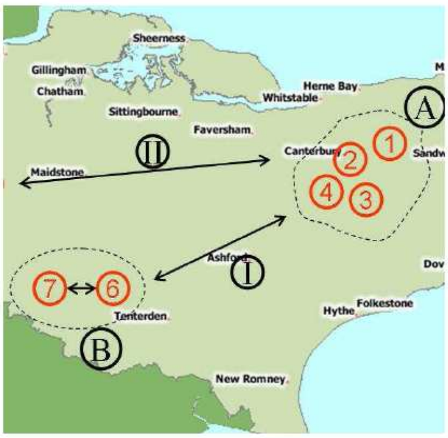
Branch
BIODIVERSITY
SPATIAL PLANNING
CLIMATE CHANGE

Adaptation of the landscape for biodiversity to climate change

Terrestrial case studies Limburg (NL), Kent and Hampshire (UK)

S. van Rooij, H. Baveco, R. Bugter, M. van Eupen, P. Opdam & E. Steingröver



This project has received European Regional Development Funding through the INTERREG III B Community Initiative

INTERREG IIIB
NORTH WEST EUROPE

Adaptation of the landscape for biodiversity to climate change

Terrestrial case studies Limburg (NL), Kent and Hampshire (UK)

Sabine van Rooij
Hans Baveco
Rob Bugter
Michiel van Eupen
Paul Opdam
Eveliene Steingröver
(Alterra, Wageningen University & Research Centre, WUR)

In cooperation with:
Sarah Taylor (Kent County Council)
Herman van Steenwijk (Province of Limburg)

Alterra-report 1543

ABSTRACT

Sabine van Rooij, Hans Baveco, Rob Bugter, Michiel van Eupen, Paul Opdam & Eveliene Steingröver, 2007. *Adaptation of the landscape for biodiversity to climate change. Terrestrial case studies Limburg (NL), Kent and Hampshire (UK).* Wageningen, Alterra, Green World Research. Annex 4 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Alterra-report number 1543. 82 pp.; 37 Figures; 9 Tables; 42 References; 9 Annexes.

This study is part of the BRANCH project, aimed at assessing the impact of climate change on species and habitats and formulating strategies for adaptation. It focuses on the local scale in three terrestrial case studies, Limburg (NL) and in Kent and Hampshire (UK).
We developed and tested: (a) a method to assess the effect of climate change on species and habitats, (b) a methodology to assess the effectiveness of a proposed climate change adaptation measure (Robust Corridor) and (c) an interactive planning method to enable stakeholders to design climate proof ecosystem networks.

Keywords: Ecological networks, spatial planning, connectivity, key areas, carrying capacity, habitat, adaptation strategies, SMALLSTEPS, LARCH

ISSN 1566-7197

This report is available in digital format at www.alterra.wur.nl and on www.branchproject.org.
A printed version of the report, like all other Alterra publications, is available from Cereales Publishers in Wageningen (Phone: +31 (0) 317 466666). For information about, conditions, prices and the quickest way of ordering see www.boomblad.nl/rapportenservice

P.O. Box 47; 6700 AA Wageningen; The Netherlands
Phone: + 31 317 474700; fax: +31 317 419000; e-mail: info.alterra@wur.nl

Alterra-report 1543/July/2007

Content

Annexes

The annexes can be downloaded from www.branchproject.org.

Acknowledgements

This work was carried out as part of the BRANCH project (www.branchproject.org.uk). This project and research has received European Regional Development Funding through the INTERREG IIIB Community Initiative. The project was also financially supported by Kent County Council, the Province of Limburg, the Dutch Ministry of Housing, Spatial Planning and the Environment (VROM), the Dutch Ministry of Agriculture, Nature and Food quality (LNV) and Wageningen UR.

In this project, many people have been working together: Representatives of the BRANCH partners that participated in the terrestrial case-studies were Herman van Steenwijk and Boena van Noorden (Province of Limburg) and Laurence Tricker and Sarah Taylor (Kent County Council). The main participants of Alterra, Wageningen University and Research Centre, WUR, were Sabine van Rooij (case study Kent, coordination of terrestrial case studies), Rob Bugter (case study Limburg), Eveliene Steingröver (case study Kent), Paul Opdam (scientific quality), Hans Baveco (modelling) and Michiel van Eupen (modelling, GIS). For the Hampshire case study Caroline Bird (Hampshire County Council) and Pam Berry (Environmental Change Institute, ECI) contributed texts and figures. Pam Berry, Jesse O'Hanley and Claire Thomson (Environmental Change Institute, ECI) provided results of the SPECIES modelling for the case studies. Claudia Chambers (Natural England) contributed from the overall BRANCH project point of view.

Other people of Alterra Wageningen University and Research Centre that contributed to this project were Arjan Griffioen and Harold Kuipers (GIS), Marion Bogers (project administration), Claire Vos (relation with BRANCH Action 3), Jana Verboom (methodology) and Bianca Nijhof (data gathering). Species experts that put in their expert knowledge were Alex Schotman (bird species) and Pieter Slim (plant species) and Herman Limpens (Bats, Dutch Mammal Society, VZZ).

Furthermore, we want to thank the Kent and Medway Biological Record Centre for their kind cooperation in this project and the provision of data.

And last, but not least we want to acknowledge the students that have contributed to the Kent case study: Quentin Chiron, Uchenna Uduaka, Berta Sanz Pena, and Paula Espinosa Aguilar.

Summary

The INTERREG IIIB BRANCH project assessed the impact of climate change on species and habitats and strategies for adaptation on two scales; on the Northwest European scale and on the local scale. In this report the assessment on the local scale is presented.

The objective of this study was to assess the effects of climate change in relation to habitat fragmentation in three terrestrial case studies, in Limburg (NL) and in Kent and Hampshire (UK). For this purpose, we linked a predictive modelling approach based on climate envelopes at the species level (SPECIES model) with ecosystem network cohesion assessment methodology (SMALLSTEPS/LARCH models). We (a) explored impacts of climate change at the local site level, (b) developed methodology for assessing the effectiveness of proposed climate adaptation measures (Robust Corridor) and (c) developed an interactive planning method for the design of climate proof ecosystem networks at a County/Province scale. We propose that our results present a promising way to proceed, acknowledging though that major improvements in basic knowledge and methodology are urgently needed.

In the Hampshire case study we showed that at the local level species responses to climate change vary. For some the local climate becomes more suitable (incoming/increasing species), for others less suitable (declining/disappearing species). As a consequence, radical changes in the species composition of local habitats and ecosystems are expected in the long term. The species composition and character of Chalk grassland and Lowland Heath in Hampshire and the South Downs are expected to change drastically in the long run (2080). Keeping conditions favourable and re-creation of habitat might help species to survive for as long as possible. Natura 2000 sites should continue to be protected and valued as land for nature conservation and as sites that provide habitat for new, incoming species.

If species disappear due to less favourable local climate, while potentially incoming species can not establish due to habitat fragmentation, climate change may result in loss of biodiversity. In the Netherlands, Robust Corridors are planned to help prevent this, these will be implemented as part of the National Ecological Network (NEN). In the Limburg case study we assessed the effectiveness of the Robust Corridor as an adaptation measure to make the NEN more climate proof. We have shown that the effectiveness of the Robust Corridor for species depends on the reaction that species show to climate change (higher or lower densities), the area requirements for viable populations and their sensitivity to habitat fragmentation. We showed that (a) the Robust Corridor has a value for declining/disappearing species, as the extra habitat and increased connectivity of habitat allows species to persist longer in suitable but fragmented habitat, and that (b) the Robust Corridor facilitates the shift of incoming/increasing species northward, by which these species can colonise new suitable areas more easy and can establish sustainable populations more quickly. This is expected to be of most benefit to less mobile species.

In the Kent case study, an interactive planning method was developed and tested that enables local stakeholders to design climate change proof ecological networks. We found that, as species react differently to climate change, different adaptation strategies are necessary for incoming/increasing species and declining/disappearing species. Incoming species will profit from increasing connectivity in adaptation zones which include those ecological networks (with one or more key areas) that will be sustainable in the near future. Declining species however, will profit from consolidation of those ecological networks (with one or more key areas) that will remain sustainable in the long term. We learned in this case study that the developed tools are suitable to assess the effect of climate change on habitat on local scale and to develop adaptation strategies.

Conclusions and recommendations:

- The various species response types to climate change require an array of adaptation strategies, both on the North West European and on the local scale. Increasing area and quality of existing habitat networks are the prime adaptation strategy for declining species, while for incoming and increasing species the prime strategy is creating key areas and connecting habitat networks.
- Regional costs and efforts for climate change adaptation can be minimized by an iterative planning process at different scales, in which key regions in the European ecosystem network pattern are planned to coincide with areas where local measures are most cost-effective and socio-economically most feasible.
- Ecological networks proved to be convenient spatial concepts for conservation planning in multi-purpose landscape.
- The implementation of Robust Corridors in the Netherlands was found to be an adequate adaptation strategy for climate change as they both improve cohesion of existing habitat networks and connectivity between habitat networks.
- We recommend this learning process can be continued during the implementation by a monitoring scheme to record the response of species to climate change at the level of ecological networks, and to learn more about the effectiveness of measures.

The gap between science and planning isn't bridged yet. The developed tools need to be elaborated and simplified. A major challenge is the coordination of adaptation at the County and Province level and the European level, which is the level at which climate change affects species distributions. Future adaptation strategies on European and national levels need to be translated to regional adaptation strategies, and regions need to coordinate strategies and their implementation. Climate change in combination with fragmentation will affect species composition of communities, with largely unknown effects for the resilience of ecosystems. Furthermore, additional research on potential negative aspects of climate change is required.

1 Introduction

1.1 Climate change, habitat fragmentation and biodiversity

Climatic conditions are an important factor in determining species distributions. This was acknowledged more than two decades ago (Woodward 1987; Huntley 1999). Consequently, climate change will cause a shift of the geographic zone where climatic conditions for species are favourable (the species “climate envelope” or "suitable climate space"). Evidence that climate change affects species distributions has been found (Parmesan and Yohe 2003).
When the climate envelope of species shifts, this usually results in climatic conditions on one side of its present geographic distribution or altitudinal range becoming unfavourable, while on the other side of the range a conditions in the bordering geographic area or along the altitudinal gradient becomes favourable. In the areas with unfavourable conditions, the species will eventually disappear while the areas with newly favourable conditions can potentially be colonised. Primarily, colonisation will depend on the speed with which the species’ suitable climate space will shift compared with the ability of species to colonise habitat areas in new suitable climate space. How fast that is will be determined by species characteristics such as dispersal rates and distances, but also by the availability and fragmentation of the habitat in the area to colonise (Opdam and Wascher 2002).

The ability of species to adapt their distribution ranges to climate change is extremely important to the preservation of biodiversity. Models that predict the movement of climate spaces are available (Berry, Dawson et al. 2002; Harrison, Berry et al. 2006), but an increasing need exists for methods to predict if or how well species distributions will be able to follow (Botkin, Saxe et al. 2007; Brooker, Travis et al. 2007).

1.2 The BRANCH-project

To investigate the impact of climate change on habitats and species in Europe the INTERREG IIIB project BRANCH (Biodiversity Requires Adaptation in Europe under a CHanging Climate) was put together (see Box 1). The effect of climate change on the distribution of species and habitats and options for adaptation of the landscape have been assessed on different scales. On the scale of Europe, climate change will have an effect on suitable climate space of species and this needs to be addressed on this broad geographical level (Action 3). At a local scale[1] strategies for spatial planning are set and adaptation measures are taken and implemented in the landscape. For terrestrial ecosystems, the impact of climate change was assessed in three case studies in Limburg (NL), Kent and Hampshire (UK) (Action 5). The methods applied to these two scales are partly overlapping (see Box 2).

For the terrestrial ecosystems, BRANCH focussed on the assessment of the combined effect of climate change and habitat fragmentation on species and habitats. Species can only colonise new suitable habitat in areas where climatic conditions become favourable if these areas are within reachable distance from a currently populated area. In other words, for species to be able to follow the shift of the climate envelope, new habitat areas need to be connected to, and therefore become part of, a sustainable habitat network. Furthermore, an important factor determining colonisation speed will be the amount of new habitat that is available and how well it is connected to the existing part of the habitat network. Habitat or ecological networks that will sufficiently allow species distributions to follow climate change are considered to be 'climate proof’.

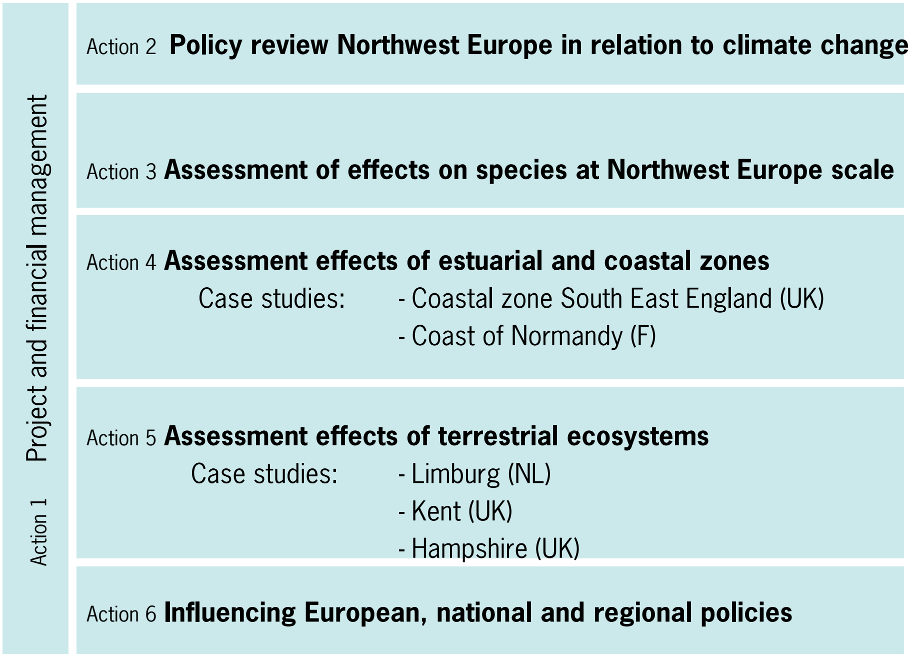
[1] Local scale in UK is the County level. In The Netherlands we refer to this scale as ‘regional’.

Box 1 Outline of the BRANCH project

The BRANCH project is a three year project (2004-2007) promoting the importance of adaptation to climate change using spatial planning systems. BRANCH brings together spatial planners, policymakers and scientists from across Europe to:

- Review existing spatial planning policies and recommend a new policy framework to provide greater resilience for our biodiversity,
- Model how European wildlife will respond to climate change,
- Develop planning options and tools to help tackle the impacts of climate change on our coasts,
- Assess the impact of climate change on inland ecosystems and ecological networks,
- Engage stakeholders so that adaptation to climate change is integrated at all planning levels.

Each of these trans-national strands were delivered by actions.

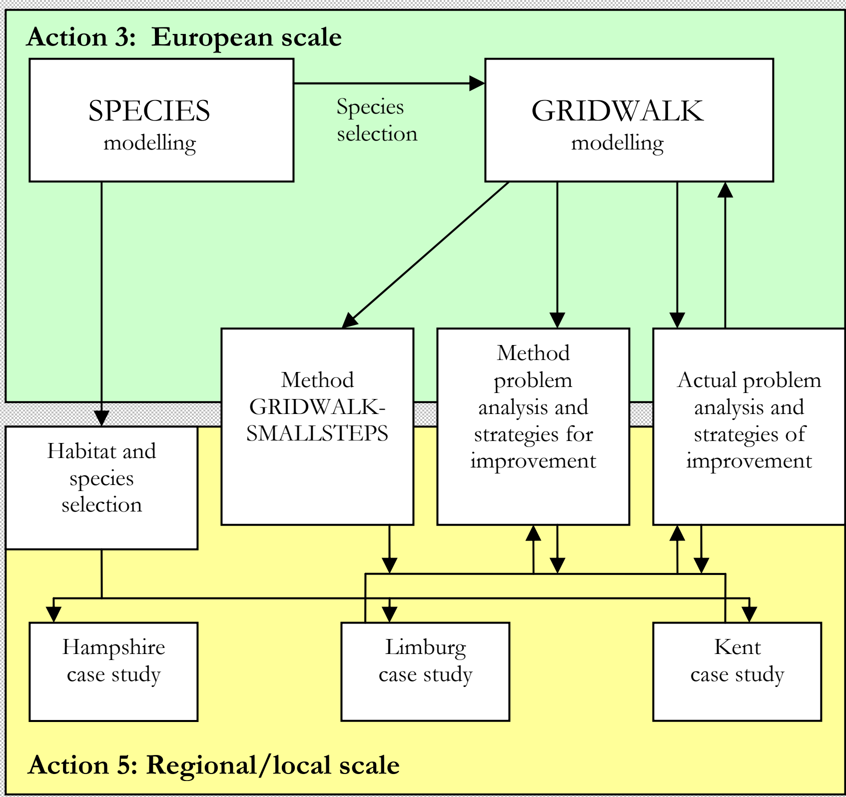


Box 2 Linking action 3 (science) and 5 (terrestrial case studies) of the BRANCH project

Action 3 assessed the effect of climate change on the potential distribution of species on the scale of Europe. The potential habitat of species, now and after climate change is assessed on the cohesion of habitat; on where species persist, on where populations decrease, and on where new populations arise if species are able to colonise these new suitable habitat patches. Generic adaptation strategies for the scale of Europe are discussed and it is indicated on habitat maps which strategy applies at which location (Berry *et al*., 2007).

There is an overlap between action 3 and 5 in methods and tools. In both actions, the results of the SPECIES modelling are used. Furthermore the coherence of habitat patches was modelled with two closely related models: GRIDWALK (suitable for input of raster maps) and SMALLSTEPS (suitable for input of vector maps). These models are both based on the metapopulation theories.

The strategies for adaptation of the landscape of action 3 and 5 are compatible. They have different characteristics as required for the different scales.



1.3 Impact climate change at the European scale

BRANCH action 3 investigated how far ecological networks at the Northwest European scale will be climate proof. Detailed results of this study can be found in the action 3 final report (Berry, Vos et al. 2007). The main findings relevant for the regional level studies are:

- Showing the importance of the region's local habitat areas for the sustainability of species and ecological networks at the larger spatial scale;

- Advised adaptation strategies on Northwest European scale:
  - Connect new suitable habitat networks to climate change proof habitat networks;
  - Enlarge colonisation power of habitat areas on the transition of climate change proof networks and new suitable habitat areas;
  - Optimise habitat networks in existing suitable areas (climate refugia).
- There is a shortage of woodland and wetland areas at the Northwest European scale. Species of these ecosystems, for which the climate envelope is shifting to the North will find much less habitat in the new suitable climate space.

1.4 Objectives of terrestrial case studies

The objectives of the terrestrial case studies was to assess the effect of climate change on species and habitats on a local level and their interaction with habitat fragmentation. Three case studies were carried out: in the province of Limburg in the Netherlands, the County of Kent, and the County of Hampshire and the South Downs in the United Kingdom (Figure 1). The research questions and methods used in the case studies are overlapping). In **all three case studies**, the effect of climate change on the potential distribution of species was assessed for a selection of species 20 to 27 species.
In the **Limburg case study**, it was also assessed how effective the chosen adaptation strategy (a Robust Corridor) will be for "climate change proofing" the Dutch National Ecological Network. In order to do so, the habitat network for the selected species was assessed in and around the case study area of Limburg in detail, both for the present situation and for future situations under a changing climate.
In the **Kent case study**, the same assessment and the effect of climate change was carried out. In this case study, the modelling results were used to develop an interactive method that local stakeholders can use to design climate change proof ecosystem networks.

To assess the issues mentioned, methods and models have been drawn up or adapted for a local scale. Some of these methods were used in another part of the BRANCH project, in the assessment of changing climate space on a Northwest European scale (see Box 2).

Hampshire Case Study
The objective in this case study was to consider how climate change might impact two import habitats, Chalk Grassland and Lowland Heath, in Hampshire and the South Downs over the next century. Furthermore, it was assessed what measures might be available to help nature adapt to the changes, e.g. re-creation opportunities.
The results of this study will help spatial planners to make the decisions necessary to fulfil commitments in present biodiversity policies (local Biodiversity Action Plans and policy commitments in the developing South East Plan).

Limburg Case Study
In the Netherlands a National Ecological Network (NEN) and 13 Robust Corridors are planned (and partly implemented) to increase connectivity of habitat and to provide sustainable conditions for wildlife. The Robust Corridors are also proposed as a measure for making the NEN "climate change proof". One of the Robust Corridors is planned in the Province of Limburg.
The objective of the Limburg case study was to assess what might happen to the connectivity of habitat in a changing climate and whether the planned Robust Corridor will make the National Ecological Network in and around Limburg climate proof.

Kent Case Study
Kent has a varied and important biodiversity resource. However habitats are highly fragmented and development pressure is significant. The objective was to assess present habitat connectivity and to explore the creation of an ecological network that will allow biodiversity to adapt to climate change. The results of the modelling will help planners and nature conservation stakeholders in Kent to design spatial solutions for biodiversity that can be implemented across the County. As local knowledge and support is very important in such a process, local stakeholders were involved and their local knowledge was used.

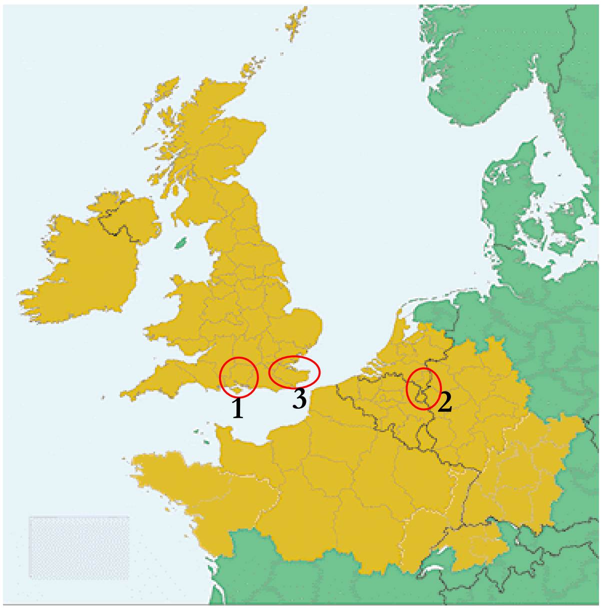


Figure 1 Location of case study areas
1: Hampshire and the South Downs (UK)
2: Robust Corridor in Limburg (The Netherlands)
3: Kent (UK)

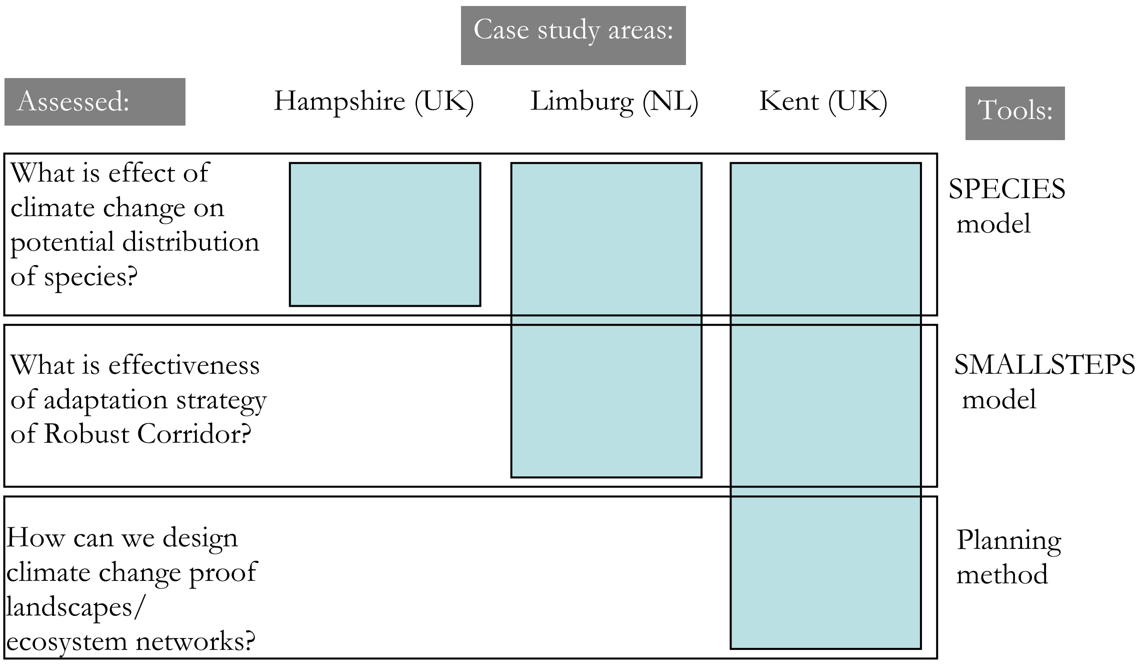


Figure 2 Research questions and tools used in the terrestrial case studies of BRANCH.

1.5 Reading guide

In Chapter 2, the general method and tools applied in the case studies are explained. In Chapter 3, the specific methods, activities and results for each case study are presented and discussed. In Chapter 4, the results and lessons learned from each case study are discussed, leading to general conclusions and recommendations.

Please note that the Hampshire case study is not fully described in this report; a separate report for this case study is available (Berry, O'Hanley et al. 2007a).

2 General methodology

To increase the readability of the report, the methodology is limited to the amount necessary to understand the overall procedure. For methodological details see annexes.

2.1 Species and climate scenario selection for case studies

On the scale of Northwest Europe, the expected climate envelopes shifts were modelled for a s*et* of almost 400 species. The species selections for the case studies were taken from this set. The selected subsets were limited in size due to the amount of work involved in the more detailed evaluation. In this project, the UKCIP02 climate change scenarios were used. These scenarios are based on a single GCM, the HadCM3 model (Hulme*,* 2002).

Per case study, 20-27 species were selected to examine in detail the shift of the climate envelope and the configuration of habitats. Species were chosen because of the expected movement of the climate envelope in or near the case study area and/or because of their special interest to the case study area or habitats. In the Limburg and Kent case study, 7 species were chosen from this selection, to assess the potential for a species to persist in or to colonise the landscape. We attempted to distribute the selection across species groups and spatial scales as much as possible. In this last selection, plant species are not included as the present knowledge on plant dispersal does not allow for modelling plant species in this way.

Hampshire
This case study looked in detail at the effect of a change in suitable climate on two habitat types that are important and characteristic habitats of the Hampshire countryside, Lowland Calcareous Grassland and Lowland Heath. A set of species related to these habitats was chosen to assess the responses of these habitats to climate change (Table 1). The time periods of the scenarios that were used were 2020s (high emissions only) and 2050s and 2080s (low and high emissions). The use of high and low emissions scenarios captures much of the range of uncertainty from emissions (Table 2).

Kent and Limburg
In these case studies, the interaction between climate change and habitat fragmentation is assessed. For this purpose a set of species was selected that differ in dispersal capacity and area requirements for a sustainable population and reaction type to climate change. To get a broad overview on a broad range of habitats and species, species with different habitat preference were selected. To be able to compare and combine the results of the two case studies, we aimed for a considerable overlap between species sets. Species assessed should be considered as a representative of a range of species with:

- similar reaction to climate change i.e. will do better (incoming/increasing species) or worse (declining/disappearing species) and
- similar sensitivity to habitat fragmentation (dispersal capacity and area requirements, (Vos, Baveco et al. 2001a).

Table 2 presents an overview of the selected species, see annex 2 for more detail. In these case studies only the high emissions 2020s and 2050s scenarios were used, because the model runs that were carried out were rather time consuming.

Table 1 Overview of the habitats and related species, selected for the Hampshire case study.

Lowland Heathland		Lowland Calcareous Grassland	
Scientic name	***English name***	***Scientic name***	***English name***
Erica tetralix	Cross-leaved Heath	*Anthyllis vulneria*	Kidney Vetch
Erica cinerea	Bell Heather	*Bromopsis erecta*	Upright Brome
Ulex gallii	Western Gorse	*Carex humilis*	Dwarf Sedge
Calluna vulgaris	Heather	*Helianthemum nummularium*	Common Rock Rose
Deschampsia flexuosa	Wavy Hair Grass	*Helictotrichon pratense*	Meadow Oat Grass
Agrostis curtisii	Bristle Bent	*Herminium monorchis*	Musk Orchid
Molinia caerula	Purple Moor Grass	*Hesperia comma*	Silver-spotted Skipper
Eriophorum angustifolium	Common Cotton Grass	*Hippocrepis comosa*	Horseshoe Vetch
Lycopodella inundata	Marsh Clubmoss	*Koeleria macrantha*	Crested Hair-grass
Carex binervis	Green-ribbed Sedge	*Polygala calcarea*	Chalk Milkwort
Rumex acetosella	Sheep's Sorrel	*Polyommatus coridon*	Chalkhill Blue
Narthecium ossifragum	Bog Asphodel	*Thymus polytrichus*	Wild Thyme
Hammarbya paludosa	Bog Orchid		
Sylvia undata	Dartford Warbler		
Plebejus argus	Silver-studded Blue		

Table 2 Overview of species selected for the Kent and Limburg case studies. Reaction type indicates if species are expected to do better (incoming/increasing species) or worse (declining/disappearing species) as a result of climate change. M: species is modelled using SMALLSTEPS and LARCH; E: trend of species is evaluated.

Scientific Name	English Name	Dutch name	Species Group	Reaction type	Kent	Limburg
Heath						
Lacerta agilis	**Sand lizard**	**Zandhagedis**	**Reptiles**	**Declining**		**M**
Sylvia undata	**Dartford warbler**	**Provencaalse grasmus**	**Birds**	**Increasing**	**M**	**M**
Lullula arborea	**Woodlark**	**Boomleeuwerik**	**Birds**	**Increasing**	**E**	**M**
Saxicola torquata	European Stonechat	Roodborsttapuit	Birds	Increasing	E	E
Caprimulgus europaeus	Nightjar	Nachtzwaluw	Birds	Increasing	E	
Calluna vulgaris	Heather	Struikheide	Vascular plants	Declining		E
Genista pilosa	Silky Leaf Woadwaxen	Kruipbrem	Vascular plants	Increasing		E
Erica tetralix	Cross-leaved Heath	Gewone dopheide	Vascular plants	Declining		E
Rhynchospora alba	White-beaked Sedge	Witte snavelbies	Vascular plants	Both		E
Wetland						
Cettia cetti	**Cetti's Warbler**	**Cetti's zanger**	**Birds**	**Increasing**	**M**	**M**
Emberiza schoeniclus	Reed Bunting	Rietgors	Birds	Declining	E	
Leersia oryzoides	Cut-grass	Rijstgras	Vascular plants	Increasing		E
Carex elata	Tufted Sedge	Stijve zegge	Vascular plants	Increasing		E
Luronium natans	Floating Water Plantain	Drijvende waterweegbree	Vascular plants	Declining		E
Gentiana pneumonanthe	Marsh Gentian	Klokjesgentiaan	Vascular plants	Increasing	E	
Thelypteris palustris	Marsh fern	Moerasvaren	Vascular plants	Increasing	E	
Woodland						
Myotis bechsteinii	**Bechstein`s Bat**	**Bechsteins vleermuis**	**Mammals**	**Increasing**	**M**	**M**
Apatura iris	**Purple Emperor**	**Grote weerschijnvlinder**	**Butterflies**	**Both**	**M**	**M**
Dendrocopos medius	Middle Spotted Woodpecker	Middelste bonte specht	Birds	Both	E	E
Rhinolophus hipposideros	Lesser Horseshoe Bat	Kleine hoefijzerneus	Mammals	Increasing	E	
Vaccinium myrtillus	Bilbery	Blauwe bosbes	Vascular plants	Declining		E
Primula elatior	Oxlip	Slanke sleutelbloem	Vascular plants	Increasing	E	
Hyacinthoides non-scripta	Bluebell	Wilde hyacinth	Vascular plants	Increasing	E	
(Chalk) grassland						
Lysandra bellargus	**Adonis Blue**	**Adonisblauwtje**	**Butterflies**	**Increasing**	**M**	
Anthus pratensis	**Meadow Pipit**	**Graspieper**	**Birds**	**Declining**	**M**	**E**
Lysandra coridon	Chalkhill Blue	Bleek blauwtje	Butterflies	None	E	
Other / combination of ecosystems						
Triturus cristatus	**Great Crested Newt**	**Kamsalamander**	**Amphibians**	**Declining**	**M**	**M**
Rhinolophus ferrumequinum	Greater Horseshoe Bat	Grote hoefijzerneus	Mammals	Increasing	E	E
Arvicola terrestris	Water Vole	Woelrat	Mammals	Declining	E	
Coluber viridiflavus	Western Whip Snake	Geelgroene toornslang	Reptiles	Increasing		E
Merops apiaster	European Bee-eater	Bijeneter	Birds	Increasing		E
Trifolium glomeratum	Clustered Clover	*Trifolium glomeratum*	Vascular plants	Increasing	E	

Table 3 Scenarios used in the case studies and projected climate changes for South East England. All scenarios: used for the Hampshire case study; scenario in bold: used for the Kent case study.

Scenario UKCIP02	**Mean Temperature rise (^oC)**	**Winter precipitation (% change)**	**Summer precipitation (% change)**
2020s High	**1 to 1.5**	**0 to 10**	**-10 to -20**
2050s Low	1.5 to 2.0	0 to 15	-10 to -30
2050s High	**2 to 3**	**15 to 20**	**-30 to -40**
2080s Low	2 to 2.5	10 to 20	-20 to -40
2080s High	4 to 4.5	25 to 30+	> -50

Table 4 Scenarios used in the case study Limburg and projected climate changes for Limburg.

Scenario UKCIP02	**Mean Temperature rise (^oC)**	**Winter precipitation (% change)**	**Summer precipitation (% change)**
2020s High	1.10	+11.4	- 14.4
2050s High	2.04	+18.6	- 24.8

2.2 Description of habitat preferences of selected species for Kent and Limburg

Below, the habitat and relevant characteristics such as dispersal capacity for the selected species are described briefly, based on literature and expert knowledge (Weeda, Westra et al. 1985 - 1994; Stace 1991; Van der Meijden 2005). Detailed information about habitat, the densities, dispersal ranges etc. used in modelling can be found in annexes 3 and 6. Species printed in bold are selected for SMALLSTEPS modelling, the other species were used for the evaluation of expected trends.

2.2.1 Heath/Acid Grassland

Sand Lizard *(Zandhagedis, Lacerta agilis): Limburg case study*

The Sand Lizard is a Habitat Directive annex IV species, a Dutch red list species and a target species for the Limburg Robust Corridor. The preferred habitat is dry Heath with a highly diverse structure, containing patches of open sand where they can bury their eggs. The defined habitats for SMALLSTEPS modelling are all Heath types. The species has a relatively short dispersal range of about 1 km and busy roads are absolute barriers.

Dartford Warbler *(Provençaalse grasmus, Sylvia undata): Kent and Limburg case study*

The Dartford Warbler is a Bird Directive annex I species. Its habitat is virtually restricted to Heaths, Acid Grasslands and, in Kent, vegetated shingle, which are the types we used for modelling. The dispersal range of the species is about 25 km and it is not sensitive to barriers.

Woodlark (Boomleeuwerik, Lullula arborea): Kent case study. For Limburg case study; see description under 'woodland')

The Woodlark is a species of sparsely grown areas like Heaths and Woodland clearings. It is a Kent Red Data Book species. In Kent, it has been evaluated as a Heath and Acid Grassland species, as here, this is a more limiting resource than Woodland. Due to its large dispersal range of around 30 km, it is less sensitive to fragmentation than the others species of those habitats. The species is modelled for Limburg using a different habitat description, as a result of different land use. See also under 'Woodland'.

European Stonechat (Roodborsttapuit, Saxicola torquata): Kent and Limburg case study

The European Stonechat prefers relatively dry habitats and is mainly a species of small scale agricultural landscapes, but also inhabits Heaths. The dispersal range is about 10 km and it is therefore more sensitive to fragmentation than the Dartford Warbler. This species is also a Kent Red Data Book species.

Nightjar (Nachtzwaluw, Caprimulgus europaeus): Kent case study

The Nightjar is a Bird Directive annex I species and a Kent BAP and Red Data Book species. It is an indicator species for medium range birds from Heathlands.

Heather (Struikheide, Calluna vulgaris): Limburg case study

Heather grows on moist to dry acid soil on Heathlands, nutrient poor Grassland and open Woodland. On Heathland it often dominates the vegetation structure. This is a very important habitat for related herpetofauna, entomofauna and avifauna.

Hairy Greenweed (Kruipbrem, Genista pilosa): Limburg case study

Hairy Greenweed is growing on more or less dry soils, poor on nutrients. In Heath, seldom in open woodland; scattered, but characteristic.

Cross-leaved Heath (Dopheide, Erica tetralix): Limburg case study

Grows on moist to dry soils which are poor in nutrients. On Heath, low laying Grassland, at bogs and usually wet Heath and moors; often dominating the vegetation structure. Sensitive to lowering of the ground water table.

White-beaked Sedge (Witte snavelbies, Rhynchospora alba): Limburg case study

Growing in raised bogs and wet acid peaty places in Heathland and then locally dominating the vegetation. Sensitive to lowering of the ground water table.

2.2.2 Wetland

***Cetti's Warbler** (Cetti's zanger, Cettia cetti): Limburg and Kent case study*

The habitat of Cetti's Warbler is thickets along rivers, streams and swamps. The dispersal range is around 50 km. This is a Kent Red Data Book species.

Reed Bunting (Rietgors, Emberiza schoeniclus): Kent case study

Bird species of Wetlands, finds its habitat in Reed beds and riverine scrubs, also a Kent Red Data Book species.

Cut-grass (Rijstgras, Leersia oryzoides) and Tufted Sedge (Stijve zegge, Carex elata): Limburg case study

Both species are typical for wetlands. Cut-grass occurs grows locally in wet meadows, ditch bottoms, canal sides, river margins and brook in nutrient rich situations. Tufted Sedge is a typical species of 'broekbos' (very wet lowland forest often comprising alder, willow or ash).

Floating Water Plantain (Drijvende waterweegbree, Luronium natans): Limburg case study

The Floating Water Plantain is a specific species of fens.

Marsh Gentian (Klokjesgentiaan, Gentiana pneumonanthe): Kent case study

This species is characteristic for wet, acid soils in Heathland, low lying Grassland and Junco-Molinion. It is sensitive to lowering of the ground water table. In the Netherlands there is a unique dependence of the butterfly Alcon Blue (*Gentiaanblauwtje*, *Maculinea alcon*) to Marsh Gentian and ant species (*Myrmica div. spec.).*

Marsh Fern (Moerasvaren, Thelypteris palustris): Kent case study

Grows in marshes and fens, often shaded among taller herbs or shrubs, also in Common Reed dominated vegetation. Sensitive to lowering of water level.

2.2.3 Woodland

Bechstein's Bat *(Bechstein's vleermuis, Myotis bechsteinii): Limburg and Kent case study*

Bechstein's Bat depends on old Woodland because it needs tree holes for roosting. Although the species can bridge quite large distances, it is a bad disperser with a dispersal range of about 500 m. This is due to the fact that this species is attached to its hunting area, which it knows very well. When an individual disperses, a new hunting area needs to be explored in detail, which is very time and energy consuming. Individuals that only disperse a small distance can partly keep their old hunting area. This leaves them with enough energy and opportunities for successful breeding. The species is extremely sensitive to fragmentation.

Purple Emperor *(Grote weerschijnvlinder, Apatura iris): Limburg and Kent case study*

The Purple Emperor is another species dependant on old forests with a dispersal range is about 5 km and is not sensitive to barriers. It is therefore much less sensitive to fragmentation when compared to the Bechstein's Bat. This is a Kent Red Data Book species.

Woodlark *(Boomleeuwerik, Lullula arborea): Limburg case study. See also under 'Heath'*

The distribution of the Woodlark in Limburg is not specifically linked to Heaths and Acid Grasslands, but to Heath with forest edges in close proximity. It is therefore modelled as a species of Heaths and woodland edges on poor soils.

Middle Spotted Woodpecker (Middelste bonte specht, Dendrocopos medius):Limburg case study

Old, preferably deciduous forests. Needs trees with rough surfaces like mature oak. Requires relatively large areas of suitable habitat.

Lesser Horseshoe Bat (Kleine hoefijzerneus, Rhinolophus hipposideros): Kent Limburg case study

Bat species, finding its habitat in broadleaved woodland and wet Woodlands.

Bilberry (Blauwe bosbes, Vaccinium myrtillus): Limburg case study

The Bilberry grows on moist to dry, acid soil in open Woodland, Heathlands and moors. In the Netherlands it is co-dominating in Heath when precipitation is relative high.

Bluebell (Wilde hyacinth, Hyacinthoides non-scripta): Kent case study

In woods, hedgerows, shady banks and Grassland in wetter regions. High temperature in summer and low temperature in winter are unfavourable for the Bluebell (preferring maritime climate).

2.2.4 (Chalk) Grassland

Adonis Blue *(Adonisblauwtje, Lysandra bellargus): Kent case study*

This Kent BAP species and a Kent Red Data Book species finds its habitat on neutral, chalk or limestone grassland that is grazed and coastal cliff tops where its foodplant, Horseshoe Vetch (*Hippocrepis comosa)* grows in short vegetation.

Meadow Pipit *(Graspieper, Anthus pratensis): Kent case study*

Inhabits open grassy areas with dense and short vegetation, upland moors, bogs, Heathlands. They nest in wet meadows. It avoids very short grass in intensive meadows or grazed pastures, as well as various forms of tall dense vegetation like woodlands or reed beds.

Chalk Hill Blue (Bleek blauwtje, Lysandra coridon): Kent case study

As the Adonis Blue, a butterfly of Chalk Grassland.

2.2.5 Other/combination of ecosystems

***Great Crested Newt** (Kamsalamder, Triturus cristatus): Limburg and Kent case study*

Amphibian that requires ponds with woodland edges, hedges or scrubs close by (750 m) for terrestrial and hibernation habitat (within more or 750 m). If good quality terrestrial and hibernation habitat are found close to a pond, more individuals will occur in a pond.

Greater Horseshoe Bat (Grote hoefijzerneus, Rhinolophus Ferrumeouinum): Kent case study

Needs linear structures like woodland edges and hedges to navigate through the landscape and to forage along. This species is modelled as an edge species (hedges, wooded banks and woodland edges).

Water Vole (Woelrat, Arvicola terrestris): Kent case study

The aquatic Water Vole inhabits waterways such as rivers, streams and ditches and occurs in England in linear habitats along banks of these rivers within 1-2 m from the sloping and well vegetated edge of the water. Tall Grasslands with ditches, slow flowing streams and some fresh water areas like ponds, marshes, wet areas in the lowlands are suitable habitats too. Moreover, reed beds are refuge against American mink, an invasive species that is predator of this species.

Western Whip Snake(Geelgroene toornslang, Coluber viridiflavus): Limburg case study

Found on mostly dry habitats offering enough cover and prey. Uses a mix of open and linear Woodland, woodland borders, open woods, bushes, ruins, gardens, damp lawns, banks of water courses.

European Bee-eater (Bijeneter,; Merops apiaster): Limburg case study

Needs steep banks where nesting holes can be built. Habitat on map is only sand quarries. Isolated breeding records have been reported for several locations in the Netherlands (but not for the case study area) from the 1990's.

Clustered clover (Trifolium glomeratum): Kent case study

Species of sandy places on sandy soil, often near the sea; dunes.

2.3 Modelling the shifting climate envelopes of species: SPECIES model

Climate exerts an important control on species distributions, especially at macro-scales i.e. national and continental scales (Pearson & Dawson, 2003). In order to establish the potential impacts of climate change on species it is necessary to capture the relationship between the species and current climate. This can be done by various correlative techniques, based on establishing a statistical relationship between the species' distribution and selected relevant climatic variables to produce its bioclimatic envelope. Bioclimatic envelopes are areas which are potentially suitable for a species in terms of climate. They do not include factors such as habitat availability or competition, which may be important at a more regional to local scale.

The SPECIES (Spatial Estimator of the Climate Impacts on the Envelope of Species) model (Pearson *et al*., 2002) has been used to simulate the potential impacts of climate change on the availability of potential suitable climate space for species (Berry *et al*., 2001; Berry *et al*., 2005; Harrison *et al*., 2006). The model uses an artificial neural network to integrate bioclimatic variables for projecting the potential distribution of suitable climate space through the characterisation of bioclimatic envelopes. A number of integrated algorithms, including a climate-hydrological process model, are used to pre-process climate (temperature, precipitation, solar radiation, vapour pressure and wind speed) and soils (available water holding capacity) data to derive relevant bioclimatic variables for input into the neural network. The variables found to be most successful for bird distributions (Harrison *et al*., 2003) and other taxa (Berry *et al*., 2003) are given in Table 5.

Table 5 Bioclimatic input variables used in the SPECIES model for birds and other taxa.

Birds	Other taxa
Growing degree days > 5°C	Growing degree days > 5°C
Absolute minimum temperature expected over a 20-year period	Absolute minimum temperature expected over a 20-year period
Mean summer temperature (May, June, July)	Annual maximum temperature
Mean summer precipitation (May, June, July)	Accumulated annual soil water deficit
Mean winter precipitation (December, January, February)	Accumulated annual soil water surplus
Mean summer water availability (May, June, July)	

2.4 Modelling the connectivity of habitat: the SMALLSTEPS model

To enable species to occupy the 'new' areas of their climate envelope or be able to persist in parts of their range where conditions will not become totally unsuitable but will merely deteriorate, will depend on the presence of enough suitable habitat in the area to sustain them. Since the habitat of most species is not continuous but fragmented this means that in both cases habitat networks need to be present that can support sustainable metapopulations of the species (for explanation see Box 3). Even if the networks for potentially sustainable populations in newly suitable areas are available, they must be accessible for a species. Both size and accessibility of networks depend on the connectivity between habitat patches. The first step in this analysis is therefore a connectivity assessment using the SMALLSTEPS model.

The SMALLSTEPS model is explained in detail in annex 1. In short the model is built to simulate the movement of individuals of species through a landscape. For a species to be modelled, a number of ecological parameters need to be specified such as habitat preferences, preferences for landscape element types to move through, movement speeds, dispersal range etc. The model then lets a large number of simulated individuals 'run' through a digitalized landscape, starting from and – if they get there within the allotted time – ending in habitat patches. The result is that for each pair of habitat patches in the landscape the probability that an individual leaving from the one will arrive in the other (and vice versa, please note there are two values for each pair) is calculated. When two patches are very close to each other the probabilities will be relatively high, when the patches are further apart than the species' dispersal range the probabilities will be zero. In the next step these probabilities can be used to determine the extent of habitat networks.

How many pairs of individuals of a species a habitat patch can support, the carrying capacity, depends on the combination of patch size and habitat quality. In return, the number of individuals dispersing from a habitat patch depends on the number of pairs. If the carrying capacity and the population dynamics of a species are known, the actual flow of individuals between patches can be calculated using the results of the previous step. Patches that have very small carrying capacities are left out as habitat. Using general metapopulation theory and species population dynamics, a threshold value for the exchange between patches can be set and used to determine which patches belong to the same network. Applied to all patches, the end result is an overview of the species' habitat networks in the evaluated landscape.

In the next step, the sustainability of these networks can be assessed using the LARCH model (see explanation in 2.5).

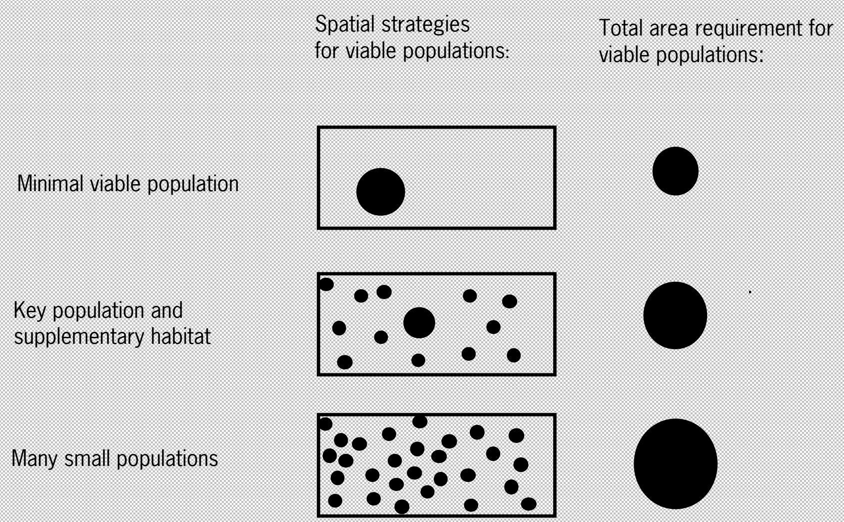
Box 3 Concept of metapopulations and ecological networks

When natural habitat becomes fragmented as a result of landscape changes, small isolated patches are often too small to sustain persistent populations. These small, local populations are always at risk of extinction, due to stochastic processes or local 'disasters' like fire, disease or pollution. When local populations are mutually connected by dispersal movements in a habitat network, the total area of habitat patches offers possibilities for persistent populations of species. Such a "population of populations" that occurs in a network of habitat patches is called a metapopulation.

A (meta)population can occur in different spatial configurations in a landscape. The more the habitat of a species is fragmented, the more area is needed for a habitat network that supports a sustainable metapopulation.

Large populations with a very low probability of extinction, the so-called "key populations", constitute the strong parts in a metapopulation occupying a habitat network (Verboom *et al.,* 2001). From these "key patches" a net flow of individuals to other habitat patches in the habitat network takes place. In this way migration can occur from a key patch to a small habitat patch where the population went extinct (Levins, 1970; Andrén, 1994). Also, for colonising new suitable areas, as a result of e.g. climate change, key patches can fulfil an important role, as these areas are important source areas of individuals looking for new habitat areas to settle, e.g. source sink population dynamics. We consider a metapopulation sustainable if the risk of extinction is less than 5% in 100 years (Shaffer, 1981; Verboom *et al.,* 2001).

Standards used to decide whether a metapopulation is sustainable are species specific. Small, short living species (for example insects) are more vulnerable and require more individuals for a persistent population than larger, long living species (like the beaver). For less mobile species habitat patches should be situated closer together to form part of the same habitat network. The habitat extent requirements of insects are, for example, smaller.



Total area requirement for a sustainable (meta) population in different configurations in a landscape

2.5 Modelling the sustainability of habitat networks: the LARCH model

Assessment of the viability of habitat networks of species in a landscape is made operational in the LARCH model (Landscape Analysis and Rules for the Configuration of Habitat). LARCH is designed as an expert system and is described in full detail elsewhere (Foppen *et al.,* 1999; Chardon *et al.,* 2000; Pouwels, 2000; Van der Sluis & Chardon, 2001).

The required input for LARCH are a habitat map (e.g. a vegetation map) and ecological standards or rules for the selected species (e.g. dispersal distance, potential density in biotope types etc.). The standards used for sustainability are based on literature, empirical studies and simulations with a dynamic spatially structured population model carried out over the past ten years (Foppen *et al.,* 1999; Foppen, 2001; Verboom *et al.,* 2001; Vos *et al.,* 2001 a&b). The potential densities that are used as inputs are derived from distribution data of the study area, areas that are comparable, or from expert knowledge and literature.

The LARCH model was used for the sustainability analysis of habitat networks. The input consisted of the output of the SMALLSTEPS model (a map of the habitat networks of a species). The sustainability analysis consists of two steps:

1. Distinguishing 'key areas': Based on the size and quality of a habitat area for a particular species, the population size that can potentially occur in a local population is calculated for each patch (Figure 3 a & b).
2. Determining the viability of the potential network population (Figure 3c). The criterion used for sustainable networks is that a network population has a chance of extinction of less than 5 % in 100 years (Shaffer 1981; Verboom *et al.,* 1997). Habitat networks that contain a key area need less area than habitat networks that do not (see Box 3).

The modelling approach for the Great Crested Newt, an amphibian, was different. Amphibians differ from other animal groups in the fact that they breed in a water body (pond) each spring and use terrestrial habitat for a part of the rest of the year. Habitat quality for amphibians in general and especially for the Great Crested Newt is therefore determined by a combination of pond density and density of the terrestrial habitat in the area. Reproductive animals gather each spring in breeding ponds. These ponds can therefore be used as the starting points for the movements of individuals. Instead of habitat networks, pond networks are established and evaluated using the same methodology. To bring in the terrestrial component, the amount of suitable terrestrial habitat within reachable distance is used to classify the habitat quality of individual ponds. For this type of species, the concept of key areas is not applicable, so a single network threshold for sustainable pond networks is used.

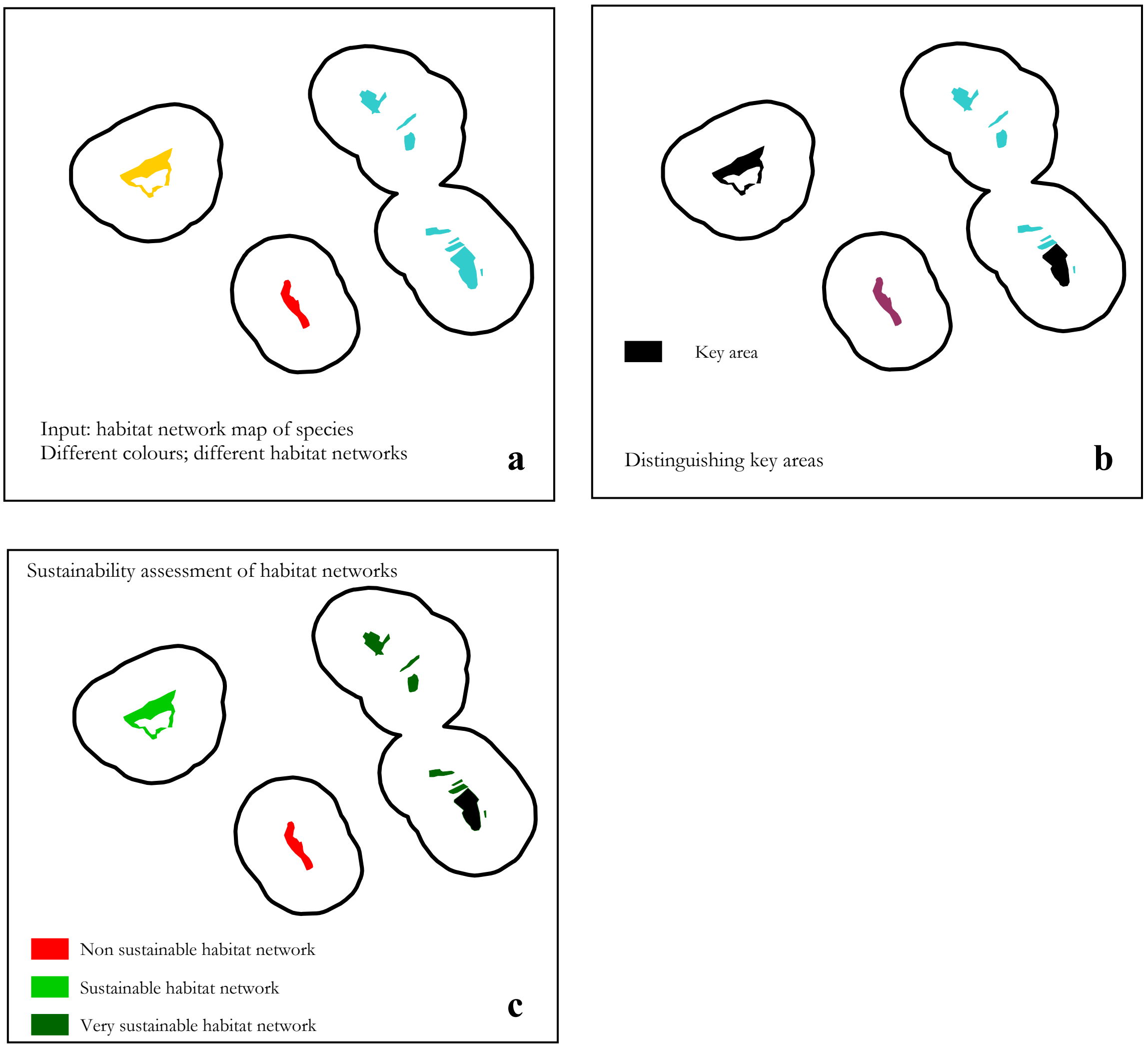


Figure 3 LARCH sustainability assessment of habitat networks.

2.6 Incorporating the effect of climate stress in the sustainability of habitat networks

The climate envelopes that were produced on the European scale show well defined borders. This suggests that in an area that becomes excluded from the envelope the climatic conditions for a species will suddenly change from fully suitable to unsuitable and the other way around in areas newly under the envelope. A more or less gradual increase in climate stress towards the edge of the envelope is far more likely.

In this study, it is assumed that the abundance of species is gradually decreasing from the centre of the climate envelope towards the edge. This was translated in the gradual change of carrying capacity of habitat as a result of gradual climate change. Gradual relationships between abundance and climate stress have often been reported, especially when climate stress interacts with other stress factors (Woodward 1987; Forsman and Monkkonen 2003). Until recently, a decreasing abundance from the middle of a species distribution area towards the edges was assumed to be a universal phenomenon (Hengeveld and Haeck 1982; Guo, Taper et al. 2005) but this was demonstrated to be an oversimplification and species abundance patterns depend on more factors than just climatic ones (Sagarin, Gaines et al. 2006). However, it is likely that a general rule will apply to the effect of climate change, i.e. when the only density related driver that changes is climate stress. Parmesan & Yohe (2003) list numerous cases where an abundance effect of climate change was shown.

Table 6 Relation between time slices T1 to T4 with carrying capacities, used in the SMALLSTEPS/LARCH modelling.

Time slices	T1	T2	T3	T4
Incoming / increasing species	10 %	20 %	50 %	Optimal situation (100 % carrying capacity)
Decreasing / disappearing species	Optimal situation (100 % carrying capacity)	50 %	20 %	10 %

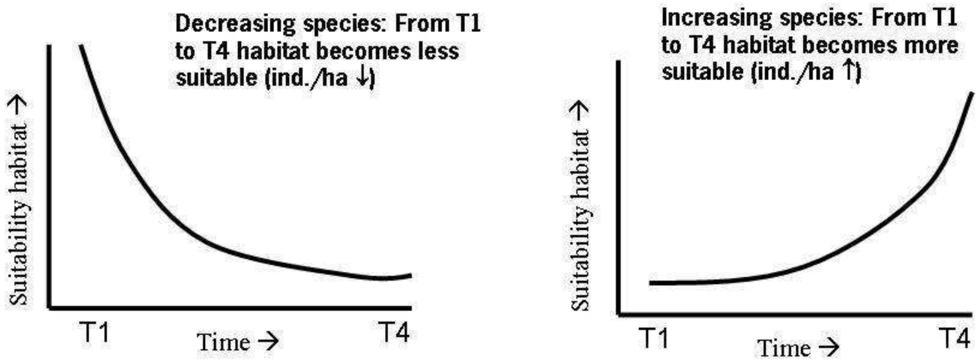


Figure 4 By varying the carrying capacity of habitat for a species, the effect of climate change on the coherence and sustainability of habitat networks was assessed.

For all species, sustainability of habitat networks was assessed at 4 different carrying capacity settings. The model was calibrated with the optimal situation, which is for declining/disappearing species considered to be the present situation, and for incoming/increasing species the situation in the far future when climate and habitat will be suitable. Then, the estimated optimal carrying capacity was increased (incoming/increasing species) or decreased (declining/disappearing species) by a factor 2, 5 and 10. That means that for incoming/increasing species, the present situation is not necessarily coinciding with the 10% density (Table 6). The present situation could be e.g. in T2.

2.7 Improving ecological networks: a planning method

The planning method for climate change proof ecological networks is based on principles used in metapopulation theories. Additional to these principles, we used rules to decide when and how to create climate change proof ecological networks. In general, it is assumed that the positive effects of species finding habitat in new suitable climate change exceeds the negative effects of species interactions such as competition. This because of two reasons:

- Expansion of a population to new suitable habitats can compensate the loss of habitat in the south part of the distribution area. For species that are already under threat of extinction, this is considered to be of importance for long-term survival.

- On a site level, ecosystems that are rich in species are often considered to be more stable, and to have a larger resilience against disturbances. An ecosystem that is only losing species as a result of climate change and not gaining new species at the same time could be more vulnerable (Box 4).

An important point of departure in the planning method is that both the present and future (most) sustainable habitat/ecosystem networks are important parts of a climate change proof network, both for incoming/ increasing and for declining/disappearing species. In such networks, declining species can survive longer despite of a more unsuitable climate, and new or increasing species can establish relatively fast a sustainable population. The second assumption is that key areas are of high importance for a climate change proof ecological network. For incoming/increasing species these areas contribute to the expansion of the species into new climate space, as key areas are important sources of dispersers. For declining/disappearing species key areas also have advantages as such relatively large areas have a stabilizing effect on the network population. Larger areas can also sustain larger heterogeneity of habitats, which will allow species to persist longer in a changing climate, when weather extremes will occur more frequently (Den Boer 1986). These first, rough assumptions will be object of further study for future refinement or adjustment of the planning method.

Stakeholder engagement is crucial to network design because incorporating local knowledge increases output quality, because stakeholders are essential in developing and choosing between alternative network designs, and because the support of a broad group of stakeholders is required for the implementation of the ecological network. Therefore, a planning method was developed which enables local stakeholders to incorporate local expertise, to identify bottlenecks, opportunities and alternative options, and to design climate-proof ecological networks. The method is based on the design method used in Cheshire (Van Rooij *et al*., 2003).

Box 4 Resilience of ecosystems

Folke (2004) states that the combined and often synergistic effect of pressures (e.g. climate change) can make ecosystems more vulnerable to changes that previously could be absorbed and, as a consequence, ecosystems may suddenly shift from desired to less desired states in their capacity to generate ecosystem services. A positive effect of new species in an ecosystem is mentioned in Elmqvist *et al.* (2003). A species has a particular response to abiotic conditions which can be complementary to the existing response diversity[2] at a site. An increase in response diversity increases the resilience of the ecosystem to environmental change. However, it is not known how new species will interact with resident species. This might compensate for the effect of losing existing species. (Suding, Gross et al. 2004) however, demonstrate for intensive restoration projects, where all species can be considered “new”, that species interactions and species dominancy are unpredictable.

[2] Response diversity: the diversity of responses to environmental change among species contributing to the same ecosystem function.

The planning method consists of 4 consecutive steps:

1. *Formulate nature conservation target*
   In this step the species and ecosystems of interest with different reaction types to climate (both incoming/increasing species and declining/disappearing species) are selected.
2. *Identify important habitat networks*
   Required input for this step are maps of present and future habitat networks of the selected species, e.g. the resulting maps of the SMALLSTEPS and LARCH modelling. To enable stakeholders to design with these maps, decision tables and worksheets were developed. As species have different reactions to climate change, different decision tables were developed for increasing and for decreasing species. With these tables, stakeholders can identify existing habitat networks that are important for developing future climate change ecological networks. Also, constraints and opportunities for habitat development in relation to other land-use functions are identified and mapped in this step.
3. *Design the alternative solutions*
   In this step stakeholders develop alternative spatial options to improve and create well-connected climate change proof habitat networks for each of the selected species, using decision tables developed for this purpose. Different decision tables were used for network design depending upon the reaction type of the species involved. For some characteristic ecosystems more than one representative species was selected in step 1. In this case separate alternative habitat networks were developed that were integrated.
4. *Select and combine*
   In this step stakeholders choose the optimal spatial alternative for each ecosystem and integrate those into one climate-proof well-connected ecological network.

2.8 Stakeholder involvement

The involvement of stakeholders was tailored to the case study: intensive involvement of many stakeholders in Kent and Hampshire, and no involvement in Limburg.

Kent County Council considered stakeholder involvement vital for the process of designing ecological networks. Stakeholders may contribute specialist, local knowledge in different fields of importance to include local circumstances in the network assessment and network planning. It therefore adds to the (ecological) quality of the plan. Furthermore, involving stakeholders from the start gives them the opportunity to include items that they consider important. This instils a level of ownership and raises support for future implementation of any biodiversity adaptation initiative in Kent. It therefore adds to the feasibility of and enthusiasm for the plan.

Hampshire County Council shared and discussed the findings with local spatial planners and ecologists. They considered this of importance to envisage future implications and to be able to take appropriate action.

The province of Limburg chose not to involve stakeholders at this time, because it had just finished a long and intensive process of stakeholder involvement planning the Robust Corridor. Involving stakeholders again for the evaluation of this corridor (does it really work?) would confuse the stakeholders, and diminish their support.

3 Case studies: specific methods, results, conclusions and recommendations

3.1 Case study Hampshire

Chalk Grassland and Lowland Heath are two important and characteristic habitats of the Hampshire countryside. Lowland Heath represents some 13 % of the European total and is mostly found in the New Forest. The nationally important Chalk Grassland habitat makes up 5 % of the UK total but is very fragmented on the steep slopes of the South Downs and chalk escarpment.

3.1.1 Methods

The potential impacts of climate change on the two habitats mentioned were assessed using the SPECIES model on a selection of species that are characteristic or dominant for these habitats. Maps were produced showing where there could be suitable climate space for the selected species nationally and in Hampshire and the South Downs, under climate change scenarios for the 2020s, 2050s and 2080s.

The potential suitable climate space for the species modelled were combined with (1) current habitat distribution and (2) previously mapped opportunities for habitat re-creation and restoration, to show where both could be available in the future. Modelling limitations and assumptions include that climate is the dominant factor affecting species' distribution, the absence of factors such as biotic interactions is not important, the species is in equilibrium with climate, the selection of species adequately reflect the habitat response to climate change. A workshop with local spatial planners and ecologists in Hampshire was held to discuss findings and future implications.

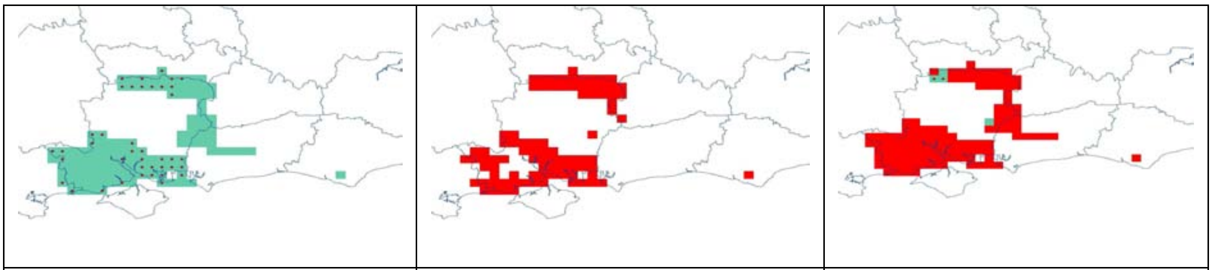
3.1.2 Expected changes in climate suitability

Climate change modelling showed individualistic species responses, with species modelled gaining or losing potential suitable climate space by varying amounts. Most species modelled are expected to lose climate space in the long run.

For a number of the Lowland Heath and Chalk Grassland species, the current areas of habitat in Hampshire and the South Downs also represent potential suitable climate space in the future. Looking at the 2080s High scenario however it appears that many of these areas become potential unsuitable climate space for some species. Thus the existence and/or character of these habitats in Hampshire and the South Downs could be called into question, as species could decrease or locally be lost unless they are able to adapt to the conditions.

For the Lowland Heath, the key ericaceous species do not suffer significant loss under the 2020s and 2050s scenarios but lose all, or nearly all, their potential suitable climate space under the 2080s high scenario. This could lead to total modification or loss of the habitat. The Chalk Grassland could also see a considerable modification in composition with the loss of dominant species, including grasses. Some of these species start to lose suitable climate space under the 2020s high and 2050s scenarios (Crested Hair Grass, Meadow Oat Grass, Musk Orchid). Under the 2080s high scenario, all suitable climate space could be lost for these species. This scenario could lead to large parts of the South Downs and south western Hampshire becoming unsuitable for many characteristic Chalk Grassland species.

The possibility of adaptation through habitat re-creation was explored. For some species habitat re-creation could contribute to maintain potential suitable space for a while, but with the total loss of climate space for some key species they may not survive under the 2080s high scenario.



a) Dartford Warbler – climate and habitat remain suitable; habitat re-creation could provide an opportunity to expand its range.	b) Bog Orchid – all suitable climate space is lost.	c) Cross- leaved Heath - almost all suitable climate space is lost; habitat re-creation provides little opportunity for the species.

Figure 5 Three possible responses of Lowland Heathland species, showing the potential suitable climate space and habitat available under the 2080s High scenario.

3.1.3 Impact on stakeholders

In the local workshops, discussions on the findings centred around the need for a sound evidence base on which to make decisions and argue the case for habitat conservation and creation in the face of competing priorities for land use. Current planning mechanisms such as SEA (Strategic Environmental Assessment) and SA (Sustainability Appraisal) tend to be static in time and longer term approaches are needed. These may include accepting Natura 2000 land as designated for non-specific nature conservation purposes in the future thus allowing species and habitats to move and change. With the potential loss of suitable climate space for particular habitats, maintaining designated areas for alternative habitats may be the only long term option.

3.1.4 Discussion and conclusions

Modelling a number of species for a given habitat gave an indication of the potential impacts of climate change on that habitat. For the next four decades, no large scale changes in the character of Lowland Heath and Chalk Grassland are expected. There is only a need to ensure that these areas are maintained in a favourable condition. On the longer term, the climate might become unsuitable, indicating that the long term existence and/or character of these habitats in Hampshire and the South Downs could see significant changes. Lowland Heath appears slightly more sensitive than Chalk Grassland.

Climate change can have an effect on the present species in an area, but also is expected to result in new species colonising the area. In this approach, only the effect of climate change on present species is assessed. Not taken into account are effects on competition between present and new species or changes in competition of present species. This might change the character of the habitat. Further research is needed in order to understand these effects. However, in modelling a comparatively large number of species for each habitat the potential impacts of climate change can start to be inferred.

3.1.5 Recommendations and further steps

A possible solution is habitat re-creation which might help species to survive in the short to medium term. In the long term, they might continue to be lost. Another option is to designate Natura 2000 sites as land for (non-specific) nature conservation or for new incoming species, and not only for the particular habitats and species for which they where designated, whilst these may not remain.

3.2 Case study Limburg

The province of Limburg forms the Southeastern part of the Netherlands and is situated between highly urbanised areas in the Netherlands, Germany and Belgium (Figure 6). The case study area consists of the Southern part of Limburg, Limburg East of the river Meuse and the adjacent 10 km wide strip of German territory (Figure 7). This part of Limburg was originally an area of high nature value that has become highly fragmented. Nevertheless, the area still contributes a high percentage of the Limburg part of the Dutch National Ecological Network (NEN). Since 2000 the province of Limburg has been planning and implementing a Robust Corridor (Figure 7) as an addition to the NEN to improve connectivity. The corridor links a chain of habitats on the eastern bank of the river Meuse, at both sides of the Dutch–German border, runs from Schinveld to the Reichswald, and includes 2200 ha habitat to be created. It is intended to improve links between habitats parts in the Dutch National Ecological Network and the Natura 2000 network at both sides of the border.

Important habitats are forests, Heath, pastures, hedges, arable fields and marshy valleys. One of the legitimacies of extending the NEN with a Robust Corridor policy was adaptation to predicted effects of climate change. Up till now, the effectiveness of these corridors to fulfil this objective has never been studied, and methods to do so have been lacking. The main objective of the Limburg case study is to develop an evaluation method for the added value of the Robust Corridor and to assess its role in adapting the NEN to the effects of climate change.

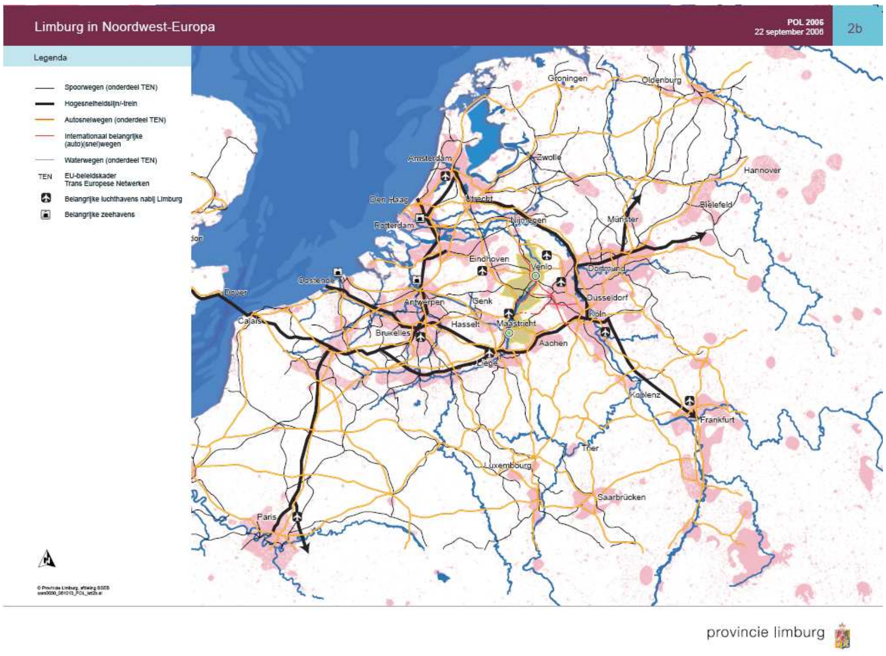


Figure 6 Green: location of the Province of Limburg (Source: Province of Limburg).

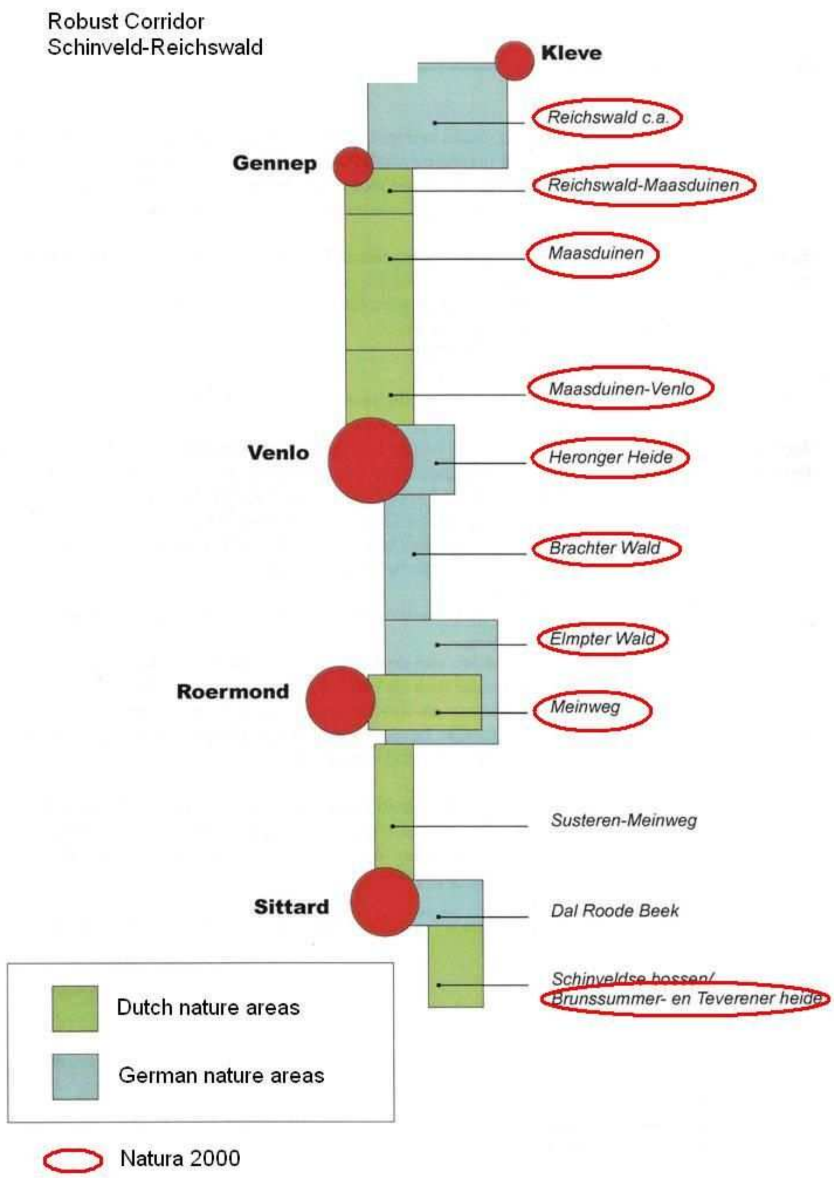


Figure 7 Robust Corridor in Limburg connecting Dutch and German (Natura 2000) nature sites.

3.2.1 Methods

For a selection of species (Table 7), connectivity and sustainability of habitat networks for the present situation without the Robust Corridor and the NEN with Robust Corridor was compared. Because of data management restrictions, the study area was limited to the southern part of Limburg and the eastern part of the river Meuse (Figure 7). Because the corridor runs close to the German border and connects nearby German nature sites, a 10 km wide German zone was included. Methods and information sources used are listed and explained in the annex 4. The required level of detail was far better for the Limburg part than for German part. When relevant, the effect of this difference in resolution will be discussed.

Data on present species distribution was obtained through the Province of Limburg. Information on relevant habitat types, expected densities in optimal, suboptimal or marginal habitat under suitable climatic conditions and sustainability thresholds were taken from the Alterra LARCH database, based on literature or previous research. Information on population dynamics, especially concerning the expected effects of climate change, expected species trends, habitat use, etc. was obtained from species experts.

3.2.2 *Expected changes in climate suitability for the selected species*

In BRANCH action 3, the changes in climate suitability in the years 2020 and 2050 were modelled on the Northwest European scale.. Table 7 lists the predicted climate effects for the species selected. For the results of the SPECIES model see annex 4.

Table 7 Overview of the species selected per ecosystem for the SMALLSTEPS/LARCH modelling (bold) and evaluation in the Limburg case study. In colour, assessment of climate suitability.

		Year	2010	2020	2050
Heath / acid grassland					
Sand Lizard	**Zandhagedis**	***Lacerta agilis***			
Dartford Warbler	**Provencaalse grasmus**	***Sylvia undata***			
Europaean Stonechat	Roodborsttapuit	*Saxicola torquata*			
Heather	Struikheide	*Calluna vulgaris*			
Cross-leaved Heath	Gewone dopheide	*Erica tetralix*			
Silky Leaf Woadwaxen	Kruipbrem	*Genista pilosa*			
White-beaked Sedge	Witte snavelbies	*Rhynchospora alba*			
Wetland					
Cetti's Warbler	**Cetti's zanger**	***Cettia cetti***			
Cut-grass	Rijstgras	*Leersia oryzoides*			
Floating Water Plantain	Drijvende waterweegbree	*Luronium natans*			
Tufted Sedge	Stijve zegge	*Carex elata*			
(Old) woodland					
Bechsteins Bat	**Bechsteins vleermuis**	***Myotis bechstinii***			
Purple Emperor	**Grote weerschijnvlinder**	***Apature iris***			
Woodlark *	**Boomleeuwerik**	***Lullula arborea***			
Middle Spotted Woodpecker	Middelste bonte specht	*Dendrocopus medius*			
Bilberry	Blauwe bosbes	*Vaccinium myrtillus*			
Grassland					
Meadow Pipit	Graspieper	*Anthus pratensis*			
Other / combination of ecosystems					
Great Crested Newt	**Kamsalamander**	***Triturus cristatus***			
Greater Horseshoe Bat	Grote hoefijzerneus	*Rhinolophus ferrumequinum*			
Western Whip Snake	Geelgroene toornslang	*Coluber viridiflavus*			
European Bee-eater	Bijeneter	*Merops apiaster*			

* The Woodlark was modeled as a forest edge species

Climate in whole of Limburg suitable
Climate in whole of Limburg only just suitable
Climate for part of Limburg suitable
Climate for whole of Limburg unsuitable

3.2.3 *Expected changes in ecological networks and the effect of the Robust Corridor*

Seven species were selected for SMALLSTEPS/LARCH modelling. The sustainability of habitat networks was assessed for the present situation as well as for the situation expected after completion of the NEN including the Robust Corridor. Because planning and implementing the NEN and the Robust Corridor (the combination from now on referred to as Robust Corridor) is not quite finished in all detail, habitat changes could not always be defined to the required level of detail, resulting in differences between species, as discussed below.

Due to lack of knowledge on the velocity of climate change and species responses, the carrying capacities used in SMALLSTEPS/LARCH modelling (see section 2.4) could not be calibrated to empirical data. Therefore, the expected trends are not absolute estimates and can only be used in a comparative way. See the annexes for the complete modelling results. Results per species are discussed below.

Heath/Acid Grassland

Effectiveness of the Robust Corridor

The Sand Lizard (*Zandhagedis*, *Lacerta agilis*) is a target species for Limburg and is on the Dutch Red List with 'vulnerable' status. It has a relatively short dispersal range of 1 km and is sensitive to barriers such as busy roads. After a long period of decline the species is now increasing in the Netherlands. The amount of Heath (the suitable habitat) left in Limburg is small and fragmented. The distribution map for the Dutch part of the case study area (data for the German part were not available) shows that the species is present in most habitat patches and that strongholds mostly correspond with key areas (Figure 8). The results of the action 3 modelling indicate that the southern edge of the species' climate envelope will probably move close to Limburg by the end of the study period (2050; Figure 9). Therefore, climatic conditions will probably worsen, but not to the point that present habitat will become unsuitable. As a result there is a possibility that population densities will experience a substantial decrease, resulting in the continued effects of habitat fragmentation, leading to increased local extinctions and decreased chances of re-colonisations. The SMALLSTEPS/LARCH modelling (T4, decreasing carrying capacity to 10%) predicts that Sand Lizard populations will survive in the largest areas. The effect of the Robust Corridor under present climate conditions is small (Figure 10), but is quite significant under a changed climate regime (Figure 11). In the Northern part of the study area the Robust Corridor ensures the persistence of the Sand Lizard even if carrying capacity drops to 10%. Under the assumptions in the models, the 'gap' in the Robust Corridor just north of Venlo will act as a bottleneck separating two sustainable networks. However, the overall persistence in Limburg of the Sand Lizard under climate change has greater likelihood if the Robust Corridor is implemented.

The Dartford Warbler (*Provencaalse grasmus, Sylvia undata*) has similar habitat preferences as the Sand Lizard, but it has a larger dispersal range and is not sensitive to barrier effects of infrastructure. Limburg will be in the species' climate envelope by 2020, and will occur there if habitat density in Belgium and Northern France allows the species to expand all the way up to Limburg.

The species is currently expending north from southern France (Hagemeijer and Blair 1997). Modelling results for the present situation (with unsuitable climate) show that the Robust Corridor has a positive effect on improving the network structure(Figure 12). If carrying capacity increases by a factor of 4 due to improved climate conditions, all habitat patches will be included in a single network. The Robust Corridor adds habitat sites, but will not improve regional distribution patterns or persistence probability (Figure 13). Due to the dispersal capacity of the species the Limburg suitable habitat areas are part of one larger network, an added value of the Robust Corridor to Dartford Warbler could be present at a larger scale but is not shown at this modelling scale. This result shows that the Dartford Warbler in Limburg does not essentially profit from the Robust Corridor in habitat connectivity terms.

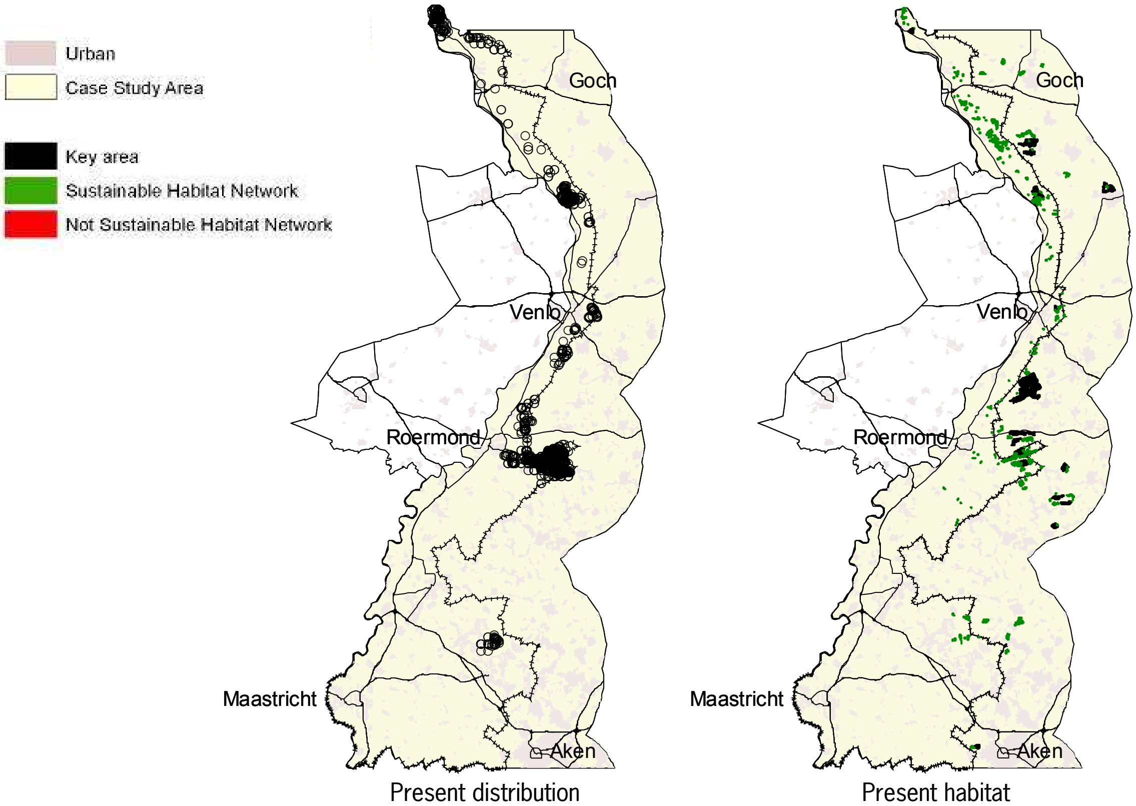


Figure 8 **Present distribution and habitat of the Sand Lizard.**

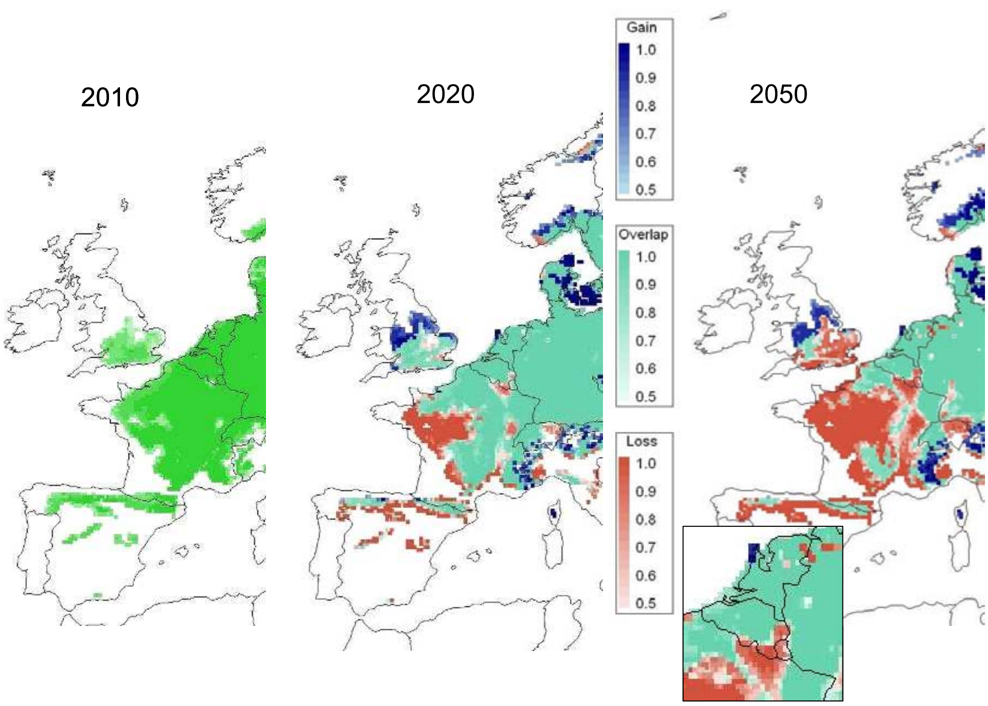


Figure 9 **Predicted shift of climate envelope for Sand Lizard.**

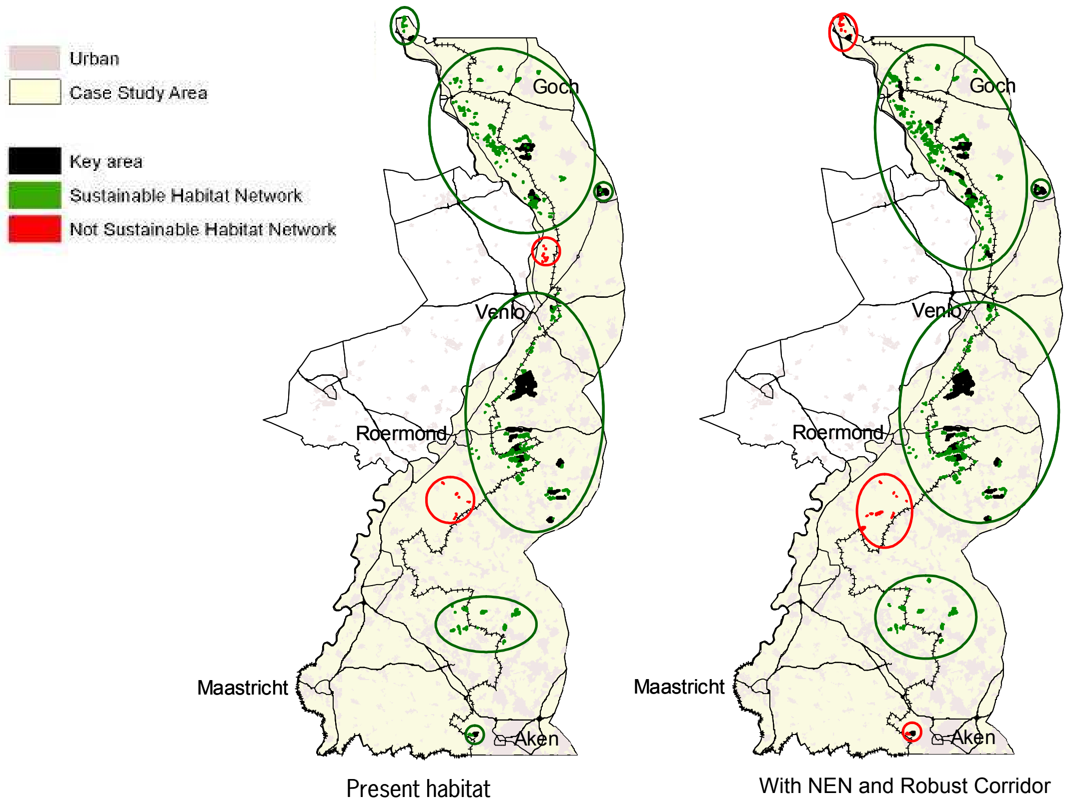


Figure 10 **Sand Lizard habitat networks at optimal carrying capacity (T1) as in present situation.**

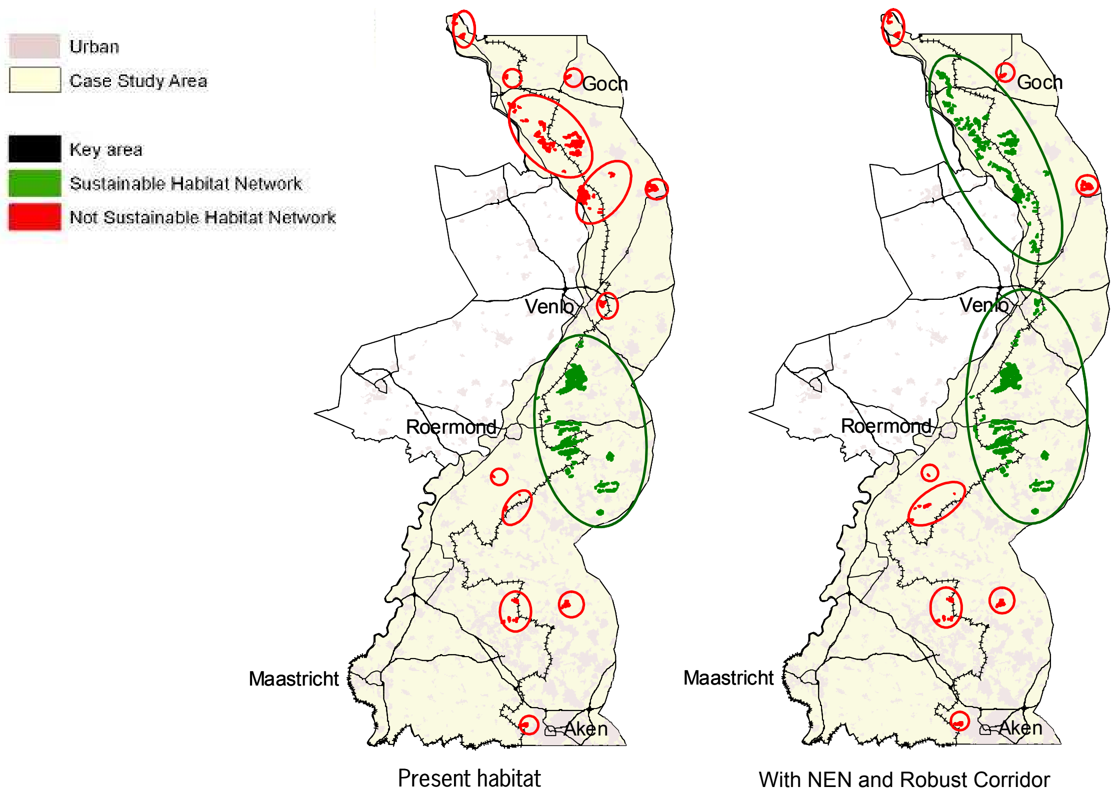


Figure 11 **Sand Lizard habitat networks at 10% of optimal carrying capacity (T4).**

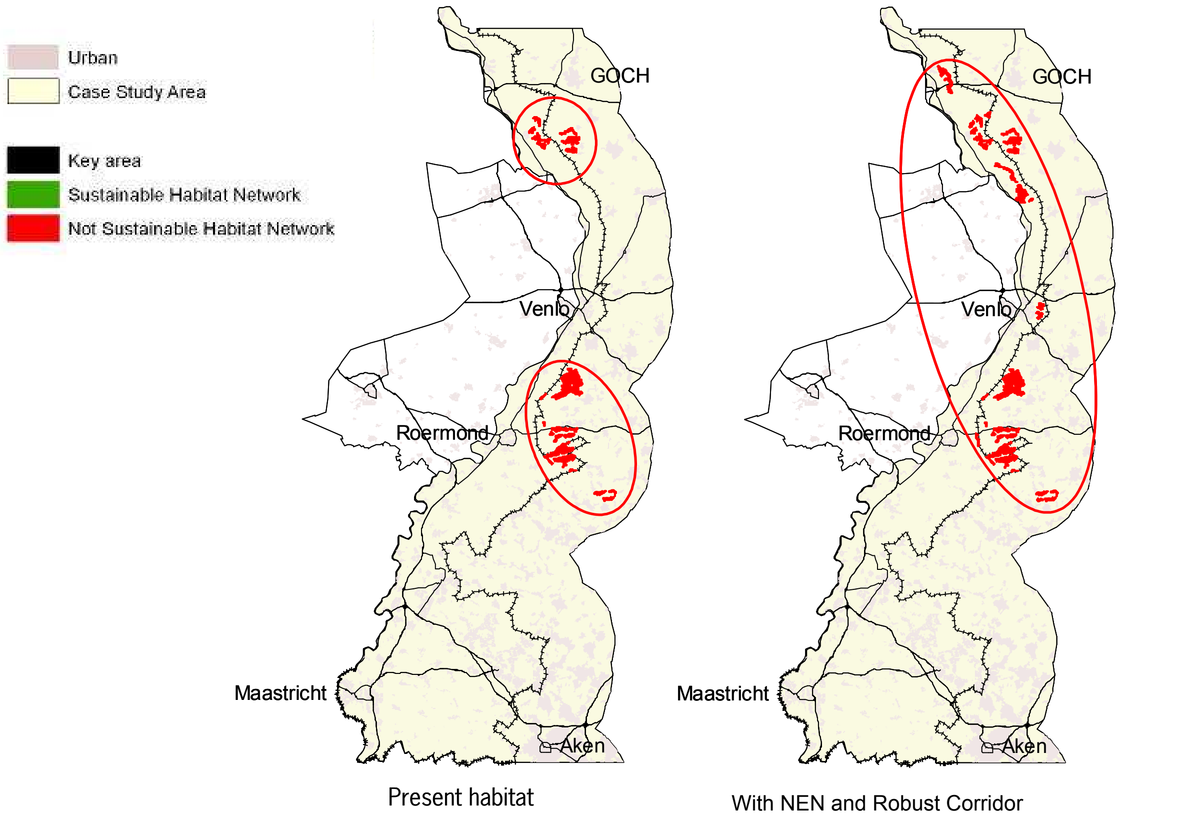


Figure 12 **Habitat networks of Dartford Warbler at 10% of optimal carrying capacity (T1), comparable to present situation.**

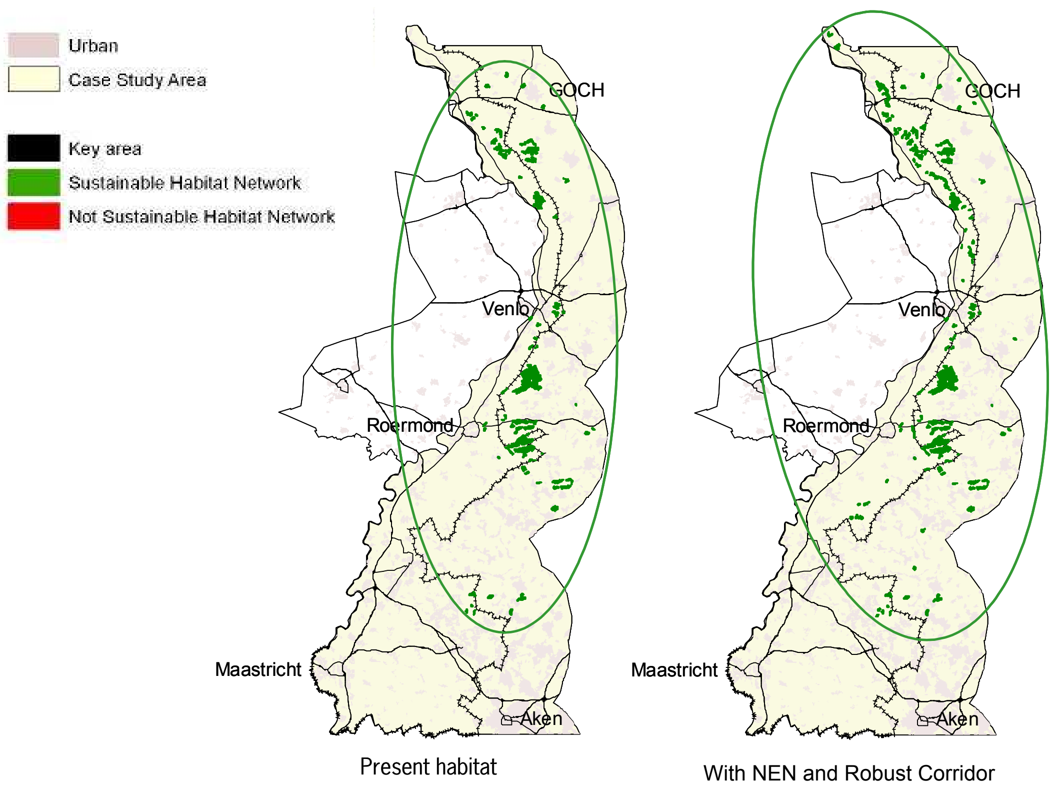


Figure 13 **Habitat networks of Dartford Warbler at 50 % of carrying capacity (T3).**

Trends for other species

European Stonechat *(Roodborsttapuit, Saxicola torquata)*

The European Stonechat is evaluated for the same habitats as the Dartford Warbler. The climate is already suitable at present (see annexes 4 and 5), and is expected to become more suitable. The species is at the moment present in the whole of the Dutch part of the study area, with the exception of South-Limburg. Since the climate envelope of the species shifts to the South-East (Hagemeijer and Blair 1997) the trend in the climate conditions may enhance the expansion of the species to the south, and the extra habitat in the Robust Corridor will probably speed up this process.

Heather (*Struikheide*, *Calluna vulgaris*) and **Silky Leaf Woadwaxen** (*Kruipbrem, Genista lilosa*)

Both species are characteristic for dry Heath. Climatic conditions for Heather as well as Silky Leaf Woadwaxen are predicted to stay suitable during our whole assessment period.

Cross-leaved Heath *(Gewone dopheide, Erica tretralix),* **White-beaked Sedge** *(Witte snavelbies, Rhynchospora alba)* **and Floating Water Plantain** *(Drijvende waterweegbree, Lurinium natans)*

Cross-leaved Heath and White-beaked Sedge are characteristic species for the wet Heath ecosystem and the Floating Water Plantain is characteristic for fens. Climatic conditions for Cross-leaved Heath are predicted to become unsuitable in the south part of the case study area as soon as 2020. Although the zone with unsuitable conditions will not have moved north significantly by 2050, the implication can be that the climatic stress of the wet Heath ecosystem will get worse. The southern edge of the climate envelope of both the White-beaked Sedge and the Floating Water Plantain will move rapidly to the north-west, and the edge is predicted to have reached Limburg in 2050. Wet Heaths in Limburg are already under considerable desiccation stress due to lowering of ground water tables. The combination of climate change and desiccation might cause drought sensitive species to decrease or become extinct.

Wetland

Effectiveness of the Robust Corridor

Cetti's Warbler (*Cetti's zanger*, *Cettia cetti*)

By 2020 the whole of the Province will be completely within the climate envelope (see annex 4). As the suitable climate zone for Cetti's Warbler is already close to Limburg and incidental occurrences during the breeding season have been recorded, there is not much doubt that the species will expand and increase in density during the next decade. Although the amount of habitat will considerably increase by completing the Robust Corridor, the total area of habitat will stay small. Modelling results show a large effect of the Robust Corridor on network size, but assuming a tenfold increase in carrying capacity of the available habitat due to improved climate conditions will not result in a sustainable network in the study area (Figure 14). However, nearby habitat on the banks of the river Meuse considerably adds to the network size. As with the Dartford Warbler, the Limburg network will be part of a much larger and probably sustainable network. The Robust Corridor will speed up the expansion process and (due to greater habitat cohesion) will increase the occurrence probability of the Cetti's Warbler in small habitat patches.

Trends for other species

Cut-grass (*Rijstgras*, *Leersia oryzoides*) and **Tufted Sedge** (*Stijve zegge*, *Carex elata*)

Both species are characteristic of swamps, Cut-grass more specifically for swamps alongside the Meuse river and Tufted Sedge more for marsh forest. Although conditions for Cut-grass might improve a little, climatic conditions for both species are not expected to change much over the assessment period.

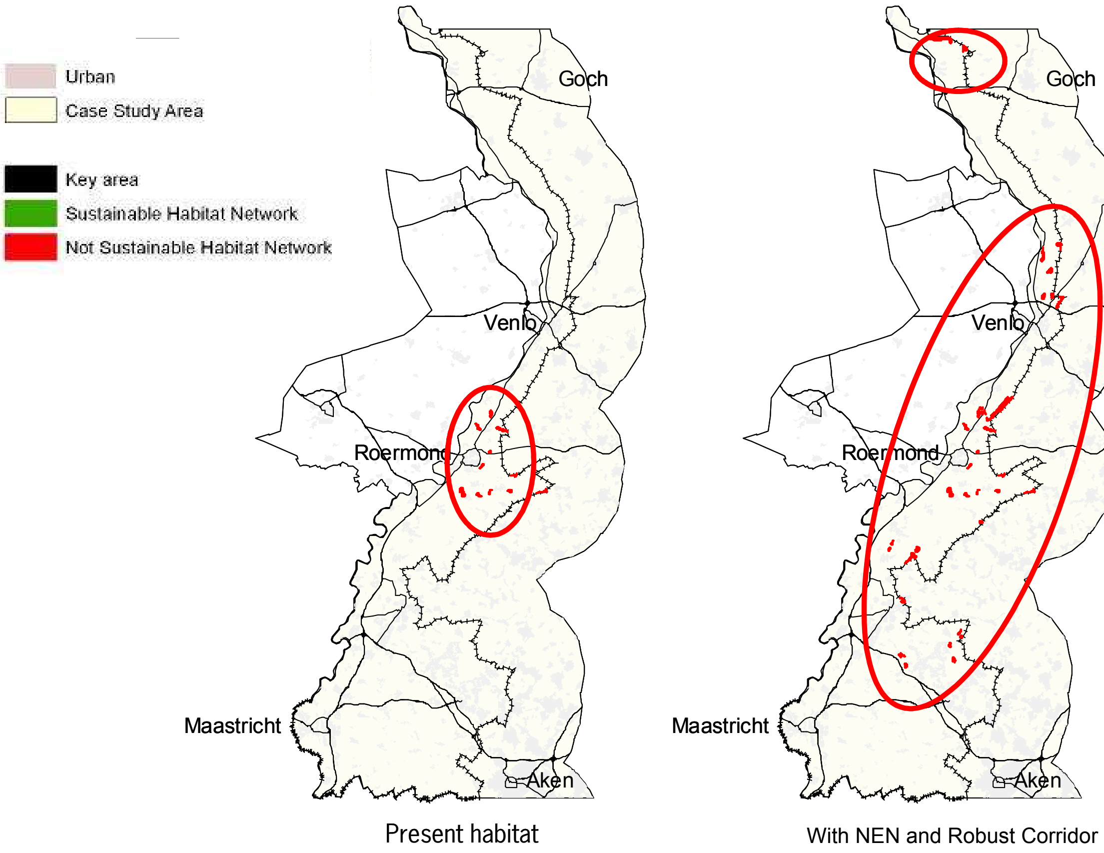


Figure 14 Habitat networks of Cetti's Warbler at optimal carrying capacity (T4).

Forest

Effectiveness of the Robust Corridor

Bechstein's Bat *(Bechsteins vleermuis, Myotis bechstenii)* **and Purple Emperor** *(Grote weerschijn-vlinder, Apatura iris)*

These are species of old forests/ancient woodland and have been modelled as if having the same habitat preferences. Because Forest age class data were available for Limburg but not for the German side, we assumed all German forests to be suboptimal habitat. According to experts, the effect of this is an overestimation of forest network area at the German side, limiting conclusions to be drawn for that part of the case study area. Both species show a similar history of presence in the study area. Both were present in the past but reduced to an occasional observation, attributed to habitat fragmentation and deterioration. The Purple Emperor occurs in some isolated populations in the South of Limburg and Bechstein's Bat is occasionally observed. Little is known about their presence at the German side. Bechstein's Bat and Purple Emperor also share approximately the same climate space. Climatic conditions will probably improve a little up to 2020, followed by a deterioration up to 2050 (see annex 4).

Results show that if the amount of old forest in all forest patches stays the same while carrying capacity improves to double of what it is at present, the effect on the expected presence of both species in the Dutch zone is moderate for the Purple Emperor (a number of small sustainable networks in the Dutch part appear) and minor for Bechstein's Bat (with only a few small non-sustainable networks establishing, see left side of Figure 15 and Figure 16). The Robust Corridor does not provide added value (results not shown), because within the time frame of our assessment period newly created forest patches in the corridor will not become old enough to serve as habitat.

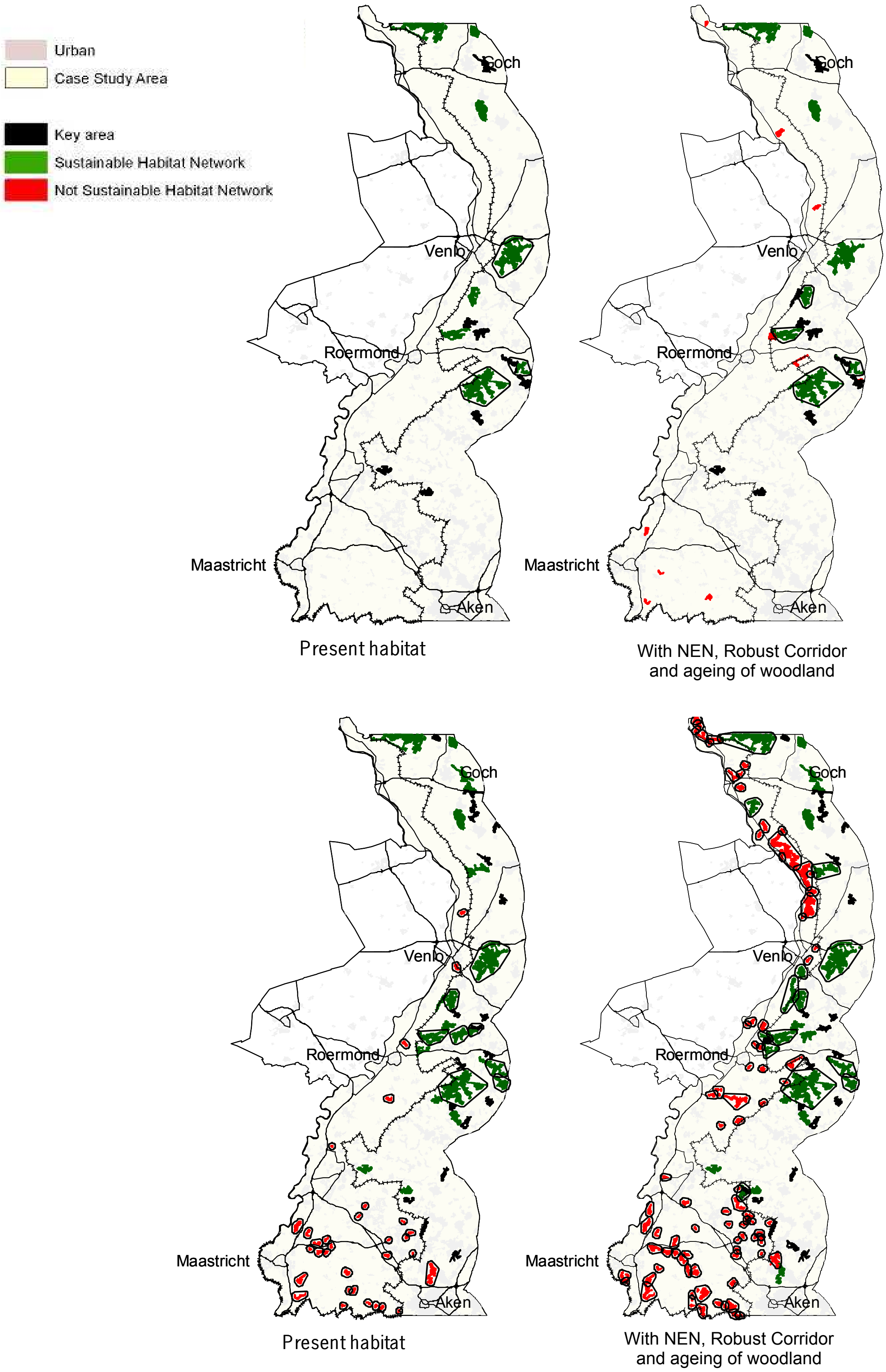


Figure 15 The effect of the Robust Corridor combined with forest ageing in the Dutch part of the case study area for Bechstein's Bat at 20% (top; T2; assumed present situation) and 50% of the carrying capacity (bottom; T3).

However, if all existing and planted forest is assumed to be of age and with the forests in the German part kept at the present age3, there is a much larger positive effect, especially in the north of Limburg (Figure 15 and Figure 16). Although the Bechstein's Bat is not expected to establish sustainable networks in Limburg, the large unsustainable network in the North could easily be connected to the German forests nearby. The Purple Emperor at double carrying capacity the species is predicted to have sustainable networks in the south and very locally elsewhere, but it is questionable whether these can be reached. With the Robust Corridor, the density of sustainable networks greatly increases, suggesting that the corridor will allow the species to expand through the whole of Limburg. An uncertain factor here is the forest age in Germany. The implications are that for species using habitats that will take long time periods to develop to full suitability, the Robust Corridor will only be profitable in the far future. Also, forest management can improve the quality of forest habitat in the short term and are important additional adaptation measures.

Woodlark (*Boomleeuwerik, Lullula arborea*)

Habitat for the woodlark is Heath, Acid Grassland and scrub, hedges and forest edges on poor soils. The whole of the Netherlands is already well in the suitable climate zone but climatic conditions are believed to be improving (see annex 4 and 5). The Woodlark has been increasing in the Netherlands and Limburg for some time. The present distribution in Limburg is mainly associated with forest edges. At the current carrying capacity, the Woodlark has a sustainable network in central Limburg, with unsustainable ones to the north and to the south (with less continuous occurrence and presumably supported by dispersers from the central Limburg population, Figure 17). Assuming a small increase in carrying capacity due to improved conditions of climate shifts most habitat sites to sustainable networks, but the Robust Corridor has no added value for this species in terms of habitat connectivity (Figure 18).

Trends for other species

Middle Spotted Woodpecker (*Middelste bonte specht, Dendrocopus medius*)

Within our assessment period, climatic conditions for the Middle Spotted Woodpecker are expected to firstly improve and later decline again (see annex 4 and 5). The species uses the same habitat (old forests) as Bechstein's Bat and the Purple Emperor, but is a far better disperser and therefore less sensitive to fragmentation. The amount of available habitat will therefore be the main problem for the species. The conclusion for the case study area is the same as for the other two species: within our assessment period it will profit far more from management that allows forest to grow old than from constructing the Robust Corridor. With decreasing climate conditions in the longer term, the extra forest created within the Robust Corridor could have an effect on the occurrence of the species in available habitat.

Bilberry (*Blauwe bosbes, Vaccinium myrtillus*)

Bilberry is an indicator species for open, light damp woodlands. Climatic conditions are predicted to become unsuitable for the Bilberry in part of Limburg near the end of our assessment period (2050).

---

[3] Consistent with keeping the amount of habitat in the German zone at the same level in the scenario's for the other species

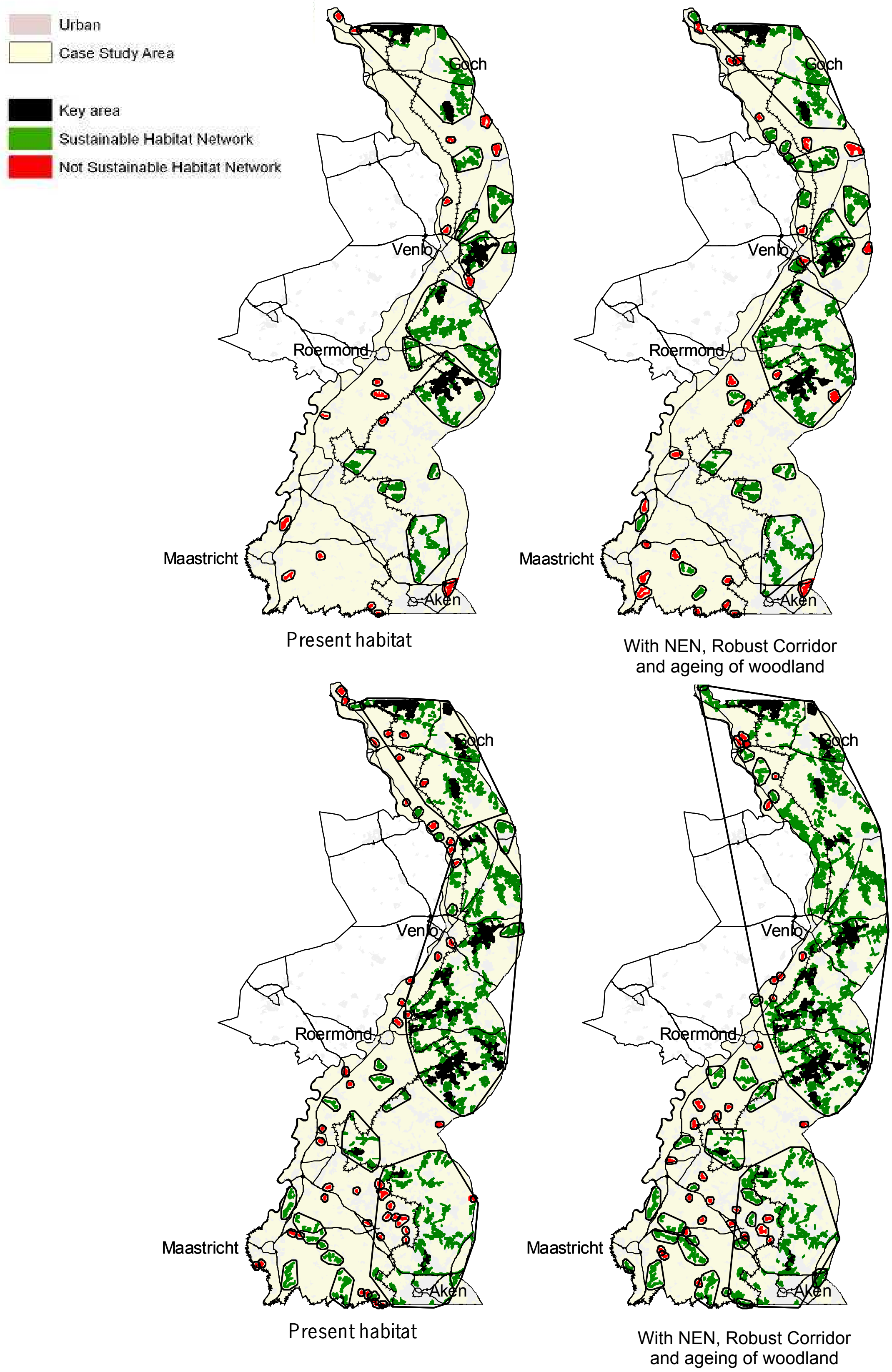


Figure 16 The effect of the Robust Corridor combined with forest ageing in the Dutch part of the case study area for the Purple Emperor butterfly at the 10% of the carrying capacity (top; T1; comparable with present situation) and at 20% (bottom; T2).

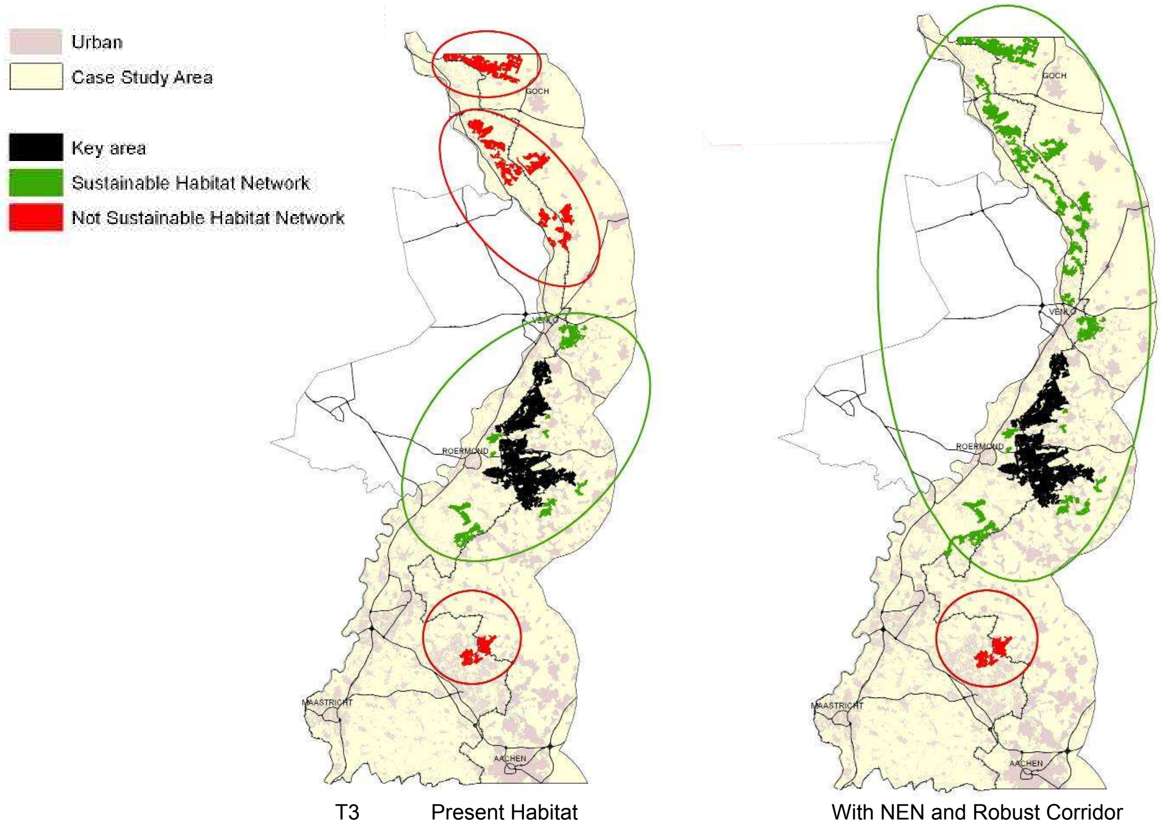


Figure 17 Habitat networks for the Woodlark at the assumed present carrying capacity.

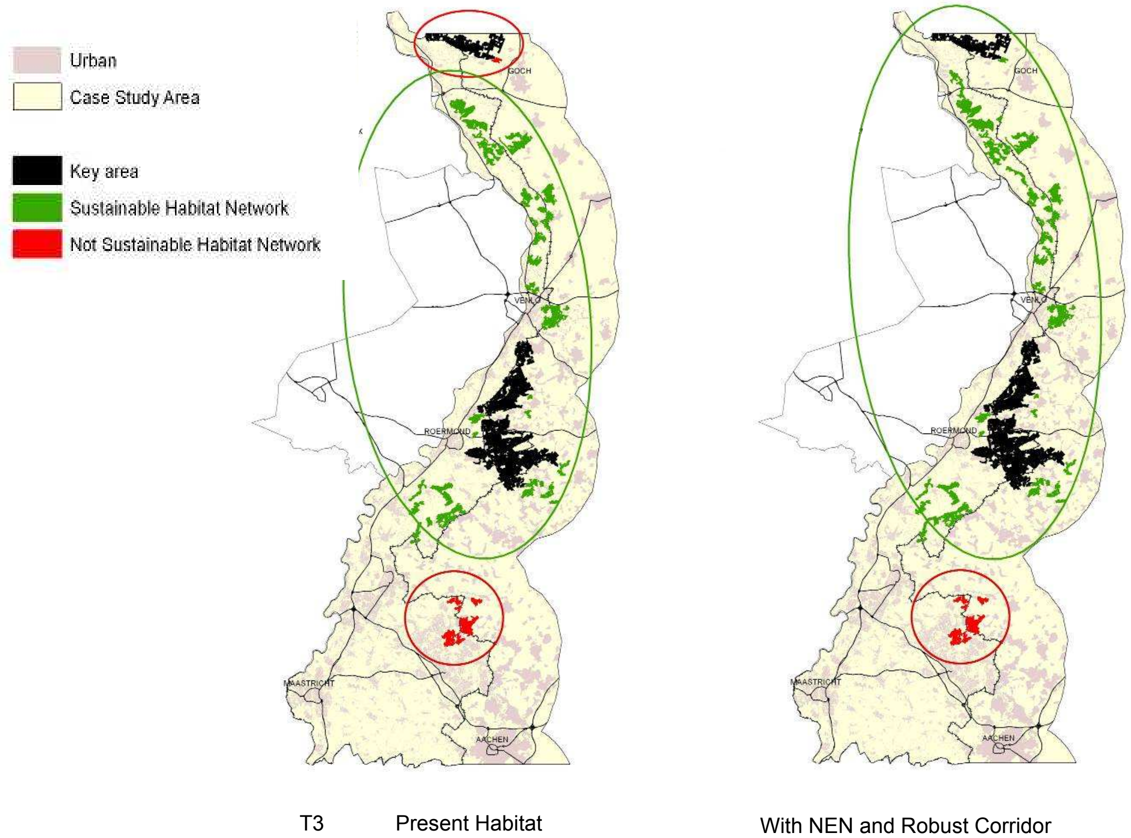


Figure 18 Habitat networks for the Woodlark at 50% (T3; comparable with present situation) and optimal carrying capacity (T4).

Grassland and related ecosystems

In the Limburg area Grasslands are generally small and part of a mixed landscape. Moreover, climatic conditions for the Meadow Pipit, the only species evaluated for the Grassland ecosystem, are predicted to become unsuitable within our assessment period, leaving us with very little result to base separate conclusions for Grassland on. Therefore we combined the Grassland and other/combination of ecosystems discussions.

Effectiveness of Robust Corridor

The Great Crested Newt (*Kamsalamander*, *Triturus cristatus*)

The Great Crested Newt is a Habitat directive II and IV species as well as a target species for both the National Ecological Network and the Robust Corridor. Its Red List status in the Netherlands is 'vulnerable'. Factors determining habitat quality for the Great Crested Newt are the density of suitable ponds and the amount of terrestrial habitat. In Limburg the species is locally common but does not reach high densities. As for the Sand Lizard, climatic conditions for the Great Crested Newt are not expected to become unsuitable by 2050, but they are likely to deteriorate (see annex 4 and 5). Modelling results show fairly large pond networks at present. When carrying capacity is assumed to become 50%, a few of these networks persist, but these are no longer sustainable when a further decrease to 20% is assumed (Figure 19). This suggests that the Great Crested newt in Limburg is sensitive to climate change.

As pond locations in the NEN and the Robust Corridor are not known in detail yet, the added value of the corridor could not be assessed. The results strongly suggest that adding ponds to networks that are currently sustainable could be an effective adaptation strategy for this species. The Kent results show that large pond networks are resistant to climate effects.

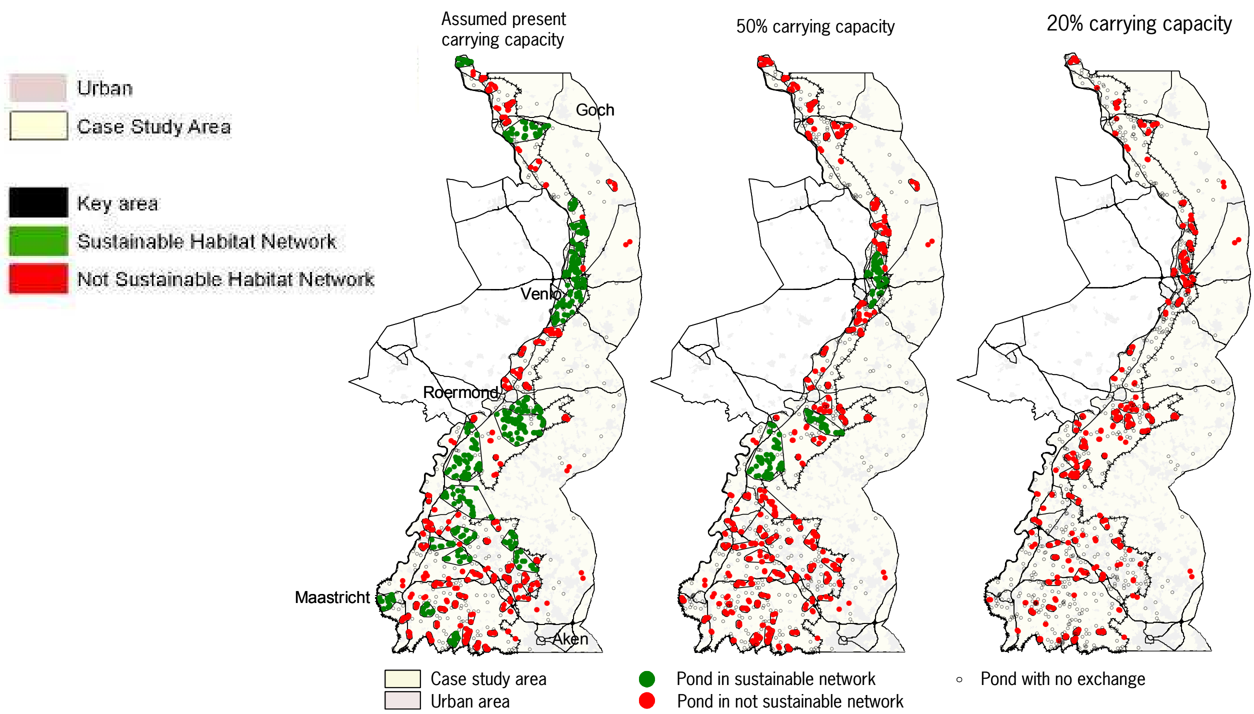


Figure 19 **Pond networks for the Great Crested Newt at the assumed present carrying capacity, at 50% and at 20% of that carrying capacity.**

Trends in other species

Meadow Pipit (*Graspieper, Anthus pratensis*)

For the Meadow Pipit, climatic conditions in the whole of the study area are predicted to become unsuitable before 2050.

Greater Horseshoe Bat (*Grote hoefijzerneus, Rhinolophus ferrumequinum*)

The Greater Horseshoe Bat uses structures like forest edges and hedges for navigation and foraging. Since climatic conditions for the species are expected to improve (see annexes), the Robust Corridor may enhance colonisation of the study area provided the species can find suitable roosting and hibernation sites.

Western Whip Snake *(Geelgroene toornslang, Coluber viridiflavus*)

The Western Whip Snake uses very different types of habitat in its present distribution area, provided there is a mix of suitable cover, open spaces to sun and enough prey is available. Climatic conditions for the species are predicted to become suitable in the whole case study area already before 2020. Barriers for the species in colonising a new area will be mainly consist of roads and urban areas, suggesting a strong added value of the proposed Robust Corridor.

European Bee-eater (*Bijeneter, Marops apiaster*)

Climatic conditions in the case study area are expected to become suitable for the European Bee-eater in a large part of the case study area by 2020, and in the whole of the area by 2050. Isolated breeding records have already been reported for several locations in the Netherlands (but not for the case study area) from the 1990's. Provided it can find suitable nesting sites (steep sandy banks), the species should have no problem colonising the case study area.

3.2.4 Conclusions

Effectiveness of the Robust Corridor

The effectiveness of the Robust Corridor as an adaptation measure to make the NEN more climate proof largely depends on the response of species to the change in carrying capacity and connectivity that the corridor brings about, see Table 8. The overall conclusion can be that the Robust Corridor will:

- allow species under stress from a changing climate to persist for longer in suitable but fragmented habitat;
- facilitate more northward expanding species to actually immigrate and reach sustainable numbers quicker, especially less mobile species.

More detailed conclusions are:

- The Robust Corridor increases the connectivity of the NEN in Limburg. The Robust Corridor allows species which are expected to expand or increase due to climate change to spread into most parts of the Limburg NEN. Bechstein's Bat, Purple Emperor and Sand Lizard, all sensitive to fragmentation on a small scale due to limited dispersal capacities, showed considerably more habitat sites occupied and better local or regional persistence. Hence, these species respond to increased connectivity. For old growth forest, with long development time, these effects are expected to occur after 2050. These results confirm the expected added value of the Robust Corridor for species with small dispersal capacities. All ecosystem types will show this trend, depending on how the corridor will be designed and managed, for example by facilitating old growth of forests.
- The Robust Corridor increases the carrying capacity of the Limburg NEN. The Dartford Warbler, Cetti's Warbler and the Wood Lark are sensitive to fragmentation on a much larger spatial scale, and consequently do not respond to changes in connectivity on a small scale. However, they do respond to adding carrying capacity if the extra habitat is a proportionally large extension of the type of habitat in the current NEN. This is the case in the Cetti's Warbler.

- Declining species. For species declining due to climate conditions getting worse, like the Sand Lizard, the Robust Corridor significantly increases the probability of persistence in Limburg under a climate change regime. The Robust Corridor decreases the degree of fragmentation, and thereby compensates for the increasing impact of fragmentation under climate stress. Larger areas of the NEN will be occupied by the species. Similar added value can be expected for other declining species that are sensitive to fragmentation, for example this is suggested for the Great Crested Newt.
- The study does not address on the connectivity of the landscape south of the study area, so we are unaware of the opportunities for species whose climate space is shifting north to Limburg to actually expand into Limburg NEN-sites. Similarly, the study does not show the effect of the Robust Corridor on the spread of species to NEN-sites further up north.

Trends in ecosystems

- Quite a large percentage of the Heath/Acid Grassland is in the German part of the case study area, including a number of key areas and the by far largest habitat patches. Also most of the forest area is at the German side. This means that 'climate proofing' the Limburg Heath/Acid Grassland ecosystem, to a large extent, depends on the proper management of the German sites.
- Grasslands and Heath ecosystems are relatively scarce, which means that adding habitat causes a proportionally great increase in carrying capacity, and consequently added value of the Robust Corridor. Higher densities make populations less sensitive to the impact of extreme weather events.

3.2.5 Discussion

The aim of the Limburg case study was to develop a method to assess the Robust Corridor as an adaptation measure to spatially adapt the NEN for climate change impacts on biodiversity. For the first time ever in science, we have applied a state of the art methodology developed to analyse large scale ecosystem patterns for constraints caused by fragmentation in the new context of climate change impacts. We based our analysis on detailed modelling of 7 species indicating different responses to habitat fragmentation and climate change. Obviously, a method based on 7 species only is not rigorous enough for generalisations up to conservation policy level, the more so because species are so different in the level of scale on which they respond to habitat pattern change and land use change, and in their response to climate change. Progress to date in science has not developed far enough to base generalisations for "biodiversity" or "nature policy" on this evidence.

Available data were adequate. All but one (the Dartford Warbler) of the species used for SMALLSTEPS modelling were used in previous projects and hence had density and threshold data available in the Alterra LARCH database. Extra information concerning their expected densities under climate stress and, in the case of the Dartford Warbler for their normal situation, was readily available from species experts. A more critical point is the quality of the habitat and movement maps. Vegetation maps supplied by the province of Limburg had more detail than the German maps, causing uncertainties about the interrelations between Dutch and German parts of habitat networks in the modelling studies. A comparable problem was the lack of detail about the precise locations of corridor elements in the current plans for the corridor. The changes in habitat area due to constructing the corridor were adequately known, but the resulting spatial configuration was not. For most modelled species this is not a problem, as long as results are not used to identify local bottlenecks. But for the Great Crested Newt, which needs specific data on pond and terrestrial habitat locations, we were unable to model the added value of the Robust Corridor.

Table 8 **Summary of predicted impact of the Robust Corridor on effect of climate change on selected species. Yellow: added value as adaptation measure within Limburg province demonstrated.**

Species information			Without Robust Corridor		With Robust Corridor	
	Expected trend	Fragmentation prone	Occurrence pattern	Persistence chance	Occurrence pattern	Persistence chance
Incoming/ increasing species						
Dartford Warbler	↑	*Moderate*	*Increase*	*Regionally good*	*Increase*	*Regionally good*
Cetti's Warbler	↑	*Moderate*	*Increase*	*Locally good*	*Strong increase*	*Regionally good*
Present/ increasing species						
Woodlark	↑	*Moderate*	*Increase*	*Regionally good*	*Increase*	*Regionally good*
Bechstein's Bat	↑	*High*	*Local increase*	*Locally good*	*Spread throughout*	*Regionally good*
Purple Emperor	↑	*High*	*Local increase*	*Locally good*	*Spread throughout*	*Regionally good*
Declining/disappearing species						
Sand Lizard	↓	*High*	*Strong decrease*	*Risk of extinction*	*Moderate decrease*	*Regionally good*
Great Crested newt	↓	*High*	*Strong decline*	*Locally good*	*No analysis possible*	

Consequently, the resulting habitat and movement maps do not allow interpretation at a detailed level, for example for locating bottlenecks. In particular, the contribution of the ecosystem sites at the German side need to be interpreted with care, especially for old forest ecosystems.

The question if the Robust Corridor makes the Limburg part of the NEN climate-proof can be answered in a more comprehensive way if :

- Adequate habitat and land use data are available, both for the current situation and the planned situation;
- Clear objectives for a 'climate proof' state are defined;
- The method explored in this study has been developed more rigorously and based on a better coverage of the species spectrum;
- Responses of species to climate change become better known.

3.2.6 Recommendations

- Considering the long development time of habitat creation, implementation of the corridor policy is urgent to harvest the added value for conservation policy. Mitigation of barrier effects of infrastructure, necessary for an effective dispersal of ground-dwelling species, is a critical prerequisite for harvesting the predicted added value of the Robust Corridor investment.
- For an optimal adaptation strategy, more detailed analyses for a variety of species with different climate responses are recommended, to explore the effects of climate change on community structure and conservation targets at the site level.
- International cooperation is crucial. The development of a climate change adaptation strategy in cooperation with neighbouring regions is recommended, including a thorough evaluation of the value of the Limburg habitats as corridors or new settlements for possible incoming species.
- Given the many uncertainties in knowledge, it is recommended to support the implementation phase with an intensive monitoring scheme and a regular re-evaluation of objectives and effectiveness of measures.

3.3 Case study Kent

3.3.1 Methods

Study area

The main objective for this case study was to develop a planning method to enable stakeholders to design a climate change proof ecosystem network. The study area comprised the County of Kent. In some cases land cover maps of surrounding Counties were used to put the habitats into a regional perspective.

The map of case study habitats

A habitat map for the species chosen was produced based on the Kent Habitat Survey 2003. The survey used the Integrated Habitat Classification System (IHS), developed by Somerset Environmental Records Centre (SERC), to map the habitats found in Kent. This habitat survey was used to map the habitat of the chosen species, and to include information on fragmentation of habitat. Maps of rivers and ponds were also used (provided by Kent & Medway Biological Records Centre; KMBRC) as were maps of infrastructure (provided by Kent County Council). Further to these, Habitat Opportunity Maps and maps in the Kent Landscape Information System (K-LIS; www.kent.gov.uk/klis; provided by Kent County Council) were used for the interpretation of distribution data and the refining of habitat maps.

Species information

Information on species was gathered from different sources:

- KMBRC provided distribution data on selected species.
- Local species experts were involved in the species selection process, they provided their specialist species and local knowledge for the modelling and gave us feed back on the first run of the results. The habitats used for each species was checked and was refined if required. Also the parameters in the model could be calibrated and tailored to the local situation.
- Species experts in The Netherlands, mainly within Alterra.
- Literature review.

Stakeholder involvement

- A wider group of policy makers, ecological experts and spatial planners were informed and involved on several occasions in the project;

- A number of stakeholder events with different scale and content were held in Kent to reach different audiences and gain different outcomes;
- An initial conference to introduce BRANCH and the Kent case study was held in spring 2006;
- Two workshops with species experts were organised in summer 2006 to verify species records and modelling;
- A conference and site visit was held in Kent in autumn 2006, focused on explaining progress so far and putting our work in a landscape context. This event included a site visit to show habitat fragmentation and infringement on the countryside, and also high quality natural habitats, in order to discuss the effects that climate change may have on them;
- A workshop on ecological network design "Creating Networks for Nature" was held in spring 2007. This was the culmination of the objectives for the Kent case study within the BRANCH project and was seen as a first step in the debate about, and eventual creation of, an ecological network for Kent.

3.3.2 Expected changes in climate suitability and ecological networks

The results of the climate envelope modelling are shown on the level of Kent for a selection of 20 species. For an example of the changing climate for Woodlark see Figure 20.The results for the 20 species are summarized in Table 9 and discussed below. The full set of results is shown in the annexes 6-8.

Seven of these species were selected to assess the effect of climate change on the abundance and sustainability of species in the future and to see how the landscape can be adapted for biodiversity. Table 9 shows if the species are already present in Kent and what is expected to happen with the abundance after climate change. For some selected species the present climate is not entirely favourable. Despite that, there are observations of these species. For some species, the observations indicate that species are already colonising areas in Kent, e.g. the Purple Emperor. For other species, as the Adonis Blue, small relict populations are expanding. In the past, when large areas of suitable habitat were available for this species, the species was abundant, despite the fact that Kent is on the edge of its distribution area. As a result of habitat degradation it has become rare. With the climate becoming more suitable, this species is expected to increase in abundance. Observations from previous decades appear to support this.

For two of the selected species, Meadow Pipit and Great Crested Newt, the present climate is very favourable. These species occur in large numbers in Kent. Based on the SPECIES modelling, it is expected that the climate will become less favourable in the future, and as a result of that, a decrease in numbers can be expected.

In this study we modelled species as a tool to explore the effects of climate change on a broader range of species. Species that use a particular type of habitat, show a particular reaction to climate change and have particular requirements for sustainable populations, were used as indicators for other species that share these characteristics or requirements. For some species, especially the Bechstein's Bat, it was not possible to model the exact habitat (old woodland) as the data required to define the precise habitat areas were not available. In these cases, the results should be interpreted in a more generic way; results of the Bechstein's Bat show the effect of climate change for 'ground dwelling'[4] species of woodland, with a low dispersal capacity, for which the climate becomes more favourable.

---

[4] Bechstein's Bat is a flying mammal with a small dispersal distance (500 m) due to its foraging characteristics. It can only shift partly its foraging area to breed successfully. Also the species is very reluctant in crossing barriers in the landscape such as infrastructure. Therefore it is a good model species for ground dwelling species with a small dispersal distance.

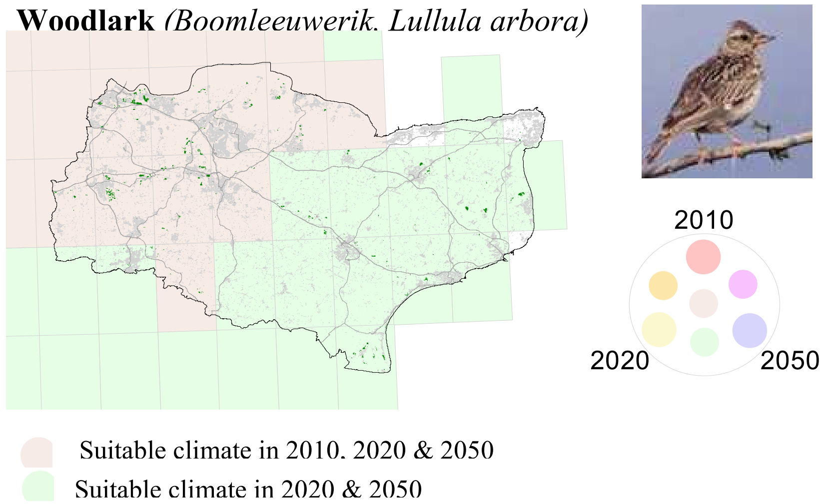


Figure 20 Expected suitability of climate for the Woodlark (Lullula arborea) in 2010, 2020 and 2050. Green patches; optimal and suitable habitat under the condition of a suitable climate.

Wet Grassland/Ponds

At present the **Meadow Pipit** is abundant in wet Grasslands in Kent, and the climate is suitable. In time, it is expected that the climate will become less suitable, resulting in a drop in numbers, or possibly the disappearance of this species in the long term.

In the present situation, breeding records of Meadow Pipit are mainly confined to wet Grassland areas, along the coast and river valleys. The habitat modelled shows a good match with the observations of breeding Meadow Pipits (Figure 21a).

The modelling results show that in the present situation (T1), nearly all habitat areas are connected in one habitat network; habitat areas are mutually connected by dispersal movements. When a local population in a part of the habitat network decreases, it is likely that this area will be re-colonised by individuals through dispersal from other areas in the network. The network population, that currently stretches across the County and beyond into neighbouring Counties, is expected to be very sustainable, and contains some key areas (Figure 21b). These key areas are the strong parts of the habitat network, and support stable populations with a low probability of extinction. Also, these population are a source for dispersers, looking for new habitat areas to settle.

When the climate becomes less favourable, the carrying capacity of the habitat areas will decrease. In Figure 21c, the habitat networks are shown in the situation that the carrying capacity is 20% of that in the present situation. This shows that many of the present habitat areas are still part of a habitat network; however the habitat network will break up in to smaller separate habitat networks. This is the result of smaller populations in separate habitat areas, which results in less young individuals that will disperse from these areas. When the chance of nearby areas being colonised by dispersing individuals is low, the areas will not be part of the same habitat network.

Also the Great Crested Newt is very abundant in Kent, especially in the High and Low Weald. This species is very sensitive to barriers. However, in the areas where the density and quality of ponds is very high, the habitat network crosses roads and railroads. The likelihood of individuals crossing barriers may be small, but due to the large numbers, the model predicts that this will happen occasionally. In the present situation, most of the ponds are part of a sustainable habitat network. In areas with much infrastructure and a lower pond density, populations in ponds are non-sustainable (Figure 21).

Table 9 Summary of the expected climate suitability for species in 2010, 2020 and 2050. Species that are selected for assessment of the effect of climate change on the abundance of species in bold (using SMALLSTAPS/LARCH models). Of these species, the present abundance in Kent is indicated in the column "present".

			present	2020	2050
Wet Grassland					
Meadow Pipit	**Graspieper**	***Anthus pratensis***	**abundant**		
Dartford Warbler	**Provencaalse grasmus**	***Sylvia undata***	**rare**		
Ponds					
Great Crested Newt	**Kamsalamander**	***Triturus cristatus***	**abundant**		
Heath/Acid Grassland					
Woodlark	Boomleeuwerik	*Lullula arborea*			
European Stonechat	Roodborsttapuit	*Saxicola troquata*			
Dartford Warbler	**Provencaalse grasmus**	***Sylvia undata***	**rare**		
Nightjar	Nachtzwaluw	*Caprimulgus europaeus*			
Wetland					
Cetti's Warbler	**Cetti's zanger**	***Cettia cetti***	**rare**		
Reed Bunting	Rietgors	*Emberiza schoeniclus*			
Marsh Gentian	Klokjesgentiaan	*Gentiana pneumonanthe*			
Marsh Fern	Moerasvaren	*Thelypteris palustris*			
Woodland					
Bechstein's Bat	**Bechsteins vleermuis**	***Myotis bechstinii***	**rare?***		
Purple Emperor	**Grote weerschijnvlinder**	***Apatura ris***	**rare**		
Lesser Horseshoe Bat	Kleine hoefijzerneus	*Rhinolophus hipposideros*			
Bluebell	Wilde hyacint	*Hyacinthoides non-scripta*			
Chalk Grassland					
Adonis Blue	**Adonisblauwtje**	***Lysandera bellarus***	**rare**		
Chalk Hill Blue	Bleekblauwtje	*Lysandra coridon*			
Other/combination of ecosystems					
Natterjack Toad	Rugstreeppad	*Bufo calamita*			
Greater Horseshoe Bat	Grote hoefijzerneus	*Rhinolophus ferrumequinum*			
Water Vole	Woelrat	*Arvicola terrestris*	**abundant**		
Clustered Clover	Trifolium glomeratum	*Trifolium glomeratum*			

* Distribution data for this species are incomplete

= Kent not in suitable climate space

= Part of Kent in suitable climate space

= Whole of Kent in suitable climate space

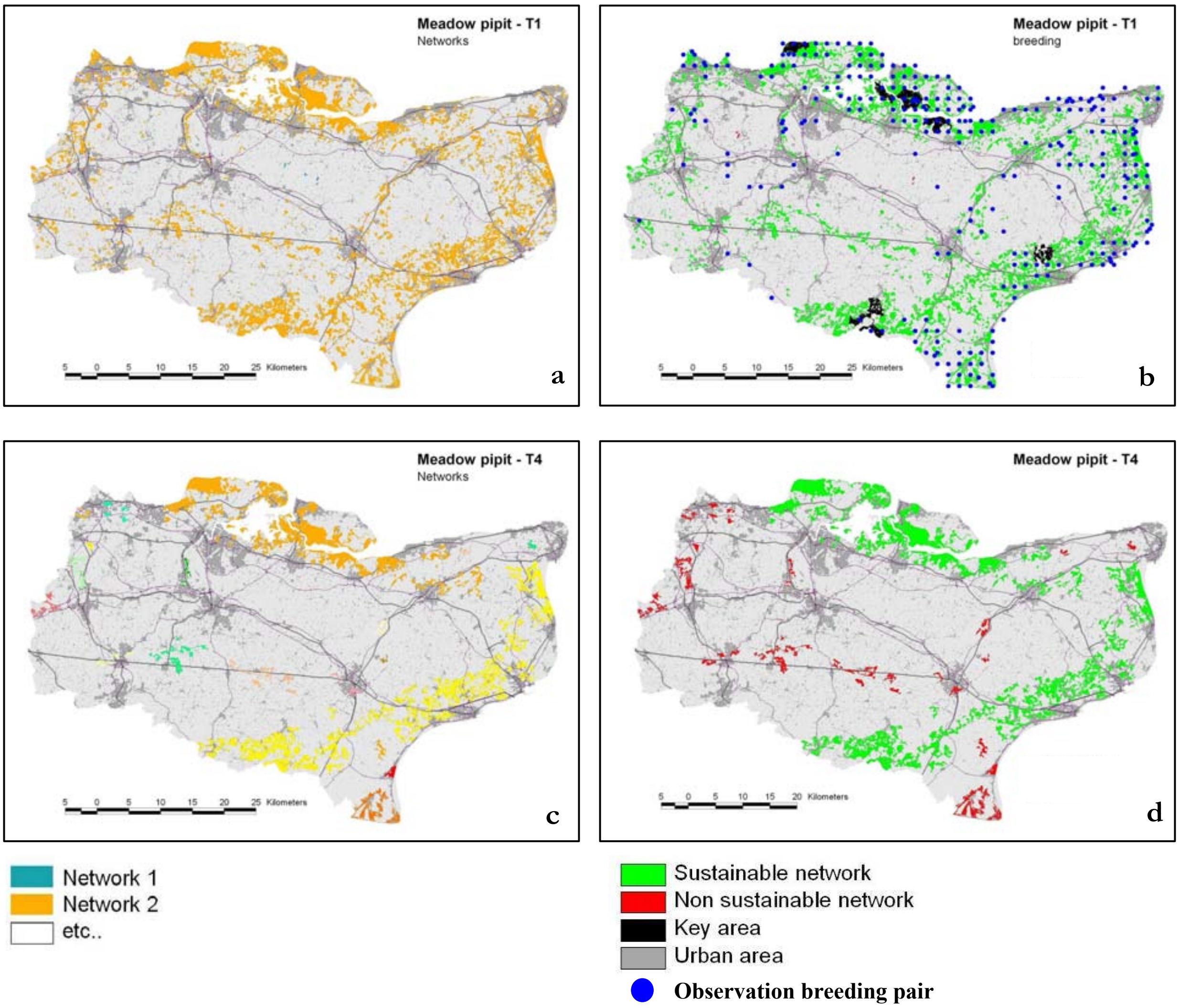


Figure 21
a) Habitat networks for Meadow Pipit under present, optimal climate conditions;
b) Sustainability of habitat networks for Meadow Pipit under present, optimal climate conditions (T1);
c) Habitat networks for Meadow Pipit under less favourable climate conditions (at 10% of the carrying capacity of habitat for breeding; T4);
d) Sustainability of habitat networks for Meadow Pipit under less favourable climate conditions (at 10% of the carrying capacity of habitat for breeding; T4).

When the climate becomes less favourable for the Great Crested Newt, as is expected to happen in the coming decades, the model shows that habitat networks become more fragmented. Ponds become isolated and are no longer part of the habitat network and disappear from the habitat network maps. This is especially happening in the areas with lower pond density. In the south however, even if the climate is very unsuitable, and the carrying capacity of ponds is ten times lower than at present, three viable habitat networks remain. These persisting areas are the strongest part of the habitat network, and might be the last areas where the species can persist when the climate becomes unsuitable.

Heath/Acid Grassland

The **Nightjar** is a species that is specifically confined to Heath and Acid Grassland, and has a large dispersal capacity of approximately 25 km (Pouwels 2000). At present, the modelled climate is unsuitable, but it is expected that a part of Kent will have a suitable climate by 2020 and the whole of Kent will have a suitable climate by 2050. Despite this the species has been recorded in Kent. Its potential habitat consists of a number of very small patches. Even with its large dispersal distance it will be difficult for this species to occupy new suitable habitat areas. This is due to the fact that habitat areas have a low colonisation power as they are very small and areas are located far from each other (more than 25 km). The colonisation rate of new suitable habitat can be expected to be very low.

For the **Woodlark**, the modelling shows that at present the edge of suitable climate space is located in Kent. It is expected that the suitable climate space expands and that by 2020 and later the climate will be suitable in the whole County. Also for this species the colonisation rate of new suitable habitat will be low, as a result of small habitat areas and a high fragmentation rate.

The **Dartford Warbler**, which is breeding in a broader range of habitat types, is now on the edge of its distribution area. In the future Kent is expected to become more in the centre of the European distribution. The species is now very rare in Kent, but is expected to increase. Even though the climate is only marginally suitable, at present the model shows a sustainable habitat network in the North of Kent which even contains a key area (Figure 23). If some breeding pairs were able to start a population there, this would be a favourable area to establish a sustainable population with, in time, dispersal capacity to other areas. When the climate is more suitable, more habitat networks will arise (also in the very south). This network is not sustainable, and in the near future the chances of dispersal movements from the habitat network in the north are small (separate habitat networks). As the climate becomes more suitable and densities rise (by 5 times in the model), more, smaller areas join the habitat network to create one sustainable habitat network. In the north, a number of key areas are expected. This area will remain the strongest part of the habitat network in Kent.

Wetland

For wetland species such as the **Cetti's Warbler**, habitat area is limited at present. The main habitat area is Stodmarsh National Nature Reserve (163 ha). At present, some breeding birds have been recorded in this area. In the present situation, this area is an isolated habitat area for species as the Cetti's Warbler. With the present low densities in a marginal suitable climate, it is expected that very few dispersal movement to the other small habitat areas will take place (Figure 24). When the climate becomes more suitable for this species, and densities rise, it is expected that dispersal movements to other wet areas will increase. For example the wet areas in the river valleys become part of the same habitat network, and could be populated from Stodmarsh. The total habitat area of the habitat in Kent however will be too small for a sustainable habitat network. The Kent habitat network of Cetti's Warbler, with its large dispersal capacity (50 km) however, is likely to be (or to become, when the climate gets more suitable) part of a larger cross-border habitat network.

The **Reed Bunting** is a species that is expected to decrease as a result of the climate becoming less suitable. By 2050 most of Kent will have an unsuitable climate. The climate will remain suitable for the typical marshland species **Marsh Gentian**. The **Marsh Fern**, a Kent Red Data Book species, for which Kent is on the edge of suitable climate space at present, seems to remain on this edge.

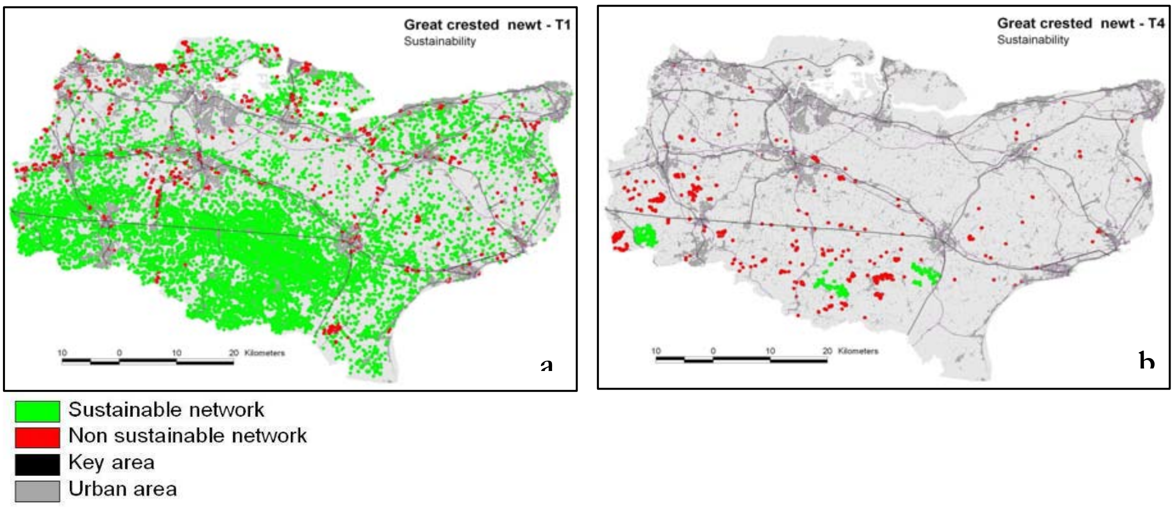


Figure 22 a) Sustainability of populations of the Great Crested Newt in the present situation (T1);
b) Sustainability of populations of the Great Crested Newt in a situation that the carrying capacity is very low, as can be expected after climate change (10% of the carrying capacity in the present situation; T4).

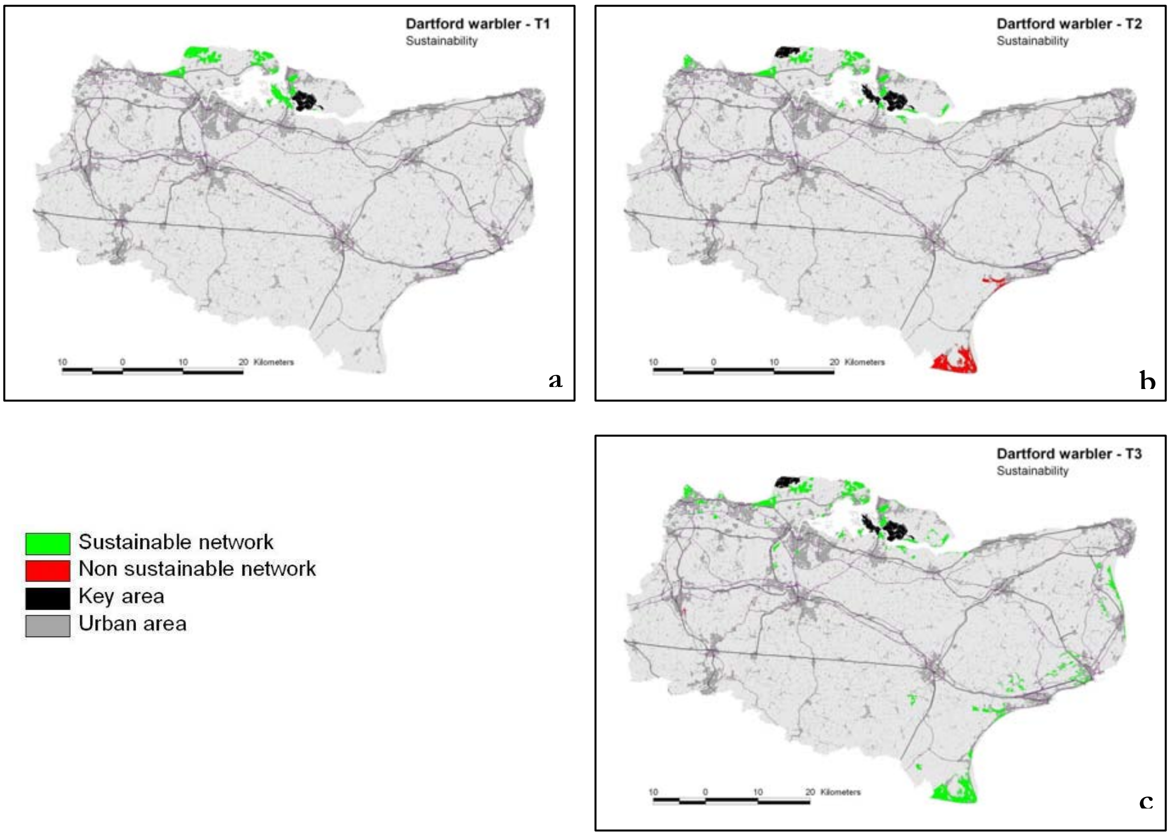


Figure 23 a) Habitat network and potential sustainability for the Dartford Warbler in the present situation, with a marginal carrying capacity (10% of optimal climate conditions; T1);
b) Habitat network and potential sustainability for the Dartford Warbler under better climate conditions (20% of optimal climate conditions; T2);
c) Habitat network and potential sustainability for the Dartford Warbler under better climate conditions (50% of optimal climate conditions; T3).

That would mean that no change in suitability of the climate, and no effect on its rare abundance of this species is expected; it has only been recorded in 5 tetrads in Kent.

Woodland

For the **Bechstein's Bat** the climate is expected to become more suitable, as Kent is now on the edge of the suitable climate space, and will become more central. This species has a very particular life cycle and habitat preference. As explained earlier, this species should be used as a model species for "ground dwelling species of broadleaved forest", as it wasn't feasible to model the exact habitat of this species.

At present, the climate for this species is not very favourable. However, as a result of the large abundance of broadleaved woodland in Kent, a number of key areas are expected for this type of species (Figure 25). Due to the small dispersal distance and high sensitivity to barriers of these species, the key areas are isolated. When the climate becomes more suitable, it is expected that more habitat areas become part of a habitat network or become key areas. Due to the fragmented character of the woodland and of the presence of infrastructure, the habitat areas are highly fragmented into many separate habitat networks. This means that, if a population of Bechstein's Bat is present in an area of Kent, it is expected that unpopulated habitat areas will be colonised at a very slow rate if at all. A condition herewith is the presence of large mature trees for this species to roost in. At present, there is a lack of these as most of the woodlands in Kent are coppiced. Letting woodland partly age wood benefit the abundance and colonization capacity of this species.

At the moment, only a small number of records of Bechstein's Bat are known in Kent. If this reflects the limited distribution of this species in Kent, it would probably take much time or would be impossible to colonise all habitat areas in Kent. However, more distribution data are required on this species. Also for the **Lesser Horseshoe Bat**, the climate is expected to become more suitable. This species is expected to be able to expand or colonise new habitat areas more easily than the Bechstein's Bat, as the latter species is extremely sensitive to both habitat quality (i.e. old woodland) and for habitat fragmentation.

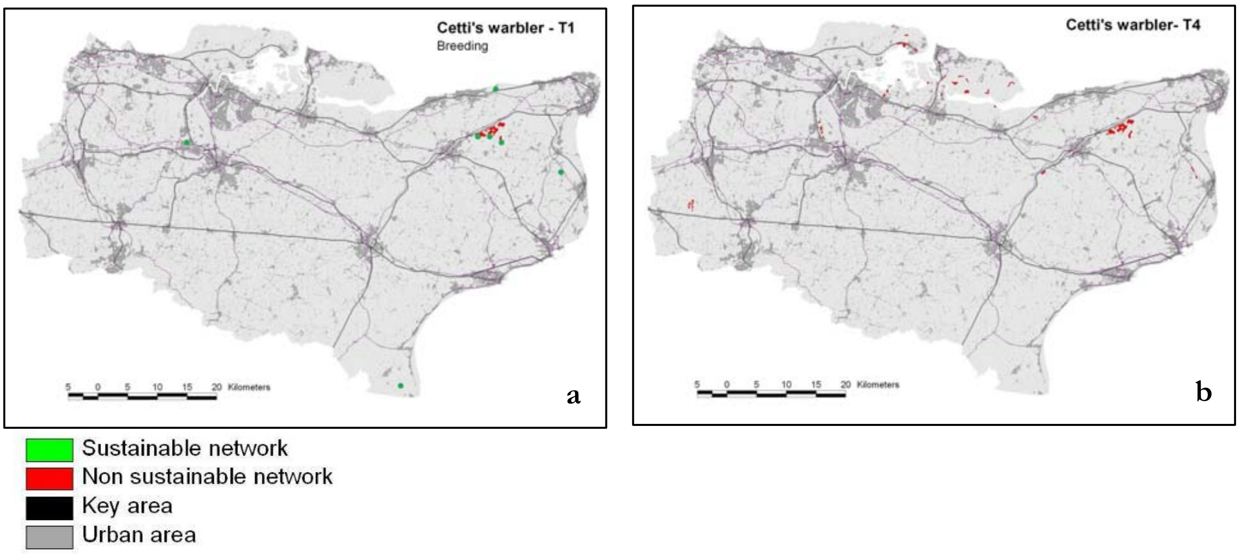


Figure 24 a) Sustainability of populations of Cetti's Warbler in at 10% of the optimal carrying capacity (T1; green dots show records in recent years);
b) Sustainability of populations of Cetti's Warbler when the carrying capacity is optimal, as expected after climate change (T4).

The **Purple Emperor's** habitat is woodland, which is widespread in Kent. Even with low densities, as expected in a marginal suitable climate, the majority of the habitat is part of a sustainable habitat network for this medium dispersing species (5 km). In the area between Canterbury and Ashford the strongest part of the habitat can be expected as the modelling shows three key areas available in the present situation. When the climate becomes more suitable, all the habitat areas of this species become part of one County wide habitat network, containing an increasing provision of key areas (Figure 26).
During the last decade, the species has been observed regularly, especially in the west of Kent. This species appears to be colonising Kent from bordering habitat areas in Surrey or East Sussex. It is expected that the colonisation rate will be low in the beginning, as no key areas, areas with a large colonization power, are present in this part of Kent.

For the **Bluebell**, a protected species under Schedule 8 of the Wildlife & Countryside Act 1981, the climate is expected to remain suitable, and no major changes in abundance are expected.

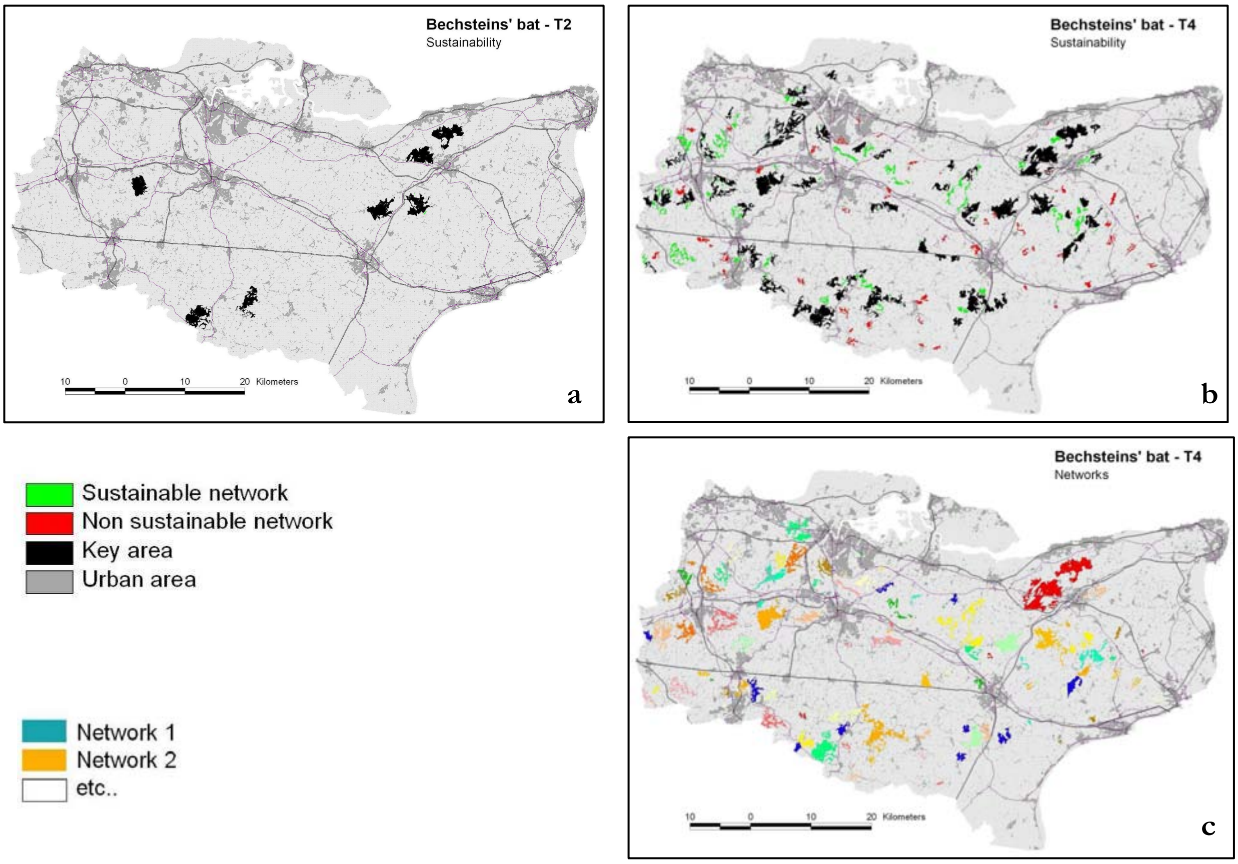


Figure 25 a) Habitat network and potential sustainability for the Bechstein's Bat in T2 (20% of optimal climate conditions);
b) Potential sustainability of habitat networks of Bechstein's Bat under optimal conditions, as expected after climate change (T4);
c) Habitat networks of Bechstein's Bat under optimal conditions, as expected after climate change (T4).

Chalk Grassland

At present, the climate is only marginally suitable for this **Adonis Blue**. The present habitat network is very fragmented, as this species is not a very good disperser (1 km). Even with the climate being marginally suitable, and the low densities that are expected, three habitat networks are sustainable; the two in the east even contain a key area (Figure 27). The other sustainable habitat network is situated at a long distance, in the west. The observations of the species, of relict populations after the degradation and disappearance of the majority of habitat, are mainly around the sustainable networks in the east. It suggests that, when the conditions became difficult for the species, in was in these areas that the populations could sustain the longest. The modelling results would predict the same, and probably explain why populations could persist in these areas. Other observations are in more remote areas. The species experts remarked that this is the result of people taking individuals of this species to these areas and is not a result natural dispersal. When the climate becomes more suitable, densities will increase in habitat areas along the Kent Downs. However, for this species, the habitat networks remain very fragmented. Therefore, the colonization of habitat is expected to take a very long time, as the chance of dispersal movements between separate habitat networks is very low. If colonization is depending on dispersal movements, it can be expected that many (sustainable) habitat networks remain unpopulated by this species for a very long time.
For another chalk Grassland butterfly, the **Chalk Hill Blue**, the climate is also expected to become more suitable. Area requirements and sensitivity of this species are not known, but it can be expected that this species is more sensitive to fragmentation than the Adonis Blue (as the former is a poor disperser), it however might need larger areas for key areas and sustainable populations.

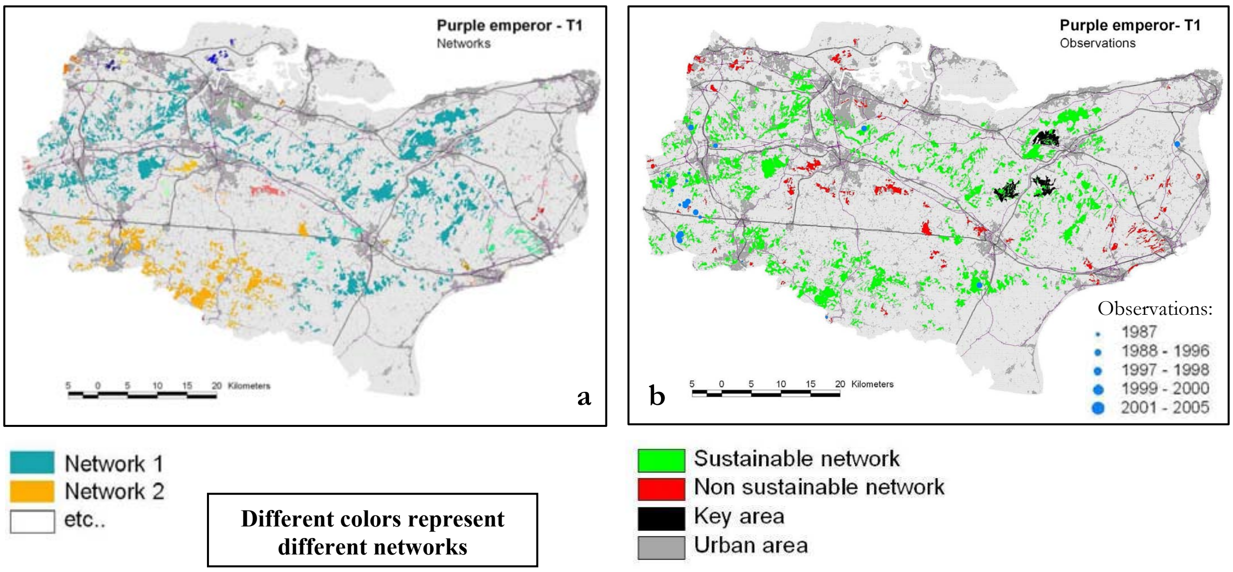


Figure 26 a) Habitat network for the Purple Emperor at T1, with a marginal carrying capacity (10% of optimal climate conditions);
b) Potential sustainability of populations of the Purple Emperor in the present situation; blue dots show the observations of Purple Emperor between 1987 to 2005; the larger the dot, the more recent the observation).

Species of other habitats

Some of the species for which we evaluated the effect of climate change on the suitability of climate space, occupy range of habitat types. For one species, the Water Vole, we could not well define the habitat in the habitat map used. These species, their habitat and the expected effect of climate change is discussed below.

The **Natterjack Toad** finds its habitat in wet Heaths, wetland areas, marine habitats, all types of supralittoral sediments (e.g. sand dunes) and salt marshes. The climate now is suitable for this European Protected and Kent and UK BAP species, and is expected to remain suitable.

The **Greater Horseshoe Bat** finds its habitat both in woodland and in cultural landscapes with hedgerows. As for the Bechstein's Bat and the lesser Horseshoe Bat, the climate becomes more favourable. As this species has a less specific choice of habitat and less sensitivity to fragmentation than the Bechstein's Bat, it is expected that this species will have less problems colonising new habitat areas.

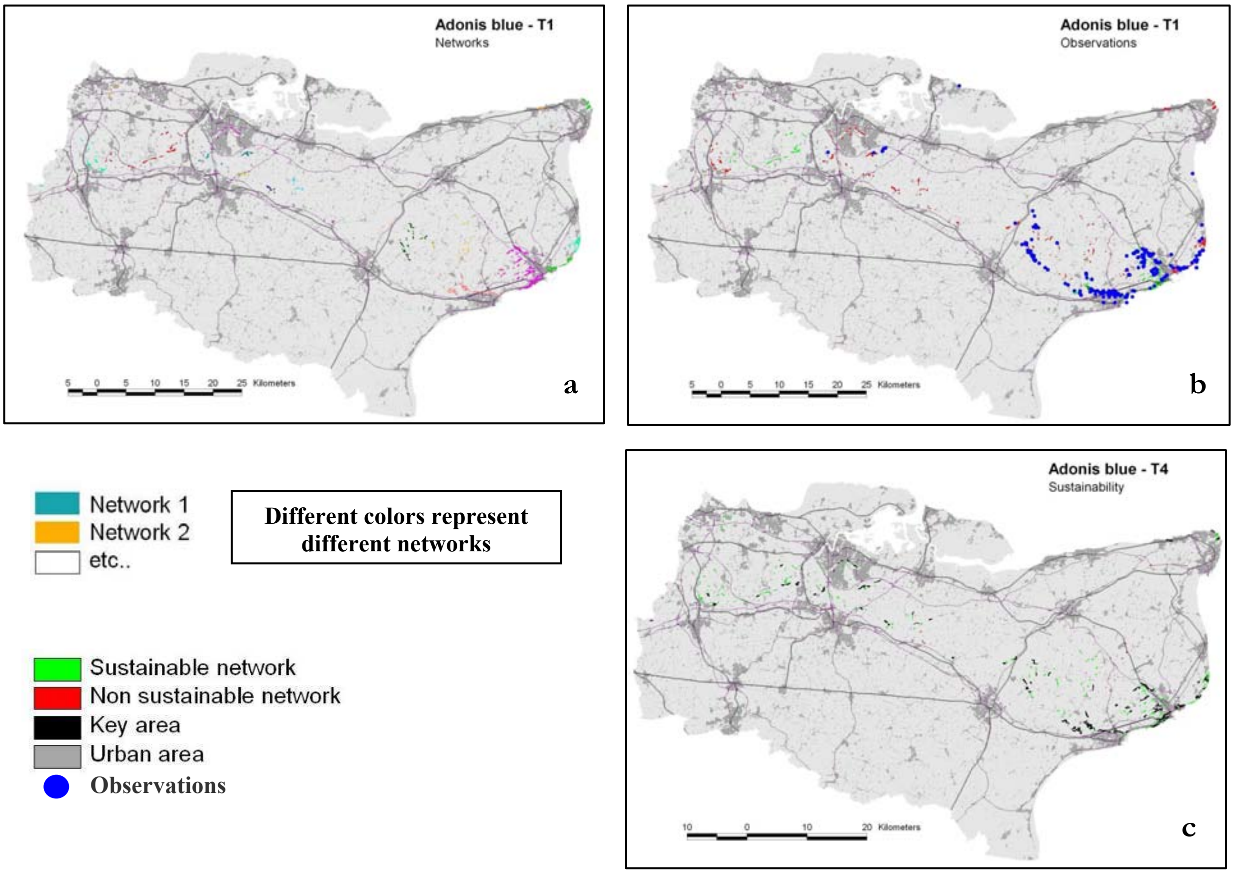


Figure 27 a) Habitat network and potential sustainability for the Adonis Blue in T1, with a low carrying capacity (10% of optimal climate conditions);
b) Potential sustainability of habitat networks of Adonis Blue at T1, as expected after climate change, and observations of individuals (blue dots);
c) Potential sustainability of populations of Adonis Blue under optimal climate conditions (T4).

The **Water Vole**, a species of wetlands, rivers and streams and Grassland areas with ditches, is expected to become less abundant in the future, as a result of a less suitable climate. This species is UK and Kent BAP species whose place of shelter is protected under the Wildlife & Countryside Act 1981.
Finally, the plant species **Clustered Clover**, a Kent Red Data Book species of sandy soils and dunes, is expected to become more abundant in the future, as a result of the climate becoming more suitable.

3.3.3 Planning "climate change proof" ecological networks with stakeholders

The modelling results for the habitat networks and the effects of climate change on these were analysed with stakeholders in order to design a strategy to allow biodiversity adapt to these changes. Also, the constraints, opportunities and threats for habitat creation were mapped. This was done for the modelled species of Grassland and woodland.

Grassland species

Analysis of effects on species showing similar attributes to the Meadow Pipit (decreasing species of wet Grassland)

In the present situation, this species is widespread, and occupies a very sustainable network of wet Grasslands, including many key areas. As time and the impact of climate change progresses, most key areas are expected to disappear. Also, the network of habitats will fragment into smaller separate, less sustainable networks. The most important remaining key areas are located in the south of Kent. These are part of a network that will remain sustainable, even when climate conditions are only marginal suitable. An appropriate strategy will be to strengthen these key areas, and try to encourage sustainability for as long as possible.

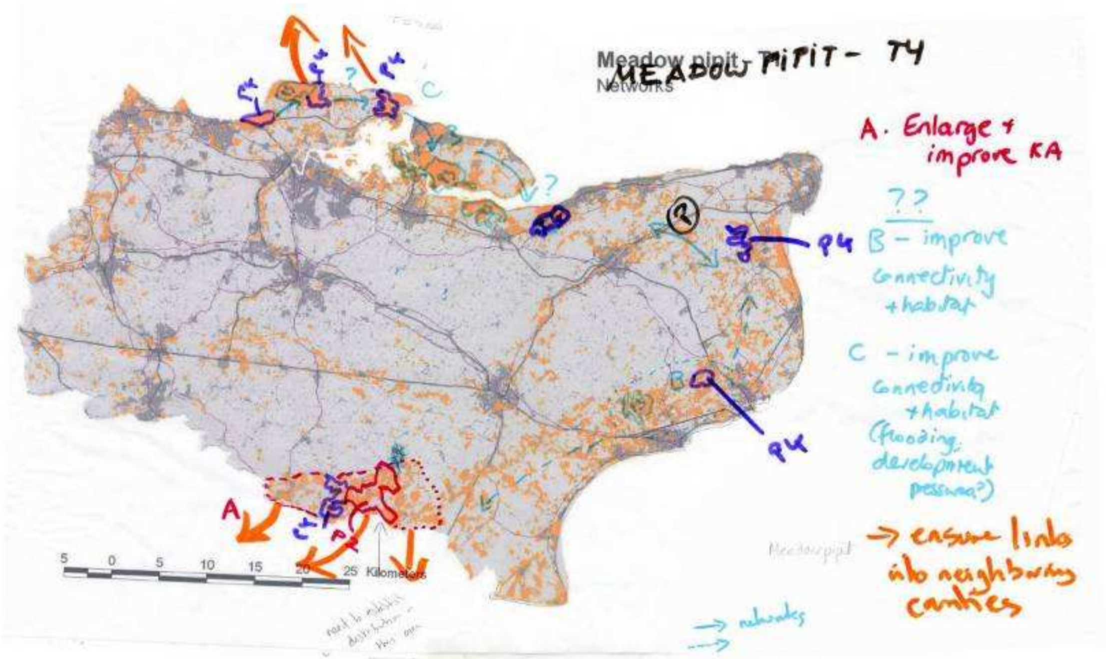


Figure 28 Result of group work for the Meadow Pipit.

Analysis of effects on species showing similar attributes to the Adonis Blue (increasing species of chalk Grassland)

Climate change could be beneficial for this butterfly. The present habitat availability consists of many separate, small habitat networks, most of which are unsustainable, even when the climate is very suitable for this species. Therefore many areas could remain unoccupied as colonisation of suitable habitat is expected to occur very slowly. Green bridges could be created to cross barriers and decrease fragmentation created by infrastructure in the landscape. The promotion of farmland/agriculture practises which are beneficial to the Adonis Blue within and between habitat networks may help to improve the network of chalk Grasslands and the permeability of the landscape for biodiversity.

Species can have different preferences of micro-habitat, for example either short or long grass. When the habitat contains a mosaic of habitat and habitat features, different species requirements may be better satisfied. For this habitat type, on the chalk ridge across the County, it is important to start conversation and negotiation with neighbouring counties.

Opportunities and threats for Grassland

The main threat for Grassland habitat networks is infrastructure. Along the motorway M2, many constraining activities take place, causing (light) pollution, disturbances, fragmentation and an increase of built-up area.

Habitat opportunities identified included the Green Grid in Kent Thameside. The establishment of a Green Grid could contribute to habitat creation and a more permeable landscape in North Kent. Furthermore, a green bridge is planned and in some areas opportunities were seen for Environmental Stewardship Schemes to contribute as a result of land owners and farmers that are willing to participate and can help to increase habitat connectivity.

The future large scale developments in growth areas as the Thames Gateway and Ashford can be both an opportunity and a threat. This depends on the way that habitat connectivity and habitat creation is taken into account in these developments.

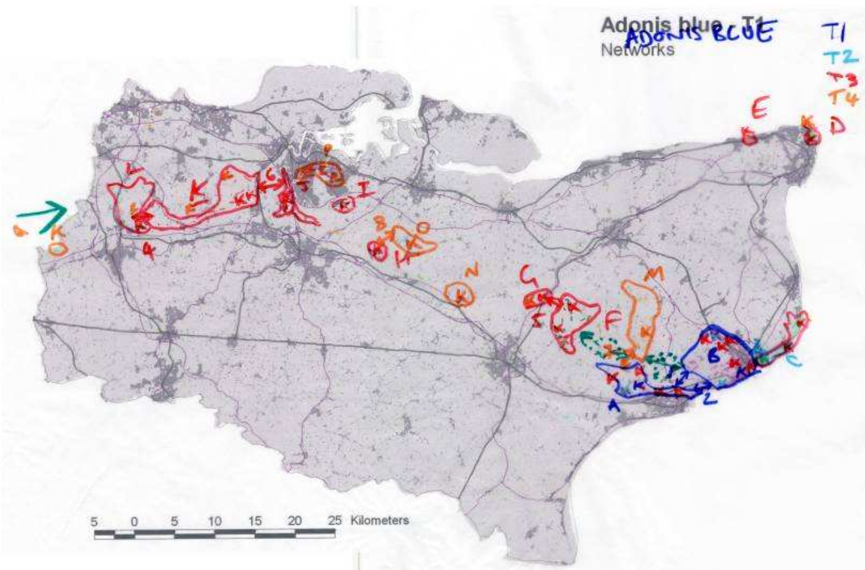


Figure 29 Results of group work on the Adonis Blue.

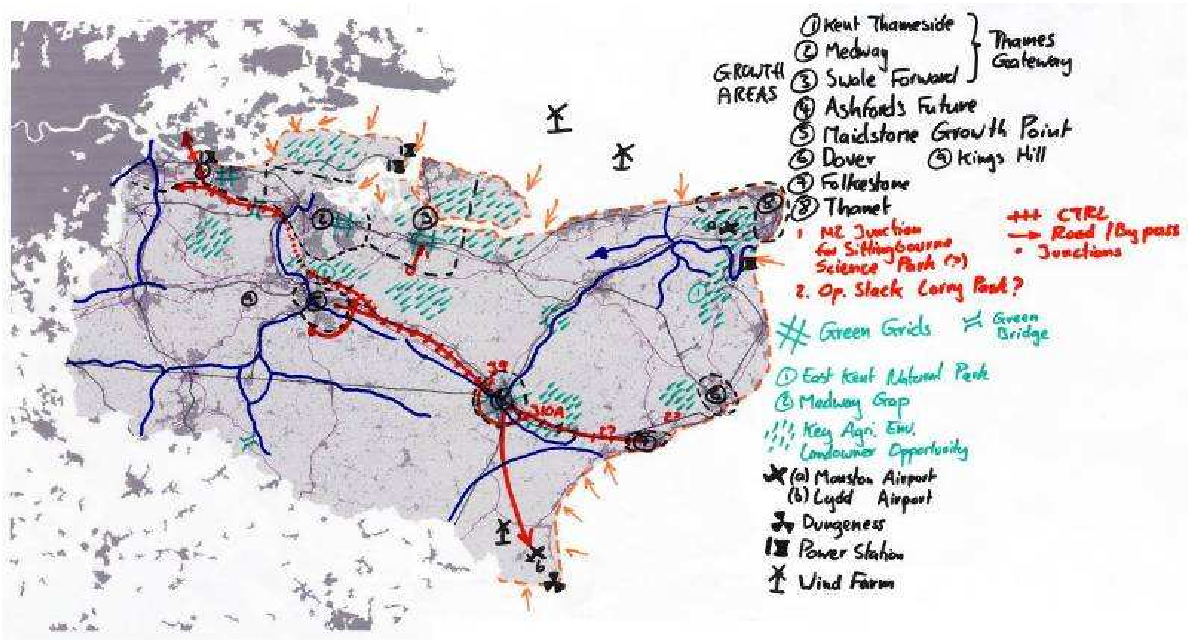


Figure 30 Result of group work on threats and opportunities for Grassland habitats.

Woodland species

Analysis of effects on species showing similar attributes to the Bechstein's Bat (increasing species)

This species has very specific habitat feature requirements within the woodland habitat. Therefore, the modelling results should be interpreted as for ground dwelling species of broadleaved woodland species with a low dispersal capacity.

The possible entry area for incoming woodland species is expected to be in the south-west (Figure 31). There is no continuity of woodland to allow Bats to move along to the other woodland areas. In the present habitat configuration, these species are expected to have problems in colonising woodland areas elsewhere in Kent.

Analysis of effects on species showing similar attributes to the Purple Emperor (increasing species)

This species has small area requirements. In Kent, looking at the present situation, there are even now many key areas which are distributed across the County. Species that act on this scale don't need particular measures. However, in the future they may be under stress due to habitat fragmentation.

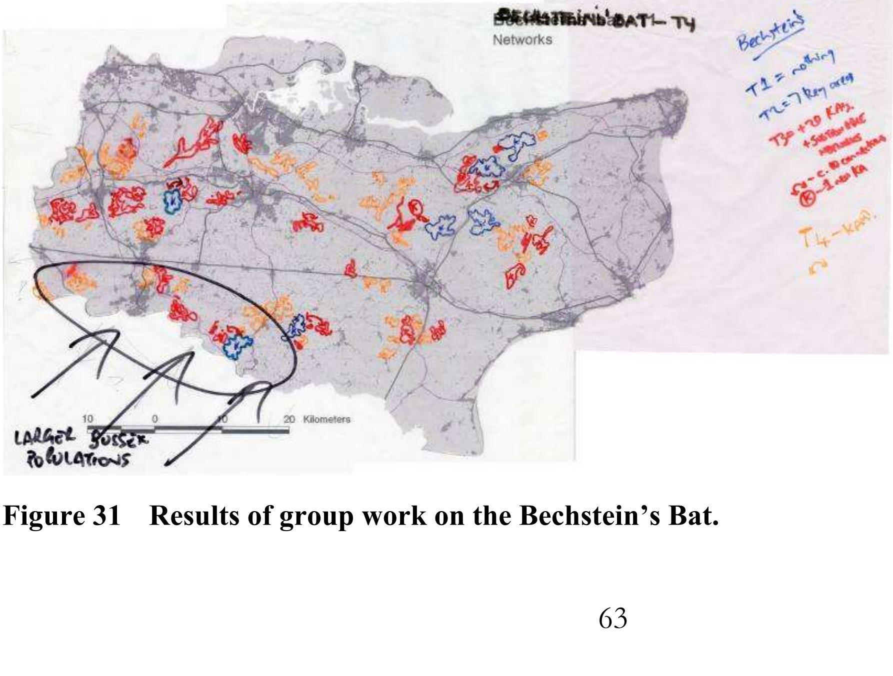


Figure 31 Results of group work on the Bechstein's Bat.

For the group of species that is represented by the Purple Emperor, it is important not to focus on climate suitability alone, but also on quality of habitat.

Opportunities and threats for woodland

The threats that were identified were development areas for instance Ashford or the Thames Gateway, airport, the new Thames Crossing, expansion of urban areas and the interface with the London area. Furthermore, transport and infrastructure fragments woodland areas. An important economic constraint for woodland development (and probably also other habitat development) that was mentioned is land speculation, as this raises the price of land and restricts the opportunities for habitat creation. Changes in water resources as a result of climate change could affect woodland species and species competition and may also cause changes in woodland species composition.

Opportunities can be found in development areas. Areas that include threats are also areas with opportunities for habitat creation. For example, transport links could lead to improvement of woodland habitats and could work as corridor links. However, growing new woodlands can't replace existing woodlands (because of the time that it would take). Quarries were mentioned as a good opportunity for creating woodland. Old quarry sites can be used to create woodland instead of putting them (entirely) back to agriculture or using them for development.

Box 5 Experiences from the planning workshop

The workshop was a valuable opportunity for stakeholders to engage in the design of an ecological network for Kent and is something Kent County Councils hopes to take further in the future. It released a great deal of informative feedback from the delegates some of which is detailed below.

Many delegates felt that the modelling methodology was very complicated the assumptions and limitations of the modelling need to be more transparent. It appeared that concentrating on indicator species could, at times, be confusing and restrictive however it was also suggested that individual species are useful as flagships for habitats as decision makers and the public respond well to individual species. Many delegates thought that a habitat focussed approach may be more useful than a species focussed approach; this is more in line with contemporary wildlife conservation thinking. It was also mentioned that wildlife conservation and spatial planning needs to move in to a new era of allowing wildlife and designated sites to adapt to climate change and therefore a more flexible, dynamic system of wildlife conservation needs to emerge.

The workshop was a good way to open the debate and get stakeholders thinking about issues such as current conservation methods and the impact climate change may have on them, future conservation priorities and future actions that need to be taken etc. It has highlighted significant questions that need to be answered and has provided constructive comments on the modelling method and workshop process. The workshop was a good first step but further progress needs to be made to make to ensure the best use of the outcomes of the BRANCH Project. The importance of working together to maximise the benefit for biodiversity has been highlighted. There are a number of bodies working on ecological network and climate change initiatives, these should be well communicated and integrated with each other to enable the habitat network concept to move forward together and present a clear and consistent argument to policy makers, decision makers and government.

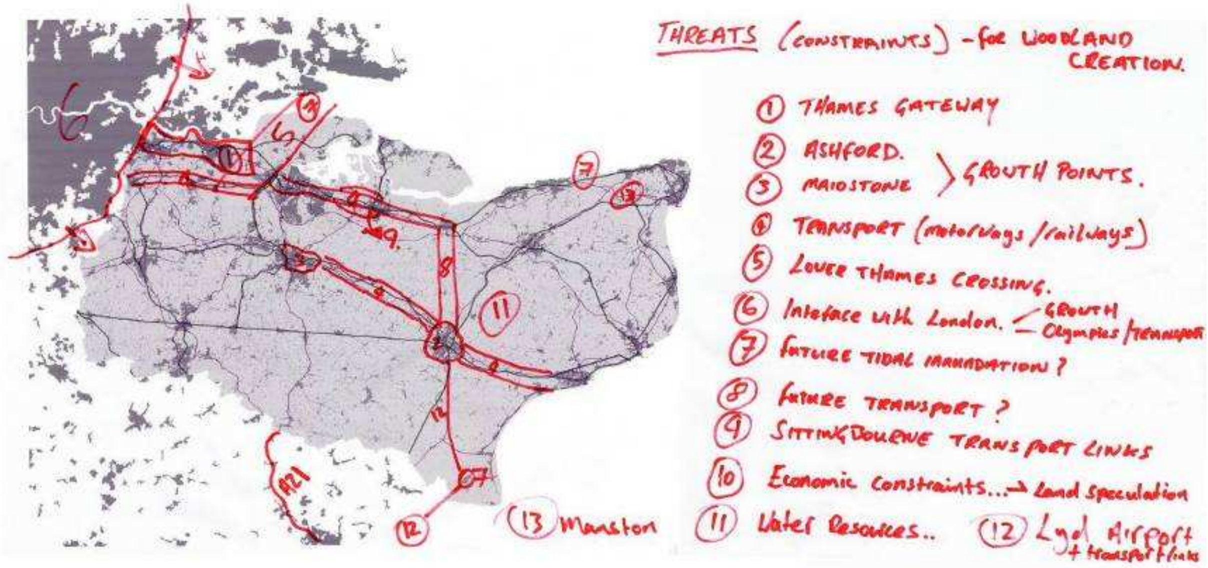


Figure 32 Result of group work on threats and opportunities for woodland.

3.3.4 Conclusions and strategies for climate change proof ecosystem networks

Wetlands

Incoming species: Cetti's Warbler

Results (Figure 33):

- The best network for T1 is an unsustainable one that includes Stodmarsh (1; largest area) and the area around the Swale (2; smaller areas)
- The direction of climate change is from SE to NW.
- Dispersal capacity is 50 km
- Habitat opportunity map: shows potential for habitat along rivers and brooks
- "Mapping the future "shows that Stodmarsh (1) is close to area indicated as "Natural East Kent": a project underway in Kent to promote and enhance the natural aspects of this area, and close to area with landowner opportunity for agri-environment schemes. Other landowner opportunities for agri-environment schemes exist around the Swale (2).

Conclusions (Figure 33):

- Option I: create key area and sustainable network around Stodmarsh (1; Figure 33); Key areas are important for incoming species as they can function as a strong source of dispersers, enhancing the colonization of new habitat areas.
- Option II: create key area and sustainable network around the Swale (2; Figure 33).

Additional strategies for incoming species with smaller dispersal capacities and/or that are more sensitive to barriers:

- Connect habitat areas and networks in adaptation zone e.g.:
  - make area between Stodmarsh and area around the Swale wildlife friendly (b; Figure 33).
  - use opportunity to create new wetland area North and North East of High Halstow (3; a; Figure 33).
- If the entrance area appears to be Dungeness (this would require monitoring), then create key area and/or sustainable network in Dungeness (c; Figure 33)and use the Great Stour river valley through Ashford to connect with Stodmarsh (d; Figure 33).

  (please note: a, b, c and d are in no particular order of preference)

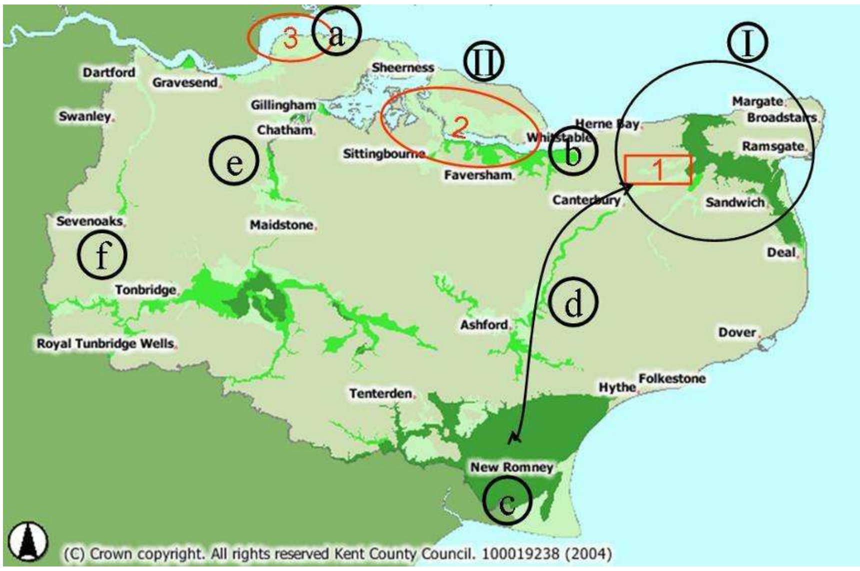


Figure 33 Adaptation strategy for Wetlands. Roman numerals: conclusions resulting from detailed modelling. Letters: conclusions based on extrapolations to other species.

Additional strategies for disappearing species:

- If the last remaining habitat network is Stodmarsh: to maintain species as long as possible see: Option I (above).

Additional strategies for species that remain in Kent:

- If the remaining species are located in areas that are not yet included in a strategy, try to create a key area and/or a sustainable network. It is important to also monitor these species, to be able to adapt the strategy if required. Examples of such areas are location e and f (Figure 33).

Grasslands

Incoming species: Dartford Warbler

Results (Figure 34):

- The best sustainable network (i.e. one sustainable network with key area) is expected to appear on the grazing marshes on the Isle of Sheppey (1), Sheerness (2) and north of High Halstow and Cliffe (3; Figure 34).
- The first breeding records of this species are in the south of Kent (4; e.g. New Romney Figure 34); this could be the entrance area for the species. This is more than 25 km away of the best climate change proof network.
- Habitat opportunity map: shows medium potential for habitat around the Swale (5), on the Isle of Sheppey (1) and minor habitat opportunities around and east of Sheerness.
- In "mapping the future" these areas area indicated to have good landowner opportunities for agri-environment schemes.

Conclusions (Figure 34):

- Option I for incoming species: Focus on quality of habitat and creating more grazing marshes on the Isle of Sheppey (1), Sheerness (2) and north of High Halstow and Cliffe (3). Create stepping stones, preferably key areas, between this area and the new Romney area (4), so that species that enter in the south can better colonise the strongest habitat network in the North.

Decreasing species: Meadow Pipit

Results (Figure 34):

- The habitat network where the species is expected to resist the longest in the habitat network along the coast, with a key area seems to be west of New Romney (6; i.e. sustainable network with key area). However, as there were not many records in this particular area, it should be checked if this is accurate.

- Dispersal capacity is 15 km.
- Habitat opportunity map: shows high potential for creation of wet Grasslands around Romney (Floodplains in K-LIS). Other opportunities on and near the Isle of Sheppey (1) and between Sandwich and Ramsgate (7). Also in the Stour valley and near Ashford potential exists for wet Grassland creation.
- In "mapping the future" around and east of Ashford, and in the Stour Valley are good landowner opportunities for agri-environment schemes.

Conclusions (Figure 34):

- Option I for decreasing species: Focus on quality of habitat and creating more grazing marshes around New Romney. Try to maintain the habitat and its connectivity of Grassland areas along the coast until Sheerness and the rest of the Isle of Sheppey, and use the opportunities for agri-environment schemes in this area (a). Another option is to use the opportunities for agri-environment schemes in the Stour Valley and to create a linkage between New Romney and the area around the Isle of Sheppey (b).

Additional strategies for incoming species with smaller dispersal capacities and/or more sensitive to barriers

- Connect habitat areas and networks in adaptation zone, which contains area I for increasing species and areas I for decreasing species, e.g.:
    - Assess and use of possibilities to increase habitat area along coastal meadows (a)
    - Assess and use of possibilities to increase habitat area and connectivity along the River Stour and create a wildlife permeable zone in Ashford (b).

(please note: a and b are in no particular order)

Additional strategies for species that remain in Kent:

- If the remaining species are located in areas that are not yet included in a strategy, try to create a key area and or a sustainable network. An example is the area around Maidstone. It is important to also monitor these species and areas, to be able to adapt the strategy if required.

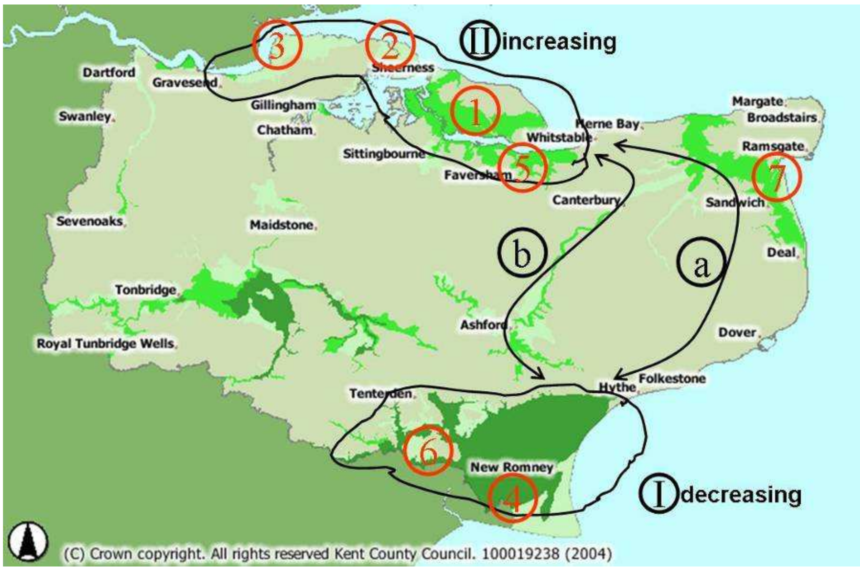


Figure 34 Adaptation strategy for Grassland. Roman numerals: conclusions resulting from detailed modelling. Letters: conclusions based on extrapolations to other species.

Ponds

Decreasing species: Great Crested Newt

Results (Figure 35):

- The habitat networks for this species are very abundant and sustainable, especially in the High and Low Weald (1), between Ashford and Royal Tunbridge wells and further east (2), and especially south of the railway between Ashford and Tonbridge.
- The species is sensitive to barriers in the landscape and has a small dispersal capacity.
- "Mapping the future" showed that a green bridge is planned over a large road, east of Royal Tunbridge Wells.

Conclusions (Figure 35)**:**

- Safeguard quality of existing ponds and keep / make landscape more permeable to wildlife through aquatic and terrestrial habitats. Focus on the strongest area, which appears to be area I.
- Additional strategies for incoming species with smaller dispersal capacities and/or that are more sensitive to barriers:
- Try to find out where you can expect incoming species to colonise (from the west, Surrey, East Sussex, or from the south east across the Channel, this requires monitoring).
- Try to create a landscape with many ponds that links the entrance area with area I and mitigate for infrastructure, both existing and planned.

Additional strategies for disappearing species:

- If disappearing species do not have their strongest networks in area I, then also focus on increasing the sustainability of this network.

Additional strategies for species that remain in Kent:

- If important Kent species are not located in area I, try to improve the sustainability of the network. It is important to also monitor these species and areas, to be able to adapt the strategy if required.

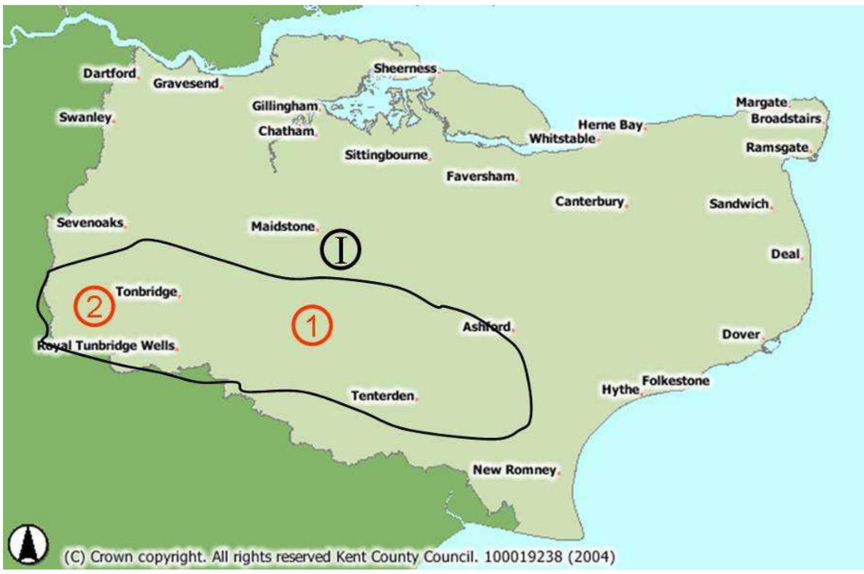


Figure 35 Adaptation strategy for Ponds. Roman numerals: conclusions resulting from detailed modelling. Letters: conclusions based on extrapolations to other species.

Woodland

Incoming species: Bechstein's Bat and Purple Emperor

Results (Figure 36):

- The best climate proof networks for these species (i.e. sustainable networks consisting of one large area) are expected to appear in several areas around the County. Figure 36, shows 4 areas that are the first to become sustainable for species such as the Purple Emperor in T1 (area 1 to 4) and 7 areas for ground dwelling species for which the Bechstein's Bat is a model, only appearing in T2 (area 1 to 7)).
- Both species are not very good dispersers; 500 m for Bechstein's Bat and 5 km for Purple Emperor.
- Entrance area (E; Figure 36) for Purple Emperor (and other similar increasing woodland species) appears to be at the border of Surrey and East Sussex (this requires monitoring).
- The habitat opportunity map shows that around all 7 areas there are high opportunities for the creation of woodland, except area 4, where opportunities are mainly medium to low.
- "Mapping the future" showed that there is one threat for the connectivity for woodland, which is relevant for the areas on the map. In the future, a transport route from Ashford to the north might be realized, between area 3 and 4 (Figure 36).

Conclusions (Figure 36):

- Link the entrance area (E) with the areas indicated on the map (Figure 36). Choose a strategy to bridge the largest gap: by creating an adaptation zone I, linking areas 7, 6 to 1 to 4, or by creating an adaptation zone II, by linking area 5 to area 1 to 4 (Figure 36). In the areas in this adaptation zone, use opportunities to establish new patches of woodland (stepping stones) and/or make the landscape more permeable for woodland species by planting / protecting hedge rows and woodland corridors.
- Also choose adaptation zones for smaller gaps (other arrows, Figure 36) and focus the creation and conservation of woodland in these areas. As incoming species are expected to enter Kent from the west, the realization of the adaptation zone for incoming species has a higher priority in this part than in the east part of Kent.

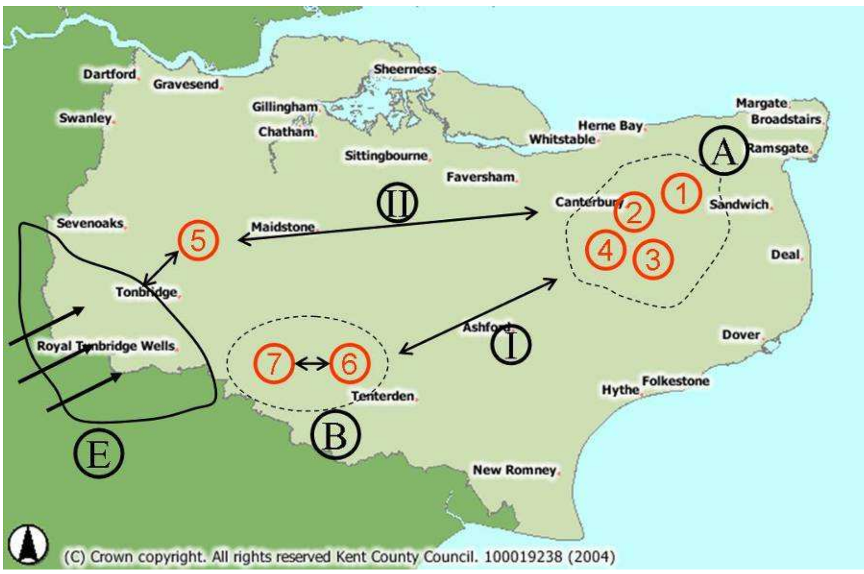


Figure 36 Adaptation strategy for Woodland. Roman numerals: conclusions resulting from detailed modelling. Letters: conclusions based on extrapolations to other species.

Additional strategies for incoming species with smaller dispersal capacities and/or that are more sensitive to barriers:

- Species such as the Lesser Horseshoe Bat can also be expected to increase in number or colonise Kent. As the species that have been modelled are very sensitive to barriers and fragmentation, it is expected that a large part of the species will profit from the strategy that is proposed for the Bechstein's Bat and the Purple Emperor.

Additional strategies for decreasing species:

- It can be expected that the first sustainable networks to appear for incoming species are also the strongest networks for decreasing species with the same spatial requirements as the species assessed. For the decreasing species the areas 1 to 4 in the west part of Kent are of more importance; these areas are situated relatively close to each other, and will be one habitat network for species with a larger dispersal capacity. For species that have a smaller dispersal distance, these areas could be linked into a strong network where they can persist as long as possible. Furthermore linking areas 6 and 7 would increase the conditions for decreasing species.
- For linking areas 3 and 4, a future threat was mentioned; the creation of a motorway from Ashford to the north. When this is planned and realised, a green bridge between these areas would be important to mitigate the fragmentation effect of this road.

Additional strategies for species that remain in Kent:

- If the remaining species are located in areas that are not yet included in a strategy, try to create a key area and or a sustainable network. It is important to also monitor these species and areas, to be able to adapt the strategy if required.

Chalk Grassland

Incoming species: Adonis Blue

Results (Figure 37):

- The best sustainable networks for these species (on T1) are expected to appear near Dover and Folkestone (1 and 2) in East Kent and between Chatham and Sevenoaks in West Kent (3).
- Entrance area for Adonis Blue (and other chalk Grassland species with similar attributes) can be from residual populations or species crossing the Channel in the strong network in the East (E1). The exit area would be the other side of the chalk downs ridge (E2; Figure 37), the link to other habitat patches in Surrey.
- Dispersal capacity is 1 km.
- The habitat opportunity map shows that the opportunities for chalk Grassland are confined to the Kent Downs, a chalk ridge running from Folkestone/Dover to Dartford. Especially in the central part of Kent, only a small strip of some kilometres has good potential for chalk Grassland.
- Mapping the future showed that there are several areas along the chalk ridge where there are good land owner possibilities for agri-environment schemes.

Conclusions (Figure 37):

- Make the entrance area a strong network by linking area 1 and 2 that can act as a source of dispersers. Furthermore, link the entrance and exit areas (E1 and E2) via area 3 in an adaptation zone. In the gap between these areas, use opportunities to establish new patches, possibly creating key areas and sustainable networks, as close to each other as possible (preferably less than 1 km; Figure 37). Options to do this were mapped in the planning workshop. Also make the landscape more permeable for wildlife between patches for chalk Grassland species.

Additional strategies for incoming species with smaller dispersal capacities and/or that are more sensitive to barriers:

- The Adonis Blue is quite sensitive to habitat fragmentation. If an adaptation zone is created that is suitable for the Adonis Blue, many species will profit from this. This may also have a negative effect, e.g. the rapid colonisation of competitive species for typical chalk Grassland species. Therefore, it is important to tailor the implementation of the network to the local situation, monitor the effects and take additional measures if required.
- For species that require larger areas, the adaptation zone as created for species as the Adonis Blue might not be sufficient. For these species, creating larger areas is required.

Additional strategies for decreasing species:

- It can be expected that the areas 1, 2 and 3, that become the first sustainable networks for incoming species, are also important as the last strongholds for decreasing species with the same spatial characteristic as the Adonis Blue (Figure 37). By strengthening these networks and linking area 1 and 2, decreasing species are expected to be able to persist longer. For species with larger area requirements, it is of importance to link these areas so that they can have larger populations (maybe even key populations) with better dispersal power.

Additional strategies for species that remain in Kent:

- If the remaining species are located in areas that are not yet included in a strategy, try to create a key area and or a sustainable network. It is important to also monitor these species (e.g. Chalk Hill Blue) and areas, to be able to adapt the strategy if required.

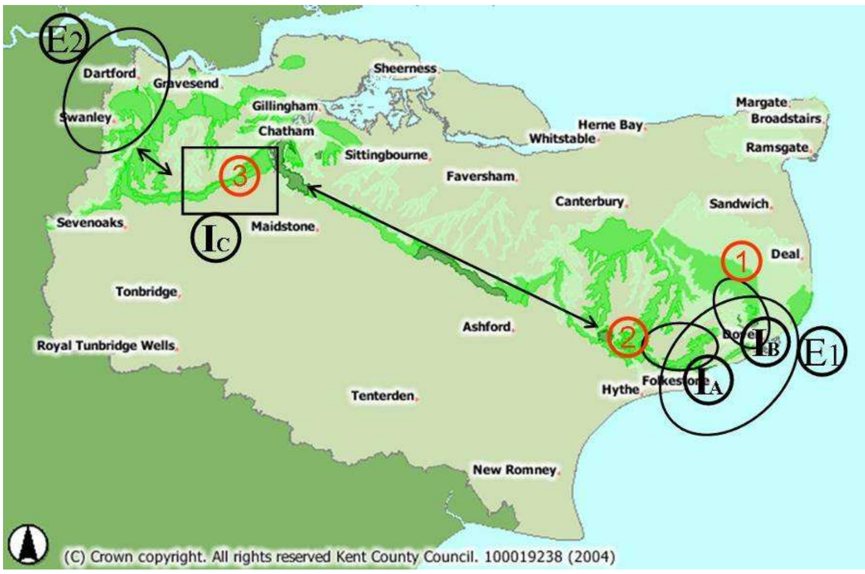


Figure 37 Adaptation strategy for Chalk Grassland. Roman figures: conclusions resulting from detailed modelling. Letters: conclusions based on extrapolations to other species.

3.3.5 Evaluation, recommendations and further steps

Evaluation of stakeholder involvement:

- A great deal of effort was put in to getting local stakeholders involved. A broad range of stakeholders were invited to the events including planners, conservation organisations, local authorities, land owners, voluntary organisations, landscape organisations, development agencies, government agencies, County recorders and the County Records Centre (The Kent and Medway Biological Records Centre). Planners were a desired but difficult audience to engage with, due to time pressures and work load priorities.

- A number of delegates have attended all stakeholder events and have had the capacity and enthusiasm to input their expertise and opinions. It has been very valuable to consider and include a wide range of opinions and expertise as it broadens the pool of knowledge to draw from for the results and conclusions of this project and their further continuation and development. It has also been a valuable experience for stakeholders with different areas of expertise to come together and discuss the concept of ecological networks and the issues in their delivery.

Recommendations:

- Continue the process of the development of a climate change proof ecological network for Kent that has been put into motion with stakeholders. Stakeholders have been engaged and are willing to continue in the process towards the design and implementation of a County wide ecological network. The BRANCH results and conclusions and strategies in the above paragraph are a good start for the further design process.
- Next steps could be the further linking of foreseen areas of interest using policies and financial instruments and making choices for areas and zones that will be part of an integrated climate change proof ecological network (a network in which the main ecosystem types are integrated with other functions).
- Communicate with surrounding counties to fine tune strategies for the ecological network, link with initiatives in neighbouring counties or overarching regions for the development for an ecological
- network, e.g. the initiatives for the development of an ecological network in South East England by the Wildlife Trusts.
- Set up a monitoring scheme. Climate change and the response of species is uncertain, and a good monitoring system can provide the required information for adaptation management and planning. Also, monitoring is required to answer or underpin remaining questions on the quality and significance of areas that are good candidates to be part of the ecological network.

Next steps of Kent County Council:

- Kent County Council wants to continue to support and facilitate the involvement of stakeholders. A Kent Case Study Final Conference is planned in September 2007 to present final results and next steps to Kent stakeholders in order to wrap up the end of the project and to advocate the future actions that have come out of the project.
- Kent County Council will re-run the Habitat Opportunity Maps for Kent using the new GIS tool. Kent County Council will display some results of the Alterra modelling on the KLIS website.
- Kent County Council will present the findings of BRANCH in sessions or meetings concerning climate change, biodiversity and planning to the district councils to ensure engagement of spatial planning stakeholders and an influence on the LDF process.
- Kent County Council will investigate and carry out actions in order to influence spatial planning policy, perhaps most importantly, to influence LDF's.
- Kent County Council is thinking about new partnerships with stakeholders and other organisations to enable us to learn from each other and work closely together and achieve maximum success in planning and implementing an ecological network for Kent.

Box 6 Examples of policies and schemes on (future) nature development in Kent County

Here some of the existing measures are discussed that are delivering habitat creation in Kent and may help in creating ecological networks in the future.

National scale:
Planning Policy Statement 9: Biodiversity and Geological Conservation sets out government planning policy with regards to biodiversity. This statement influences the content of regional and local spatial planning documents along with controlling development. One of its key principles is not only to protect biodiversity but also to enhance it. It also mentions the importance of ecological networks, and that climate change and its affect on biodiversity must be addressed.

The South East Plan is the Regional Spatial Strategy for South East England. It has identified Areas of Strategic Opportunity for Biodiversity Improvement (ASOBI's) which identify broad indicative areas of greatest regional-scale potential for enhancement, restoration and re-creation of priority habitats. These broad areas must be translated in to specific site allocations for creation of priority habitat by the District Councils. They must be included in Local Development Frameworks (LDF's) which are produced by District Councils to provide a spatial strategy at a local level and are guided by the South East Plan policies. There is also the scope for LDF's to include policies that enable the protection and enhancement of wider biodiversity and ecological networks. Kent County Council should aim to influence the content of the LDF policies to include consideration of adaptation of biodiversity to climate change. Development Control as influenced by planning policy can contribute to the management, creation and enhancement of habitats for wildlife by firstly avoiding fragmenting habitats already in situ and secondly by designing in biodiversity enhancements and connectivity.

Agri-environment Schemes also provide opportunities to create a more permeable landscape for biodiversity adaptation to climate change. The scheme gives funds to farmers and land managers who carry out effective environmental management on their land. One of the main objectives is to conserve biodiversity. This is an area where habitat connectivity features such as hedgerows can be created and enhanced, and more wildlife friendly permeable agricultural habitats can be created in order to input positively in to the creation of ecological networks and a landscape more suitable for biodiversity adaptation to climate change. The aim is to have 70% farms/land mangers in Kent in Entry Level Stewardship by 2007 (Natural England). The budgets for ELS schemes are allocated on quarterly basis so they are not predictable. The ELS is non competitive so anyone can apply and there will be funding made available.

Countyscale:
The Kent Biodiversity Action Plan (BAP) Partnership is a broad network of organisations, each with a common focus for biodiversity conservation in Kent. The Partnership aims to make Kent a place where plants, animals and habitats are protected and enhanced, both for their own sake and as an integral part of the quality of life. The Kent BAP focuses on priority Habitat Action Plan habitats (HAPs) which include action plans and targets for the delivery of habitat enhancement and creation in Kent. Different organisations lead on the delivery of these and are responsible for coordinating and reporting on progress. Habitat creation targets could be amended in Kent in response to the conclusions and recommendations of the BRANCH Project.

Other initiatives:
Nature conservation organisations in Kent, such as Natural England, Kent Wildlife Trust, RSPB, Woodland Trust etc often work towards the acquisition of further land in order to manage it for nature conservation and habitat management. This will contribute to the quantity of land managed for wildlife and could contribute to an ecological network if monitored and acquired strategically. The Wildlife Trusts have produced an approach to ecological network creation in SE England, presented in the document, 'A Living Landscape for the South East'. This is an area where the Kent County Council can collaborate with the Wildlife Trust, particularly in Kent, to further the opportunity for realisation of an ecological network.

The maintenance, enhancement and expansion of the current portfolio of designated sites will contribute to the permeability of the landscape. As above the strategic purchase of designation of land pockets could contribute to the ecological network in Kent. However a more dynamic system for nature conservation that allows designated sites to adapt to climate change will be needed in the future. The management and enhancement of non designated sites for wildlife will also contribute to the permeability of the landscape for biodiversity adaptation to climate change. The Kent BAP, along with initiatives such as 'Gardening for Wildlife', run by the Kent Wildlife Trust, may contribute to this.

Landowners, including Kent County Council and the District Councils, should ensure that the impact on biodiversity and ecological networks from their own property and developments is minimal and that every effort is made to contribute to the enhancement of wider biodiversity and defragmenting habitats.

4 General Discussion

4.1 Overall conclusions and recommendations

Climate zones for species are moving (Berry, Dawson et al. 2002; Pearson, Dawson et al. 2002; Del Barrio, Harrison et al. 2006; Harrison, Berry et al. 2006) and evidence that species are responding spatially has been found (Parmesan and Yohe 2003). How these changes will interfere with ecosystem fragmentation and land use patterns is largely unknown (Opdam and Wascher 2004; Botkin, Saxe et al. 2007; Brooker, Travis et al. 2007). Regional planning for biodiversity conservation has not yet adopted the potential consequences of climate change. We have applied methodology which had been used to assess spatially explicit biodiversity conservation policies (Verboom *et al*. 2001, Opdam *et al*. 2003, Verboom & Pouwels, 2004) in the context of climate change impacts, and extended methods for interactive design of ecosystem networks (Van Rooij *et al.* 2003) into methods for planning adaptation strategies to ameliorate climate change effects. To this purpose, we linked a predictive modelling approach based on climate envelopes at the species level (Environmental Change Institute, ECI, University of Oxford) with ecosystem network cohesion assessment methodology (Alterra, Wageningen Research Centre, WUR), and (1) explored impacts of climate change at the local site level, (2) developed methodology for assessing the effectiveness of proposed climate adaptation measures (Robust Corridor) and (3) developed an interactive method for the design of climate proof ecosystem networks at a County/province scale. Our results open up a promising way to proceed, acknowledging though that major improvements in basic knowledge and methodology are urgently needed. This conclusion is specified in the following points.

Exploring impacts of climate change on regional level.

- At the local level species responses to climate change vary. For some the local climate becomes more suitable (incoming/increasing species), for others less suitable (declining/disappearing species).
- As a consequence, radical changes in the species composition of local habitats and ecosystems are expected in the long term. Climate change may result in loss of biodiversity if species disappear due to less favourable local climate, while at the same time potentially incoming species do not establish due to habitat fragmentation.
- The developed tools are suitable to assess the effect of climate change on habitat on local scale and to develop adaptation strategies.

Robust Corridor as climate change adaptation measure

- Regional costs and efforts for climate change adaptation can be minimized by an iterative planning process at different levels of scale, in which key regions in the European ecosystem network pattern are planned to coincide with areas where local measures are most cost-effective and socio-economically most feasible.
- The various species response types to climate change require an array of adaptation strategies, both on the North West European scale and on the local scale. Increasing area and quality of existing habitat networks are the prime adaptation strategy for declining species, while for incoming and increasing species the prime strategy is creating key areas and connecting habitat networks.
- The implementation of Robust Corridors in the Netherlands was found to be an adequate adaptation strategy for climate change as they improve cohesion of existing habitat networks and connectivity between habitat networks.

Adapting regions for unwanted climate change impacts in biodiversity

- We propose to further develop our multi-time adaptation planning method, and to test it under various circumstances for effectiveness. In particular, we advocate the implementation of our method into multi-purpose land use planning approaches, including adaptation strategies for other functions, such as flood prevention; this asks for integrating species strategies in to ecosystem strategies and linking biodiversity to other land use functions that are affected by climate change.
- Ecological networks proved to be convenient spatial concepts for conservation planning in multi-purpose landscape. Regional stakeholders of different disciplines were readily involved in making decisions about which species, ecosystems, and adaptation strategies to focus on. By doing this, they developed a clear insight into the complex effects of climate change on biodiversity and developed support and ownership as well as a vision on a climate change proof landscape plan.
- We recommend enhancing this learning process during implementation by a monitoring scheme to record the magnitude and rate of the response of species to climate change at the level of these networks, and to learn the effectiveness of measures.

Future research issues

- The gap between science and planning isn't bridged yet. The developed tools need to be elaborated and simplified so that stakeholders can better use them. For example, the planning method needs to include decision support to enable planners to choose species to represent habitats that need adaptation strategies. To be suitable for policy, adaptation strategies need to be differentiated in steps to be taken for the short and the long term.
- A major challenge is the coordination of adaptation at the County/province level and the European level, which is the level at which climate change affects species distributions. Future adaptation strategies on European and national levels need to be translated to regional adaptation strategies, and regions need to coordinate the strategies and their implementation.
- Climate change in combination with fragmentation will affect the species composition of communities, with largely unknown effects for the resilience of ecosystems. More research on potential negative aspects of climate change is required (invasive species, pathogens, etc.).

4.2 Transferring science to society

This study is based on the latest scientific developments in the field of climate change, using models and planning tools that were adapted and developed for the specific purpose of designing climate change proof ecological networks and to enable policy makers to plan for future climate proof landscapes. An important issue that has to be addressed before discussing whether current ecological networks are climate proof or not, is how to define a climate change proof network.

In the Limburg case study for example, species responses to climate change and the effect on ecological networks and the Robust Corridor was analysed. It is one thing to conclude that the Robust Corridor is ameliorating the situation for the selected species, but can we conclude at the same time that the NEN will become climate proof? The same question can be asked in relation to planning of "climate change proof" ecological networks. When are we satisfied and when do we call an ecological network climate change proof? In this study an ecological network is considered climate change proof when it is sustainable and contains at least one key area..

These questions need to be answered in the societal domain, rather than in the scientific domain. A good definition for a climate change proof ecological network is still lacking and this discussion has to take place both in the scientific and in the society community. But ultimately it is society that decides and plans necessary adaptation measures, with science playing an important role in pinpointing consequences of choices made by society.

The planning method gives a step by step guide to assist in planning for the integration of nature conservation into spatial development planning and is based on metapopulation principles. For the purpose of interactive design by local stakeholders these principles were translated into simple design rules, that have been successfully used on a number of occasions, but not in the context of climate change (Van Rooij *et al.*, 2003, Opdam *et al.*, 2006; see also www.planningfornature.wur.nl). In this study the design rules were adapted to include decisions on when and how to create climate change proof ecological networks.

Using the planning method to design and adapt ecological networks for climate change has several advantages. Firstly, the design process can be made region specific by taking into account the interests and knowledge of local stakeholders and experts. In Kent, local knowledge about habitat quality and species distribution and characteristics were incorporated. This not only resulted in improving the quality of the recommendations, but at the same time increased local stakeholder support. Secondly, the planning method enables stakeholders to design alternative spatial options. These alternatives can be ranked in order of ecological profit. This allows stakeholders to discuss and choose the spatial option that is most suited to local resources and circumstances. Thirdly, the step by step planning method is flexible and can be modified as desired, but is also quite robust. The resulting alternative spatial options and their ecological ranking will probably remain much the same. The future, the definition of a climate change ecological network may change, the availability of resources may change and monitoring may lead to improved insights into the speed of climate change. Based on these changes, planners may opt for another spatial solution compared to the one they might choose today. But although changed arguments may lead to different choices in future, the best ecological solution will not have changed.

The interactive planning method for stakeholders appeared to be working and effective. The workshop in which the method was applied yielded a good level of understanding of and support for the development of a climate change proof ecological network by the stakeholders. Stakeholders involved were helpful and constructively critical and much local knowledge and knowledge gaps were uncovered and shared. However, on some points the planning method needs improving. Firstly, the planning method needs to be further simplified and more time needs to be reserved for the design process with stakeholders. The mental jumps required and the theory to be taken in at the workshop asked a lot of flexibility of the stakeholders. Secondly, the planning method is currently focused on species as representative of other species and habitats. For effective use in spatial policy the adaptation strategies should be scaled to regional level and include all selected species and ecosystems. Thirdly, stakeholders indicated that biodiversity alone was not enough reason for adapting the landscape to climate change. Combination with other necessary adaptation measures, e.g. for water or other functions like recreation, makes it much easier to get adaptation for biodiversity accepted and realised.

4.3 Reflections on the method

In this study, three different models were used to assess the effect of climate change on the sustainability of species in the landscape. Models always include uncertainties and limitations in the questions answered. Also, input data are required, which have their own level of uncertainty and limitations. Despite uncertainties and limitations, the method provided insight into the subjects of research and questions could be adequately addressed. Below, uncertainties and limitation of the method and its effect on the robustness of the conclusions are discussed.

SPECIES model

This model uses the correlation between climate and abiotic factors and the present distribution of a species to predict their future distribution. The model is sensitive to factors correlated to the distribution pattern of a species. This sensitivity is reflected in the so-called κ value that indicates how well the current distribution is predicted by the model (Berry *et al*.; 2007). For the case studies, only species were selected with a sufficiently large κ value.

SMALLSTEPS model

This model simulates the movement of individuals of a species through a complex, heterogeneous landscape and calculates the connectivity between habitat patches. The parameters that define the permeability of the landscape and the correlated random movement of a species were mostly based on expert judgement, as no other data were available. The maximum number of movement steps an individual was allowed to make was based on observed dispersal distances, derived from studies and literature.

A point of uncertainty is the relation between the time slice that is modelled and the actual point in time that it is expected to happen. This will vary among species; some species will be able to move along with the shifting climate envelope more rapidly than others. This means that T2 for species x can be reached in 2015 and for species y in 2040. This however has no effect on the conclusions drawn on the effectiveness of the Robust Corridor and the strategies for adaptation in Kent and would not really change under influence of the dating of the time-slices.

LARCH model

The standards used in LARCH for sustainability of populations are based on species densities in present climate conditions. As it is expected that the weather extremes become larger and more frequent, standards for sustainable populations should probably be more severe, as populations need to be larger to cope with larger fluctuations in numbers. Standards for sustainability in a changed climate are being developed at the moment, and will be available in the LARCH model in the near future.

From this perspective, the results of this study may underestimate the impact of climate change on the sustainability of species. Therefore, the positive effect of the implementation of the Robust Corridor may even be larger than we now assume, compared to the situation without this adaptation measure. Also, it might turn out that a greater area and/or connectivity is required for adaptation to climate change as a result of larger weather extremes.

Species interaction

In the approach adopted, species interaction and competition were not taken into account. The colonisation of new suitable areas by a species will result in competition with existing species, resulting in a change in densities. Also, climate change might change competition equilibriums between present species. This might be important to take into account in adaptation strategies on a lower level; it might appear that in some cases a certain level of isolation could be beneficial for the persistence of species.

Choice of species

The information on the North-Western European distributions of species was not always present or complete. This resulted in a considerable bias in the species for which climate envelopes were modelled; small and/or difficult to observe fauna species could not be modelled. Furthermore, the present level of knowledge on plant dispersal is insufficient to allow the modelling of plant species with SMALLSTEPS. Apart from that, connectivity modelling is only sensible for species with a dispersal range that is large relative to the scale of the habitat maps used. Most of the excluded species are either small or relatively immobile and will have problems following the shift of the climate envelope. Therefore, these species are expected to be hampered more by fragmentation than the species assessed. Therefore a greater loss in species richness is to be expected.

Despite all uncertainties and limitations related to the application of the models, the approach contains building blocks to provide insights into the effect of climate change on the local response type of species (incoming/increasing or declining/disappearing), the combined impact of landscape permeability and climate effects, and on the required spatial adaptation measures. We see the approach as a framework for future research to improve the scientific quality of its constituent building blocks and, by that, improve the predictive power of the composite tool.

Literature

Andrén, H. (1994). "Population responses to habitat fragmentation: statistical power and the ramdom sample hypothesis." Oikos **76**: pp. 235-242.

Berry, P., J. R. O'Hanley, et al. (2007a). "Spatial planning for chalk grassland and heathland habitats in Hampshire."

Berry, P. M., T. P. Dawson, et al. (2002). "Modelling potential impacts of climate change on the bioclimatic envelope of species in Britain and Ireland." Global Ecology and Biogeography. **11**(6): pp. 453-462.

Berry, P. M., R. J. Nicholls, et al. (2007b). "Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change."

Botkin, D. B., H. Saxe, et al. (2007). "Forecasting the effects of global warming on biodiversity." Bioscience **57**(3): pp. 227-236.

Brooker, R. W., J. M. J. Travis, et al. (2007). "Modelling species' range shifts in a changing climate: The impacts of biotic interactions, dispersal distance and the rate of climate change." Journal of Theoretical Biology. **245**(1): pp. 59-65.

Chardon, J. P., R. P. B. Foppen, et al. (2000). "LARCHRIVER: amethod to assess the functioning of rivers as ecological networks." European Water Management (3): pp. 35-43.

Del Barrio, G., P. A. Harrison, et al. (2006). "Integrating multiple modelling approaches to predict the potential impacts of climate change on species' distributions in contrasting regions: comparison and implications for policy." Environmental Science & Policy **9**(2): pp. 129-147.

Den Boer, P. J. (1986). "What can carabid beetles tell us about dynamics of populations?" In: P.J. den Boer, M.L. Luff, D. Mossakowski & F. Weber (eds.): Carabid beetles, their adaptations and dynamics. Gustav Fisher, Stuttgart.: pp. 315-330.

Elmqvist, T., C. Folke, et al. (2003). "Response diversity, ecosystem change, and resilience." Frontiers in Ecology and the Environment(1): pp. 488-494.

Folke, C., S. Carpenter, et al. (2004). "Regime shifts, resilience, and biodiversity in ecosystem management." Annual Review of Ecology Evolution and Systematics(35): pp. 557-581.

Foppen, R. (2001). "Bridging gaps in fragmented marshland." Alterra Scientific contributions 4. Alterra, Wageningen.

Foppen, R., N. Geilen, et al. (1999). "Towards a coherent habitat network for the Rhine. Presentation of a method for the evaluation of functional river corridors. ." IBN-research report 99/1. IBN-DLO / RIZA, Wageningen, The Netherlands.

Forsman, J. T. and M. Monkkonen (2003). "The role of climate in limiting European resident bird populations." Journal of Biogeography **30**(1): 55-70.

Guo, Q. F., M. Taper, et al. (2005). "Spatial-temporal population dynamics across species range: from centre to margin." Oikos **108**(1): 47-57.

Hagemeijer, W. J. M. and M. J. Blair, Eds. (1997). The EBCC Atlas of European Breeding Birds: Their Distribution and Abundance. Londen, T & A D Poyser.

Harrison, P. A., P. M. Berry, et al. (2006). "Modelling climate change impacts on species' distributions at the European scale: implications for conservation policy." Environmental Science & Policy. **9**(2): pp. 116-128.

Hengeveld, H. and J. Haeck (1982). "The distribution of abundance." Journal of Biogeography **9**: pp. 303-316.

Hulme, M. M. (2002). Climate Change Scenarios for the United Kingdom: the UKCIP02 Scientific Report.

Huntley, B. (1999). Species distribution and environmental change. Ecosystem Management: Questions for Science and Society. E. Maltby, M. Holdgate, M. Acreman and A. Weir. Egham, UK, Royal Holloway Institute for Environmental Research, University of London.**:** pp. 115-129.

Levins, R. (1970). "Extinction. ." In: M. Gerstenhaber (ed.). Some mathematical problems in biology. American Mathematical Society, Providence.: pp. 77-107.

Opdam, P., J. Verboom, et al. (2003). "Landscape cohesion: an index for the conservation potential of landscapes for biodiversity." Landscape Ecology **18**: pp. 113-126.

Opdam, P. F. M., E. G. Steingröver, et al. (2006). "Ecological networks: A spatial concept for multi-actor planning of sustainable landscapes." Landscape and Urban Planning **75**(3-4): pp. 322-332.

Opdam, P. F. M. and D. M. wascher (2004). "Climate change meets habitat fragmentation: linking landscape and biogeographical scale levels in research and conservation." Biological Conservation **117**(3): pp. 285-297

Parmesan, C. and G. Yohe (2003). "A globally coherent fingerprint of climate change impacts across natural systems." Nature **421**(6918): pp. 37-42.

Pearson, R. G. and T. P. Dawson (2003). "Predicting the impacts of climate change on the distribution of species: are bioclimate envelope models useful?" Environmental Change Institute, School of Geography and the Environment, University of Oxford, UK.

Pearson, R. G., T. P. Dawson, et al. (2002). "SPECIES: A Spatial Evaluation of Climate Impact on the Envelope of Species." Ecological Modelling **154**(3): pp. 289-300.

Pouwels, R. (2000). "LARCH: een toolbox voor ruimtelijke analyses van een landschap." Alterra-report 043. Wageningen. The Netherlands.

Sagarin, R. D. and S. D. Gaines (2006). "Moving beyond assumptions to understand abundance distributions across the ranges of species." trends in Ecology & Evolution **21**(9): pp. 524-530.
Shaffer, M. L. (1987). "Minimum Viable Populations: coping with uncertainty." In: M.E. Soulé (ed.). Viable populations for conservation. Cambridge University Press, Cambridge.: pp. 69-83.
Stace, C. (1991). "New flora of the British Isles." Cambridge: Cambridge University Press.
Suding, K. N., K. L. Gross, et al. (2004). "Alternative states and positive feedbacks in restoration ecology." Trends in Ecology and Evolution(19): pp. 46-53.
Van der Meijden, R. (2005). "Heukels' Flora van Nederland." Wolters-Noordhoff bv, Groningen/Houten, The Netherlands.
Van der Sluis, T. and J. P. Chardon (2001). "How to define European ecological networks. ." Proceedings Ecosystems and Sustainable Development ECOSUD III. Alicante, Spain. Ed. Y. Villacampa, C.A. Brebbia, J-L. Uso. Wessex Institute of Technology, Southampton, UK: pp. 119-128.
Van Rooij, S. A. M., E. G. Steingröver, et al. (2003). "Networks for Life. Scenario development of an ecological network in Cheshire County." Alterra-report 699. Wageningen.
Verboom, J., R. Foppen, et al. (2001). "Introducing the key patch approach for habitat networks with persistent populations: an example for marshland birds." Biological conservation **100**: pp. 89-101.
Verboom, J., P. luttikhuizen, et al. (1997). "Minimumarealen voor dieren in duurzame populatienetwerken (minimum areas for animals in sustainable population networks)." IBN-research report 259. IBN-DLO. Wageningen.
Verboom, J. and R. Pouwels (2004). "Ecological functioning of ecological networks: a species perspective. I." n: R. Jongman and G. Pungetti, Editors, Ecological Networks and Greenways: Concepts, Design and Implementation, Cambridge University Press, Cambridge, UK.: pp. 56-72.
Vos, C. C., H. Baveco, et al. (2001a). "Corridors and species dispersal. In Concepts and Application of Landscape Ecology in Biological Conservation." Edited by K. J. Gutzwiller. Springer-Verlag, New York .
Vos, C. C., J. Verboom, et al. (2001b). "Towards ecologically scaled landscape indices." American Naturalist **157**: pp. 24-51.
Weeda, E. J., R. Westra, et al. (1985 - 1994). "Nederlandse Oecologische Flora. Wilde planten en hun relaties. Five volumes." Instituut voor Natuurbeschermingseducatie en VARA.
Woodward, F. I. (1987). Climate and Plant Distribution., Cambridge University Press.

ISSN 1566-7197

Alterra-report 1543

This report is available in digital format at:
www.alterra.wur.nl and on www.branchproject.org.

A printed version of the report, like all other Alterra publications, is available from Cereales Publishers in Wageningen (Phone: +31 (0) 317 466666). For information about, conditions, prices and the quickest way of ordering see :
www.boomblad.nl/rapportenservice