SCIENTIFIC ASSESSMENT OF THE LANDSCAPE AND SPECIES ECOLOGY CONCERNING THE PRINCETHORPE GREAT WOOD PROJECT

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BY

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INTRODUCTION

This report explores in greater detail the potential responses and effects on organisms and the landscape to the Princethorpe Great Wood Proposal. It is based upon the earlier informal report (Smith, 2004) and provides greater depth of analysis. It is designed to provide a baseline of landscape structure and some modelling of species dynamics.

The report is separated in to three sections, the first deals with landscape ecology issues whilst the second two are more species specific and focus on the Hazel Dormouse (*Muscardinus avellanarius*) and target butterfly species.

PART 1 - LANDSCAPE ANALYSIS

The general landscape of the area under study is primarily that of patches of woodland embedded in an agricultural matrix. Connectivity on the face of it is particularly high due to a large number of hedgerows, however this connectivity is highly localised due to severance impacts caused by a number of major highways that further separate the woodlands and farmland in to essentially the state of islands therefore Island Biogeography models can be used to explore their nature.

Figure 1 shows the landscape context and the distribution of the Woodlands in question.

1.1 Methodology

The primary data sources for the analyses were habitat and land use maps gained from the Habitat Biodiversity Audit. These are the most up to date habitat maps available were unfortunately 6 years old. A lot of landscape change can occur in that time, especially concerning hedgerow connections, however as the only data available at the time and with the assumption that the actual structure of the landscape (Size, shape and position of Roads, Woods and Houses) has remained relatively consistent, it was deemed suitable upon which to base simple assumptions.

The maps provided a base from which to describe the landscape in a quantitative way. This quantitative approach utilised a range of landscape metrics adapted from (Hinsley *et al*, 1994). The metrics used in the study can be seen in Figure 2.

Lacking any GIS the target region was analysed in a very basic way. The base maps were simply digitised on a scale of 1 square to 100m such digitisation is often part of

Figure 1 Background Landscape Map

The map illustrates the core patches in the network and the key severance features such as the main roads that create the fragmented landscape shown.

many metapopulation and percolation theory models and renders the landscape to a level upon which measures can be quickly made and altered to assess changes in impact. This digitised map can be seen in Figure 3, the map plots woodland, hedgerows as well as roads. The matrix could be considered essentially hostile to both sets of core species and so was considered relatively homogenous with no distinction between arable and pasture. This digital landscape is used heavily in the species specific analyses used in part 2 where dormouse dispersal patterns are explored.
The simplified map allows a quick and easy analysis of the landscape and provides data that can be used to compare between the woods.
The Metrics listed in Figure 4 were calculated for each wood. In some cases continuous woodland such as Weston and Waverley woods were considered as one Woodland in landscape terms.

Figure 2 Landscape Metrics(Hinsley *et al*, 1994).

Metric	**Measurement**
Type	N/A
Management	N/A
Area	Hectare
Area*	Squares
Length*	Squares
Width*	Squares
Perimeter	Kilometres
Perimeter*	Squares
Accessibility	Arbitrary Units
Elongation	Arbitrary Units
Compactness	Arbitrary Units
Patch Isolation	Arbitrary Units
Distance to Nearest Neighbour*	Squares
Number of Hedges connected to Wood	Percentage
Perimeter of Wood adjoining Woodland	Percentage
Perimeter of Woodland adjoining Fields	Percentage
Study Butterfly Species Present	Names
Presence/Absence of Dormice	Presence/Absence
Core Vegetation	Core Species in Canopy, Shrub and Field Layer

* Measurement made from digital landscape

** All formulae described in the appendix

1.2 Landscape Analysis

The network of woodlands is a dominant feature in the landscape in this area. The patches are randomly distributed; this distribution is supported by the calculation of nearest neighbour or Patch Dispersion. The woodland network yields a value of 0.74, values below 1 are considered to irregularly distributed, such a distribution supports the view that the woods are of a natural origin. Clumped or regular distributions tend to suggest man made or artificial landscape features.

Floristically the woods are species rich as a whole with a mean number of 11 canopy or shrub layer species. The least diverse is Weston Wood and the most Ryton Wood. This is a reflection of their respective management and environmental conditions. Ryton of managed by Warwickshire Wildlife Trust as a reserve whilst Weston is

Figure 4 Woodland Metric Analyses

	Bull and Butcher	The Coppice	North Cubbington	South Cubbington	Princethorpe	Weston and Waverly	Dukes	Bubbenhall	Wappenbury	Ryton
Area in Ha	20	7	18	19	37	128	-	25	-	105
Area in Squares	28	11	21	20	43	125	22	27	87	106
Length	6	3	5	7	8	16	4	6	12	11
Width	7	4	5	3	8	10	5	6	9	16
Perimeter in Metres	30	20	20	28	36	68	14	24	52	66
Perimeter (Km)	3	2	2	2.8	3.6	6.8	1.4	2.4	5.2	6.6
Accessibility	N/A	N/A	16.9	N/A	N/A	2.8	9.9	43.7	8.9	4.3
Elongation	1.17	1.33	1	0.4	1	0.62	1.25	1	0.75	1.45
Compactness	0.62	0.58	0.81	0.57	0.64	0.58	0.60	0.76	0.64	0.55
Patch Isolation	30.2	30.3	32.9	35.1	22.9	28.2	22.1	21.8	20.7	23.4
Distance to Nearest Neighbour in Squares	13	14	1	1	8.5	19	8.5	11	15	14
No. hedges connected to wood	6	6	5	6	9	10	7	7	13	11
Perimeter adjoining Woodland (%)	0	0	0	0	0	0	7	0	2	0
Perimeter adjoining fields (%)	100	100	80	72	73	60	50	58	82	100

commercially managed like several of the woods. Commercial Forestry management may seem a negative aspect in the landscape but does in fact contribute a wider diversity of habitats and niches across the whole network.

The woods most at risk on the landscape scale are Bull and Butcher and The Coppice, not only are these woods small but they are also highly isolated. Their isolation values are approximately 30, 4 points higher than the mean and higher only than North and South Cubbington Woods. These woods however despite being at the extremities of the target area are better connected to other woodlands and with much closer nearest neighbour values. The most secure woods in a connectivity sense are Wappenbury and Weston. Both of these are of a reasonable size and well connected to at least 2 other woodlands. Wappenbury Wood is centrally placed and can be considered a viable hub in the network

The number of roads both major and minor (See Figure 1 and 3) slice up the wooded landscape in to discrete portions. These large islands can contain a number of patches within them but are kept distinctly separated from other sections of the network. Historically of course the whole area would have been contiguous woodland as part of the Forest of Arden such a structure is now only remnant.

The woodlands are all managed as is the surrounding matrix. Such management over the years has created the shape of the woodlands we see today. The measure of elongation explores the orientation and basic shape of a patch in numerical terms. These values give an insight in to possible fragmentation risks. Woods with an elongation value of 1 are roughly circular; such woods if of sufficient size have a more stable nature than elongated ones. Values lower than 1 are vertically elongated and higher than 1 horizontally elongated. Long woods tend to have a smaller proportion of core habitat compared to edge. Edges or ecotones are important in landscape ecology. Ecotones act to stabilise the microclimate of the wood, buffering and regulating the interior from radiation, wind and water flux (Saunder *et al,* 1991). The ecotones vegetation is often a gradation of the interior to the matrix and is often composed of generalist species.
The ecotones effect can be particularly seen in coniferous woods. Conifer plantations without an ecotone will suffer greater stress from high winds which are buffered by broadleaved vegetation in woods with a wider ecotone. Narrow woods are also more susceptible to fragmentation by way of barrier creation. Only a short distance needs to be created for a wood to be divided in two.

When analysing the accessibility or connectivity of the Woods it can be seen that not all woods in the network are actually connected, Bull and Butcher, The Coppice, Princethorpe and South Cubbington are all isolated and are not connected to any other wood by way of hedgerow or woodland, therefore they have no accessibility. The accessibility values in Figure 4 further illustrate the importance of Weston/Waverly, Ryton and Wappenbury these three woods have a low figure. The value is a representation of inter-patch distances and destination patch size, the larger the value the less connected a wood can be considered. Connectivity is therefore a weighted average of patch isolation and can help highlight the ability of organisms to access a habitat and therefore the probability that a metapopulation persists. In other words any links that do exist from that wood are likely to be long and connect to small patches. The connectivity values can then be further analysed to create a network connectivity value and further to produce a value termed by Hanski (1999) as Neighbourhood Habitat Area. The values in this case yield a network connectivity value of 86.75 and a Neighbourhood Habitat Area of 85.14. In general terms the higher a value the less fragmented a system is. These figures mean very little on their own and are used mainly to gauge differences between two outcomes, for instance if all the hedgerows were improved and distances between the Ryton and Wappenbury and Weston/Waverly were shortened to minimum distances these values would change to 153 for network connectivity and 112 for Neighbourhood Habitat Area whilst the removal of several key hedges at the same interfaces thereby increasing distances renders values of 65 and 81 respectively. In this way comparisons can be made between alternatives.

1.3 Individual Wood Character Assessments

North Cubbington Wood

- Broadleaved Woodland with some Coniferous Plantation
- Canopy: Oak, Ash, Silver Birch, Beech, Scots Pine
- Shrub: Hazel, Broom, Holly
- Butterflies present: Silver Washed Fritillary
- No Dormice Recorded.

South Cubbington Wood

- Broadleaved Semi-natural woodland including a patch of NVC W8b Acer-Dogs Mercury Woodland.
- Canopy: Oak, Ash, Elder, Field Maple
- Shrub: Hawthorn, Hazel, Holly, Dog Rose, Honeysuckle
- Field: Herb Robert, Red Campion, Bramble, Lords and Ladies, Greater Stitchwort, Dogs Mercury, Ground Ivy.
- Butterflies present: Silver Washed Fritillary
- No Dormice Recorded

Princethorpe Wood

- Ancient Broadleaved Woodland
- Canopy: Oak, Ash, Willow, Silver Birch, Aspen, Field Maple, Beech, Sweet Chestnut, Wytch Elm.
- Shrub: Hazel, Dog Rose
- Field: Bramble, Ragged Robin, Primrose, Common Spotted Orchid, Dogs Mercury, Wood Anemone, Wood Vetch, Wild Strawberry, Sannicle.
- Butterflies present:
- No Dormice Recorded.

Weston/Waverley Woods

- Weston Wood is Broadleaved Semi-natural woodland and Waverley Mixed and Pine Plantation.
- Canopy: Oak, Ash, Silver Birch, Elder, Poplar, Aspen, Beech, Scots Pine, Larch, Sycamore.
- Shrub: Hazel, Broom, Honeysuckle
- Field: Foxglove, Common Catsear, Thyme leaved Speedwell, Birds-foot-trefoil, Greater Stitchwort, Ragged Robin, Nettle, Red Clover, Black Knapweed, Selfheal, Violet sp. Marsh Thistle, Wood Sage, Black Horehound, Yellow Rattle, Scarlet Pimpernel, Vetch sp. Barren Strawberry.
- Butterflies present: White Admiral
- Record of 65 dormice in Weston Wood in 1995.

Bubbenhall Wood

- Semi-natural Broadleaved Woodland with Conifer Plantation.
- Canopy: Oak, Ash, Silver Birch, Elder, Aspen, Wild Service Tree, Scots Pine, Norway Spruce, Goat Willow, Western Red Cedar, Field Maple, Wytch Elm, English Elm.
- Shrub: Hawthorn, Crab Apple, Hazel, Honeysuckle, Holly.
- Field: Bluebell, Red Campion, Foxglove, Yellow Archangel, Wood Sorrel, Western Hemlock, Wood Anemone, Bramble, Primrose, Bugle, Common Dog Violet, Greater Stitchwort, Enchanters Nightshade, Barren Strawberry.
- Butterflies present:
- 60 dormice released in 1998. 1 Dormouse recorded in 2004

Wappenbury Wood

- Broadleaved Semi-natural Woodland.
- Canopy: Oak, Silver Birch, Elm, Goat Willow, Aspen, Cedar,
- Shrub: Hazel, Dog Rose, Blackthorn, Hawthorn, Holly, Privet.
- Field: Smooth Tare, Creeping Cinquefoil, Common Mouse-ear, Rosebay Willowherb, Hedge Bedstraw, Lesser Spearwort, Common Cats-ear, Toad Flax, Bramble, Meadowsweet, St Johns Wort, Birds-foot-Trefoil, Skullcap, Betony, Barren Strawberry, Lesser Stitchwort, Forget-me-not, Pignut, Greater Stitchwort, Wood Anemone, Silverweed, Selfheal, Ragwort, Wild Angelica, Hedge Parsley, Wood Sorrel, Bluebell, Tormentil, Creeping Thistle, Common Spotted Orchid, Yellow Rattle, Foxglove, Bugle, Filed Rose, Perennial Sow Thistle, Common Valerian, Ragged Robin, Enchanters Nightshade.
- Butterlies present: Essex Skipper, Grizzled Skipper, Wall Brown, White Admiral, Silver Washed Fritillary
- No Dormice Recorded.

Ryton Wood

- Broadleaved Semi- natural Woodland.
- A Warwickshire Wildlife Trust Reserve with Copping management.
- Canopy: Oak, Ash, Willow, Silver Birch, Small Leaf Lime, Elder, Poplar, Sycamore.
- Shrub: Hazel, Honeysuckle, Dog Rose, Hawthorn, Guilder Rosem Alder, Blackthorn.
- Field: Common Figwort, Field Mouse-ear, Greater Birds-foot-trefoil, Creeping Thistle, Burdock, Lesser Stitchwort, Hogweed, Common Cats-ear, Teasel, Yellow Pimpernel, Wood Sorrel, Field Forget-me-not, Hedge Woundwort, Marsh Willowherb, Meadowsweet, Thyme leaved Sandwort, Herb Robert, Hoary Willowherb, Bracken, Bramble, Marsh Thistle, Ragged Robin, Tormentil, Creeping Buttercup, Large Trefoil, Dock, Selfheal, Common Spotted Orchid, Coltsfoot, Wild Vetch, Bush Vetch, Meadow Vetchling, Rosebay Willowherb, Enchanters Nightshade, Broad leaved Helleborine, Violet sp. Campion sp. Silverweed, Greater Stitchwort, Bluebell.
- Butterflies present: Dingy Skipper, Essex Skipper, Grizzled Skipper, Green Hairstreak, Marbled White, Pearl Bordered Fritillary, Small Pearl Bordered

Fritillary, Small Heath, Wall Brown, White Admiral, Wood White, Silver Washed Fritillary

- No Dormice Recorded.

The Coppice

- Broadleaved Semi-natural woodland with some Plantation.
- Butterflies present: Small Pearl Bordered Fritillary.
- No Dormice Recorded.

1.4 Landscape Recommendations

The key improvements on the landscape scale involve improving the connectivity of the woods and buffering small woods from edge effects. Every wood would benefit from internal management and specifically habitat enrichment.

The Coppice, Bull and Butcher and South Cubbington, all isolated woods, require buffering and interior improvement. Where there is agreement enlargement of these woods would be desirable to increase viable population areas and decrease edge effects.

There are two main interfaces that would yield a large return on both connectivity and fragmentation issues and those are the ones between Ryton and Wappenbury and Weston and North Cubbington. In both cases only a short distance of matrix separates the patches. Weston could easily be connected by woodland whilst the Ryton interface could be marginally improved by stepping stones if contiguous woodland is unachievable.

The landscape has a large number of hedgerows but year upon year they are lost or fall in to poor quality. Hedgerows are important landscape elements and especially where species dispersals are concerned need to be complete with few or no breaks therefore major improvements of hedges and field margins may provide a good return.

These measures build upon and reiterate the statements made in the earlier August report.

PART 2 - CORE SPECIES ANALYSIS

THE HAZEL DORMOUSE

The Hazel Dormouse, *Muscardinus avellanarius,* is a native to British deciduous woodland. It is a nationally scarce species and is Schedule 5 listed on the Wildlife and Countryside Act 1981 and Schedule 2 listed on the Conservation (Natural Habitats etc) Regulations 1994 (Bright *et al*, 1996 and Morris,2004).
The Dormouse is largely arboreal and diurnal in behaviour. It weighs between 10-30g and is 50mm in length with a 50mm tail.
In terms of distribution Dormice seem to aggregate more in the south of the country, perhaps a reflection of the effect of temperature on the dormice life cycle, although successful introductions in Wales and other counties has broadened its range (Morris, 2004). In Warwickshire dormouse communities are rather sporadic both in spatial and temporal terms despite several suitable sites being available.

The Dormouse life cycle is heavily dependant upon its winter hibernation. Dormice usually hibernate between November and March although this isn't always a complete hibernation and can be interspersed with short periods of activity (Morris, 2004). Hazel Dormice as the name implies feed on hazel nuts; however its diet is broader than this despite being a selective feeder. In spring it will eat fresh flower stamens from Hawthorn, Honeysuckle and Bramble. Later, as plants begin to fruit the diet moves to Blackberries, Yew berries, Beech nuts, Hazel nuts and Ash keys. Dormice will also supplement their diet with some insects especially Aphids (Morris, 2004). Both sexes of dormice hold territories although only the males will defend them vigorously. Territories are established in habitats containing available food sources and the important physical structure of being contiguously wooded, with multiple tree height connections. This makes Dormice highly dependant on management practices such as coppicing. The Dormouse's unique habitat requirements and feeding habits mean that it can become incredibly sensitive to change on any scale. In addition the slow lifestyle with periods of torpor and long hibernation means that they can become very sensitive to changes in temperature and in particular long winters, that stretch the amount fat reserves used up.

2.2 Dormouse Life Table Analysis

Using recent literature and research it is possible to plot the life history of the dormouse. Life Table analysis is a technique that explores a species ability to survive over time. This survivability can be helpful in assessing populations and predicting population growth.

Life tables tabulate mortality patterns associated with age by factoring adult and infant mortality with annual fecundity. In this study very basic information was used to create a life table for the dormouse. The table uses simple life history parameters as input values and in the approach taken assumes that adult mortality is independent of age. Hopefully further research into dormouse ecology and age structures will improve the accuracy of this measure. Figure 5 illustrates the parameters used to construct the table.

Figure 5 Dormouse Life History Traits (Bright *et al*, 1996; MacDonald and Rushton, 2003 and Morris, 2004)

Mean Litter Size	*3-4 (1-2 surviving to next generation)*
Life Span	*5 years*
Adult Mortality	*0.3*
Juvenile Mortality (1st Year)	*0.5*
Dispersal Distance	*60-80m (up to 150m in hedgerows)*
Home range	*0.1-1.0 ha*
Population Density	*3-5pha*

Using the Life History parameters and detailed knowledge of the number of dormice and sex of dormice in a wood it is possible to predict and model population growth. By factoring in population density data it is therefore possible to predict when a woodland will change from a ‘sink’ population (one that is open to receiving new individuals either by birth of immigration) to a ‘source’ population, where maximum population density is reached and the woodland becomes closed to immigrants and new births create immigrants to other woods.

2.3 Life Table Results and Findings

The completed life table can be seen in Figure 6. The table tabulates the survival rates at each age interval this is the values given as l_x, the Standardised Survivorship. This value standardises the basic number from the Survivorship Schedule (N_x) and gives the probability an individual at age x will reach age x+1. The Fecundity schedule illustrates the contribution of daughters to each generation and is a measure of the species capability to reproduce (Krebs, 1994). M_x at age 0 is zero as dormice do not become sexually mature until they are a year old (Bright *et al*, 1996 and Morris, 2004)

Figure 6 Life Table for the Hazel Dormouse

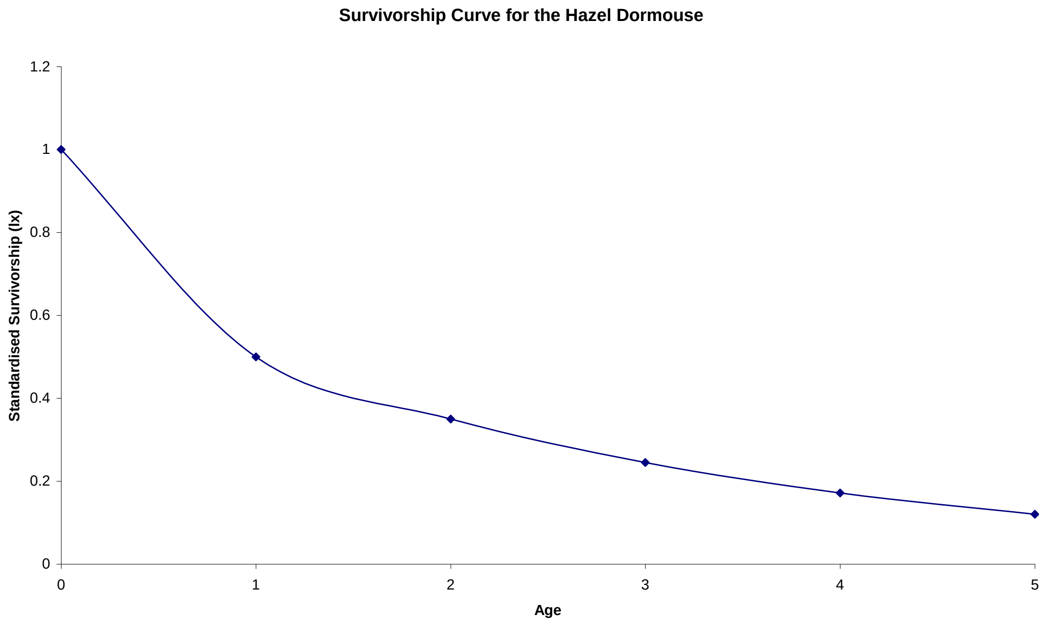
Age (x)	Survivorship Schedule Nx	Standardised Survivorship lx	Fecundity Schedule Mx
0	3.00	1.00	0.00
1	1.50	0.50	2.25
2	1.05	0.35	1.58
3	0.74	0.25	1.10
4	0.52	0.17	0.77
5	0.36	0.12	0.54

The values derived from the life table can be further analysed to calculate Gross Reproductive and Net Reproductive Rates, these rates give an estimate of the state of the population. The Net Reproductive Rate (R_O) derived in this analysis is 2.14 any value above 1 illustrates an increasing population and therefore indicates a population that is doubling where each female replaces herself when mortality is fixed.
Figure 7 shows what is termed the Survivorship Curve for the Dormouse and is created by plotting age (x) against standardised survivorship (l_x). The curve shown in the graph represents a Type III curve (Krebs, 1994). This form of curve describes a population that has a high juvenile mortality that stabilises over time. It illustrates that few individuals will reach the age of 3 and that there is only a 12% probability that an individual will reach 5 years of age.

2.4 Population Growth Results and Analysis

The life table analysis highlights how fragile a dormouse population can be. It shows that survivorship declines rapidly with age (Figure 7). This helps focus attention upon 1 and 2 year olds the need to secure young populations is vital to population survival. Using the same life history parameters and making simple and sensible assumptions it is possible to model population change over time. This can then be compared with actual population records.

Figure 7 Graph illustrating the Survivorship Curve for the Hazel Dormouse.



The model takes into account the difference in mortality between juveniles and adults and is density dependant.

The model makes the following assumptions:

1. That all the area of the wood inputted is of viable habitable quality.
2. That mortality factors (0.3 for Adults, 0.5 for Juveniles) represent all removals from the population and therefore includes natural death, death from predation, disease or parasitism and lastly emigration/dispersal.
3. Mortality is density dependant to factor in the effect a large population has on predation rates, food availability and nest site availability.
4. Birth factors are based upon a random litter size (Between 0 and 7) that is assumed to be constant across the population, i.e. all females in a year have the same number of young per litter. This is designed to reflect habitat fluctuations such as a poor crop of food or a cold winter which would alter litter sizes in all individuals.
5. The ratio of male to female births is assumed to be random.

The model follows the population through 50 years and is designed to see at which point a population can be stabilised. Of course any population is highly dependant upon random effects, several hard winters can dramatically cause populations to crash (Morris, 2004) and it has been illustrated that once a dormouse population falls below 20 individuals there as little chance of long term population survival. This is particularly worrying when taken in light of results being recorded in Bubbenhall and

Weston Woods. In Bubbenhall's case a release of 60 in 1998 within 5 years had crashed to only a single individual (Figure 8).

Figure 8 Predicted Population Trends from basic Life History Analysis

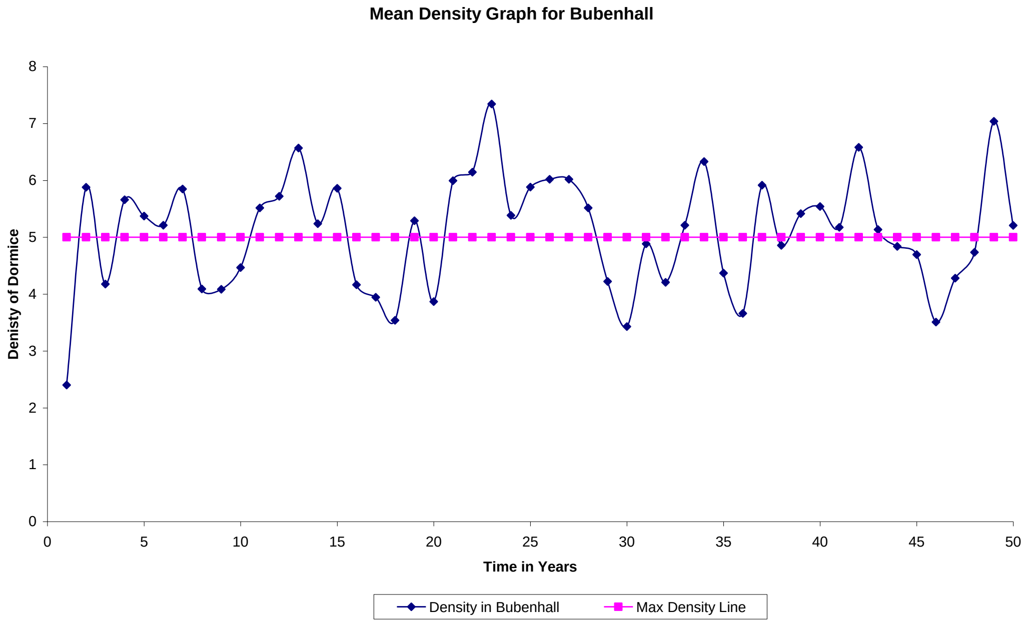
	Bubbenhall Wood		**Weston Wood**	
Year	**Population Size**	**Source or Sink Population**	**Population Size**	**Source or Sink Population**
1995	-	-	45 (45)	Sink
1996	-	-	91	Sink
1997	-	-	94	Sink
1998	60 (60)	Sink	122	Source
1999	138	Source	119	Source
2000	123 (8)	Sink	71	Sink
2001	113 (32)	Sink	108	Source
2002	103 (3)	Sink	116	Source
2003	150 (1)	Source	123	Source
2004	147	Source	95	Sink
2005	155	Source	109	Source
2006	137	Source	111	Source
2007	100	Sink	83	Sink

*( ) Actual Populations

The data in figure 8 and the graphs in figure 9 illustrate the wide differences between observed and predicted population values. In the case of Bubbenhall it is clear that the actual record of dormice is far lower than what might be assumed by the model. Therefore here it seems prudent to explore the limitations of the methodologies. The population model in a very simplistic one and can only be used as a rough guideline, a tool to assess general rather than specific trends.

The other problem comes from the sourcing of the actual data and the difficulties in assessing population size. It may well be that there are more dormice present than recorded however the difficulties in recording them make populations hard to estimate. The easiest method is to record numbers hibernating in artificial nest boxes. This however doesn't account for those that found natural nest sites. The Great Nut Hunt in 1993 (Morris, 2004) provided valuable distribution data on the Dormouse but

Figure 9 Graphs illustrating predicted population and density trends.



used the identification of feeding evidence to identify presence and absence in a wood. This of course does not give a representation of the population size and there is no sensible way to predict numbers from a ratio of nuts eaten.

The ideal methodology is mark-capture-release such as Lincolns Index (Krebs, 1994). This technique is highly restricted to most groups or organisations in that a licence is required to handle dormice.

These limitations in data collection have a knock on effect on effectively monitoring populations. A release may be made but any potentially dangerous drops in population may not be registered until it is too late to buffer.

Just looking at the population model (There are copies for both woods in the Appendix) it is clear that the dormouse is highly fragile, the data used in Figure 9 show an average of 10 trials. In that average there are incidences of periods of low birth rate that cause the population to crash to below the terminal survivability limit of 20 dormice. Given more time this analysis could be made more robust with further trials and greater examination, but for now it serves to illustrate that life history parameters have a profound effect upon the stability of dormouse populations.

It is interesting to note that the evidence from Figures 8 and 9 feed into the dispersal analysis in the next section. It can be highlighted that for Bubbenhall the key drops in population often occur after a large rise in the number of potential emigrants. The density graph shows that the population changes from a Sink to a Source 7 times in a 50 year period resulting in a total of 730 emigrants ready to disperse. These individuals are available to disperse to new woodlands and habitats; however in the case of Bubbenhall these dormice are not removed, they have no links through which to disperse. Therefore the density dependence increases the rate of mortality. As the pressures of predation, food availability and disease increase to a critical point a major crash in the population is caused. If such a crash coincided with a number of long hard winters or a major reduction in viable habitat then it is easy to see a population going locally extinct.

So why then are the predicted model and the actual so disparate and what can account for such a major decline in numbers? The answer lies in the fact that there are so many factors at play in ecological modelling, so many that a model can never hope to fully mirror an actual population in all cases.
The assumption that the whole wood is viable habitat (Although using the HBA Phase 1 Map the area assigned to Weston was only that taken by broadleaved woodland i.e. 20ha) means that naturally a greater abundance is predicted than otherwise would be seen, it assumes a maximal. It would be beneficial to run the model again with more

realistic appraisal of the actual quantity of available habitat but as the HBA maps from 1998 were the most recent, it was those that were used in the calculations.

Aside from habitat area there is the question of other community effects. Predation is not a major pressure on dormice (Morris, 2004). Their natural predators like them are nocturnal and are mainly Tawny Owls, although it is recorded that dormice only make up a small part of an owls diet, though this could be more due to rarity than preference. Likewise the occasional predation by Weasels of nest sites presents only a small pressure unless their own populations are particularly high.
Mortality does tend to be more weather dependant. Weather after all effects hibernation survival and the abundance of fruit and flowers therefore harsh winters and/or poor springs in 1999 and 2001 could account for the drops seen.
The real threats come from inter-specific competition. Dormice share their food resources with the Grey Squirrel; a boom in their population could cause a decline in dormice in sensitive periods. Grey Squirrels are much more generalist feeders, hence their ability to out compete the Red Squirrel, and are more able to buffer themselves against environmental change. During the Great Nut Hunt nearly 70% of the nuts that people thought were eaten by dormice were in fact eaten by Grey Squirrel (Morris, 2004) further highlighting this particular niche overlap.
Deer are another major problem. Grazing by Red, Roe, Fallow and Muntjac can effect the distribution of vital shrubs and the implied connectivity within a wood for dormice. Grazing can have such an effect as to prevent hazel regeneration completely. Often damage by deer can kill young saplings removing not only habitat structure but sources of food (Morris, 2004).
The last factor to consider is the availability of nests. Suitable sites can often be competed for by birds and this is often why dormouse management involves the provision of nest boxes. Not only does this provide a secure nest site but also provides a tool for monitoring.

2.5 Predicting Dormouse Dispersal Patterns

The dormouse has a well researched range of dispersal parameters and habitat requirements; this makes it possible to model in a very general way the manner in which it will respond to particular management styles or habitat changes. The model used in this study is based upon Spatially Realistic Metapopulation Theory (SMT)

(Hanski, 1999). SMT combines heterogeneous patch occupancy models where patches have different extinction and colonisation probabilities with assumptions as to how the landscape affects these probabilities. In this case extinction and colonisation probabilities are unknown so instead a homogenous spatial patch occupancy model was used. This assumes a network of patches which are either occupied of empty. The model makes simple assumptions based on life history information.

Methodology

Using the digitised landscape prepared for the landscape analysis a simple set of rules to mimic a standardised range of behaviours was written. Each square was assigned a value according to its suitability to habitation. For example Woodland is set to equal 1; therefore there is always a 100% chance that a dormouse would move in to that square. Open fields and roads were set to 0 whilst hedgerows were split up into types. Hedgerows with trees were deemed to be more useful than simple side cut monoculture hawthorn ones (Bright and MacPherson, 2002) to reflect this Hedges with Trees had a suitability value of 0.95 and the others a value of 0.75. These values represent how likely a dispersing dormouse is likely to enter such an area. It draws together the fact that dormice require heavily vegetated habitats with a large number of woody species and enough interconnections between plants to be able to safely travel without coming down to the ground (Bright *et al*, 1996, Morris, 2004) It was assumed that a Dormouse would never enter a square that was totally unsuitable, such as open fields or a road.

Using the rule that a dormouse could travel in any direction (Up, down, left, right and all diagonals) it was therefore possible to start an imaginary dormouse in a particular wood and then chart its movement across the landscape. To ensure the data was more rigorous the procedure was repeated in all cases for 500 dormice each individual was allowed to move up to 50 squares (which is the equivalent of 5km).

The maximum distance is far in excess of the mean travel distance recorded in the literature which is predicted at 70m in woodland and up to 120m in hedgerows (Bright *et al*, 1996, Morris, 2004), this however doesn't state whether this was yearly dispersal distances or daily. By giving the dormouse a maximum of 50 moves it covers the smaller ranges of movement up to what could be considered an unrealistic dispersal distance. In this way relating one square of 100m to being equivalent to one dispersal event (i.e. An amalgam of the 70m and 120m ranges) it is possible to derive a broad idea of how many times a dormouse would need to make a dispersal event in order to reach a new wood.

A successful dispersal was any sequence of moves that took the dormouse from its start point (the centre of the designated wood) to any other wood or in the case where varying width analysis was made, to the destination one. This methodology relies upon and is restricted by a number of assumptions:

1. It is assumed that a dormouse has no increased risk of predation during dispersal than in its home-range.
2. It is assumed that if a dormouse's selected route is into unsuitable habitat it will remain where it is and in the next turn make another choice.
3. The dormouse dispersal is entirely random and it may travel in any direction in any given step.

2.6 Dispersal results

With the existing woodland and hedgerow network it is possible to work out current probabilities of a Dormouse being able to move from one wood to another. Given the degree of fragmentation from roads there are only a handful of possible routes available, figure 10 shows the success rate of such dispersals and the mean number of moves necessary to make such a journey.

Figure 10 Table of base line dispersal potentials

Possible Woodland Movement	Distance between Woods in Squares	Distance between Woods in Metres	Percentage of Successful Dispersals	Mean number of Moves
Ryton to Wappenbury	7	700	4.8	31.7
Ryton to Bubbenhall	12	1200	0	0
Ryton to Dukes	16	1600	0.2	55
Wappenbury to Ryton	6	600	0.4	42
Wappenbury to Bubbenhall	7	700	0.6	41
Wappenbury to Dukes	4	400	22	26
Bubbenhall to Ryton	6	600	0	0
Bubbenhall to Wappenbury	5	500	12.2	27.7
Bubbenhall to Dukes	14	1400	0	0
Dukes to Ryton	10	1000	0	0
Dukes to Wappenbury	3	300	23	25.5
Dukes to Bubbenhall	14	1400	0	0
Weston/Waverly to N.Cubbington	8	800	2.8	36
N. Cubbington to Weston/Waverley	3	300	6.4	28

Figure11 The Relationship between the distance between patches and the success of dispersal events.

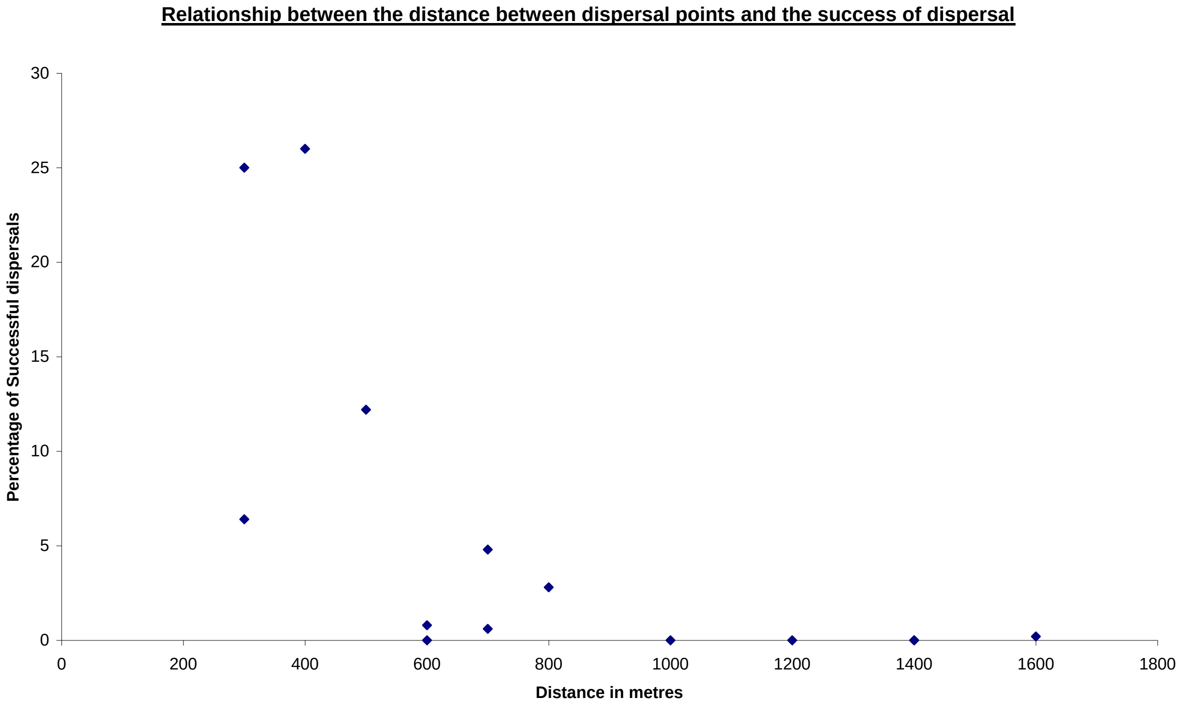
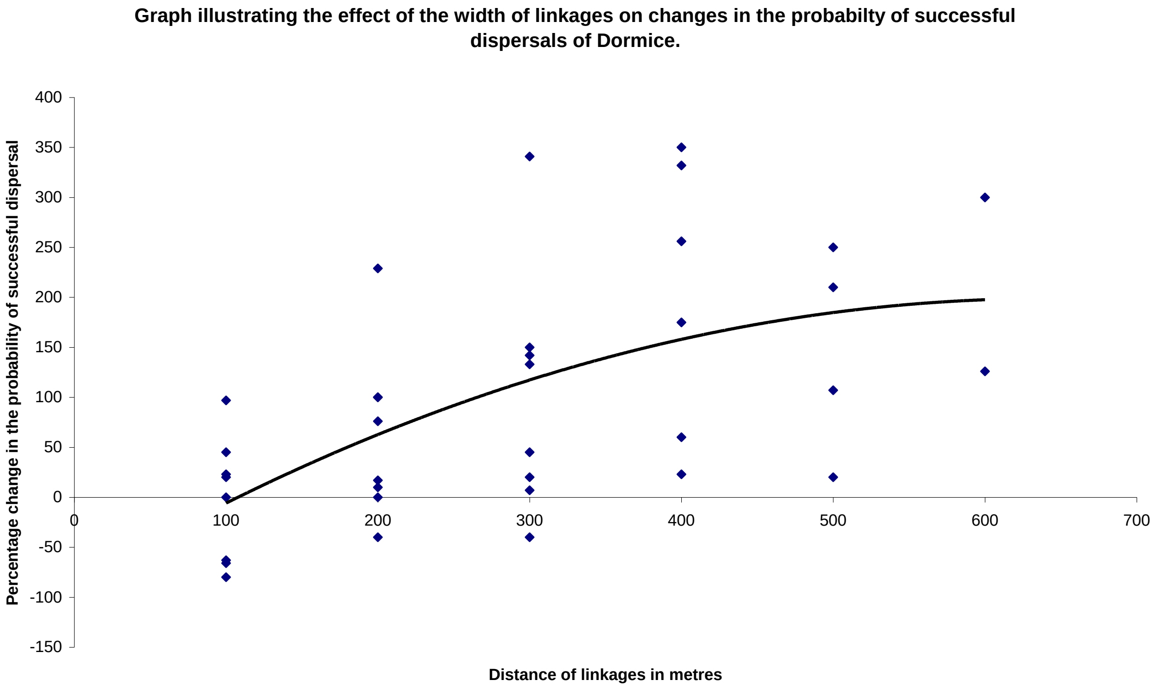


Figure 11 illustrates clearly the relationship between dispersal success and distance. Successful dispersal rapidly decreases with increasing distance; therefore any measures introduced that decrease this distance in a contiguous way would be highly beneficial in maintaining dormouse populations over time by minimising the isolation constrictions existing in metapopulations.

2.7 Examination of the effect on dispersal of linking Woodlands with new strips of Woodland

It is clear from the analysis that on the whole the wider the strip connecting two woods the greater the improvement there is to dispersal. Connectivity between North Cubbington and Weston/Waverly is considerably improved, in fact only a connection of 200m width would triple dispersal potentials to North Cubbington. As Weston/Waverly is a site known to have had dormice in the past (1995) such a move would enable North Cubbington to become a satellite population to a main reservoir

Figure 12 Change in success of dispersal against width of linkage.



population in Weston/Waverly, furthermore if habitat improvements were made to South Cubbington and conduits (i.e. Dormice ropeways erected over the road) there is potential for increasing the quantity of habitat available for colonisation.

The linkage between Dukes and Wappenbury Woods is already very close and so doesn't benefit significantly from extra contiguous wooded contact. Instead the linkage between Ryton and Wappenbury holds a greater return with strips increasing dispersal potentials significantly (Appendix). Unfortunately neither Ryton nor Wappenbury currently hold viable populations of dormice. Previous reintroductions were made to Bubbenhall Wood (1998) and whilst this wood provides a good habitat it is somewhat isolated with a limited scope for improving connectivity, in fact even a 500m strip of new woodland only yields a small and inconclusive positive effect on modelled dispersal patterns (Appendix).

2.8 RECOMMENDATIONS:

- Monitor and/or control Deer in target woodlands to minimise damage. Erect fences to protect regenerating Coppice.

- Provide an increased number of nest boxes and link to a long term monitoring scheme to assess population growth and change.
- Coppicing maintain coppicing of the woods and ensure coppice rotation in contiguous with existing patches.
- Increase the amount of viable habitat within woodlands by encouraging the growth of food plants and shrubs.
- Increase the links between viable patches within a wood to enable movement to new feeding and nesting area.
- Improve network wide connectivity to allow dispersal to take place and provide an avenue for possible rescue effects. Introduce new woodland with connections of between 300-400m in width.
- Careful reintroductions of populations to suitable areas or to bolster existing ones.

PART 3 CORE BUTTERFLY ANALYSIS

3.1 INTRODUCTION

The analysis of a butterflies response to any potential management is complicated by their specific life histories and often non-overlapping niches; therefore any management maybe beneficial to some species and not others, by analysing each requirement it maybe possible to optimise any strategy that may wish to be employed. The woods in the project all have a broad diversity of butterfly species, this like with most invertebrate species is due to the very small niche requirements on a landscape scale and is indicative of the number of habitats and micro-habitats in the area. The woods also support some of the counties rarest species. In total the woodlands support 33 species, rather than analyse all 33 the range of species studied was reduced on a basis or county rarity. Using data from Butterfly Conservation (Warmington and Vickery, 2003) any species occurring in less than 25% of 1km squares in the county were considered rare enough for study. This segregation reduced the number of target species to 12 and they can be seen in figure 13. Of these twelve, five can be considered extremely rare in the context of Warwickshire, the Wood White, Pearl-Bordered Fritillary, Small Pearl-bordered Fritillary and the Green Hairstreak. Population and distribution data was sought from the local branch of Butterfly Conservation. The data received whilst highly valuable was in some places

Figure 13 Life History information of Target Butterfly Species (Butterfly Conservation,2004).

Larval/Adult Food plants and Eggplants	Dingy Skipper	Essex Skipper	Grizzled Skipper	Green Hairstreak	Marbled White	Pearl-Bordered Fritillary	Small Pearl-Bordered Fritillary	Silver-washed Fritillary	Small Heath	Wall Brown	White Admiral	Wood White
Agrimony			*									
Creeping Cinquefoil			*									
Strawberry sp.			*									
Tormentil			*									
Birds Foot Trefoils	*			*			*					*
Bugle						*	*					
Buttercup sp.							*					
Ragged Robin							*					
Thistle sp.							*					
Vetchlings												*
Vetches	*											*
Violet sp.						*		*				
Grass sp.		*		*	*				*	*		
Honeysuckle											*	
Rock Rose sp.				*								
Broom				*								
Dogwood				*								
Buckthorn				*								
Rarity Index (% Occupancy of Squares in County)	5	9	6	2	24	0	0	1	29	12	5	0.4
Measure of dispersal distances	A Few Km		1.5 Km		7.3 Km							

inconsistent and gives for some species a sketchy picture of their distribution in the target area. In some cases the most recent information was from 1996. Ryton Wood had the highest calibre of data with consistent records running from 1995 up until 2003.

3.2 Discussion of Butterfly Analysis

Butterfly dispersal is often bi-modal, either long distances or very short/not at all (Hanski, 1999). These strategies create 'open' and 'closed populations. Currently the majority of butterflies in the Princethorpe area exist in discrete metapopulations ('closed' populations), that is to say colonies exist in isolated patches with little or no dispersal between them. This makes populations highly susceptible to any fluctuation in micro-climate or habitat changes. Where emigration is available from other populations a stressed colony can be supported in a form of rescue effect.

Lifetime emigration rates of specialist butterflies from typical patches range from 10-30% and though most migrants may travel only a few 100m some can reach patches several kilometres from their natal patch (Hanski and Gagiotti, 2004).

Work by J. Paul Chardon *et al* (2003) has used GIS systems to try and plot Speckled Wood (*Parage aegeria*) movement in relation to connectivity. They settled on a cost-distance approach, such distances can be seen as effective distances and used to estimate practical real term dispersal potentials. The real drawback is calculating accurate suitable cost vales from what is often limited behaviour or life history knowledge for many of the species resident in the UK.

Part of the problem for management is that it often creates significant changes in the habitat such changes whilst necessary mean that a colonies position in space is often highly ephemeral. For instance populations are often driven to move with coppice rotation, and where such changes are dislocated whole populations can fail and the patch have to be recolonised. This is particularly evident in the Grizzled Skipper where a separation of 100m even in woodland is sufficient to create a new colony (Butterfly Conservation, 2004). This species has a typical bi-modal distribution with taller border vegetation creating closed populations and low vegetation open ones. Therefore if coppice rotation is not concurrent, for example subsequent clearance is over 100m from the original coppice either a new and discrete colony will be founded or the whole population will fail.

All of the butterfly species in question in this study are highly light dependant, a result of their dependence on flowering plants for both egg and food plants. Very few flowering plants can tolerate high degrees of shading. Average quantities of direct sunlight range between 50-80%. This high value rules most species out dense conifer plantations of parts of broadleaf woodland that have a particularly dense canopy and or shrub layer. This need for flowering plants and therefore a certain degree of direct sunlight means that most species prosper on woodland margins; in glades and rides or in coppiced areas. Such coppice strategies dovetail with the management requirements of Dormice discussed earlier.

The maps shown with each species (page 29) illustrate that the potential for butterfly distribution is currently under utilised. Nearly all of the woodlands have suitable vegetation requirements and yet distribution is highly localised both spatially and temporally.

Roads provide a significant barrier to dispersal. Wind disruption to flight and the physical danger of moving traffic can affect successful movement. There is however potential within the network to improve overall butterfly distribution.

Wappenbury Wood is a critical woodland and should be targeted to act as a nexus for population emigration and recolonisation. Its central location with close access to Ryton, Bubbenhall and Princethorpe through Dukes wood makes it ideal as a release point. If populations can be stabilised there then there is the chance that population survival in surrounding woods would be improved. Ryton Wood is already well managed for butterfly species as evidenced by the quality, quantity and nature of the records from there. It too would make an excellent source for recolonisation or reintroduction efforts.

To stabilise populations in Wappenbury (and or Ryton to a lesser degree) would create a source for colonisation to the other woods and in turn self support its own populations.

To the west there are also opportunities for improvement, Weston and Waverly Woods are large woods and therefore offer a potentially high diversity of habitats. In particular the Grizzled Skipper should do well in these woods. The stands of conifer

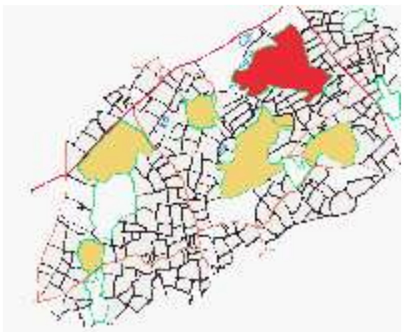
plantations are a habitat that Grizzled Skippers have been known to frequent. The site also includes the species larval food plants.
Weston Wood like Wappenbury is a focal point, stabilise this woodland and colonisation probabilities for North Cubbington, South Cubbington and Waverly are improved.

Bull and Butcher and The Coppice woods are highly isolated and there is little possibility of improving connectivity enough to break the metapopulation dynamic. Bull and Butcher did have a Small Pearl-bordered Fritillary, this has either now died out or remains in such small numbers that they have gone unrecorded. Given that connecting these woods up to improve dispersal and immigration potentials is unlikely. Effort should be concentrated on maintaining current populations. The emphasis here instead is to ensure that the metapopulations of the species in those woods have the necessary requirements to survive in perpetuity without or with little chance of recolonisation or rescue effect. In time it maybe possible to stabilise the populations to a point where they are self sufficient internally. This whilst maintaining a fragile community (where a poor summer or minor change in climate or habitat to occur the species could be eradicated in that patch) is perhaps the best that can be hoped for. With such a high degree of fragmentation it is in these two woodlands that management will be of vital importance.

3.3 Individual Species Assessments (Butterfly Conservation, 2004)

Dingy Skipper

- Has a univoltine metapopulation life history.
- Exists in discrete colonies of less than 50 individuals.
- Highly sedentary but can move several kilometres
- Needs long ungrazed shoots of Bird-foot Trefoil therefore woods need bare ground or sparse vegetation and light grazing

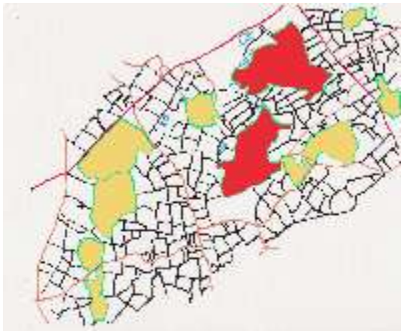


(Red = Site with record of presence Yellow = Site with suitable habitat but no record of presence)

Recommendations: Stabilise current populations in Wappenbury Wood thereby enhancing dispersal possibilities to Bubbenhall and Princethorpe.

Essex Skipper

- Requires tall dry grassland. Open Sunny patches, Woodland Rides.
- Records of presence in woods could be from colonies that exist in surrounding pasture or hedgerows and forage within the wood.



(Red = Site with record of presence Yellow = Site with suitable habitat but no record of presence)

Recommendations: As a generalist species, dependant upon grass species for egg laying and food plants it would be best to allow natural dispersal of this species. It is likely with time and favourable seasons its spread will increase. Improvement of hedgerows, ensuring both food and egg plants are present would facilitate dispersal to other suitable woods. Wappenbury provides a key core dispersal location.

Grizzled Skipper

- Species with Low Mobility. Maximum moves of 1.5km steps. Can cross 100m of mature woodland.
- Exists as a metapopulation
- Early lifecycle highly sedentary, larvae may only move 30cm from egg to pupation this makes colonies highly susceptible to localised change.
- 100m of woodland and 500m of grassland will create new colonies, therefore populations can be highly localised.
- Active in coppiced woodland but heavily dependant on management.
- Relies upon a range of spring nectar plants and at least one larval food plant in short less than 10cm herb rich vegetation.

(Red = Site with record of presence Yellow = Site with suitable habitat but no record of presence)

- Distribution is determined by size and quality of patches. Tall vegetation leads to Closed populations, short to Open ones.
- Can tolerate young conifer plantations which may lend itself to survival in Weston/Waverly Woods.
- Larval Food plants include Silverweed and Clover sp.

Recommendation: Utilise Wappenbury and Ryton Woods as sources for colonisation. Improve management and links to Dukes Wood and Bubbenhall to allow natural dispersal. Consider possible introduction to Weston/Waverly.

Green Hairstreak

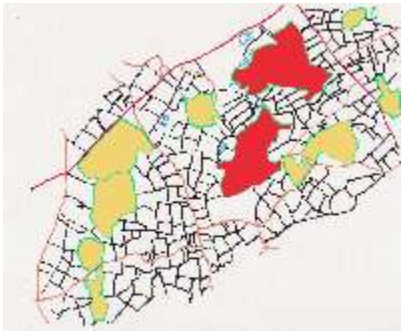
- Thrives on Calcareous grassland and woodland rides.
- Strong association to scrub and shrubs.

(Red = Site with record of presence Yellow = Site with suitable habitat but no record of presence)

Recommendation: High potential for success in most woods in the area. Focus on encouraging dispersal from Ryton to Wappenbury and then stabilising a population there. Then allow Wappenbury to act as dispersal source for other woods. Consider introduction to Weston Wood and thereby allowing colonisation of the western woodland network.

Marbled White

- Has a large potential for movement with migration distances up to 7.3 km (Hanski, 1999)



(Red = Site with record of presence Yellow = Site with suitable habitat but no record of presence)

Recommendation: With such a large potential migration distance and with all woods containing some suitable vegetation for the species it is possible the Marbled White, given time could colonise all the woods in the area naturally. This however relies on Ryton and Wappenbury being managed to maintain the current populations and increase them to a state where emigration occurs.

Pearl-Bordered Fritillary

- Exist in small colonies of fewer than 100 individuals.
- Main habitat is dry open deciduous woodland.
- Violets are very important in the life cycle where it is the preferred egg plant especially in sunny open places. It can select Bracken as an egg plant as it has a warm microclimate
- Requires areas with at least 60% direct sunlight.
- Scrub encroachment that threatens Violet growth can very quickly remove a population.
- Increased Adult densities correlate with 25% or less cover.

(Red = Site with record of presence Yellow = Site with suitable habitat but no record of presence)

- Can disperse along rides and occasionally over the canopy, suggesting that roads may not present a major barrier.
- Eggs are predated by Wood Ants and so populations are likely to do less well in woods where they are endemic.

Recommendations: The Pearl-bordered Fritillary where it does survive does so in very small populations. Increased distribution is going to require concentrated efforts to maximise habitats and provide colonisation opportunities. It was last recorded in Ryton, from there populations need to be stabilised and numbers increased before efforts to spread them are made. Movements should be first to Wappenbury and from there to Bubbenhall; there is also the possibility of introduction to Waverley if habitat management is available.

Small Pearl-Bordered Fritillary

(Red = Site with record of presence Yellow = Site with suitable habitat but no record of presence)

- The Sml P-Bordered Fritillary is a univoltine species that is dependant upon Bugle and species with Yellow Flowers for food.
- Like the Pearl-Bordered Fritillary it utilises Violet species but frequents denser taller vegetation and is more tolerant of damp conditions. Violets occurring in woodland need to receive at least 50% direct sunlight.
- It is able to thrive in a transitory way in commercial plantations and therefore may find Weston/Waverly and Bubbenhall suitable.
- Highly reliant upon rich mix of nectar species on sunny open rides and clearings
- Population growth is maximised in woodlands that are slow growing or mildly grazed.
- Is able to disperse along rides and can survive at low densities on woodland margins.
- Predated severely by Crab Spiders

Recommendation: Similar to that of the Pearl-bordered Fritillary but limited by presence and abundance of Crab Spiders although given that it seems hardier, able to survive in margins and plantations there is greater potential for species stabilisation.

Small Heath

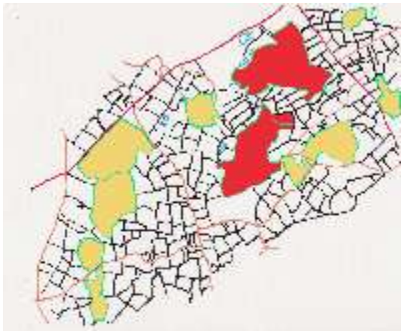
- Inhabits woodland rides and glades
- Prefers fine grasses in well drained areas where the sward is maintained short.

(Red = Site with record of presence Yellow = Site with suitable habitat but no record of presence)

Recommendation: The Small Heath is fairly generalist. Its preference for fine grasses does enable it to find suitable conditions in all of the woods in the region. So far it has only been recorded in Ryton Wood and as the least rare species in the analysis it should be possible to allow this species to disperse naturally.

Wall Brown

- Inhabits short open grassland where the turf is broken or stony.



(Red = Site with record of presence Yellow = Site with suitable habitat but no record of presence)

Recommendation: The Wall Brown is another generalist and is most probably a matrix species that encroaches upon the woodland. It has been recorded in two woodlands and there are suitable habitats in all the woods in the network. Like the Small Heath there is little need for specific management any general moves will probably facilitate its spread.

White Admiral

- Has the Honeysuckle as its sole food plant that makes it sensitive to any change in abundance and distribution of that species.
- Prefers shady places and is associated with neglected or mature woodland with sunny glades and patches of Bramble.

(Red = Site with record of presence Yellow = Site with suitable habitat but no record of presence)

Recommendation: The White Admiral despite its dependant upon one resource, the honeysuckle, seems to be doing relatively well and has already been found in 4 woods. Maintaining stands of honeysuckle in those woods and introducing them to the other woods would probably increase distribution considerably, although population dispersal will be dependant upon suitable hedgerow connections for example wooded ones.

Wood White

- Is reliant upon leguminous plants for egg laying and food.
- Sedentary larvae that move only a few metres between hatching and pupation. This makes natal sites particularly sensitive and fragile.
- Pupation is often on grasses and wild roses at a height of 10-70cm.
- Mortality from egg to emergence is highly dependant upon the presence of parasites. Mortality can be as high as 90.1-98.3%. This makes the species very easy to be wiped out locally if an infestation occurs. Primary parasites are Chalcid Flies and 2 species of Ichneumon Wasp.
- Is capable of surviving in marginal vegetation when it is cut every 3-6 years.
- The species requires shade levels of 20-50% with small numbers found in areas with less than 20%.

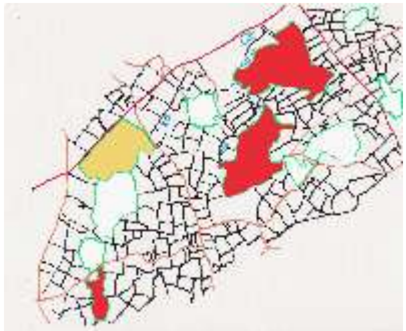
(Red = Site with record of presence Yellow = Site with suitable habitat but no record of presence)

Very sensitive to annual changes in temperature during the flight period that effects egg laying.	This concentrates populations in rides, clearings and open coppice with a canopy of 2-5

Recommendation: The Wood White has a highly sensitive life cycle. Its sensitivity to temperature and its very high mortality from parasites means that stabilising any population or creating new ones can be very difficult. Habitat wise there is potential for growth with again Wappenbury forming a key site for creating a dispersal nexus. Currently only observed at Ryton and at low densities the first step should be on creating a viable population in that wood before attempting introductions or linkages to others.

Silver-washed Fritillary

- Whilst feeding in sunny glades and rides it actually breeds in shadier parts.
- Highly dependant on the Common Dog Violet
- Prefers broadleaf woodland especially Oak. It is also able to breed in wooded hedgerows.



(Red = Site with record of presence Yellow = Site with suitable habitat but no record of presence)

Recommendations: Improve the hedgerows between all woods with recorded presence. Stabilise the populations in Ryton and Wappenbury and then encourage spread eastwards to Dukes and Princethorpe and North Cubbington to Weston.

PART 4 CONCLUSIONS

The Princethorpe Great Wood Project has a great potential to return this landscape to a state when the county was heavily forested. The network of woodlands provide one of the densest concentrations of woodland in the county. As has been demonstrated in this report and the previous one (Smith, 2004) there are a number of key issues concerning the project. Some of these issues are fixed such as the severance impact of the roads whilst others such as management are flexible.

The study as a whole has highlighted a number of common themes, areas where improvement would greatly improve the ecology of the area. These are:

1. Accessibility/Connectivity: This one factor alone holds the key to long term success. By connecting the woods up in a comprehensive way not only improves the landscape structure but would help stabilise all species in the area. The analysis of connecting up the woods to improve Dormouse dispersal has shown that any linkage between woods would increase dispersal

potentials. Improvements to the hedgerow networks would also facilitate species movement and help improve the surrounding matrix.

2. Management: Management of the physical structure of the wood would help stabilise existing populations. Special attention to the provision of butterfly food and larval plants is needed to ensure populations persist.
   Management can be tailored too each woodland and balanced to fit its nature. For example some are already designated Nature Reserves and already managed for Wildlife, others are commercially farmed and done so in a sympathetic way.
   Coppicing seems to be the most productive method of management not only does this fit with Dormouse management but also provides suitable habitats for most of the core butterfly species, providing the necessary open space and allowing suitable flowering plants to grow.
3. Species Control: For Dormice the key factors in stabilising and spreading the species are deer control and monitoring of Grey Squirrels. Provision of Nest Boxes is additionally very advantageous. The support of butterfly species requires the careful monitoring of food plants and careful planning of glade and ride management as most species seem highly reliant upon both glades and rides. Given the butterflies short generation time there is an inherent fragility to their communities however the same trait means that it is easier to establish new colonies if conditions are maintained especially in multi-voltine species.

GENERAL RECOMMENDATIONS

Most of the recommendations and findings are included in text but here is a list of general recommendations that draw together all the threads of the study.

- Focus efforts on getting Wappenbury to an optimum state. Use this as a focal point of all activities allowing further change and effects to radiate out from it.
- Manage Deer in all Woods
- Monitor Grey Squirrel Numbers
- Introduce Dormice to Wappenbury and Ryton either by encouraging dispersal or by releases. Ensuring the development of optimal habitat.
- Monitor Dormice Populations
- Add nest boxes to Weston, Bubbenhall, Ryton and Wappenbury Woods.

- Improve Hedgerows between all woods. Plant trees, widen and ensure continuity by filling gaps with new planting.
- Plant a strip of woodland at least 200m wide between North Cubbington and Weston Woods
- Plant a strip of woodland at least 300m wide between Wappenbury and Ryton.
- Focus connectivity efforts on linking Bubbenhall and Wappenbury either by hedgerow improvement or by woodland.
- Monitor core butterfly species regularly.
- Introduce key Butterflies to recommended key woods such as Wappenbury.
- Encourage wider involvement in the project in the woodland network perhaps by improving limited access to some woods.

EVALUATION

This report works very heavily upon theory, like most theory it is only through experimentation and trials that their veracity be gained. The models used in the report are all scratch built based upon metapopulation theory. Whilst every effort was made to ensure that they were robust further trials would improve the analysis, such as an increase to 1000 trials for dispersal, and a hundred for the population modelling. In the long run the project offers a chance to cross check the findings predicted and to assess exactly how much effect on Dormice per se such connectivity issues actually have in quantitative terms.
A more exhaustive literature search may also have yielded greater depth of information as well as greater contact with other parties such as English Nature who have led the field in this country on fragmentation issues.

PART 5 REFERENCES AND APPENDICES

5.1 REFERENCES

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5.2 APPENDICES

Formulae

Population Sheet for Bubbenhall

Population Sheet for Weston Wood

Individual Width Graphs for all Woods

Formulae

Elongation: $E = w/l$

Compactness: $K_1 = (2\sqrt{\Pi A})/p$

Accessibility: $a_i = \Sigma d_{ij}$

Patch Isolation: $r_i = (1/n)\Sigma d_{ij}$

$L_x = N\Omega/N_0$

Connectivity = $\acute{\Gamma}_i = \Sigma \exp(-\alpha d_{ij})A_j$

Neighbourhood Habitat Area = $(\Sigma\Sigma \exp(-\alpha d_{ij})\ A_i\ A_j)/\ \Sigma\ A_i$

w = width

l = length

A = Area

d_{ij} = Distance between patch i and j.

α = mobility factor

N = Number

i = Patch i.

j = Patch j.

Population Sheet for Bubbenhall

Population Sheet for Weston Wood

Individual Width Graphs for all Woods