do Para constructing a 'low-tech' propagator at Belem, Brazil

- the role of microsymbionts (especially mycorrhizal fungi) in tree establishment;
- the effects of nitrogen-fixing trees on soil amelioration;
- the silviculture of regenerated forests.

In parallel with conducting research, an important function is to improve the skills of local staff so that they are better equipped to manage their own natural resources. This training is accomplished in a variety of ways: from short in-country technical training courses run by ITE staff in collaboration with local organisations to full PhD programmes which are usually run in parallel with long-term field-based research projects.

We now have over 20 years of experience in training students of all ages and grades from tropical countries, and have focused this training particularly on the fields of vegetative propagation, mycorrhizal techniques and entomology. Staff are well equipped to provide such training because, having worked extensively in developing countries, they understand the need to work at the appropriate level of technology, and they have the necessary breadth of experience and research background on which to base decisions. All the students trained have returned to their home countries to continue their careers, which indicates that the training provided is appropriate for their country's needs.

Vegetative propagation

Wild tree species can be rapidly brought into cultivation through cloning, which has many benefits for tree production in tropical countries (Leakey, Newton & Dick 1994): it enables the direct capture and utilisation of superior genotypes, which can be rapidly bulked up, and it circumvents the problems of erratic seed supply and poor storage that are common to many tropical trees. In addition to its use as a means of producing trees as planting stock, vegetative propagation is also a valuable tool for *ex situ* conservation of endangered species.

We have adopted a 'low-tech' approach to cloning, through the use of simple methods of vegetative propagation which have been applied to more than 200 tropical timber and non-timber tree species from different environments and families. Leafy stem cuttings are obtained from stockplants (often developed from coppice shoots of mature trees), which are managed to produce shoots in the appropriate physiological condition for propagation. Their leaves may be trimmed to reduce transpiration, and rooting hormone may be applied to the base of the stem before the cuttings are placed in a propagator. Much of the research of ITE and its collaborators has focused on the efficient production of rooted cuttings of high quality. This depends upon a number of factors, including stockplant management (pruning, shading, nutrient regime), cutting dimensions and hormone treatment, and propagator design and conditions (temperature, humidity and rooting medium). A 'low-tech'

Plate 20. Assessing the effects of inoculation with endomycorrhizal fungi on the growth of *Terminalia brownii* at Marimanti, Kenya

Plate 21. CATIE staff discussing shoot borer damage assessment protocols in the ITE/CATIE *Cedrela odorata* provenance/family trial near CATIE, Costa Rica (photo: A D Watt)

propagator which requires neither electricity nor a piped water supply has been designed and is now in use by forestry departments and rural communities in a number of countries, including Kenya, Malaysia, Brazil, Costa Rica and Cameroon (Plate 19).

In addition to the forms of training outlined above, nursery manuals (Longman 1993, 1995) and a training video are also available. The earlier manual and the training video have been translated into Bahasa Malay, and further translations into other languages are under discussion.

Mycorrhizal studies

Mycorrhizas are symbiotic associations between plant roots and fungi, which are extremely widespread. Virtually every tree growing in native forest (temperate or tropical) can be assumed to be mycorrhizal. Mycorrhizas have a number of functions, including the transfer of mineral nutrients from the soil to the plant and, consequently, have a fundamental role in determining plant productivity and the functioning of ecosystems (Mason & Wilson 1994).

In recent years, we have run a number of short training courses in specific aspects of mycorrhizal work, on either a one-to-one basis or with groups, both in the UK and overseas. We have also provided training through long-term projects with colleagues in national institutions in Indonesia, Brazil and Cameroon to evaluate the effects of site disturbance, such as occurs during logging, upon indigenous mycorrhizal inocula, both arbuscular and ectomycorrhizal, and the impacts upon subsequent forest regeneration and the establishment of plantations. Different aspects have been considered in Chile and Kenya, where we have been concerned with the introduction of appropriate inoculum for exotic trees and the application of inoculum for indigenous trees to aid their establishment on degraded sites (Plate 20).

Entomology

Training in entomology has been carried out in two separate areas:

- identification, damage assessment and population dynamics of insect pests, and
- assessment of insect diversity in forests and plantations.

These two areas require distinct approaches: the first involves specific pest species, their impact on trees and approaches to pest management; the second involves a variety of sampling methods and the identification of a wide range of insects and other arthropods.

Among the projects on pest species which have involved a substantial training element are those in Costa Rica on the macadamia nut borer and the mahogany shoot borer. A Costa Rican student, working at Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), with supervision from ITE and Edinburgh University, has just completed a PhD on the *Ecdytolopha torticornis*, a tortricid moth which is a relatively new pest of macadamia, an increasingly important crop in Costa Rica, Guatemala, Colombia, Brazil, Venezuela and Ecuador. Her work has, for the first time, quantified the damage done by the macadamia nut borer, and explored methods to minimise its impact. In contrast, mahogany shoot borers have long been known to be serious pests of *Swietenia, Cedrela, Khaya* and other valuable timber trees Although a great deal of research has been done on shoot borers, the ITE/CATIE link project is the first attempt to seek and develop plant resistance as a pest management strategy (Plate 21) This project, comprising tree improvement work on several tree species, has involved MSc students at CATIE and has developed links with organisations involved in reforestation work in Costa Rica and other Latin American countries

Training in insect diversity has been an important part of the research being carried out by ITE and the UK Natural History Museum in Cameroon One of the aims of this research has been to quantify the impact of forest clearance on the abundance and diversity of insects and other arthropods, and to assess the value of different types of forest plantation in maintaining biodiversity Sampling methods which have been developed for use in forests have been demonstrated in Cameroon, and training in insect identification has been provided in Cameroon and in the UK

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