STAG BEETLES

Findings of the 1998 National Survey

PEOPLE'S TRUST
FOR ENDANGERED SPECIES

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Findings of the 1998 National Stag Beetle Survey

People's Trust for Endangered Species
15 Cloisters House
8 Battersea Park Road
London
SW8 4BG

Registered Charity Number 274206

Claire Percy
Georgina Bassford
Valerie Keeble
(1999)

Edited By
Clare Robb
(Dec 2000)

Survey Co-ordinator 1998: Doug Napier

ENGLISH NATURE
Contact Point

PEOPLE'S TRUST FOR ENDANGERED SPECIES
Lead Partner

Champion

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The production of this report is the result of a cooperative effort by Claire Percy, Georgina Bassford, Clare Robb and Valerie Keeble.

EXECUTIVE SUMMARY

The survey, whose results are presented here, was carried out during the flight season of 1998. Wide publicity and a high profile public launch spearheaded by Mr Michael Meacher, the Minister for the Environment, ensured that a high level of interest among the general public was generated nationwide. As a result, 100,000 leaflets about the species and its conservation needs were distributed and approximately 10,000 records of stag beetle sightings were received by PTES.

Analysis of the data shows that the current distribution of the stag beetle has changed little when compared to its historic range, although anecdotal evidence suggests that its abundance may be declining in many areas. The stag beetle's stronghold remains the south east with a few populations persisting in South Wales, the South West of England and areas in Worcestershire. No records were received from north Yorkshire or Clwydd where, it is thought, stag beetles had persisted until recently.

One of the most important facts highlighted by this survey is that over 70% of records came from urban and suburban areas which suggests that gardens are an extremely important habitat for the species and are likely to assume an ever-greater importance as further development and consequent habitat loss takes place. This result also highlights the fact that people spend a lot of time in their gardens. As with all public surveys the results do not necessarily give a true representation of stag beetle distribution, as surveying effort was not evenly distributed in all areas.

Very few records were received from rural areas. The reasons for this are unclear at present. During 1999, some targeted surveying was attempted but very few records were again received.

Data has already been made available to all those local Wildlife Trusts requesting it to assist in the preparation of local BAPs and conservation work.

The stag beetle was originally chosen as a BAP species mainly because it is becoming increasingly rare on the continent, due in part, it is feared, to trade in the species. We are pleased to report that this does not appear to be a problem in the UK at present.

It was also feared that pubic perception of the species might not be favourable. Early work by the Focus Group into this matter showed this not to be the case. As a result of our contact with the general public during the course of the survey, we can confirm this. With only few exceptions, the surveyors were keen to participate and learn about the species.

We looked at our data against a number of factors including temperature, rainfall and soil type. The current distribution of stag beetles correlates well with areas of highest mean temperature. The chalky North and South Downs seem to form barriers to dispersal, as do the Chilterns. In some areas the distribution seems to follow river courses, confirming earlier suggestions that this may be the case.

The 1998 survey provides valuable base-line data against which to measure the success of future conservation initiatives.

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[1] More recent data was not available

PREFACE

This survey has been of immense value in furthering our understanding of the ecology of this species. It has highlighted the areas in which the insect most frequently occurs and has suggested that there are a number of population 'hotspots' for it. Our task now is to understand the reasons for these hotspots and to document the biology and ecology of the beetle within them.

Some most interesting facts have emerged and these include the tendency for the beetle to be associated with urban areas. Indeed, the majority of records seem to come from this type of habitat. In some ways this is surprising, given the requirement of the larvae for buried dead wood - one would have thought that this type of habitat would most commonly be found in large, densely wooded areas. In another way, it is most encouraging, as it gives us a real chance to influence the provision of habitat and to enhance the long-term conservation needs of the beetle.

The survey has identified the main mortality factors of the species and shows that many die as road casualties. This is clearly another feature of its urban lifestyle, but it also sheds some light on its dispersal ability, another feature we must understand if we are to enhance its population size. The insect also appears to be associated with soil overlying particular geological strata, for example, it does not appear to be associated with chalk. It is likely that this reflects the habitat requirements of the subterranean larvae.

In summary, this survey has been an unqualified success. It has given us much useful information on the current status of the insect and has set the agenda for research in the next few years.

Dr Alan Gange
School of Biological Sciences,
Royal Holloway University of London,
October 2000

The stag beetle, *Lucanus cervus* (L.) 1767, is Britain's largest and most striking terrestrial beetle. It belongs to the order Coleoptera and the family Lucanidae. There are between 800 and 1,250 species in the Lucanidae family worldwide but only three occur in Britain, one of which is the stag beetle. The other two species are *Dorcus parallelipidedus* (L.) (the Lesser stag beetle) and *Sinodendron cylindricum* (L.).

Appearance

Males can be more than 70 mm in length while females are generally smaller, usually 40-50 mm (Figure 1). The males have large, stag-like 'antlers' that give the species its common name, which are, in fact, greatly enlarged lower mandibles. In both sexes, the wing cases are a characteristic shiny, chestnut brown colour (as are the male's antlers) and the head and thorax are shiny black.

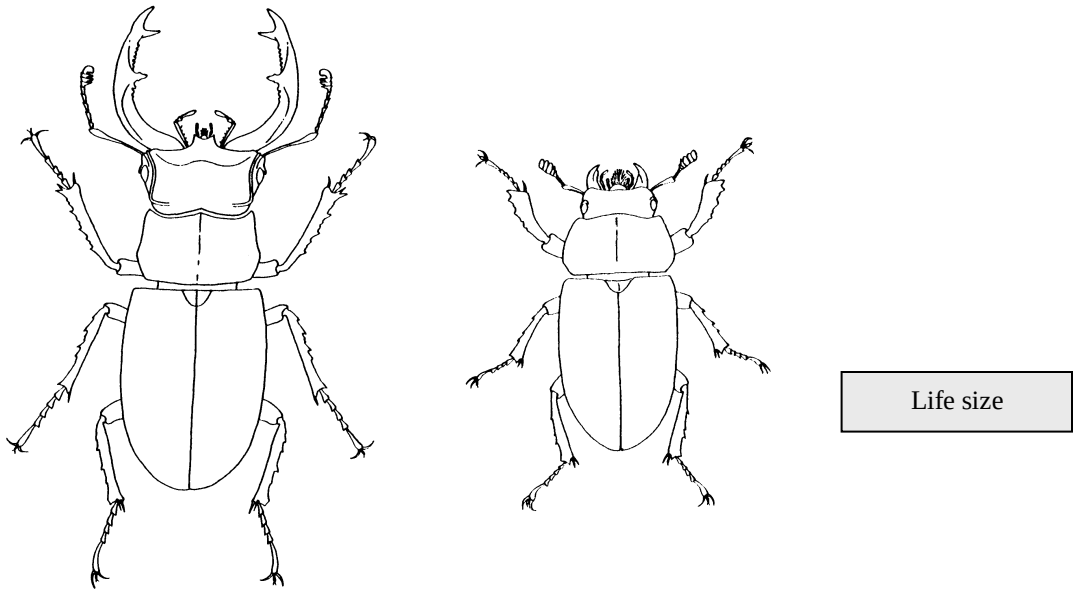


Figure 1 *Male (left) and Female (right) stag beetles [Source:Colin Hawes, Suffolk Naturalists' Society]*

Life cycle

The stag beetle has a long life cycle of up to eight years during which it goes through four life stages; the egg, the larva, the pupa and the imago (the adult stag beetle). In late summer, females lay small, round eggs near or within dead wood 30-50 cm below ground. These quickly develop into horseshoe-shaped larvae (Figure 2). The larvae, which can be 10-11 cm in length, are cream in colour with brown heads and they live underground, feeding on decaying dead wood for at least three years. It is thought that they can eat as much as 250 cm^3 of dead wood every month[1]. A stable and secure supply of dead

[1] (they may also eat particles of humus and plant root hairs)

wood is, therefore, essential during their long development. The wood must be at least partially decayed especially when the larvae are small as, at that stage of development, they can only bite through soft wood.

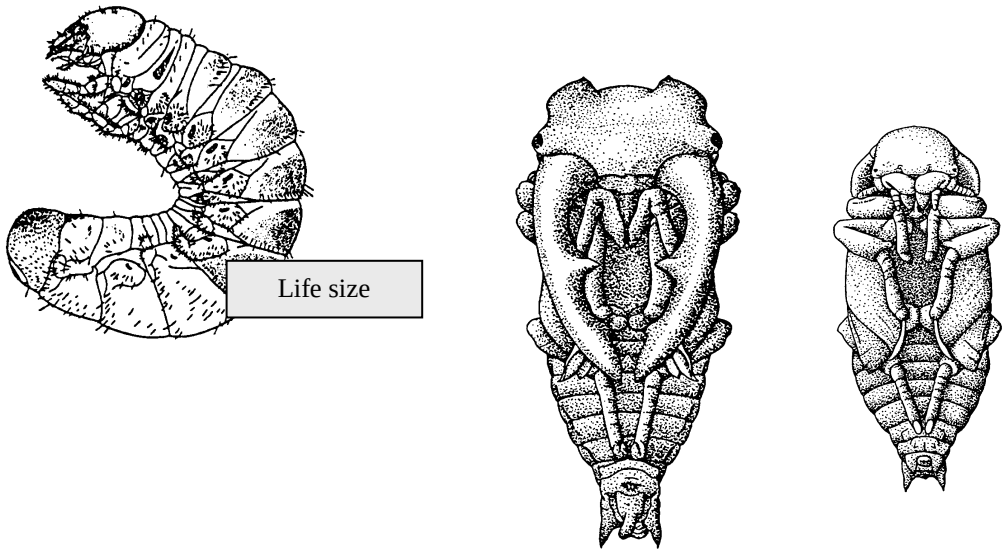


Figure 2 *Stag beetle larva* *pupae - male (left) and female (right)*
[Source: Klausnitzer, 1995]

After 3-5 years, in the autumn, each larva builds a waterproof but permeable, ovoid-shaped cocoon in the soil, 15-20 cm below ground. This cocoon takes 2-3 weeks to build and can be as large as an orange. The larvae then pupate (Figure 3) and finally metamorphose into adult beetles. Each beetle remains inside its cocoon throughout autumn and winter until late spring or early summer the following year when it emerges and moves vertically upwards to the soil surface. The males then search for a suitable mate, probably using their antlers in courtship battles with other males. During their life span of approximately 40 days stag beetles feed only, if at all, on sap-runs[2] and mature fruits.

They are generally found at ground level during the day and towards dusk, on warm summer evenings, the males climb to a vantage point (often a tree or wall of a house) to launch themselves into flight. They are inelegant fliers and they take off almost vertically. Females tend to stay close to the site from which they emerge, and are not seen flying as frequently as males. When they do it is to look for a new site to lay their eggs.

Although some beetles have been observed overwintering it is thought that at the end of the season the beetles die. The eggs, which the females lay in wood underground, will become the next generation of beetles.

Status and protection under current legislation

The stag beetle is classified as 'Nationally Scarce Category B'. In the UK that means that it is likely to occur in 100 or fewer 10 km squares of the national grid. In April 1998, it received protection from sale under Schedule 5, Section 9(5) of the Wildlife and Countryside Act 1981 (as amended) stating that it is illegal to trade in the species. In 1995, the UK Biodiversity Group wrote a Species Action Plan (SAP) for the stag beetle (Appendix 1). The SAP contains objectives, targets and proposed actions for

[2] A sap-run is a flow of tree sap running down the trunk of trees from where the bark has been pierced

stag beetle conservation. In 1998, the People's Trust for Endangered Species became the Lead Partner in implementing the SAP with English Nature as the Contact Point.

Collaboration with other organisations

The People's Trust is working on the stag beetle with a number of co-partners including English Nature (EN), the Joint Nature Conservation Committee (JNCC), the Forestry Commission, Suffolk Naturalists' Society, Colchester Museums, the Natural History Museum, London Wildlife Trust, the Corporation of London, Berks, Bucks and Oxon Wildlife Trust, Hampshire Wildlife Trust, the London Borough of Bromley, universities and other wildlife trusts.

CHAPTER 2 METHOD

The 1998 National Stag Beetle Survey

A high profile, UK-wide National Stag Beetle Survey was carried out in 1998 to enable the collection of as much data as possible from across the whole of the UK. Members of the public were encouraged to report all sightings of stag beetles, including information such as, colour, sex, time of sighting, precise place and date of sighting and anything else of potential interest. People were encouraged to include a photograph (or the specimen if the beetle was found dead).

The aims of the survey were:

- to establish the current UK distribution of stag beetles and identify any changes from its historical range,
- to increase public awareness of the stag beetle and its conservation needs,
- to identify factors affecting its distribution, and
- to make suitable recommendations for stag beetle conservation and ensure their implementation.

The National Stag Beetle Survey was launched at the beginning of the flight season in May 1998 in Richmond Park by Mr Michael Meacher, the Minister for the Environment. Over 100,000 public information leaflets were distributed to schools, Wildlife Trusts, naturalist societies, museums, ecology centres and members of the public upon request. The leaflet gave information on the known distribution of the beetle, how to recognise it and how to help conserve it. It also contained a survey form to complete and return to PTES or the appropriate local Wildlife Trust. A leaflet containing advice on how to manage land appropriately for stag beetles was written and was sent to specialists and land managers nationwide.

Throughout the year, articles and reports appeared in newspapers and magazines, including BBC Wildlife, the National Trust magazine, The Times, The Telegraph and the RSPB and BTO members' magazines. The survey also received extensive coverage on radio and television including the Today programme on Radio 4 and Blue Peter as well as numerous local radio and television programmes. Mileta Tog 24 became the Champion of the stag beetle as part of the government's initiative to involve companies and industries in environmental and conservation issues.

How the data was analysed

Data was stored on the widely used environmental recording database package, Recorder (version 3.12b) which also provided descriptive statistics about the data.

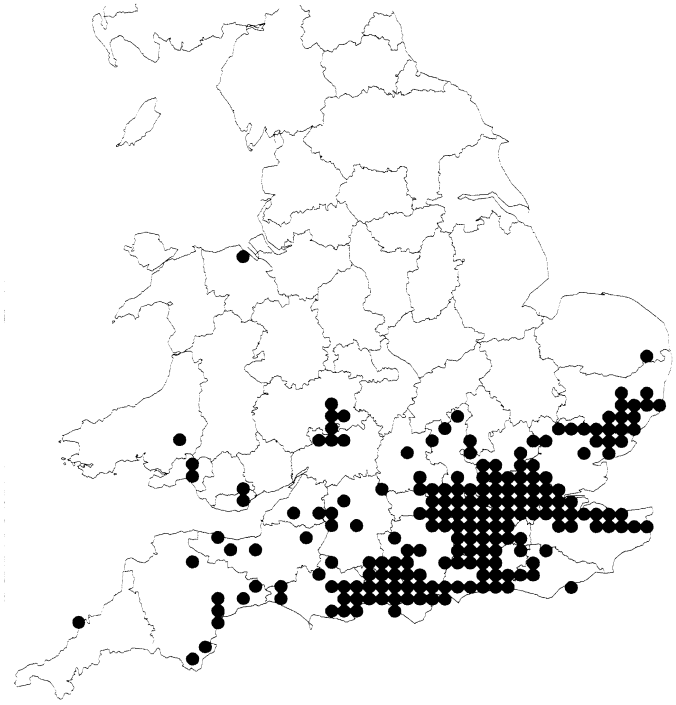
The data was imported into JNCC's Countryside Information System (CIS) version 5.4. This package enabled us to map the presence or absence of stag beetles in every 1 km grid square across the UK and allowed more detailed analysis of the data. Data was also analysed using Microsoft Excel. Multiple regression analysis and chi-squared tests were used where appropriate to show the relationship between the beetle's density and different soil types and were carried out by Bob Smith at the Durrell Institute for Conservation and Ecology (DICE) at the University of Kent.

Distribution

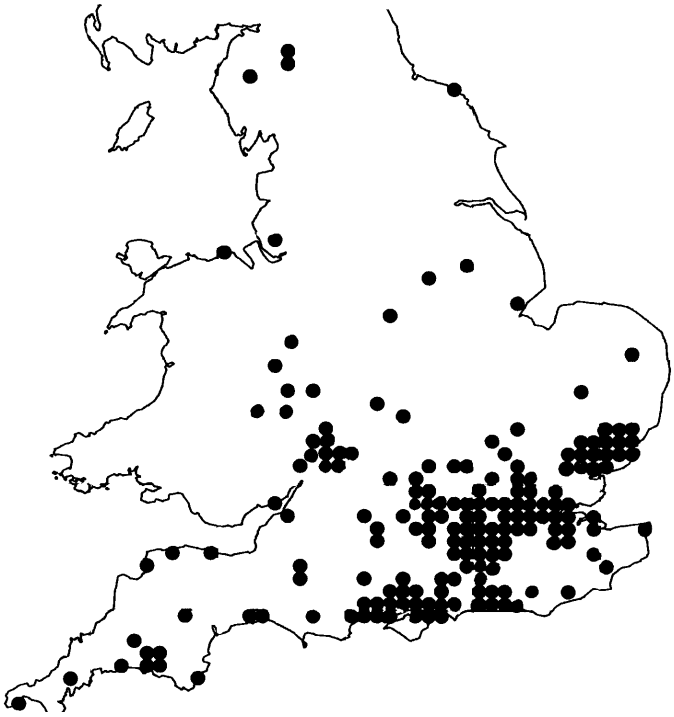
The current stag beetle distribution obtained from the 1998 National Stag Beetle Survey was very similar to the historical distribution. This can be seen by comparing Map 1 with Map 2.

Historically, the stag beetle has been found in localised populations in south and southeast England and Wales. With the exception of a few more northerly populations existing in isolation (notably Gloucestershire and south Wales) the majority of stag beetles were to be found in the area enclosed by an imaginary line from the Wash down to the Severn Estuary. The main areas for stag beetles were Essex, Suffolk, London and the Thames Valley and parts of the south coast. There were small clusters of records from Devon and Cornwall.

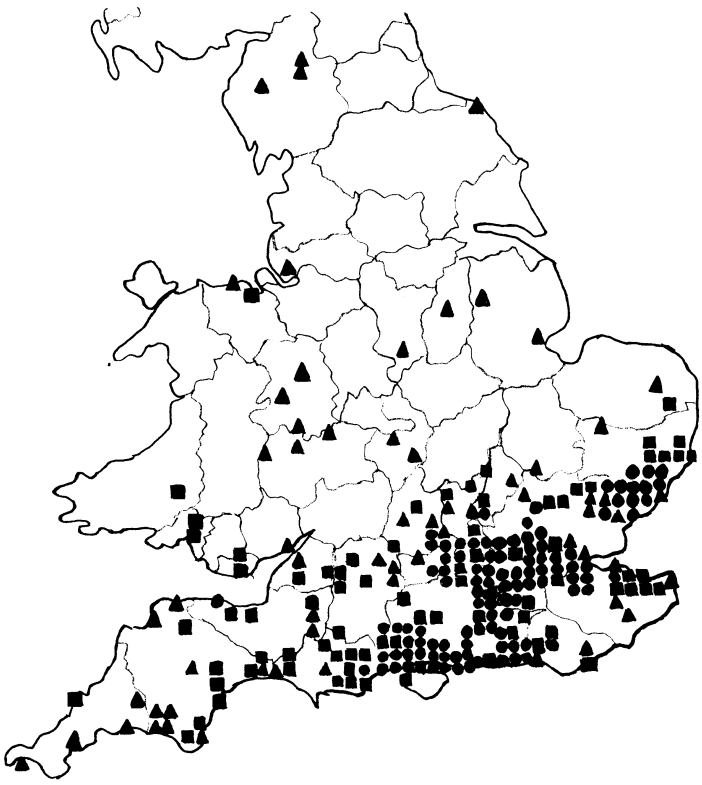
Present distribution varies little from what was previously known. The main strongholds for the stag beetle are still London and the Thames valley, the Essex/Suffolk border, north Kent and areas along the south coast. The small cluster of records around the Gloucester/Worcestershire border persist as do a number of records in Devon and Cornwall. Stag beetles were found in the greatest abundance in the counties of Berkshire, Bucks, Dorset, Essex, Hampshire, Kent, Greater London, Oxfordshire, South and West Glamorgan, Suffolk and Surrey, and in the following towns and cities; Colchester, Ipswich, Woodbridge, parts of south London, Guildford, Kingston-upon Thames, Worthing and Southampton. Some previously known peripheral populations failed to be recorded in the 1998 survey, notably those in Clwyd and North Yorkshire.

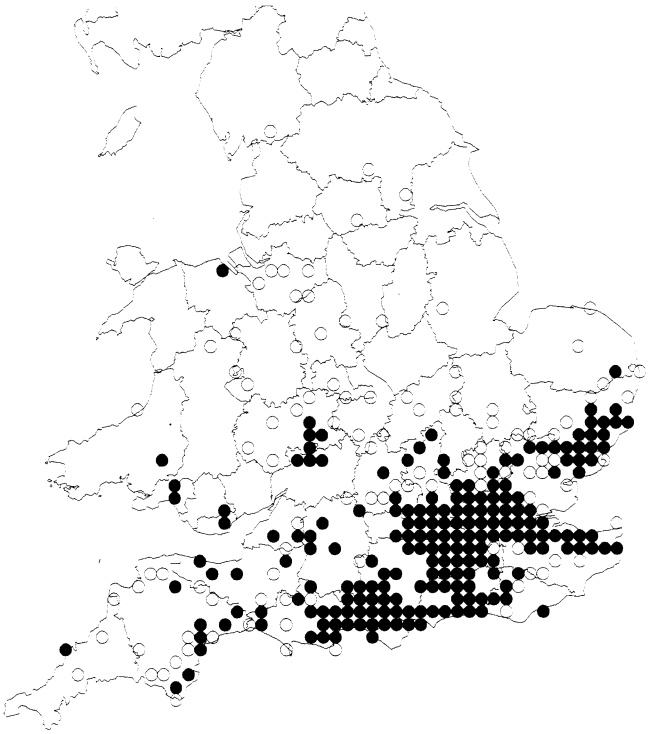


Map 1 *Stag beetle distribution from 1998 Survey. Symbol: Stag beetles present in 10 km square*



Map 2 *UK stag beetle distribution prior to the 1998 National Stag Beetle Survey [Sources: JNCC's Invertebrate Site Register, Clark (1966) and BRC.] Symbol: Stag beetles present in 10 km square*





Map 3 is an amalgamation of maps 1 and 2.
Map 4 shows category 1 and category 2 records (see box below for explanation).

Key
Circles = Pre 1998 and 1998 records
Triangles = Pre 1998 records only
Squares = 1998 records only
Category 1 data only.
Each symbol represents 10km^2

Map 3 *All stag beetle records*

Key
Filled circle = Category 1 records
Empty circle = category 2 records
All circles represent 10km^2

Map 4 *Category 1 and Category 2 records for 1998 (9822 records in total: 9173 category 1 records and 649 category 2 records)*

Category 1 and Category 2 records – an explanation

Each record received in the 1998 survey was assigned to one of two categories:

Category 1 Reliable Stag beetle records based on details provided including:

e.g. Size given was appropriate (stag beetles are usually more than 2.5 cm in length)
Recorders mentioned ‘antlers’ or ‘huge jaws’
Shiny chestnut coloured wing covers
Creamy, U-shaped larvae, 9-11 cm long
The inclusion of a photo or the beetle if found dead also provided clear evidence for a category 1 sighting.

Category 2: Category 2 was assigned where there was reason to question the sighting due to insufficient information.

There were records of sightings from some areas and yet no sightings at all in areas very close by, for example, there were many records from Worthing and yet none from neighbouring Brighton.

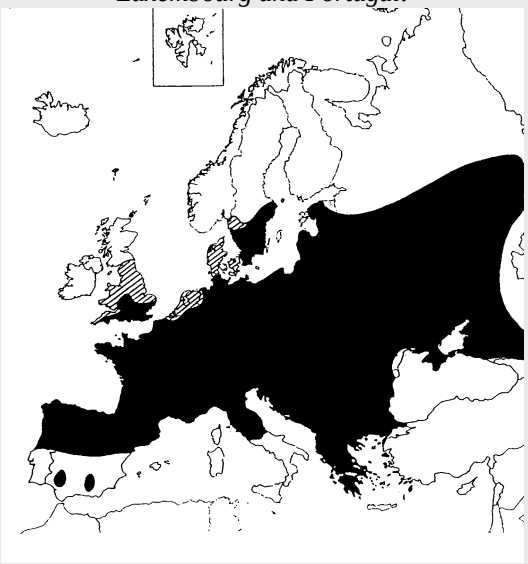
Traditionally, stag beetles have been associated with forests and woods, such as Epping Forest. However, it seems that nowadays one is just as likely to see the beetles thriving in cities and city suburbs. In fact, many more beetles were reported from urban areas than rural ones. This could be because fewer people were looking for them in the countryside, rather than because stag beetles are fewer there (for this reason abundance figures were not used in any statistical analysis). Efforts will continue to collect more records from rural areas.

Although the current stag beetle distribution has not altered dramatically from the historical distribution provided by JNCC, the total numbers of stag beetles may be declining, even in stronghold areas. Many people who submitted records noted that they had not seen as many stag beetles in recent years as 5 - 10 years ago.

The beetles are still present in northern parts of the Isle of Wight but there has been no evidence of a breeding colony on the island. The records are clustered around Cowes and Yarmouth suggesting that the beetles may have reached the island via the ferry from Lymington on the mainland, where there have been many reported sightings. Alternatively, adults could have been blown across the Solent by the wind.

Distribution in Europe

The stag beetle occurs throughout a large part of Europe, in the Balkan region and the Near East. It has been found in Sweden, the Netherlands, France, Portugal, Italy, Belgium, Austria, Czech Republic, Turkey, Syria, the United Kingdom, Spain, Germany, Greece, Luxembourg and Poland. It is not present in many parts of northern Europe and seems to be declining in the northern limits of the beetle's range (Map 1). It is extinct in Denmark and in decline in France, Germany, Sweden and the Netherlands. Its status is unknown in Belgium, Greece, Italy, Luxembourg and Portugal.



Map 5 *Known range of stag beetles in Europe in the past (hatched) and present (black). [Source: van Helsdingen,*Willemse & Speight *(1995) cited in Tullett (1998)]*

The total number of good quality (category 1) records received was 9173. These records provided 9381 individual stag beetle sightings over 26 counties. This can be seen in table 1.

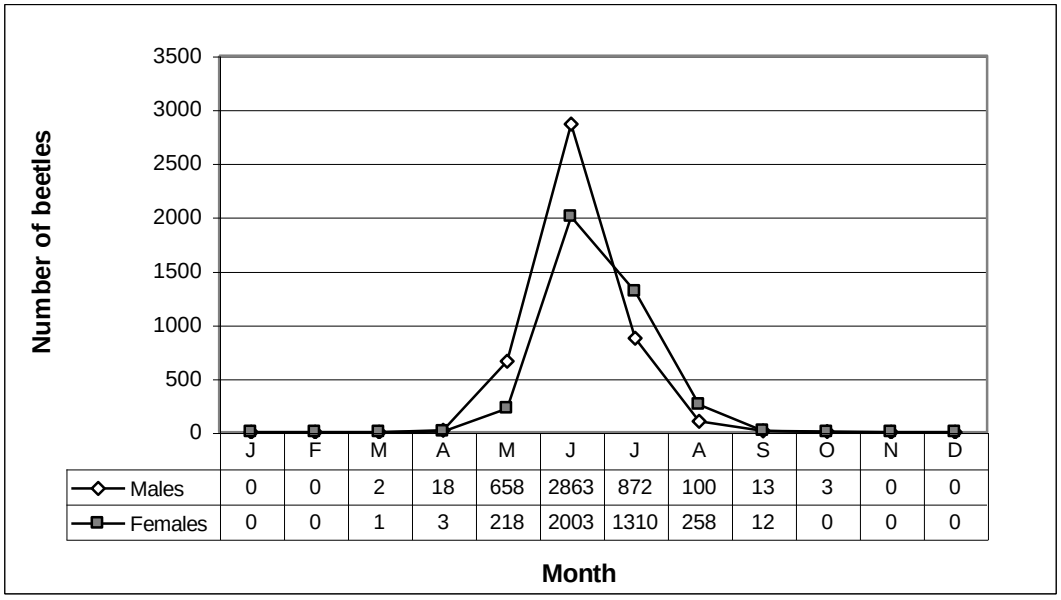
County	Number of beetles seen in each county
Avon	4
Bedfordshire	1
Berkshire	662
Buckinghamshire	193
Clwyd	1
Cornwall	1
Devon	12
Dorset	636
Dyfed	1
East Sussex	8
Essex	538
Gloucestershire	3
Hampshire	950
Hereford & Worcestershire	17
Hertfordshire	62
Kent	464
London (Greater)	2936
Norfolk	1
Oxfordshire	176
Somerset	4
South Glamorgan	2
Suffolk	856
Surrey	1295
West Glamorgan	2
West Sussex	547
Wiltshire	9
TOTAL	**9381 records**

Table 1 *Number of stag beetle records from each county*

Variation in numbers throughout the flight season

Stag beetle sightings were reported between May and October and peaked in June (see Graph 1). As has been reported from other studies, the males were seen earlier in the season than females, and

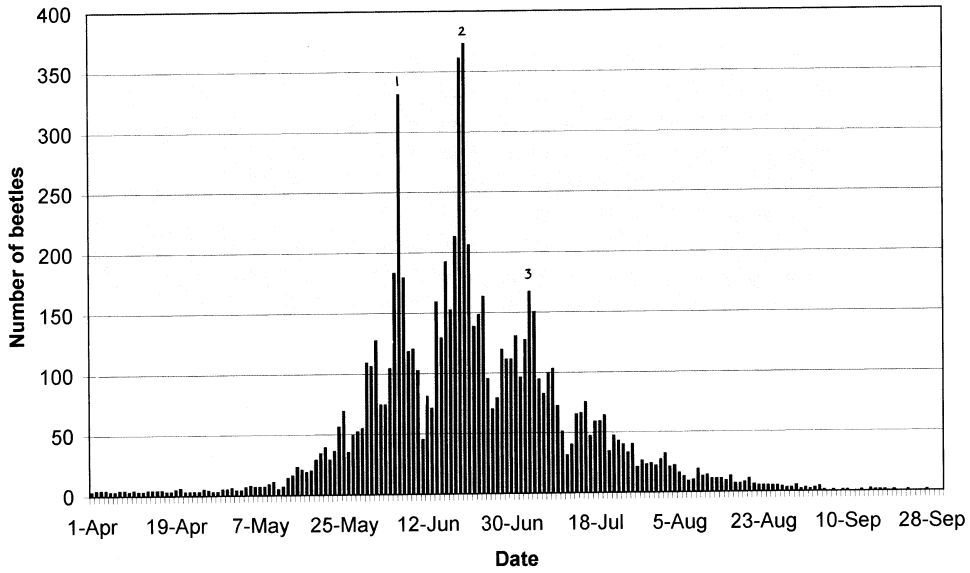
females seemed to be seen more frequently than males later in the season. Male stag beetles have also been reported to emerge before females. This could be because the pupal cocoons of males lie closer to the surface of the soil and so respond more readily to changes in air temperature (Tullet, 1998, cited in Tochtermann, 1992), but our study did not attempt to confirm this.



	J	F	M	A	M	J	J	A	S	O	N	D
Males	0	0	2	18	658	2863	872	100	13	3	0	0
Females	0	0	1	3	218	2003	1310	258	12	0	0	0

Graph 1 *Number of male and female stag beetles reported per month*

Graph 2 shows the number of adult stag beetles reported per day during the 1998 survey.



Graph 2 *Number of stag beetles reported per day*

Most sightings were reported in June and early July with a peak on 20th June (373 records) when the majority of beetles had emerged and many (especially males) were flying in search of a mate. The beetles take advantage of the warm, dry June and July evenings. The sightings tailed off steadily through July and August.

Type of Record

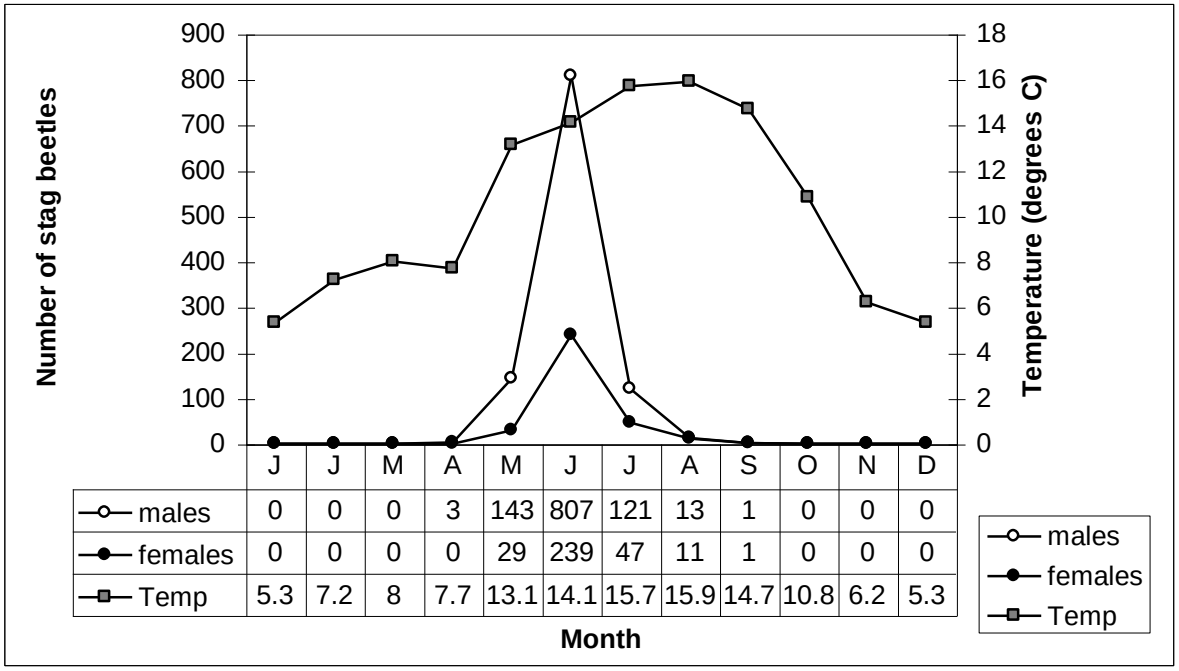
Each record was categorized depending on what it was seen to be doing. This is shown in table 2.

Description of sighting	Number of records with this description
Dead on road	208
Killed by predator	294
Dead (reason unknown)	37
Squashed by human	171
Drowned/drowning/rescued	153
On its back (alive or dead)	263
Attracted to light	107
Fighting	36
Mating	97
Flying	1649
Feeding	5
Burrowing	40
Burrow occupied (beetle underground)	25
Field record (i.e. seen, crawling, sitting)	6290

Table 2 *Type of stag beetle record (showing what the beetles were doing when found)*

Flight

1649 (18%) of the records were of stag beetles flying. They prefer to fly on warm, calm evenings, usually when the daytime temperature is around 23 to 25°C. Most flying beetles seen in 1998 were seen in June, which had an average temperature of around 16°C (this is an average of temperatures over a 24-hour period). This can be seen in graph 3.



Graph 3 *Average monthly air temperature in 1998 and the number of male and female stag beetles seen in flight per month*

Males are seen in flight far more frequently than females, perhaps because they need to fly in order to disperse to other breeding sites[1]. Females, on the other hand, may need only remain within a short distance from their emergence site, providing the site still has sufficient supplies of dead wood for larvae to develop in future.

Species of trees utilised

Stag beetles were found associated with up to 103 different species of tree and shrub. This list is shown in Appendix 1.

On the whole, it seemed that the exact species of tree was not critical to the stag beetle. However, some tree species were mentioned more than others in the records (although this could be more a factor of the types of trees found in gardens rather than an actual preference on the part of the beetle). The following section looks in more depth at the tree species used in the various stages of the stag beetle's life history:

a) Larval feeding sites

The results showed that larval development is not limited to just a few species of tree. Previously, stag beetles were thought to be strongly linked to oak, and indeed, 131 records in our survey mentioned oak as a suspected or actual foodplant. However, the records obtained by PTES showed that stag beetles can exploit almost any broadleaf species of tree as long as it is in a sufficient state of decay. 43 different tree species were reported as larval food plants; those most frequently mentioned in the

[1] an evolutionary adaptation to maintain genetic variation

records were apple, ash, cherry and oak. Other species mentioned included pine, pear, maple, elm, horse-chestnut and silver birch. Appendix 2 shows the full species lists.

b) Female oviposition sites (sites where females lay eggs)

A total of 34 different tree species were reported as suspected or confirmed oviposition sites; those most frequently mentioned in the records were: oak, cherry, elm, pear, beech and ash. The full list of species is shown in Appendix 3.

c) Tree perching sites (trees on which stag beetles were found)

148 of the total records mentioned that beetles were found sitting or 'perching' on trees. In total, 72 different tree species were recorded. The full list of species is shown in Appendix 4.

d) Adult feeding

Only five records mentioned adults feeding. These reports were a stag beetle 'feasting on the fungus growing at the bottom of the garden', 'feeding on pear core', 'eating a rotten banana' and 'eating a laurel leaf'. The last record described apple as being a food source for a stag beetle. Although it is thought that the beetles may feed on sap runs, there were no such records in our survey.

Function of wood upon which the beetles were found

The survey showed that, on the whole, it didn't matter what form the deadwood took or what purpose it served provided it was in contact with the ground (Table 3). Tree stumps were noted as being the type of dead wood used most frequently. Log piles, fence posts, roots and wood chippings were also frequently mentioned. There was a bias towards broadleaved wood with conifer species rarely mentioned. A number of records of stag beetles (and larvae) came from compost heaps.

Type of dead wood the beetle was found on	Number of records that mentioned stag beetles associated with this type of dead wood
Fence posts	31
Tree stumps	329
Roots	25
Log piles	146
Wood chippings	19

Table 3 *Type of dead wood most commonly associated with stag beetle records*

Mating

Mating stag beetle pairs were noted in 97 records. Some males were attracted to crushed females on roads or pavements, as well as to live females, possibly attracted by a female pheromone.

Predators and other hazards

The most significant stag beetle predators were animals found in urban areas. The large, slow-moving beetles are easy prey for animals such as magpies, sparrows, cats, foxes, squirrels, bats and frogs. People accounted for many stag beetle deaths. There were many reports of beetles squashed on pavements and roads. Appendix 5 shows a full list of the animals associated with the stag beetle at the time of sighting.

294 beetles were found killed by successful predators, most commonly, magpies, cats, foxes, humans and blackbirds. The most frequently mentioned unsuccessful predators were cat and sparrow.

There were reports of stag beetle 'massacres' - numerous stag beetle carcasses found, often on lawns, after attacks by birds, especially magpies. Once the magpies found the emergence site it seemed that they returned time and again to the same spot to kill and eat the “soft fleshly” parts of adult beetles.

153 records of drowning or drowned stag beetles were received.

263 records were of stag beetles found on their backs, either alive or dead (they have difficulty righting themselves once upside down).

There were 36 reports of male stag beetles fighting, often with a female nearby. It is not known whether these fights were fatal to either party.

Singleton records and records on the periphery of the range

Records of a single stag beetle in a 1km square were called ‘singleton’ records. 82% of all singleton records were in suburban areas. [These beetles probably do not represent a significant population but instead are more likely to have been beetles that had dispersed from their emergence site in search of a mate or possibly food.] The singleton records in sparsely (human) populated areas may be part of significant populations. Further research is needed to discover whether this is so.

Records on the periphery of the stag beetle's range, or ‘outlying records’, were those records that were received from outside the stag beetle’s current strongholds. These sightings could represent significant or struggling populations.

If both males *and* females are present in an outlying area then it is more likely to be a breeding site. If beetles of only one sex were found, then the possibility that these were lone individuals seeking mates or oviposition sites, or that they were misidentifications, is greatly increased.

Table 4 lists the main records from peripheral sites. The records include category 2 beetles (i.e. records of dubious accuracy).

By Town & County	*Number of male sightings in 1998*	*Number of female sightings in 1998*
East Sussex		
Cooksbridge	1	0
Uckfield	1	0
Ringmer	4	1
Barcombe	1	0
Crowborough	1	0
Bexhill-on-sea	0	1
Gloucestershire		
Cheltenham	1	1
Newent	0	1
Apperley	2	1
Avon		
Bristol	1	0
Batheaston	0	1
Bath	1	0
Isle of Wight		
Cowes	4	1
Yarmouth	2	1
Dyfed		
Llandeilo	1	0
West Glamorgan		
Neath	1	0
Swansea	1	0
South Glamorgan		
Cardiff	1	1
Clywd		
Lixwm	0	1
Hereford & Worcs.		
Upton-on-Severn	3	1
Worcester	1	0

Table 4 *Number of male and female records* on the periphery of the stag beetle's range*

**Some records are 'category 2'*

The towns of Ringmer, Upton-on-Severn[2], Apperley, Cheltenham, Cardiff, Cowes and Yarmouth all had both male and female sightings in 1998. And, with the exception of Ringmer, all are on the edge of the known range for the species. Further study may show whether in fact there are viable populations in these areas.

[2] The population in Upton-on-Severn has been confirmed and work is already underway to create further suitable habitat to sustain it.

[3] Targeted surveying is planned for the flight season of 2001.

CHAPTER 4 POSSIBLE FACTORS AFFECTING DISTRIBUTION

The requirements of a species at every stage of its life cycle will ultimately determine its geographical distribution. Relevant and useful conservation measures can only be applied once these requirements are fully understood. Habitat availability, air temperature, soil, geology and rainfall were each looked at as possible factors affecting stag beetle distribution. In addition, both inter- and intra-specific competition were considered.

Habitat availability

The stag beetle relies upon dead wood at every stage of its life cycle. Supplies of dead wood have been diminishing in the UK for three main reasons and they are as follows:

1. The trend towards 'clean and tidy' gardens means that many garden owners choose to quickly remove rotten trees, tree stumps or old roots from their gardens.
2. Dead wood is not being created at the same rate as it was in the past because there are far fewer trees in the UK than there used to be. The beetles took advantage of diseased Dutch Elm trees and wood created by natural phenomena, such as the great storm of 1987. These sources of wood are now drying up.
3. Councils and landowners feel compelled to remove dead trees in the interests of public safety (in many cases the trees themselves may not actually be dangerous).

Break down of sightings in different habitats
Two computer packages were used to classify the stag beetle sightings into different habitat types. Recorder provided a broad classification whilst CIS allowed a more detailed picture. Both showed similar results. These results can be seen in Tables 3 and 4.

Land Cover Class	*Percentage of beetles*
Suburban	42.11
Managed grass	33.52
Tilled Land	10.85
Urban	7.51
Deciduous woodland	3.44
Sea/estuary	1.18
Coniferous woodland	0.72
Inland water	0.31
Coastal bare	0.21
Open shrub heath	0.10
Saltmarsh	0.05

Table 5 *Stag beetle sightings in different habitats as defined by CIS*

CIS enabled the analysis of selected areas for a proportion of each of the 11 land classes defined by CIS.

In total, stag beetles were reported from 1945 1 km squares out of a total 240222 in the UK.

The table (opposite) shows the percentage of these squares that were covered predominantly by each land class.

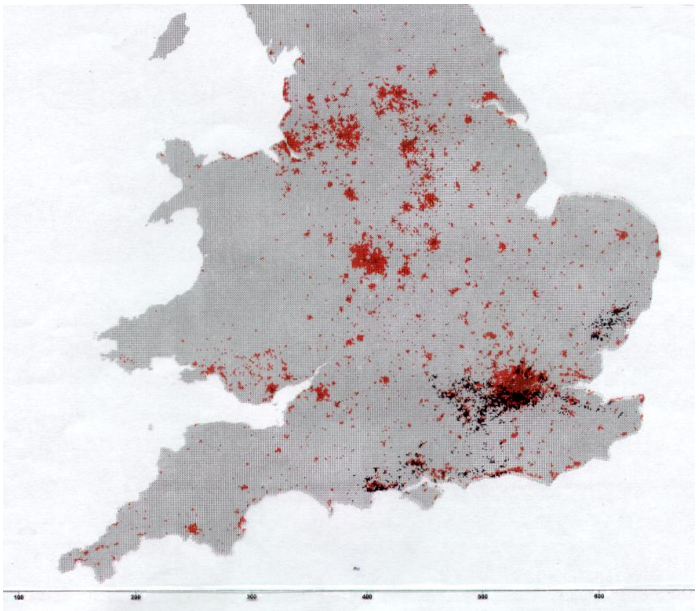
However, recent reports (Dec 2000) suggest that the amount of woodland in the UK is beginning to increase.

Type of habitat	***Proportion (and %age) of records***
PRIVATE GARDENS *Includes sightings from private gardens in Britain (urban and rural)*	6455 out of 9173 ***70.37%***
URBAN RECREATION AREAS *Includes sightings from public parks and gardens, playing fields, school grounds, churchyards, town commons, greens, ornamental gardens, urban nature reserves, golf courses, pub or hotel gardens, allotments, riding stables, hospital grounds, plant nurseries, canals, boatyards, University campuses.*	483 out of 9173 ***5.27%***
TOWNSCAPE *Includes various artificial/hard urban areas such as roads, pavements, car parks, houses, shops, commercial premises, railway stations, schools etc. Village and countryside buildings are also included.*	2071 out of 9173 ***22.58%***
COUNTRYSIDE *Includes various rural locations such as woods, farmland, fields, meadows, rural nature reserves, estate grounds and country parks. No buildings are included.*	170 out of 9173 ***1.85%***

Table 6 *Stag beetle sightings in different habitats using Recorder*

Urban and Suburban

According to CIS classification, the majority of sightings (49.62%) were in suburban or urban land classes. This is shown in Map 6.



KEY

Urban (all built developments larger than the minimum resolution of the map, without significant permanent vegetation – city and town centres, major industrial and commercial sites, areas of tarmac and concrete, car parks and tips)

Suburban (all areas with a mix of built-up land and permanent vegetation at scale lengths shorter than the minimum resolution of the map. Includes: small rural industrial estates, glasshouses, train stations, rural roads, villages and small retail sites).

Black dots: Stag beetles in 1 km square

Map 6 *Areas of England and Wales classified by CIS as urban or suburban overlaid with stag beetle distribution*
[Source: Dominant Land Cover data, CIS]

Recorder showed similar results to those from CIS. Beetles in urban and suburban areas were making use of remaining deadwood. Historically, there was a substantial amount of deadwood available in and around towns including old tree stumps in gardens, allotments and parks, rotting fence posts and log piles.

Suitable habitat in towns is generally fragmented, separated by roads, pavements and buildings. The many town sightings from roads and pavements were probably beetles attempting to disperse in search of fresh habitat and mates.

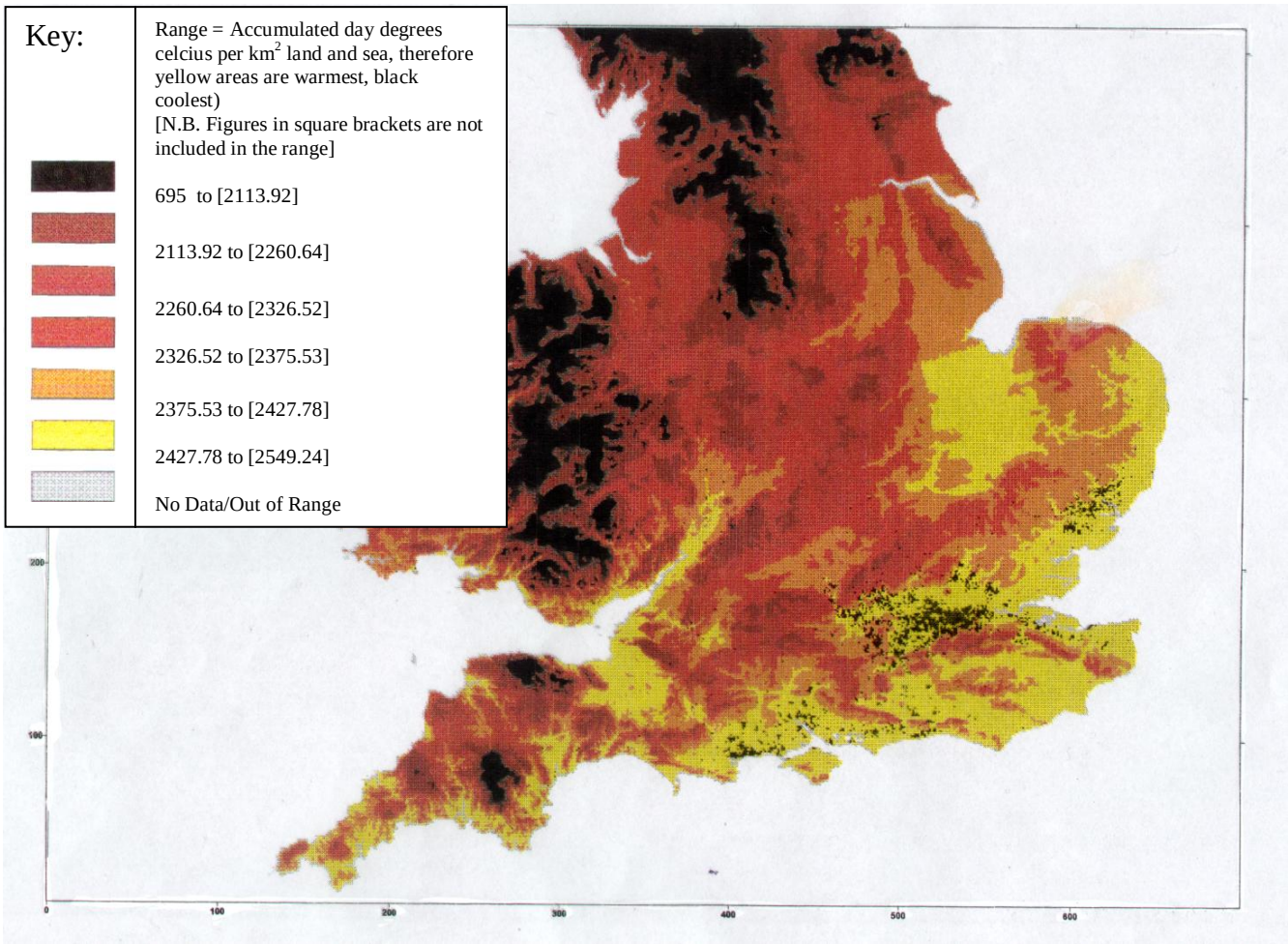
Gardens, both in urban and rural areas, are therefore important providers (and potential providers) of suitable habitat for the species in the future. Gardeners and landowners should be made aware of the benefits to stag beetles and other wildlife both of not removing dead wood and of creating suitable habitat, e.g. by building partially buried log piles, leaving them undisturbed and replenishing them by putting further wood carefully on top at a later date as necessary.

Woodlands/Rural Areas
Using CIS only 4.16% of 1km squares with sightings were in the woodland category. Recorder showed that only 1.85% of sightings were from rural areas. Many parts of the countryside undoubtedly have a ready supply of dead wood suitable as larval foodstuff. Since woodland is known to be good stag beetle habitat, it is probable that there are viable populations in some of these areas, despite no records being received. This is an area that needs further investigation.

NOTE: The custom-made RECORDER codes and the CIS land classes are based on very different information. The RECORDER codes were defined in-house and each stag beetle record that was entered onto the database was assigned a habitat code according to the location given by the recorder. The CIS land classes are based on a general UK survey to determine the main land use in each 1km square. The resulting habitat statistics from the two sources are therefore not directly comparable.

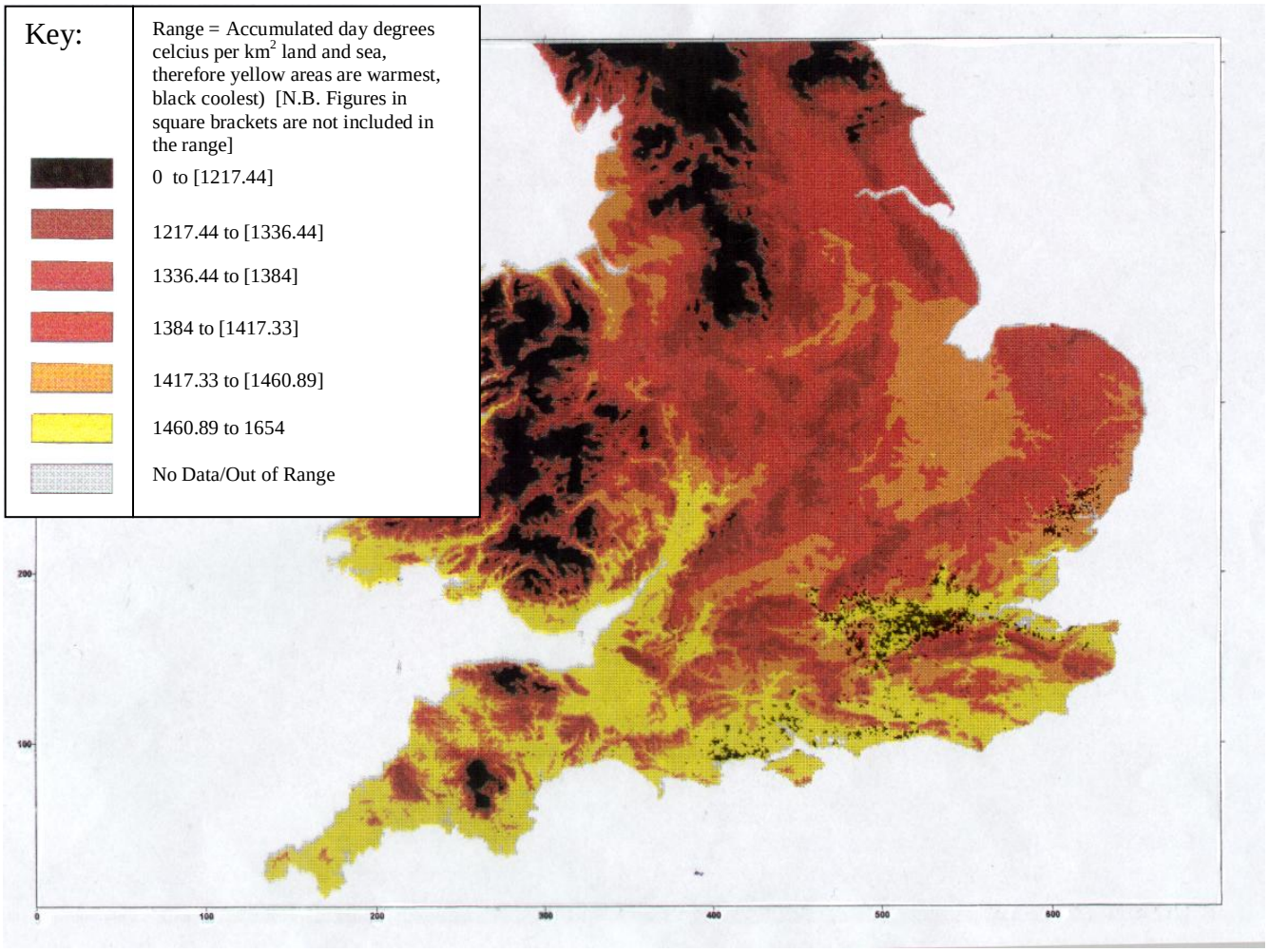
Temperature

The stag beetle records were overlaid onto a map showing long term, average, nationwide temperature data. A CIS dataset was used (data from FRCA) which was in the form of accumulated day degrees (ADD) from April to September and from January to June (data from September to December was not available). The ADD figure is the total of all the daily average temperatures above 0°C in the period stated; therefore, the higher the ADD, the warmer the period. This is shown in Maps 7,8 and 9.



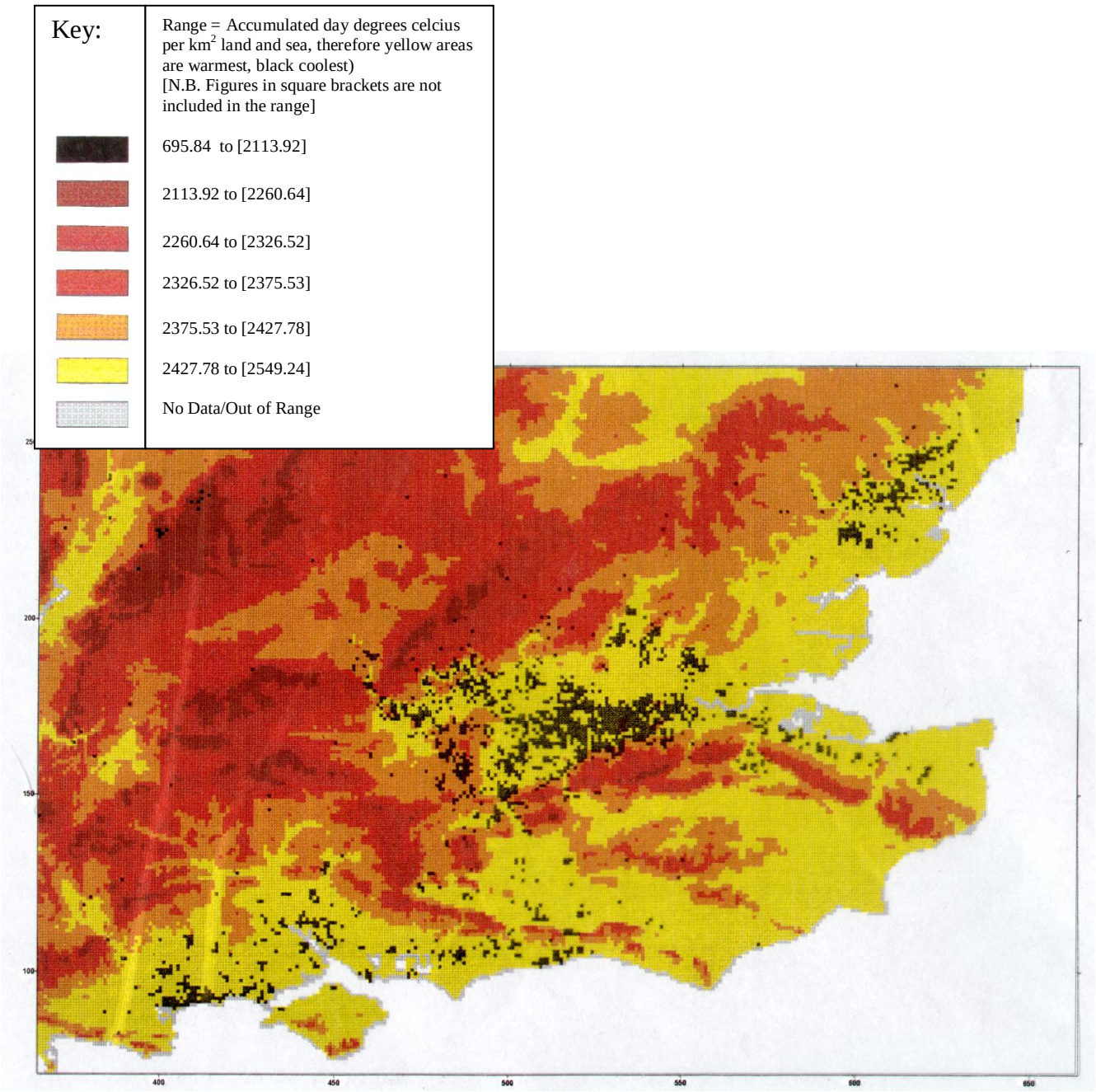
Map 7 *Accumulated median temperature (above* 0°C*) from April to September (1961-1980)*[1] *[Source: FRCA/Met Office] and stag beetle records*

[1] More recent data was not available



Map 8 *Accumulated median temperature from January to June and stag beetle records (1961-1980)*[2] *[Source: FRCA]*

[2] More recent data was not available



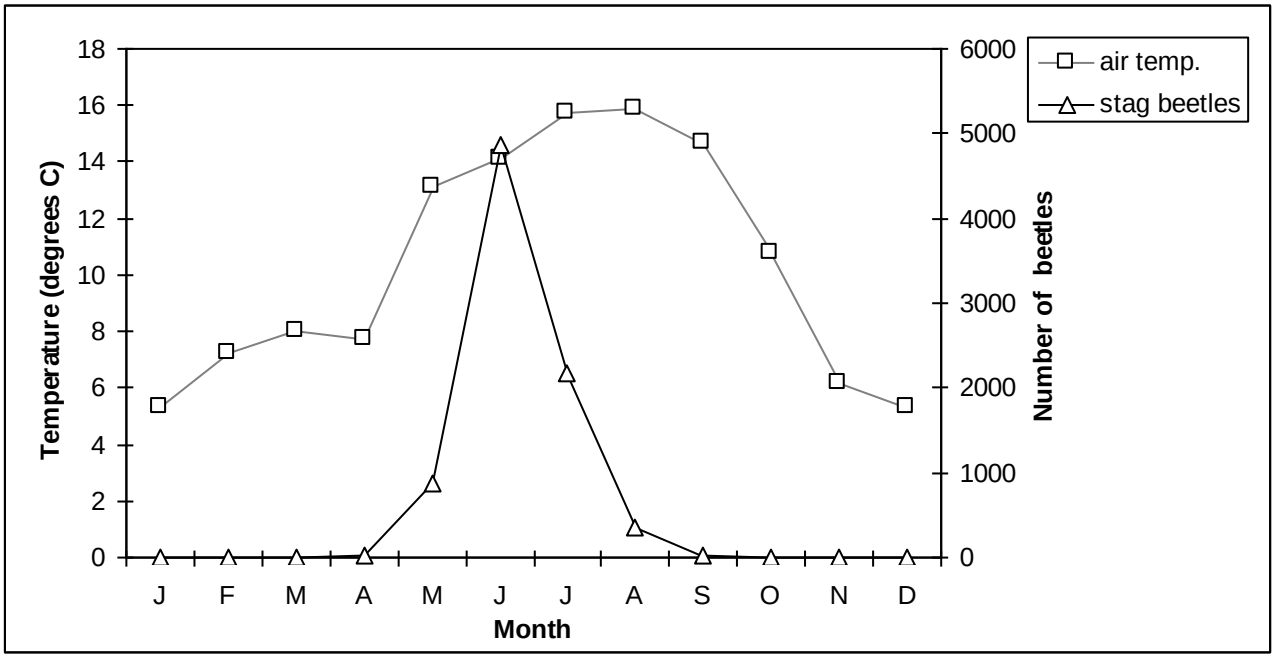
Map 9 *Accumulated median temperature from April to September and stag beetle records (1961-1980)*[3] *(southeast detail) [Source: FRCA]*

These maps clearly show that the areas of the UK with the highest temperatures (yellow areas) contained the majority of the stag beetle sightings. This is also the case in areas of high stag beetle

[3] More recent data was not available

concentration as well as in areas on the edge of its range, such in south Wales, parts of the southwest, and the cluster of records on the Gloucestershire /Worcestershire border.

Graph 4 shows that during April and May the air temperature and the number of stag beetle sightings increase simultaneously. Air temperature may be acting as a cue for emergence above ground.



Graph 4 *Air temperature against number of stag beetles reported per month (Source: Meteorological Office's website)*

There may be a minimum temperature below which stag beetles are unable to fly. Like most insects, stag beetles depend on a minimum air temperature to achieve a thoracic temperature sufficient for locomotion and flight. They require the entire length of the day to warm their flight muscles to the temperature needed for flying, and, indeed, on cooler days, may not achieve this temperature and consequently not be able to fly on those particular evenings. Flight is vital for dispersal and searching for mates.

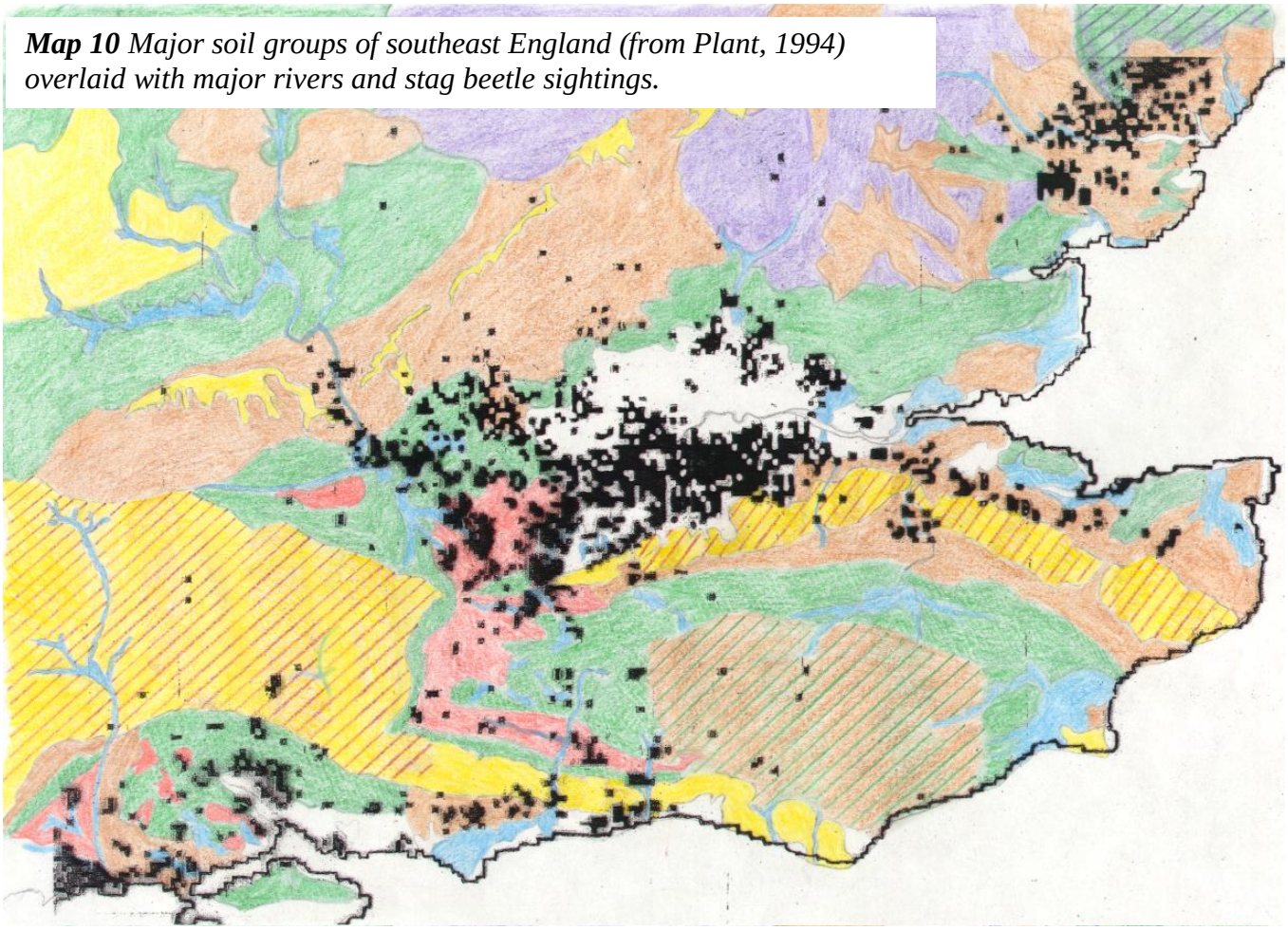
Soil

Stag beetles are in contact with the soil for much of their life. The physical properties of the soils are thought to either enhance or inhibit the stag beetle's ability to inhabit particular areas.

- Females lay their eggs in the soil (oviposition)
- Larvae move within the soil to reach fresh food supplies and to construct their pupal cocoons.
- Having emerged from their cocoons, beetles travel through the soil to reach the soil surface.

Soil temperature, humidity, particle size and the degree of drainage are likely to influence stag beetle distribution. Waterlogging of the soil or summer desiccation are possible reasons why the beetles avoid some chalk and clay areas.
The stag beetle records in the southeast were overlaid with a map of the major soil groups and major rivers as shown below.

Map 10 *Major soil groups of southeast England (from Plant, 1994) overlaid with major rivers and stag beetle sightings.*



Key: ***Blue: Ground-water gley soils Purple: Pelosol soil Brown: Brown soils Red: Podzolic soils***
Green: Surface-water gley soils White: Lge urban areas[1] Yellow: Lithomorphic soils
Brown& green striped: Brown & surface-water gley soils Green & purple striped: Surface-water gley& pelosols

[1] The Soil Survey of England and Wales does not include areas classified as urban. Large urban areas are therefore white on the map. Small urban areas have been identified with the soil type that surrounds them.

Map 8 shows that stag beetles occur on podzolic, brown and ground-water gley soils in the southeast and that they very rarely occur on surface-water gley soils (which become easily waterlogged in the upper layers) or on lithomorphic or pelosol soils (both calcareous/chalky). Waterlogged and chalky soils would probably be difficult for stag beetles to burrow into. If present, they might also be vulnerable to drowning.

Results of a multiple regression analysis of soil data from CIS [2] seem to show that beetles actively avoid lithomorphic and man-made soils[3] (see Appendix 6). A few of the main points which are illustrated on Map 10, include:

- A large proportion of south Essex and neighbouring Hertfordshire is made up of surface-water gley soil, which was virtually devoid of sightings.

- There is a persisting cluster of stag beetle records in north Essex and south Suffolk[4]. This cluster lies on predominantly brown soil and ground-water gley.

- No records were received from the area that begins just north of Ipswich. The soils in this area are pelosols and surface-water gleys.

- The large amount of chalky pelosols present in the west of Essex seems to be preventing stag beetles from spreading into that part of the county.

- The North and South Downs are made up of chalky soils (brown and lithomorphic) and in these areas stag beetles are rare. The Weald, the area between the North and South Downs containing much of East Sussex and Kent, is also largely devoid of stag beetles.

- There are virtually no stag beetle records between Winchester and Basingstoke and in areas west of Andover. This large area, including Salisbury Plain, is also predominantly lithomorphic (chalky) soils and brown soils. It is also possible that these areas are generally cooler throughout the year (see previous section about air temperature).

- In northwest Berkshire there is a line of sightings following ground-water gley soils along the course of the river Thames northwards, through the Chilterns, avoiding the chalky soil on either side. This same line of chalky soil runs in a northeast direction through Buckinghamshire, forming the Chiltern Hills, which could be forming a barrier preventing stag beetles from spreading any further north.

- In Suffolk, a close association has been noted between the distribution of Stag Beetles and deep, well drained, loamy soils overlying sands and gravels, and the loamy soils of river valleys.*

A separate section at the end of this chapter discusses the London distribution.

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[2] Carried out by Bob Smith at the Durrell Institute for Conservation and Ecology at (DICE) at the University of Kent
[3] Man-made soils do not appear on the Map 10. They are soils with man-made top soils or a disturbed subsurface layer (containing disturbed fragments of soil horizon) to at least 40 cm depth. They result from the addition of earth containing manure, or the restoration of soil material after mining and quarrying. These soils are mainly found in the Midlands and North England.
[4] The vast majority of our records in these counties were from Colchester and Ipswich
* See reference p36 of this document, Hawes C.J. (2000).

Rivers

The soil that is generally found along and around rivers and other water features is ground-water gley. It appears that stag beetles may follow the route of rivers, along the ground-water gley soils, which lie on either side thereby using them as a means of dispersal through otherwise impenetrable habitat.

River valleys are the only places in the chalky North Downs where stag beetles are found. This can be seen in north Kent, between Gillingham and Maidstone, where the River Medway cuts through the North Downs. It can also be seen along the Mole Valley near Dorking in Surrey.

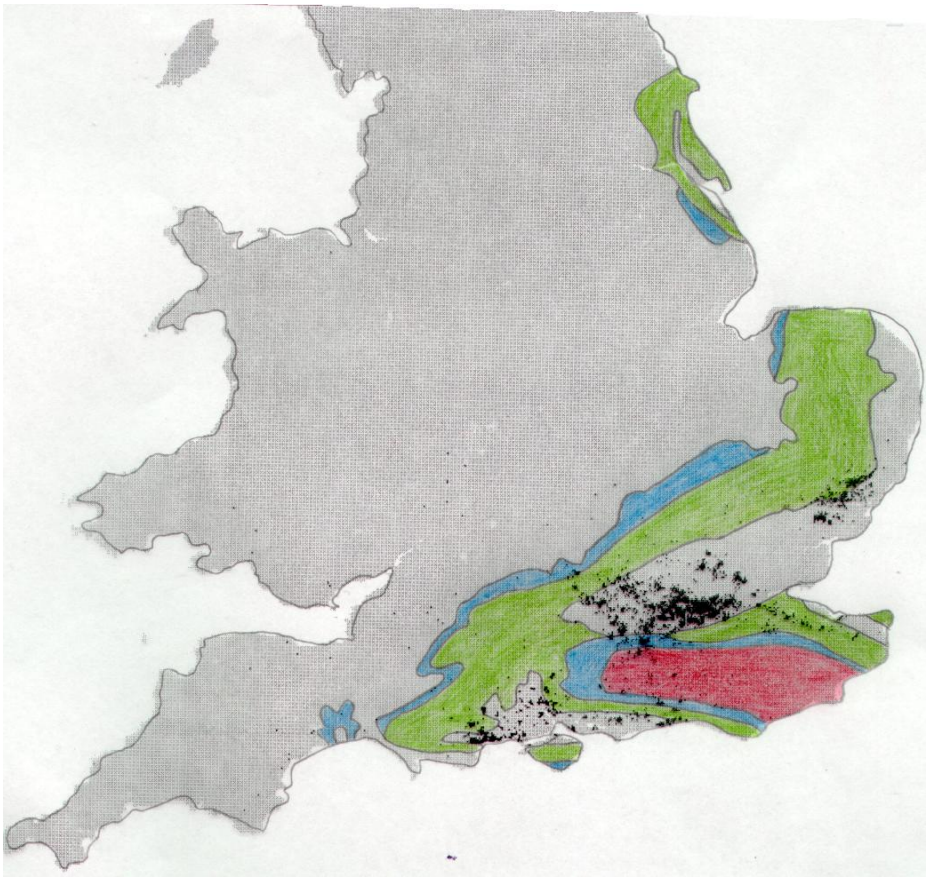
A further example can be seen on the south coast. Here, bands of ground-water gley soils start from the coast and end north of the South Downs. One band of ground-water gley soil is found at the confluence of the River Arun and the River Rother and another band is along the River Adur. Stag beetle sightings appear to follow these bands where they cut through the Downs.

In Suffolk, a close association between the beetle and the county's river valleys has been pointed out by Hawes (2000). Whitehead (1993) suggests that stag beetle populations found along river basins are remnants from when these areas were mixed oak forest. Rivers were often lined with woodland. It is therefore also possible that these river valleys sometimes still provide corridors of suitable habitat (of oak or other species) for stag beetles.

Geology

Relatively recent geological deposits are likely to affect the composition of the soils that lie above them and it is this soil with which the stag beetles are in contact for much of their life cycle. A number of authors have mentioned suspected relationships between geology and stag beetle distribution in their areas of study. Hawes (1998) reports the absence of stag beetles from the boulder clay of Suffolk and suggests a link between stag beetle distribution and well-drained, deep loamy or sandy soils and glaciofluvial/aeolian drift geology (Hawes 1999).

Results of a multiple regression analysis of CIS geology data seem to show that beetles occur on most types of geology with no preference. However, a map of Cretaceous (chalky) geology showed a visual correlation between absence of Creataceous rocks and stag beetle sightings. See map 11.



KEY TO MAP:

Blue
Gault and Greensand (sandstones)

Red
Wealden

Green
Chalk

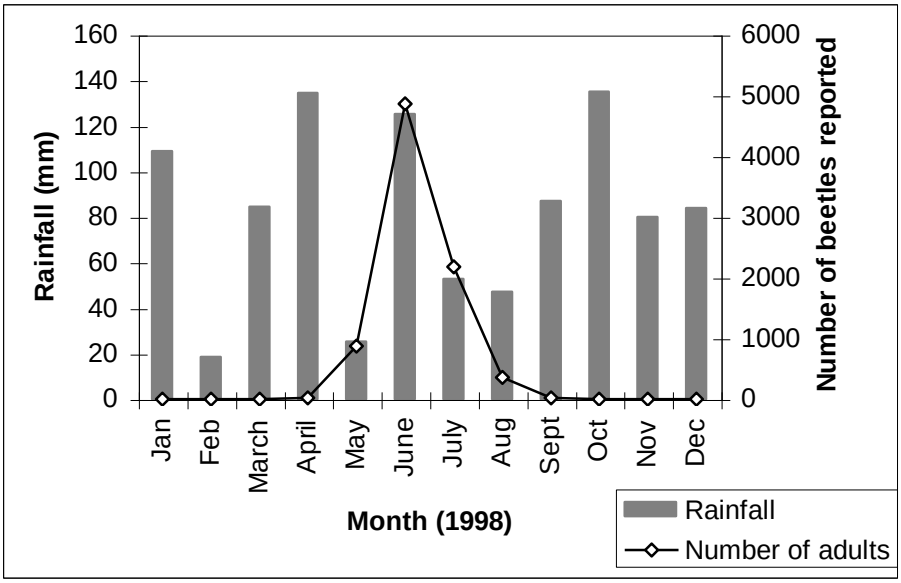
Grey
Undefined area

Map 11 *The main outcrops of Cretaceous rocks in Britain with stag beetle records[Source: Ager, 1975]*

Most of the Cretaceous areas of the map do not contain significant numbers of stag beetles (the main exception being a line of stag beetle records through North Kent). This agrees with the earlier finding that stag beetles are not present in large numbers on chalky soils (found above Cretaceous geology).

Rainfall

Daily rainfall data (average for the whole of the UK) for 1998 were obtained from the Meterological Office. The data is shown in Graph 5 plotted against the number of stag beetles reported.



Graph 5 *Monthly rainfall and numbers of stag beetles reported per month [Source: Meteorological Office]*

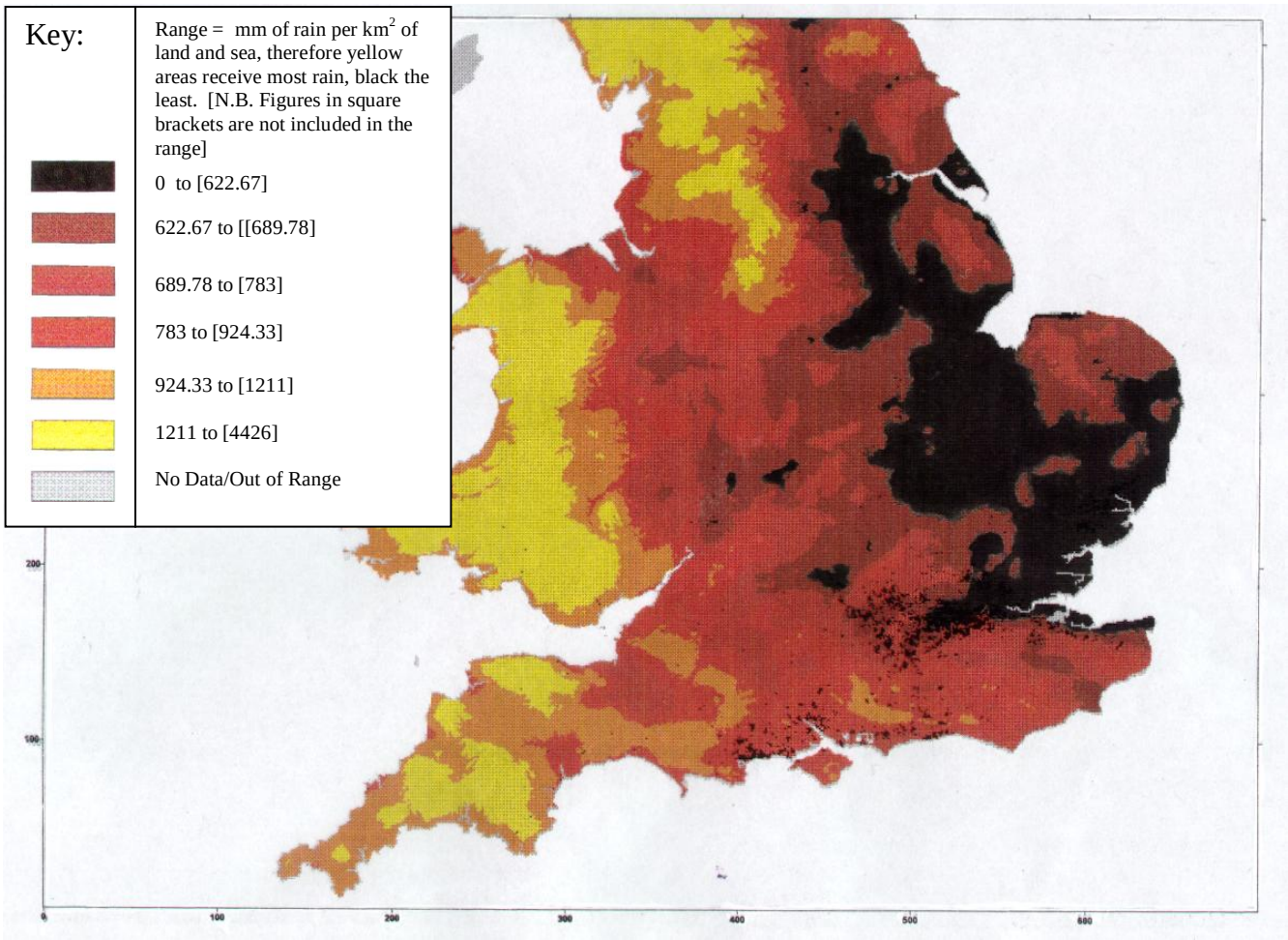
Even though June was an extremely wet month (it was the 5th wettest June the 20th century) it was still the peak month for sightings and, presumably, stag beetle activity. Further studies may shed some light on the relevance and impact of rainfall on the stag beetle life cycle.

Table 7 The table below shows temperature and rainfall data for June 1990 to 2000 inclusive.

Year	Monthly Mean Temperature / deg. Celsius	Monthly Rainfall Totals /mm
1990	15.2	39
1991	13.7	89
1992	17.4	23
1993	17.0	44
1994	16.3	17
1995	15.7	11
1996	17.0	12
1997	16.2	79
1998	15.9	90
1999	15.7	98
2000	16.0	19
Average	**16.0**	**47.4**

Data provided by the MET Office for London (Heathrow) Airport

The majority of stag beetle sightings fell within the areas of lowest and second lowest average annual rainfall (see Map 12).



Map 12 *Accumulated average annual rainfall (1941-1970)*[1] *and stag beetle sightings [Source: FRCA/Met Office]*

[1] More recent data has yet to be released.

Competition

Species like the stag beetle that are rare in some particular areas within their geographical ranges may be so because:

1. They are exploiting a narrow ecological niche, or
2. Interspecific (between species) competition is keeping the population low.

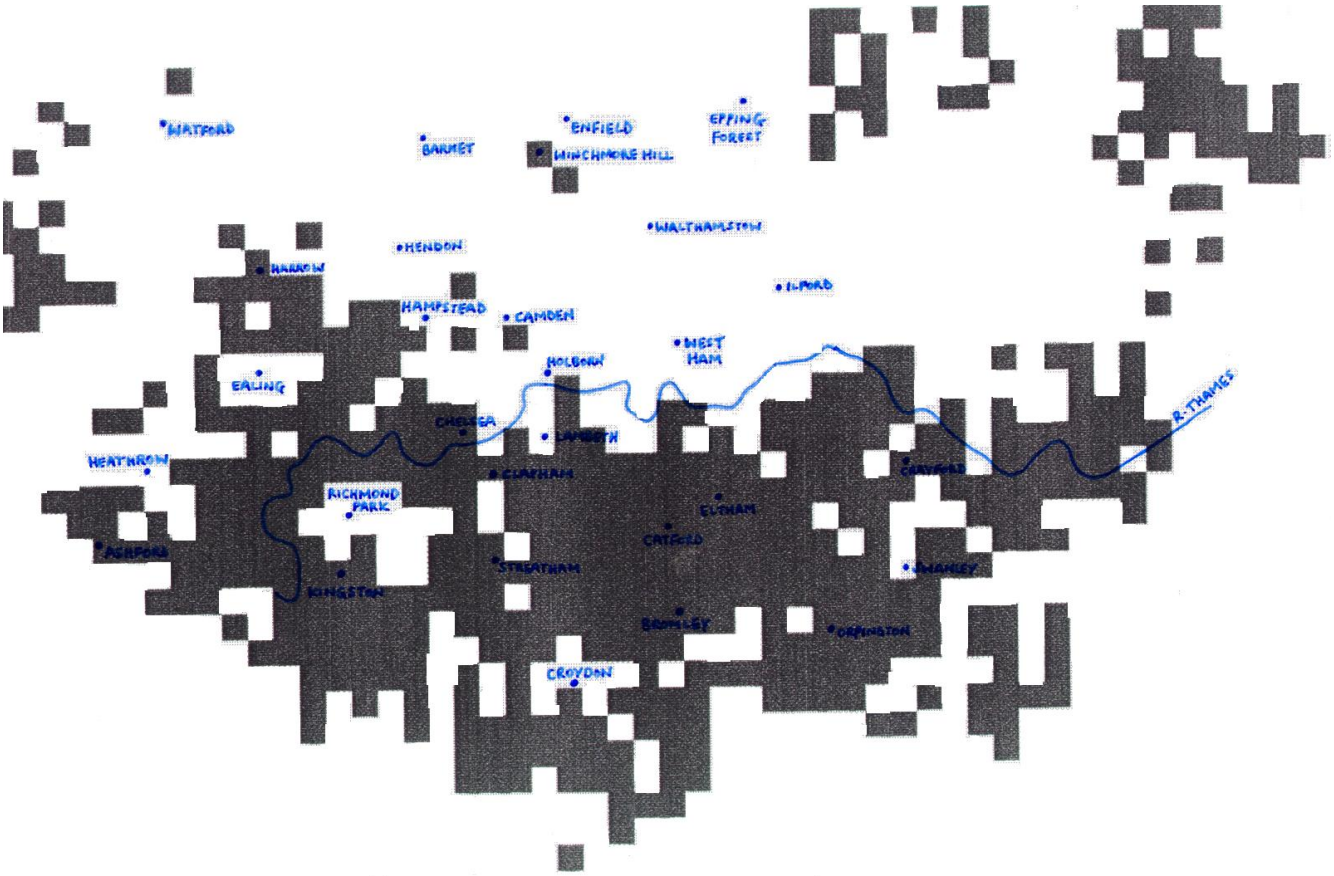
The results of the survey were not used to look for any new information about interspecific relationships. Little is known about the interspecific relationships between larvae of the beetles of the family *Lucanus* in Britain although it is known that larvae of all three species, *Lucanus cervus, Dorcus parallelipipedus* (Lesser stag beetle) and *Sinodendron cylindricum* can inhabit the same piece of rotten wood (Owen, 1992).

In such a situation the larvae would almost certainly compete for food with each other. This is an area which needs further study.

Focus on London

Nearly a third (2936) of the stag beetle records (32%) were reported from London, which is a significant proportion of all the beetle sightings. In fact, the stag beetle is listed as a priority species for the London Biodiversity Action Plan (BAP) and as well as for a number of local Borough BAPs.

The vast majority of the sightings in 1998 were made in south London, which is shown in Map 13.



Map 13 *Map of stag beetle records in Greater London (each black square represents 10 km^2)*

The highly urban landscape most likely explains the lack of sightings in Central and North London. Historically, London originated north of the Thames and has had much more time to be built upon and to develop industry and commerce than South London. Therefore, areas north of the Thames tend to be more built up and industrialized with fewer parks and green spaces than the more leafy south. These areas would be unsuitable habitat for stag beetles. The habitat that is available is highly fragmented. These tiny fragments of suitable habitat, being few and far between, are not able to sustain populations of beetles.

There has been no previous mention in the literature of this north-south divide. Preliminary results from targeted surveying in the 1999 flight season again suggest a lack of stag beetles north of the

Thames. Further, targeted work is needed. The greater urban development north of the Thames would seem to explain the distribution in stag beetles. However, there are other possibilities.

- *Variations in soil type*
  Central and North London are mainly London Clay and non-glacial sands and gravels. However, stag beetles do occur on these surface deposits in south London, as well as on Blackheath beds and brick earths.

- *Uneven effort in stag beetle sightings*
  One cannot expect surveying effort to be uniform during a public survey, but biases do become less important the greater the number of records received.

  Although there were no records received from Richmond Park, it is known to be a common place for stag beetles (Roger Key and Peter Hammond, pers. comms.). The lack of records could be explained by the fact that few people visit the park between 6 pm and 10 pm, which is most the common time to find stag beetles flying.

- *Variations in geology*
  Stag beetle sightings were reported from nearly all of the surface and solid geology types in London[1] although the density of the beetles varied.

[1] A map of surface geology of London (Plant, 1994) was used in conjunction with our map of stag beetle sightings in London to assess the importance of geology as a variable affecting stag beetle presence or absence

CHAPTER 5 SUMMARY OF MAIN FINDINGS

- Stag beetles can utilise many types of broadleaf dead wood. Some species are more commonly used than others: oak, apple, ash and cherry are the predominant species mentioned in the survey.

- Stag beetles prefer areas of Britain with high air temperatures throughout the year (1460.89 to 1654 Accumulated Day Degrees January-June and 2427.78-2549.24 Accumulated Day Degrees April-September).

- Stag beetles prefer light soils. Certain soil types act as barriers to dispersal.
  Stag beetles are now mostly reported in urban and suburban gardens. Sympathetic gardening is, therefore, likely to become increasingly important when considering future conservation measures.

- Stag beetles seem to follow river courses. This was thought to be due to a combination of three factors
  - the presence of ground-water gley soils
  - the presence of alluvium geology, and
  - the possibility that these areas contain(ed) good dead wood habitats (especially oak).

- There is anecdotal evidence of declines in local abundance of stag beetles in recent years.

- The general public was keen to learn about the stag beetle and to help conserve it. A positive attitude towards the beetle was successfully fostered, despite earlier fears that it might have a negative image.

  Potential problems were:
  - Misidentification
  - Vague records
  - Sex variations- males are much more noticeable than females
  - Survey effort was not standardized across the whole country
  - The profile of the stag beetle was higher in certain areas due to previous local surveys
  - Publicity for the survey was more successful in towns and cities and possibly less so in rural areas

CHAPTER 6 RECOMMENDATIONS

Identify and monitor Key Sites

A total of 20 suggested national key sites for stag beetles have been identified. We hope that these will be set up and monitored with the cooperation of the Wildlife Trusts, local authorities, landowners and other agencies. The key sites have been chosen from four categories, as follows (the number in brackets beside each county is the number of records received from that county in 1998):

1) **Stag beetle 'hot spots'**
These are areas where beetles are present in large numbers and appear to be doing relatively well. The towns listed were found to be important sites for stag beetles in 1998 and every effort should be made to ensure that these populations are maintained in the future.

SUGGESTED SITES		
County	***Town(s)***	***Other options***
Berkshire (662)	Reading	Wokingham, Slough
Bucks (193)	Marlow	
Dorset (636)	Poole/Bournemouth	Wimborne
Essex (538)	Colchester	Manningtree
Hampshire (950)	Hythe/Dibden Purlieu	Southampton
Hertfordshire (62)	Cheshunt	
Greater London (2936)	Kingston-Upon Thames (SW); Beckenham/Bromley (SE); Romford/Hornchurch (E)	Winchmore Hill (N);
Kent (464)	Gillingham/Rainham	Gravesend, Rochester
Oxfordshire (176)	Wallingford	Henley-on-Thames
Surrey (1295)	Guildford	Godalming, Woking
Suffolk (856)	Ipswich	Woodbridge
West Sussex (547)	Worthing	Steyning, Henfield

2) Peripheral areas
These are areas on the edge of the stag beetle's current range and where they were found in 1998 but only in small numbers. Further work will identify to what extent the stag beetles are surviving in each area. Once this is done, attempts can be made to boost and maintain the populations.

SUGGESTED SITES	
County	***Town(s)***
Avon (4)	Bath/Batheaston/Bristol
Bedfordshire (1)	Tottenhoe
Clwyd (1)	Lixwm
Cornwall (1)	Treyarnon Bay
Devon (12)	Dawlish/Exmouth/Axminster/Totnes/Exeter/Starcross/Ottery St Mary

Dyfed (1)	Llandeilo
East Sussex (8)	Ringmer
Gloucestershire (3)	Cheltenham, Newent, Apperley
Herefordshire & Worcs (17)	Upton-on-Severn
Norfolk (1)	Wallingford
Somerset (4)	Minehead/Bridewater/Yatton
South Glamorgan (2)	Cardiff
West Glamorgan (2)	Swansea, Neath
Wiltshire (9)	Salisbury Plain, Trowbridge Chippenham, Swindon

3) **Sites where no sightings were reported during the 1998 survey**
In these areas, the beetle has (apparently) become locally extinct.

SUGGESTED SITES	
County	***Areas***
Greater London	Richmond Park, and other areas
Cumbria	to be identified
Lincolnshire	to be identified
Cambridgeshire	to be identified
Warwickshire	to be identified
Shropshire	to be identified
Derbyshire	to be identified
Nottinghamshire	to be identified

In these areas, further research is recommended to identify whether in fact stag beetles persist. If no beetles can be found then a case could be had for reintroductions into these sites once a suitable reintroduction strategy has been agreed.

4) **Sites which are currently proposed as SACs (Special Areas of Conservation) by JNCC**
Although we received no records from these areas, the beetles do still occur (Roger Key pers. comm.).

pSACs (proposed)
Epping Forest
New Forest

cSACs (candidate)
Wimbledon Common
Richmond Park
Chiltern beechwoods

Listed as “insignificant presence” at Windsor and Exmoor

Education and Conservation Work

The 1998 survey showed that public awareness campaigns on a large scale are achievable. We want to build on the knowledge that people now have about stag beetles by encouraging gardeners and those

with responsibility for stag beetle habitat to manage land appropriately for the species. The following actions were taken in 2000:

- Production and wide distribution of a new information leaflet for members of the public including information learnt during the 1998 survey. Emphasis was on:
  Maintaining suitable habitat:
  People were encouraged to leave tree stumps and old roots in gardens (cover up with foliage if necessary).
  Creating suitable habitat:
  People were encouraged to create an area in the garden for stag beetles and other dead wood invertebrates by building partially buried log piles, Covering water containers, rescuing drowning and upturned beetles was also advised.
  Advice on the mitigation of predation by other animals was given
  Emphasis was placed on the fact that the beetle is harmless to humans and other insects.

- Provision of information and advice on stag beetle conservation to land owners, managers, local councils, wildlife trusts, wardens and tree officers, which can inform decisions about how land is managed.

These aims were met by a number of leaflets produced by PTES and initiatives are still continuing to promote deadwood and raise awareness. PTES hopes to repeat the survey at a later date to gather further data for comparative purposes.

Further study

- Targeted survey work – Targeted survey work is needed in areas from which we have no recent records but where records have been made in the past, and areas at the edge of the beetle's known range. Targeted survey work is needed especially in rural and woodland areas to establish whether the lack of records reflects the true situation in these areas.

- Agrochemicals – Assess the possible effects of agrochemicals on stag beetles living in close proximity to arable land.

- Dispersal - There have been no studies specifically focusing on the dispersal capabilities of the stag beetle. We do not yet know how far stag beetles can travel to find mates or suitable oviposition sites and if this varies between the sexes.

- Attractants – Research into possible attractants between males and females has been initiated.

- Singleton records – Further research in areas from where single records were received is needed, especially where they were on the edge of the stag beetle's range, to discover whether the beetles were; a) misidentifications, b) part of a small, struggling population, c) part of a well-established population d) isolated migrants, or e) had been transported to the area.

- Soil temperature – Given the apparent associations which we revealed between soil types and accumulated temperatures, soil temperature would seem to be a vital area for further study.

- Soil Type – the relationship between soil type and stag beetle breeding sites should be studied further.

- Abundance – is currently being investigated using road kill and garden surveys (2001).

- Habitat availability – trials are underway to determine whether stag beetles conservation can be enhanced by the provision of man-made ovipositing boxes.

Reintroductions, translocations and captive breeding

Translocation is a method for re-establishing the beetle in areas where it no longer occurs.

Although it is possible to successfully breed stag beetles in captivity, captive breeding is labour intensive and brings with it the possible risk of introducing disease and parasites from a controlled, captive environment into the wild. (Prof. J. Owen pers. comm..)

The role of captive breeding should therefore remain for the present a research tool, and an education tool in zoos and conservation centres.

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Appendix 1 List of tree & plant species associated with stag beetles at all stages of its life cycle

Species	*Common name*
Acer campestre	Field maple
Acer platanoides	Norway maple
Acer pseudoplatanus	Sycamore
Acer saccharinium	Silver maple
Aesculus hippocastanum	Horse-chestnut
Ailanthus altissima	Tree of Heaven
Anthriscus sylvestris	Cow parsley
Aucuba japonica	Spotted laurel
Berberis vulgaris	Barberry
Betula pendula	Silver birch
Buddleia davidii	Butterfly bush
Buxus sempervirens	Box
Carpinus betulus	Hornbeam
Castanea sativa	Sweet chestnut
Cercis siliquastrum	Judas tree
Chamaecyparis lawsoniana	Lawson's cypress
Cistus laurifolius	Laurel-leaved cypress
Clematis montana	Himalayan clematis
Clematis viticella	Purple clematis
Coniferae sp.	A conifer
Cornus sanguinea	Dogwood
Corylus avellana	Hazel
Cotoneaster sp.	A cotoneaster
Crataegus monogyna	Hawthorn
Cupressocyparis leyland	Cypress
Cupressus sempervirens	Italian cypress
Dipsacus fullonum	Teasel
Escallonia sp.	Escallonia
Eucalyptus globulus	Gum
Eucalyptus parvifolia	Gum
Eucalyptus urnigera	Gum
Fagus sylvatica	Beech
Fagus sylvatica pyrpurea	Copper beach
Ficus carica	Fig
Forsythia suspensa	Forsythia
Forsythia suspensa x viri	Forsythia
Fraxinus excelsior	Ash
Hedera helix	Ivy
Hedera helix sp.	Common ivy
Ilex aquifolium	Holly
Ipimorpha subtusa	Olive

Species	*Common name*
Iris sp. Cultivar	Garden Iris
Jasminum officinale	Summer jasmin
Juglans regia	Walnut
Juniperus communis	Juniper
Laburnum anagyroides	Laburnum
Laurus nobilis	Bay
Ligustrum ovalifolium	Garden privet
Ligustrum sp.	Privet
Lonicera japonica	Japanese honeysuckle
Lonicera periclymenum	Honeysuckle
Magnolia acuminata	Cucumber tree
Malus domestica	Apple
Malus sp.	Apple
Malus sylvestris	Crab apple
Morus nigra	Black mulberry
Papaver sp.	Poppy
Parthenocissus quinquefol	Virginia creeper
Philadelphus coronarius	Mock orange
Philadelphus sp.	Mock orange sp.
Pinus sp.	Pine sp.
Pinus sylvestris	Scots pine
Populus balsamifera	Balsam poplar
Prunus sp.	Cherry sp.
Prunus avium	Wild cherry
Prunus domestica	Wild plum
Prunus domestica ssp dom	Plum
Prunus domestica ssp. Ins	Damson
Prunus domestica x spinos	Cherry
Prunus laurocerasus	Cherry laurel
Prunus persica	Peach
Prunus spinosa	Blackthorn
Pyracantha coccinea	Firethorn
Pyrus communis	Pear
Pyrus sp.	Pyrus sp.
Pyrus pyraster	Wild pear
Quercus sp.	Oak sp.
Quercus ilex	Oak
Rheum hybridum	Rhubarb
Rheum palmatum	Ornamental rhubarb
Rhododendron	Rhododendron
Rhus hirta	Stag’s horn sumach
Rhus typhina	Stag’s horn stomach

Appendix 1 List of tree & plant species associated with stag beetles at all stages of its life cycle

Species	*Common name*
Ricinus communis	Castor oil plant
Robinia pseudoacacia	False acacia
Rosa sp.	A rose
Rosa sp. Cultivar	Cultivated rose
Rubus fruticosus	A bramble
Salix cinerea x repens	A willow
Salix fragilis	A willow
Salix sp.	A sallow
Salvia x superba	Sage
Sambucus nigra	Elder

Species	*Common name*
Sorbus aucuparia	Rowan
Syringa vulgaris	Lilac
Tamarix gallica	Tamarisk
Taxus baccata	Yew
Tilia sp.	A lime
Ulmus procera	English elm
Ulmus sp.	An elm
Viburnum opulus	Guelder rose
Viburnum tinus	Laurustinus
Viburnum x rhytidophylloi	A viburnum

Appendix 2 Plant species mentioned as larval food plant

Species	Common name	Total number of records mentioning species	Number of records mentioning species as larval food plant
Acer platanoides	Norway maple	1	1
Acer saccharinium	Silver maple	1	1
Acer sp.	Maple	2	1
Carpinus betulus	Hornbeam	2	1
Cotoneaster sp.	Cotoneaster	3	2
Crataegus monogyna	Hawthorn	16	2
Cupressocyparis leyland	Cypress	8	1
Escallonia sp.	Escallonia	1	1
Eucalyptus globulus	Gum	5	1
Fagus sylvatica purpurea	Copper beech	3	1
Forsythia suspensa x viri	Forsythia	2	1
Fosythia suspensa	Forsythia	2	1
Fraxinus excelsior	Ash	45	16
Ilex aquifolium	Holly	16	3
Juglans regia	Walnut	4	1
Laburnum anagyroides	Laburnum	8	3
Ligustrum ovalifolium	Garden privet	7	3
Malus sp.	Apple	74	24
Philadelphus sp.	Mock orange	5	1
Pinus sp.	Pine	9	2
Pinus sylvestris	Scots pine	2	2
Populus sp.	Poplar	9	1
Prunus avium	Wild cherry	1	1
Prunus domestica ssp. Dom	Plum	9	3
Prunus domestica ssp. Ins	Damson	3	1
Prunus domestica x spinos	Cherry	3	1
Prunus laurocerasus	Cherry laurel	9	1
Prunus persica	Peach	2	1
Prunus sp.	Cherry	58	13
Pyracantha coccinea	Firethorn	1	1
Pyrus communis	Pear	38	4
Pyrus pyraster	Wild pear	1	1
Pyrus sp.	Pyrus sp.	1	1

Quercus sp.	Oak	128	11
Rhus hirta	Stag's horn sumach	3	2
Rhus typhina	Stag's horn sumach	1	1
Robinia pseudoacacia	False acacia	5	1
Salix sp.	Sallow sp.	11	4
Sambucus nigra	Elder	5	1
Sorbus aucuparia	Rowan	11	5
Syringa vulgaris	Lilac	40	4
Ulmus procera	English elm	53	4
Ulmus sp.	Elm sp.	39	4

Appendix 3 Plant species mentioned as a suspected or confirmed oviposition site

Species	Common name	Total number of records mentioning species	Number of records mentioning species as oviposition site
Acer pseudoplatanus	Sycamore	32	6
Aesculus hippocastanum	Horse-chestnut	19	2
Ailanthus altissima	Tree of heaven	3	1
Berberis vulgaris	Barberry	3	1
Betula pendula	Silver birch	27	7
Betula sp.	Birch	24	6
Buddleja davidii	Butterfly bush	6	2
Buxus sempervirens	Box	6	4
Corylus avellana	Hazel	4	1
Cupressocyparis leyland	Cypress	8	2
Eucalyptus urnigera	Gum	1	1
Fagus sylvatica	Beech	38	12
Forsythia suspensa x viri	Forsythia	1	1
Fraxinus excelsior	Ash	45	8
Ilex aquifolium	Holly	16	1
Juglans regia	Walnut	4	2
Laburnum anagyroides	Laburnum	8	1
Ligustrum ovalifolium	Garden privet	7	1
Malus sp.	Apple	74	7
Pinus sp.	Pine	9	1
Populus sp.	Poplar	9	1
Prunus domestica	Wild plum	1	1
Prunus persica	Peach	2	1
Prunus sp.	Cherry	58	19
Pyrus communis	Pear	38	14
Quercus ilex	Evergreen oak	3	1
Quercus sp.	Oak	128	35
Robinia pseudoacacia	False acacia	5	1
Salix cinerea x repens	Willow	2	1
Salix sp.	Sallow	11	3
Syringa vulgaris	Lilac	40	3
Tilia sp.	Lime	19	4
Ulmus procera	English elm	53	11
Ulmus sp.	Elm	39	5

Appendix 4 Plant species mentioned as a perch for adults

Species	Common name	Total number of records mentioning species	Number of records mentioning species as adult perch
Acer campestre	Field maple	1	1
Acer platanoides	Norway maple	1	1
Aesculus hippocastanum	Horse-chestnut	19	7
Anthriscus sylvestris	Cow parsley	2	1
Aucuba japonica	Spotted laurel	2	1
Betula pendula	Silver birch	27	4
Castanea sativa	Sweet chestnut	6	1
Cercis siliquastrum	Judas tree	1	1
Chamaecyparis lawsoniana	Lawson's cypress	3	2
Cistus laurifolius	Laurel-leaved Cypress	1	1
Clematis montana	Himalayan clematis	2	1
Clematis viticella	Purple clematis	1	1
Coniferae sp.	Conifer	21	9
Cornus sanguinea	Dogwood	1	1
Corylus avellana	Hazel	4	1
Crataegus monogyna	Hawthorn	16	7
Cupressocyparis leyland	Cypress	8	1
Cupressus sempervirens	Italian cypress	1	1
Dipsacus fullonum	Teasel	1	1
Eucalyptus parvifolia	Gum	1	1
Fagus sylvatica	Beech	38	6
Ficus carica	Fig	2	2
Fraxinus excelsior	Ash	45	3
Hedera helix	Ivy	8	6
Hedera helix sp.	Common ivy	2	2
Ilex aquifolium	Holly	16	6
Ipimorpha subtusa	Olive	1	1
Iris sp. Cultivar	Garden Iris	1	1
Jasminum officinale	Summer jasmin	2	1
Juniperus communis	Juniper	1	1
Laurus nobilis	Bay	2	2
Ligustrum ovalifolium	Garden privet	7	1
Ligustrum sp.	Privet	6	1
Lonicera japonica	Japanese honeysuckle	1	1
Lonicera periclymenum	Honeysuckle	5	3
Magnolia acuminata	Cucumber tree	5	2
Malus domestica	Apple	1	1

Malus sp.	Apple	74	11
Malus sylvestris	Crab apple	1	1
Morus nigra	Black mulberry	2	2
Papaver sp.	Poppy	1	1
Parthenocissus quinquefol	Virginia creeper	3	3
Philadelphus coronarius	Mock orange	1	1
Philadelphus sp.	Mock orange	5	3
Pinus sp.	Pine	9	2
Populus balsamifera	Balsam poplar	1	1
Prunus domestica ssp dom	Plum	9	3
Prunus domestica ssp. Ins	Damson	3	1
Prunus laurocerasus	Cherry laurel	9	3
Prunus sp.	Cherry	58	6
Prunus spinosa	Blackthorn	1	1
Pyrus communis	Pear	38	4
Rheum hybridum	Rhubarb	3	2
Rheum palmatum	Ornamental rhubarb	1	1
Rhododendron		7	1
Ricinus communis	Castor oil plant	1	1
Robinia pseudoacacia	False acacia	5	2
Rosa sp.	Rose	4	3
Rosa sp. Cultivar	Cultivated rose	5	4
Rubus fruticosus	Bramble	1	1
Salix fragilis	Willow	1	1
Salix sp.	Sallow	10	2
Salvia x superba	Sage	1	1
Sorbus aucuparia	Rowan	11	4
Syringa vulgaris	Lilac	40	3
Tamarix gallica	Tamarisk	1	1
Taxus baccata	Yew	7	2
Ulmus procera	English elm	53	4
Ulmus sp.	Elm	39	2
Viburnum opulus	Guelder rose	1	1
Viburnum tinus	Laurustinus	1	1
Viburnum x rhytidophylloi	Viburnum	1	1

Appendix 5 Animal species associated with *Lucanus cervus*

Species	Common name	Number of records that mentioned the species	Successful predator (S) Unsuccessful predator (U) Possible predator (P) Defence response to (D)
Apis mellifera	Honey bee	2	
Athene noctua	Little owl	1	S
Bat sp.	Bat	3	U (1) and P (2)
Canis familiaris	Domestic dog	5	U (1), P (2)
Corvus corone corone	Crow	11	S (6), P (2) and U (2)
Corvus monedula	Jackdaw	2	S
Erinaceus europaeus	Hedgehog	9	S (2) and P (7)
Falco tinnunculus	Kestrel	1	S
Felis domesticus	Domestic cat	116	S (16), U (89) and P (6)
Formica cunicularia	Ant	1	U
Formica pratensis	Meadow ant	16	S (9), U (4) and P (1)
Garrulus glandarius	Jay	6	S
Homo sapiens	Human	54	S (8 killed by humans), D (21) and perch (23)
Lasius niger	Small black ant	1	
Parus caeruleus	Blue tit	1	U (1)
Parus major	Great tit	1	S (1)
Passer domesticus	House sparrow	20	S (2), U (14) and P (2)
Pica Pica	Magpie	140	S (107), U (13) and P (14)
Picidae sp.	Woodpecker	1	P
Rana temporaria	Common frog	3	U (3)
Rattus norvegicus	Brown rat	1	P
Scirus carolinensis	Grey squirrel	2	S (2)
Sorex araneus	Common shrew	1	P
Strix aluco	Tawny owl	2	S (1) and P (1)
Sturnus vulgaris	Starling	2	S (1) and U (1)
Turdus merula	Blackbird	12	S (8), U (2) and P (2)
Turdus philomelos	Song thrush	2	S (2)
Vespula sp.	Wasp	1	
Vulpes vulpes	Fox	19	S (12), U (1) and P (6)

Appendix 6 Significant results of a multiple regression analysis on soil types

Beetle density is significantly and negatively related to the transformed area of lithomorphic soils and man-made soils. The data was transformed using the Arcsine transformation.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.649	.421	.357	.3347
1	.649	.421	.357	.3347

a Predictors: (Constant), TR_MANS, TR_LITHO

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.466	2	.733	6.542	.007
1	Regression	1.466	2	.733	6.542	.007
	Residual	2.016	18	.112		
	Residual	2.016	18	.112		
	Total	3.482	20			
	Total	3.482	20			

a Predictors: (Constant), TR_LANDS, TR_BEACH
b Dependent Variable: BEET_DEN

Coefficients

Model		Unstandardised Coefficients B	Std. Error	Standardised Coefficients Beta	t	Sig.
1	(Constant)	1.681	.471		3.567	.002
1	(Constant)	1.681	.471		3.567	.002
	TR_LITHO	-5.330	2.140	-.804	-2.490	.023
	TR_LITHO	-5.330	2.140	-.804	-2.490	.023
	TR_MAN	-555.916	157.567	-1.139	3.528	.002
	TR_MAN	-555.916	157.567	-1.139	-3.528	.002

a Dependent Variable: BEET_DEN

Carried out by Bob Smith at the Durrell Institute for Conservation and Ecology at (DICE) at the University of Kent