# Adaptation strategy for climate-proofing biodiversity

Policy Studies

Netherlands Environmental Assessment Agency

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**Adaptation strategy for climate-proofing biodiversity**
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# Findings

# Adaptation strategy for climate-proofing biodiversity


## Summary

### The Dutch climate is changing

- Over the last few decades the Netherlands has become warmer and wetter, with more extreme rainfall events. Climate scenarios indicate that these trends will continue, but the magnitude and rate of climate change remain uncertain.

- Ecosystems are dynamic; there is a continuous development of successional stages. Climate change adds an extra dynamic to this, because ecosystems and biodiversity will also be subject to disturbances, such as increasingly frequent and intense precipitation and dry periods. The impacts on ecosystems and biodiversity are already visible and are expected to increase. Some species will decline in number or possibly even disappear from the Netherlands; other species, though, will be able to become established. Habitat conditions and species compositions will be in a constant state of flux. This will present risks to biodiversity in the Netherlands. As the climate changes, biodiversity can be maintained if ecological systems have sufficient capacity to adapt to these changes.

### Climate resilience is a key objective of government policy

- One of the key objectives of government policy is to increase the Netherlands' resilience to climate change. However, when current nature policies were drawn up neither the impacts of climate change nor the opportunities presented by climate change were explicitly taken into account.

- This study develops a strategy the government could pursue to climate-proof ecosystems and biodiversity. The starting points for the study were the government's ambitions for nature policy, such as conserving and developing biodiversity, giving priority to the ecosystems, habitats and species for which the Netherlands has a major international responsibility and which are characteristic of the Netherlands, and facilitate natural processes, such as sedimentation and erosion.

- In pursuing these objectives the government has to make important choices about how to deal with uncertainties and risks over the long term, and the degree to which synergy should be sought between nature policy and other policy areas, such as flood safety, agricultural production, landscape, recreation and housing.

### Current nature policy will not climate-proof biodiversity

- Under the current nature policy, biodiversity in the Netherlands will still remain under pressure. Biodiversity is declining in many ecosystems. As the climate changes, ecosystems and biodiversity will be affected by an increasing number of extreme weather events; larger areas and larger populations will be needed to absorb the impacts of these events. Even after the completion of the National Ecological Network (NEN) many protected areas will still be too small.

- The suitable climate zones for species may shift as global temperatures rise and precipitation patterns change. Dutch ecosystems and habitats are fragmented, which hinders or impedes the migration of some species to new suitable habitat areas. Cross-border connections between areas are also limited, preventing species from migrating long distances from areas where the climate is currently suitable to areas where the similar climatic conditions will exist in future, which may be hundreds of kilometres away.

- Environmental pressures on ecosystems and biodiversity have been declining in recent decades. Despite this reduction, water table drawdown, eutrophication and acidification continue to exert adverse effects on ecosystems and biodiversity. Climate change may exacerbate these problems.

- Current policies are increasing the ability of ecosystems and biodiversity in the Netherlands to adapt to these changes. However, the implementation of current policies will not remove the vulnerability of ecosystems and biodiversity to the consequences of climate change. The Netherlands Environmental Assessment Agency (PBL) has therefore developed an adaptation strategy to reduce the risk of biodiversity loss.

### Adaptation measures are needed

- Adaptation measures are needed to accommodate climate change. In this study we propose an adaptation strategy to increase the adaptive capacity of ecosystems, and by extension to make them climate-proof. By 'adaptive capacity' we mean the capacity of ecosystems to continue functioning despite disturbances. Because there are still many uncertainties regarding the magnitude and rate of climate change and its impacts on ecosystems and species, it is important that the strategy satisfies the following criteria:
  - The tempo and the scope of the strategy can be 'scaled up' to match the rate of climate change.
  - The strategy is able to accommodate different types of disruption, such as extreme dry and wet conditions.
  - The strategy can be integrated into nature policy and is flexible enough to allow adjustments to policy in the light of advances in scientific understanding.

- A strategy designed to strengthen the adaptive capacity of ecosystems and species satisfies these criteria. Moreover, this strategy protects ecosystems and biodiversity not only against climate change, but also against all existing disturbances, such as eutrophication and water table drawdown. We therefore call it a 'no regret strategy': should the rate or magnitude of climate change be less severe than anticipated, the strategy will not be a disinvestment.

- Adaptive capacity can be strengthened by amending certain elements of nature policy. These elements are: increasing the size of protected areas and the connections between them (both within the Netherlands and internationally), increasing habitat and landscape heterogeneity, and improving environmental and water conditions, thereby facilitating natural processes.

- When and to what degree existing policy will need to be amended will depend on the rate of climate change, how the government decides to deal with the risks to ecosystems and biodiversity, and the degree to which the implementation of the strategy ties in with other policy goals.

### Short-term policy measures

- The climate is already changing, but is mainly a long-term phenomenon. However, the government can take measures in the short term and adjust nature policy to anticipate and respond to the potential impacts of climate change. Here we briefly describe the steps the government can take within the National Ecological Network (NEN) and under the Birds and Habitats Directives (BHD), and how it can combine nature conservation objectives with other objectives.
  - NEN and BHD: A climate-proof nature policy requires making amendments to national and EU nature policies. These amended policies should be geared more towards ecosystem functioning and increasing the adaptive capacity of ecosystems and less than at present to the conservation of specific species in specific sites. Climate-proofing biodiversity implies maintaining high biodiversity, increasing the size and connectivity of protected areas, facilitating natural processes, habitat heterogeneity and ecological gradients, and improving site conditions.
  - NEN and BHD: The adaptive capacity of ecosystems and biodiversity to climate change can be increased by concentrating measures in the climate adaptation zones proposed in this report. We propose an international climate adaptation zone for the dunes, the coastal ecosystems and wetlands. For heathlands and forests we propose a national strategy consisting of clusters of heaths and branches of the European climate adaptation zone for forests. For small habitat areas we propose a regional adaptation strategy. We recommend adjusting the NEN. Combating habitat fragmentation remains important, but the areas of land still to be acquired or restructured for inclusion in the NEN will preferably be within the proposed climate adaptation zones.
  - EU: The adaptive capacity of the BHD sites can be increased by developing climate adaptation zones containing a coherent Natura 2000 network at the EU level. An important element in this approach is the development and implementation of the concept of 'green infrastructure'. This is a new concept in EU policy which pulls together various aspects of biodiversity policy, including the linking

together of protected areas. It will most probably be included in the post-2010 biodiversity policy. At the end of 2010 the European Commission will present a biodiversity action plan to achieve its biodiversity objectives.

- The policy for climate-proofing biodiversity can be integrated with other policies for different activities and goals. The development and implementation of the Delta programme, the Room for the River programme and similar programmes in neighbouring countries present such opportunities. These opportunities must be exploited over the next few years, because decisions made in these programmes will lead to irreversible long-term developments. Some long-term spatial developments will be incompatible with the proposed strategy, such as the rise in the water level in the IJsselmeer proposed by the Delta Commission. However, other public interests in rural areas, such as flood protection and the diversification of agricultural activities to include landscape services, are compatible with the creation of climate-proof habitats.

## Introduction

Climate change entails risks and opportunities for ecosystems and biodiversity, and also has consequences for nature policy and its objectives. In its 'Strategic Outlook 2009–2019' (*Strategische Verkenning 2009-2019*, LNV 2009) the Ministry of Agriculture, Nature and Food Quality (LNV) states that the government will have to amend its nature policy to take account of the changing climate, and questions whether current policy is sufficiently adaptive. To answer this question the government has launched various initiatives.

In 2008 the Ministry of Housing, Spatial Planning and the Environment (VROM) asked the Netherlands Environmental Assessment Agency (PBL) to carry out research into climate-proofing the spatial development of the Netherlands. This research set out to identify the options available to the Netherlands to develop a robust strategy for the long-term spatial development of the country. The report 'Roadmap to a climate-proof Netherlands' (*Wegen naar een klimaatbestendig Nederland,* PBL 2009c) contains the initial results. This was followed by the PBL study 'A climate-proof Netherlands' (*Klimaatbestendig Nederland*, KBNL). In addition, LNV and VROM explicitly asked PBL to conduct a 'thematic assessment of climate change, biodiversity and spatial planning'.

The findings presented here are from a report recently published by PBL (Vonk et al. 2010). Some of the conclusions of this report will be published in the journal *Landscape Ecology* (Vos et al. in press). The present findings contain a proposal by PBL for a long-term adaptation strategy for climate-proofing biodiversity and for a climate-proof nature policy. Partly concurrent with this research, PBL and Wageningen University and Research Centre (WUR) contributed to a study by the Interdepartmental Policy Research working group on Nature (*Interdepartmentaal Beleidsonderzoek werkgroep Natuur*), which explored possible answers to the question of how biodiversity in the Netherlands can be safeguarded in the most effective and efficient manner (IBO 2010). PBL also develops long-term visions for nature and nature policy in the Netherlands within the framework of the 'Nature Outlooks' project (*Natuurverkenningen*, NVK). The adaptation strategy we present in this present report builds on the Interdepartmental Policy Research study and provides input to the 'climate-proof Netherlands' study and the Nature Outlook variants. The adaptation options in this report are included in the long-term visions and will be developed further for the Nature Outlooks. The results of the Nature Outlooks will be published in 2011.

The PBL report on climate-proofing biodiversity is primarily exploratory and agenda-setting in nature. We have analysed the strategies the national government could follow, based on appraisals of what is necessary (with a view to the objectives of nature policy) and of what is possible (given the changing climate). In doing so, we were guided by the government's stated ambitions for nature: conservation and development of biodiversity, priority attention to the ecosystems, habitats and species for which the Netherlands has a major international responsibility and which are characteristic of the Netherlands, and building on natural processes. These three underlying principles were first set down in the Nature Policy Plan (LNV 1990) and developed in the policy document 'Nature for People, People for Nature' (LNV 2000). To realise these ambitions it is important that the government knows how it can best respond to the uncertainties and risks associated with climate change over the long term, and the degree to which it can exploit synergies between nature policy and policy sectors such as flood safety, agricultural production, landscape, recreation and housing.

## The influence of climate change on biodiversity

### Phenological changes

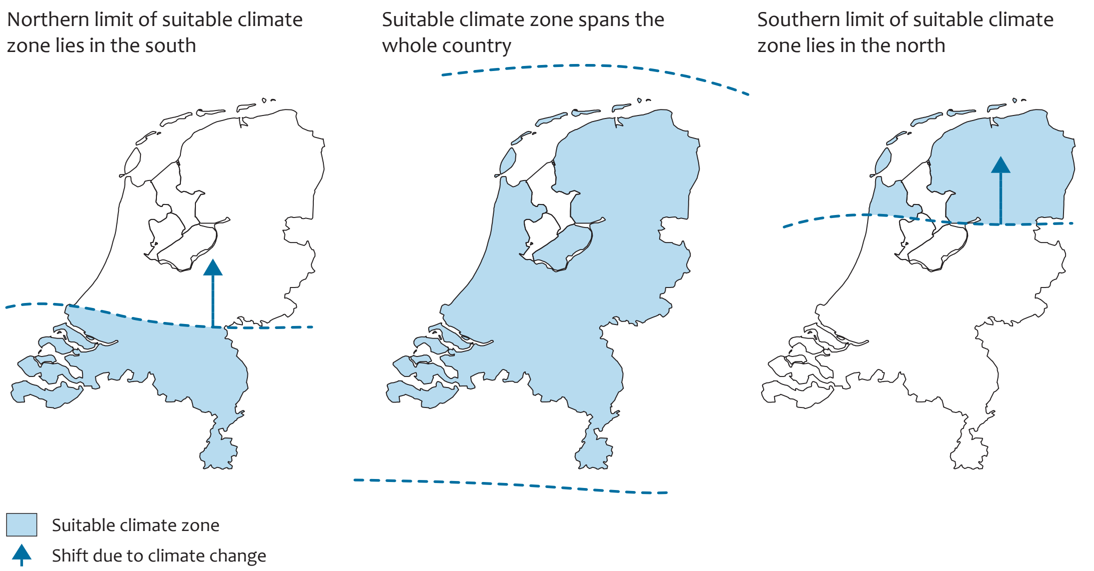
Temperature plays a key role in the timing of phenological processes in the annual cycle of plant species, such as the start of the vegetation season, the timing of fruit set and such like. For many species the growing season begins earlier and lasts longer: spring plants like lesser celandine and cow parsley now flower two to three weeks earlier than 150 years ago (van Vliet 2008) and there are also clear signs that insects and amphibians are becoming active earlier in the season than they used to be (EEA 2008). For migratory birds the picture is mixed: species that normally arrive late in the season seem to be bringing their arrival date forward less than species that arrive early (Leysen & Herremans 2004). These shifts in the annual cycles of organisms can lead to mismatches in the interaction between species, for example in the relations between predators and their prey species and between plants and their pollinators, which can cause structural changes in the functioning of ecosystems (EEA 2008; Schweiger et al. 2008).

### Changes in geographical distribution and population size

Biodiversity in the Netherlands is changing. Suitable climate zones for individual species may shift as global temperatures rise and precipitation patterns change (Figure 1). The milder winters, in particular, have caused species to shift their range northwards and onto higher ground (EEA 2008). Longer periods of drought in the summer are also less suitable for some species. Species are declining in numbers towards the southern limit of their ranges, while at the same time expanding their ranges northwards. Range expansion towards the North Pole (or the South Pole in the southern hemisphere) and onto higher ground has now been observed for many species groups, such as plants (van der Staaij & Ozinga 2008; Tamis et al. 2005), butterflies (Warren et al. 2001) and birds (Julliard et al. 2004).

The Dutch climate has already become less suitable for 7 per cent of the species currently present in the Netherlands, and by 2100 this proportion will have risen to at least 15 per cent. On the other hand, about 15 per cent of species already profit from climate change and this will rise to more than 20 per cent in 2100 (Figure 2). This means that in 2100 almost 40 per cent of the species currently present in the Netherlands will be 'on the move' in response to climatic conditions and that a shift in species composition is to be expected. The effects of climate change differ between species groups. According to the models, the climate in the Netherlands in 2100 will be suitable for a larger number of amphibian, butterfly and reptile species (van der Veen et al. 2010). For higher plants the

**Shift in suitable climate zones in the Netherlands due to climate change** **Figure 1**




*Suitable climate zones in the Netherlands are shifting. Species which reach the northern limit of their distribution in the southern part of the Netherlands will expand their range further into the Netherlands; species which reach the southern limit of their distribution in the northern part of the Netherlands will retreat northwards and their ranges in the Netherlands will contract.*

situation will remain almost the same, whereas the number of bird species for which the climate in the Netherlands will become unsuitable is relatively large.

The question is whether species can keep up with this shift in suitable climate zones. The ranges of species that are not able to adjust their distribution in pace with the shift in climatic conditions will contract; if climate change is not halted in time, some species will become extinct. Whether species are actually able to expand their ranges will also depend on the availability of suitable habitat at distances within their dispersal capabilities.

From an examination of range data on 99 species, Parmesan & Yohe (2003) came to the conclusion that range boundaries are shifting northwards by an average of 6.1 kilometres every ten years. An analysis of population trends indicates that the breeding bird community in France has shifted northwards by more than 90 kilometres over the last 20 years (Devictor et al. 2008). In the same period, however, the temperature has moved at least 270 kilometres, leaving the bird community at least 180 kilometres behind the new northern boundary of their suitable climate space. These results show that birds, despite their relatively good dispersal capabilities, are having difficulty in keeping up with the shift in their suitable climate space. This may be because suitable habitat is not available in the new suitable climate space. Habitat fragmentation exacerbates the impact of climate change on the geographical distribution of species (Warren et al. 2001; Ozinga et al. 2007; Vos et al. 2008). From an examination of range data on 99 species, Parmesan & Yohe (2003) came to the conclusion that range boundaries are shifting northwards by an average of 6.1 kilometres every ten years. An analysis of population trends indicates that the breeding bird community in France has shifted northwards by more than 90 kilometres over the last 20 years (Devictor et al. 2008). In the same period, however, the temperature has moved at least 270 kilometres, leaving the bird community at least 180 kilometres behind the new northern boundary of their suitable climate space. These results show that birds, despite their relatively good dispersal capabilities, are having difficulty in keeping up with the shift in their suitable climate space. This may be because suitable habitat is not available in the new suitable climate space. Habitat fragmentation exacerbates the impact of climate change on the geographical distribution of species (Warren et al. 2001; Ozinga et al. 2007; Vos et al. 2008).

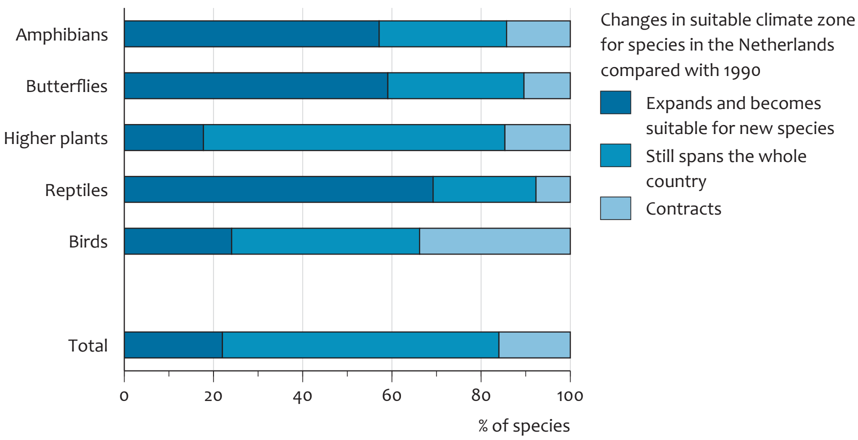
There is already increasing evidence of a decline in the population sizes of cold-loving species in the Netherlands; examples are the short-eared owl and the moor frog. However, warm-loving species, such as the swallowtail butterfly and the nightjar, are increasing in numbers (Figure 3). The same trends apply also to plants (Tamis et al. 2005). In addition, new species have colonised the Netherlands, such as the red mullet in the North Sea and 'pest species' like the oak processionary caterpillar, and others will do so in future.

Extreme weather events are also expected to have an impact on biodiversity. Relatively little is yet known about the size of the impacts of extreme weather events. Extreme weather events and more erratic weather patterns will cause population sizes to fluctuate, which increases the likelihood of small populations becoming extinct (Verboom et al. 2001; Vos et al. 2007; Piessens et al. 2008). Moreover, populations take longer to recover from the effects of extreme weather events when their habitat is fragmented (Foppen et al. 1999).

### Impacts on environmental and water conditions

The quality of species' habitats may also change. As temperature and atmospheric $CO_2$ concentration rise,

**Changes in suitable climate zones, 2100** **Figure 2**




Source: van der Veen et al. (2010); calculations by PBL (based on different climate scenarios and empirical data)

*According to the models, the climate in the Netherlands in 2100 will be suitable for a larger number of amphibian, butterfly and reptile species. For higher plants the situation will remain almost the same, whereas the number of bird species for which the climate in the Netherlands will become unsuitable is relatively large.*

decomposition rates increase and more nutrients become available. This increases plant production, particularly in nutrient-poor ecosystems like heaths. It is expected that in heathland ecosystems this will lead to further invasion of grasses (Heijmans & Berendse 2009).

Depending on the magnitude and direction of climate change, the changes in the water regime will have both positive and negative effects on site conditions. Climate change will mainly affect vegetation types that depend entirely on the atmosphere for their supply of water (Witte et al. 2009a,b). Groundwater-independent vegetation, such as dry heath, dry grasslands and dry forests on the higher sandy soils, will face greater water deficits during the growing season. This development may be positive for dry heath, because the vegetation will become more open and develop a more varied structure.

Wet ecosystems and rain-fed ecosystems may also undergo large changes. Increasing fluctuations in the moisture and temperature regime will make conditions less favourable for characteristic habitats such as raised bog, bog pools and wet heath. Under the warmest and driest scenario for the Netherlands (W+ scenario, KNMI 2006), the situation will even become critical for the development of living raised bog. If the infiltration area is large enough, the flow of seepage water to lower-lying areas, such as stream valleys and dune valleys, may increase, which will be beneficial for the communities that depend on seepage water for their survival. The quality of the water in ditches and lakes will probably decline because of higher water temperatures in summer, an increased risk of drying out and salinisation, and a greater influx of sulphate-rich water from the main rivers. Higher water temperatures will also lead to a higher incidence of problems such as blue-green algal blooms and botulism (van de Bund & van Donk 2004; Mooij et al. 2005; Wanink et al. 2008).

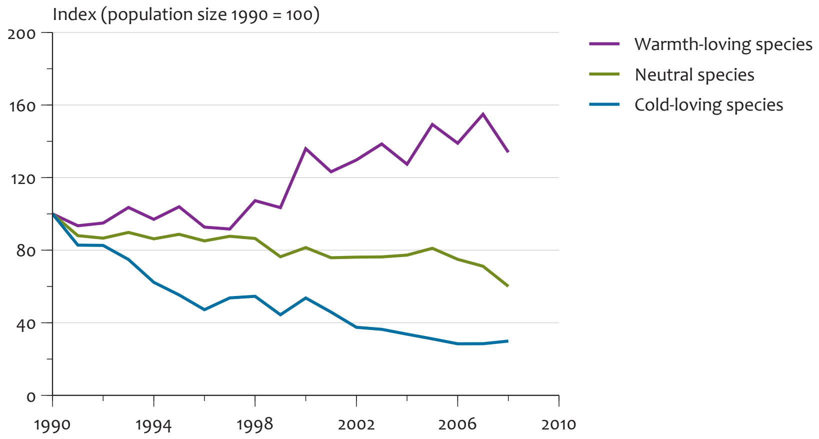
Rising sea levels will lead to a reduction in the area of intertidal flats and shallow waters in the sea inlets and estuaries. But in the Wadden Sea the expected rise in sea level of 35–85 centimetres during the course of this century (KNMI 2006) will probably be compensated by the natural accretion of sand and silt (van Dobben & Slim 2005). The intertidal flats in the Wadden Sea will therefore probably remain intact.

### Consequences for biodiversity and ecosystem functioning

If climate change persists, during this century ecosystems will experience continuous changes in species composition and site conditions, and will be exposed to disturbances of increasing frequency and intensity. As species do not all react in the same way to climate change, some of the existing relations between species within communities may be broken and ‘gaps’ may appear in ecosystem functioning (Schweiger et al. 2008). The degree to which ecosystem functioning will be altered as species compositions change or biodiversity declines depends on the roles played by the species that disappear from the ecosystem (Kramer & Geijzendorffer 2009). The effects will be greater when the species lost played a dominant role in shaping the structure or functioning of the ecosystem. The arrival of new species can also have a major effect on the functioning of ecosystems. Climate change therefore has consequences for biodiversity and by extension for the strategic goal of nature policy (conservation and development of biodiversity).

The changes in site conditions are complex and still partially unexplained. They appear to have both favourable and unfavourable effects for biodiversity, and depend partly on the specific location. The different effects are also likely to interact, making it difficult to predict the total impact on ecosystems. For example, the expected faster growth of vegetation as a result of higher temperatures and $CO_2$ concentrations will not occur during extreme drought conditions. Natural succession in forests can have a buffering

**Influence of climate change on species** **Figure 3**




Source: CBS, NEM

*The population sizes of cold-loving species whose suitable climate zones in the Netherlands are predicted by the models to contract have been declining steeply in recent years. The population sizes of warm-loving species for which the climate in the Netherlands is becoming more suitable, either because their suitable climate zone is expanding or because of the milder winters, are increasing. The population sizes of neutral species for which the climate in the Netherlands will continue to be suitable will remain more or less stable.*

effect on cold-loving species; in the slope forests of southern Limburg these species have even increased in numbers during the last 20 years (van der Staaij & Ozinga 2008).

## Climate-proofing ecosystems by increasing adaptive capacity

The uncertainties about the magnitude and rate of climate change, how society will respond, the impacts on ecosystems and the interactions with other adverse factors, such as eutrophication and habitat fragmentation, point to the need for a strategy based on adaptive management. This means that the tempo and scope of the strategy can be 'scaled up' to match the rate of climate change and can accommodate the different disturbances, such as extreme dry and wet conditions. It is also important that the strategy can be integrated into policy and can be adapted in the light of advances in scientific understanding. A strategy designed to strengthen the adaptive capacity of ecosystems satisfies these criteria (Figure 4). By 'adaptive capacity' we mean the capacity of an ecosystem to continue to function despite disturbances.

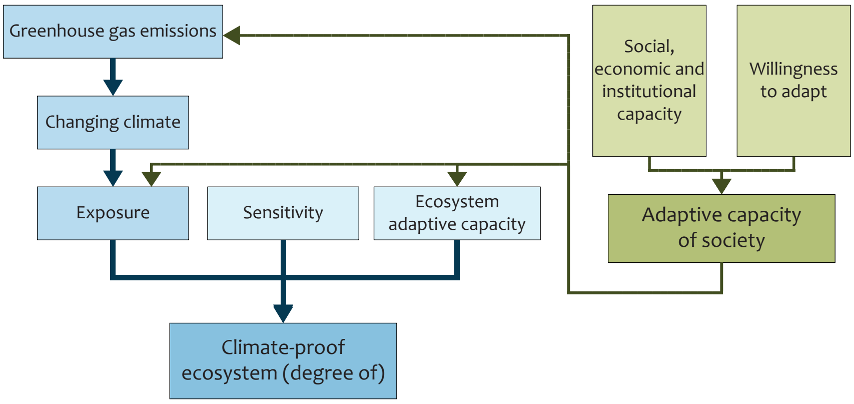
Whether measures will actually be taken or not depends firstly on the adaptive capacity of society itself: the capacity and willingness of society to respond to a changing environment by taking the necessary adaptive measure. Society is now aware of the risks associated with climate change and various actions have been set in motion, including national and international climate policies to limit greenhouse gas emissions (PBL 2009b) and the Delta programme to make the Netherlands climate-proof. The European Commission has published a white paper on vulnerability and adapting to climate change (COM 2009) and several Dutch conservation organisations have launched the 'Natural Climate Buffers' project (Andriesse et al. 2007), an initiative on integrating adaptation to climate change into conservation management and nature policy. In addition, the Interdepartmental Policy Research working group on Nature has investigated how biodiversity can be safeguarded in the most effective and efficient manner, taking account of climate change (IBO 2010).

### Increasing adaptive capacity by increasing biodiversity

Biodiversity is an important component of the adaptive capacity of ecosystems, because a high biodiversity spreads the risks (see also Kramer & Geijzendorffer 2009). An ecosystem consists of relations between species in various functional groups. A functional group consists of species that perform more or less the same function in an ecosystem, such as pollinators, litter decomposers, herbivores and insectivores. There is a risk that many representatives of functional groups, or even whole functional groups, will disappear locally as a result of extreme weather events, such as flooding or drought, leading to impaired ecosystem functioning. A high functional diversity spreads the risk, because the ecosystem then contains a higher diversity of species' functional characteristics. If a species with a certain characteristic cannot survive, its place may be taken by another species with a different characteristic.

In addition, the response diversity of the species – how species within a functional group respond differently to disturbance – is critical for the adaptive capacity of the ecosystem. The adaptive capacity increases as species within a functional group move across different spatial and temporal scales. For example, if an insect species that can become a pest under favourable conditions is only eaten by a single specialised predatory beetle with a lifespan of one year and a dispersal capability of a few dozen metres, the pest species can easily escape from the predator and develop into

**Factors affecting the degree to which ecosystems are climate-proof** **Figure 4**




*The degree to which ecosystems are climate-proof depends not only on their exposure and vulnerability to the effects of climate change and their adaptive capacity, but also on the adaptive capacity of society.*

a pest (Tscharntke et al. 2005). However, if the pest species is also eaten by insect species that live for several years and can disperse over hundreds of metres, the chance of a pest outbreak is considerably reduced. Moreover, if there are birds that eat the pest species and can collect food over distances of several kilometres, the chance of a pest outbreak is reduced even further.

### Increasing adaptive capacity by increasing internal heterogeneity and natural dynamics

The internal heterogeneity of environmental conditions in an area is a key factor in the recovery of the populations in that area following a disturbance (den Boer 1986; Piha et al. 2007). Internal heterogeneity or gradients arise in areas where there is room for transitional zones between wet and dry, open and closed vegetation, variations in elevation, etc. Recovery begins in those parts of the area that were not affected and from which the affected areas can be recolonised. Natural landscape-forming processes are equally important for adaptive capacity. If natural dynamics are given room to function, new communities can arise that are better adapted to the changed climate.

### Increasing adaptive capacity through large populations in ecological networks

Populations fluctuate more when subjected to extreme weather events, such as periods of sustained drought or extreme precipitation, which in turn increases their likelihood of extinction. Larger populations are better able to withstand fluctuations in numbers, which may be caused by a year of failed reproduction or higher death rates, than smaller populations (Verboom et al. 2001). Larger populations also recover from disturbances more quickly. Moreover, larger populations are able to colonise new areas of habitat more quickly, making them better able to keep pace with climate change. For species to survive when the likelihood of extreme weather events increases, therefore, they need to have larger populations and larger areas of habitat. However, many wildlife habitats in the Netherlands are so small that they are liable to be damaged in their entirety when affected by adverse conditions, such as long periods of drought, which can result in the disappearance of whole functional groups. Recovery is then only possible through recolonisation from habitat patches in the surrounding area. Ecological networks of ecosystems are therefore crucial for recovery capacity, because they enable such recolonisation from other parts of the network (Opdam & Wiens 2002). The network should contain all successional stages to ensure the restoration of species richness and the local ecosystem in the affected area.

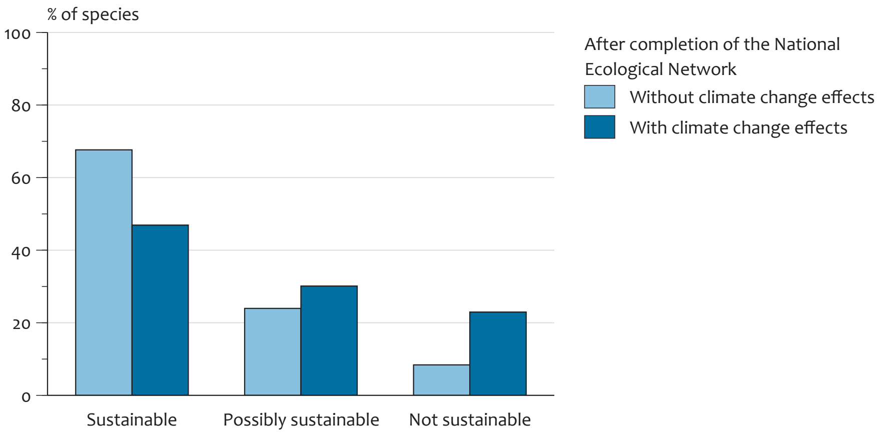
## Biodiversity is not climate-proof under current nature policy

A large adaptive capacity is an important condition for climate-proof ecosystems. The question is whether characteristics that determine adaptive capacity – biodiversity and the size, environmental quality, heterogeneity, dynamics and spatial connectivity of areas – are sufficiently robust to deliver the desired climate resilience.

Biodiversity in the Netherlands is under pressure (PBL 2009a) and is declining in many ecosystems. Even after the completion of the National Ecological Network (NEN) many areas will still be too small and fragmented. With optimal site conditions, the protected areas will be large enough for an estimated two-thirds of the faunal target species (Figure 5). However, when the effects of climate change are taken into account, this proportion falls to about half of the species. This is because as the climate changes ecosystems and habitats will be subject to an increasing number of extreme weather events, and larger areas and larger populations will be needed to absorb the impacts of these events. Moreover, larger areas provide more space for internal heterogeneity, which buffers the effects of extreme conditions. In theory, therefore, extreme weather events will exert a big influence on the effectiveness of current nature policies. The probable frequency and magnitude of extreme weather events in future is uncertain, and relatively little is known about their effects on the survival of species.

The size of protected areas and habitats is not the only spatial constraint. Plants and animals must be able to cross the distances between protected areas to reach new areas

**Faunal target species and climate change** **Figure 5**




*The size of protected areas after the completion of the NEN will be sufficient to support about two-thirds of the faunal target species. When the effects of climate change are taken into account, this proportion falls to about half of the species. In this analysis we explored the assumption that key areas for populations should be twice as big for the populations to withstand extreme weather events.*

of habitat. A random survey revealed that for 40 per cent of the animal species in the Netherlands the habitat patches in one or more of the locations they occupy lie too far apart to permit migration. Some species, such as the bittern, have a single large network within the Netherlands, whereas less mobile species with more modest area requirements, such as the great crested newt, have very many small networks that are not connected to each other. In addition, cross-border connections between areas must be improved to allow species to migrate over long distances from areas where the climate is currently suitable to areas where the same climatic conditions will exist in future, which may be hundreds of kilometres away.

The environmental pressures on ecosystems and biodiversity have been declining in recent decades (PBL 2009a). Despite this reduction, water table drawdown, eutrophication and acidification continue to exert adverse effects. Climate change may exacerbate these problems. Depending on its magnitude and direction, climate change will have both positive and negative effects on site conditions (see 'Influence of climate change on biodiversity').

Current policies are increasing the adaptive capacity of ecosystems and biodiversity in the Netherlands by improving connectivity between habitat patches and the water and environmental conditions in protected areas. However, under the implementation of current policies biodiversity will remain vulnerable to the consequences of climate change. The Netherlands Environmental Assessment Agency (PBL) has therefore developed an adaptation strategy to reduce the risk of biodiversity loss.

## Adaptation strategy for climate-proofing biodiversity

The adaptation strategy for biodiversity consists of three pillars which, in combination, increase the adaptive capacity of ecosystems and species and thereby contribute to the climate resilience of Dutch biodiversity (Figure 6).

Pillar 1. Connect protected areas (within the Netherlands and internationally) to permit species dispersal and migration. Enlarge protected areas to make them more resilient to extreme weather events.

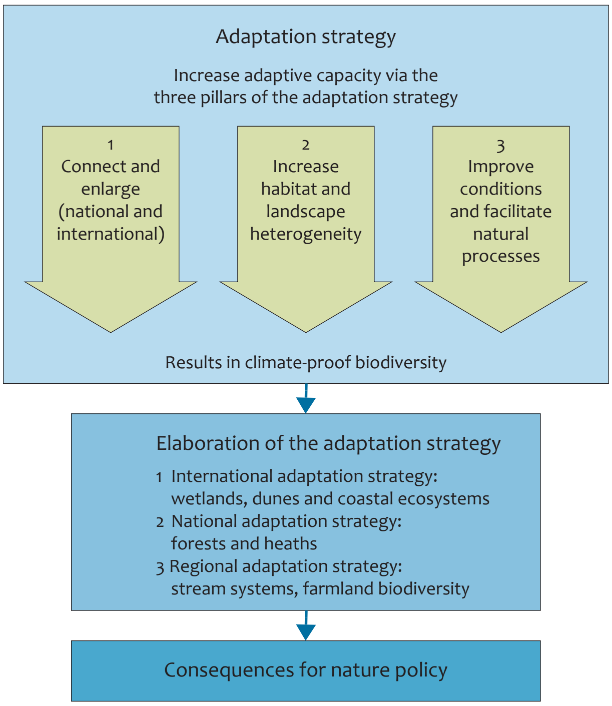
Pillar 2. Increase heterogeneity and gradients in protected areas and in the surrounding landscape to make them more resilient to extreme weather events.

Pillar 3. Improve site conditions in protected areas, making optimum use of natural landscape-forming processes.

The measures in the three pillars are intended to remove constraints that may arise as a result of climate change and to seize the opportunities for ecosystems and species that climate change may present. The measures can be included in an integrated adaptation strategy that links conservation objectives to other policy objectives, for example for flood safety, river and coastal management, and recreation (e.g. Secretariat of the Convention on Biological Diversity 2009). They can be taken within and outside protected areas to strengthen the links with the surrounding landscape.

The underlying principles of the strategy are the strategic conservation objectives of the Ministry of Agriculture, Nature and Food Quality: *the conservation and development of biodiversity in the Netherlands* (LNV 2007). The strategy is also based on the distribution of protected areas and other wildlife habitats. The current conservation objectives, however, are not by definition fixed in advance, because they may change in response to climate change or even as a consequence of the adaptation strategy itself. This means that the implementation of the adaptation strategy has consequences for nature policy.

**Adaptation strategy for climate-proofing biodiversity** **Figure 6**




*Structure of the proposed adaptation strategy for climate-proofing biodiversity.*

Because ecosystems and communities differ with respect to their international significance, their vulnerability to climate change and the opportunities that climate change present, separate strategies are described for the dunes, coastal ecosystems and wetlands, for heathlands and forests, and for small habitat areas in the landscape. Inherent in this choice is that the landscape-ecological relations between different ecosystem types are not revealed as clearly as they could be. It is important that these relations are properly taken into account in the further development and regional implementation of the proposed adaptation strategy.

If we look at Dutch nature in a European context, the Netherlands has a relatively big international responsibility for ecosystems typical of lowland deltas: dunes, salt flats and salt meadows, and wetlands. For these ecosystems there is a clear need for an international adaptation strategy. For heaths and forests we propose a national strategy. The remaining areas of heath are so fragmented that an international adaptation strategy is not a realistic option. For forests, the Veluwe is one of the largest protected areas in our part of Europe, which makes this area of great nature conservation value. From a European perspective, though, it makes more sense to single out the extensive forested areas in Central and Northern Europe as a concentration area for adaptation. The third category is a regional adaptation strategy for small habitat areas. Here the emphasis is on a varied habitat mosaic in multifunctional landscapes, often of high cultural and heritage value. A regional, multifunctional adaptation strategy in which biodiversity conservation is one of the functions of the landscape offers good prospects. Stream systems, for example, can play an important part in strengthening regional climate resilience because they collect and retain water.

## International adaptation strategy for the dunes, coastal ecosystems and wetlands

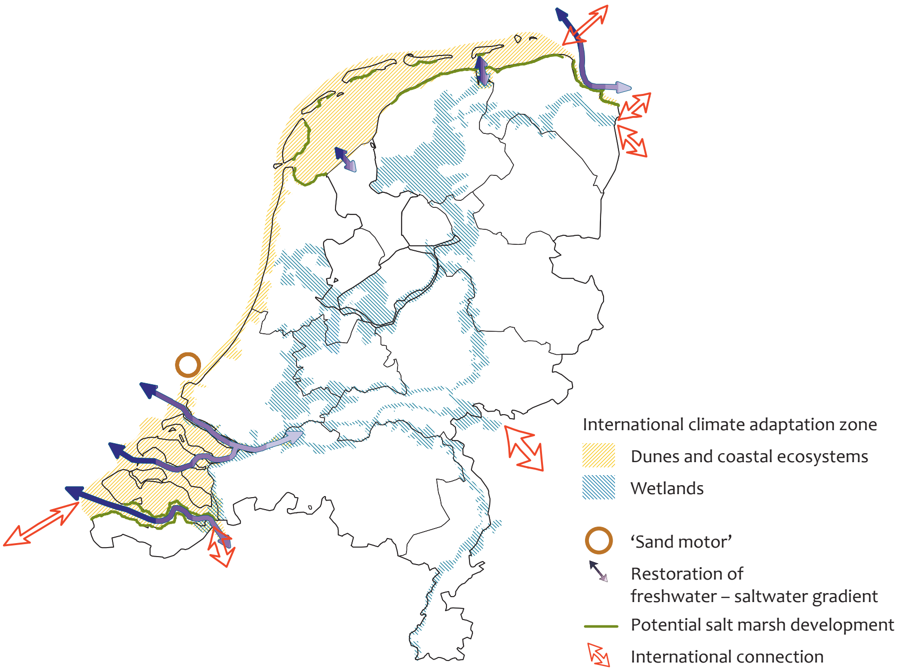
### International climate adaptation zones for dunes and coastal ecosystems and the restoration of natural processes

The Netherlands is an important part of an international dune and coastal ecosystem. Ecosystem connectivity can support the northward migration of species and a large part of the dune and coastal area is big enough to absorb the effects of climate change. Only the areas along the coast in Zeeland and parts of the coast in Noord-Holland and Zuid-Holland are fragmented and therefore require more extensive alterations to the landscape structure and layout.

Given this situation, the proposed strategy identifies the Netherlands as an important element within the climate adaptation strategy at EU level. This strategy comprises the development of an international climate adaptation zone for the dunes and the coastal ecosystems (Figure 7), a search area within which measures can be taken to increase the adaptive capacity of the dune and coastal ecosystem. The key measures within the climate adaptation zone are intended to restore the natural landscape-forming processes, such as sedimentation and erosion (Figure 6, pillar 3). These natural processes promote heterogeneity within the system (pillar 2). Within the climate adaptation zone it will also be necessary to increase the area of dunes and remove barriers to migratory species (pillar 1).

Coastal protection measures taken in the past have inhibited the natural dynamics and natural processes in the coastal zone and led to the loss of much of the heterogeneity of the system, especially freshwater – saltwater gradients and early

Adaptation strategy for the dunes, coastal ecosystems and wetlands **Figure 7**




*The development of an international adaptation zone for the dunes, coastal ecosystems and wetlands, and other measures, such as the construction of a 'sand motor', will increase the adaptive capacity of the ecosystem.*

successional stages of vegetation. Our current understanding is that natural processes work to improve coastal defences (Deltacommissie 2008), which underlines the importance of restoring these natural processes, for example through sand suppletion. This can be effected by constructing a sand island off the coast to act as a 'sand motor' (VenW 2008).

The tidal flats along the northern coast of the Netherlands (the Wadden) are part of a single system that continues along the coasts of Germany and Denmark. The dunes on the Belgian coast are highly fragmented, but do offer opportunities for further dune development. It is possible that constructing an island off the coast to act as a 'sand motor' could also be used to protect the Belgian coast against rising sea levels and at the same time enhance the spatial connectivity of the dune system.

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### International climate adaptation zone for wetlands (search area for measures)

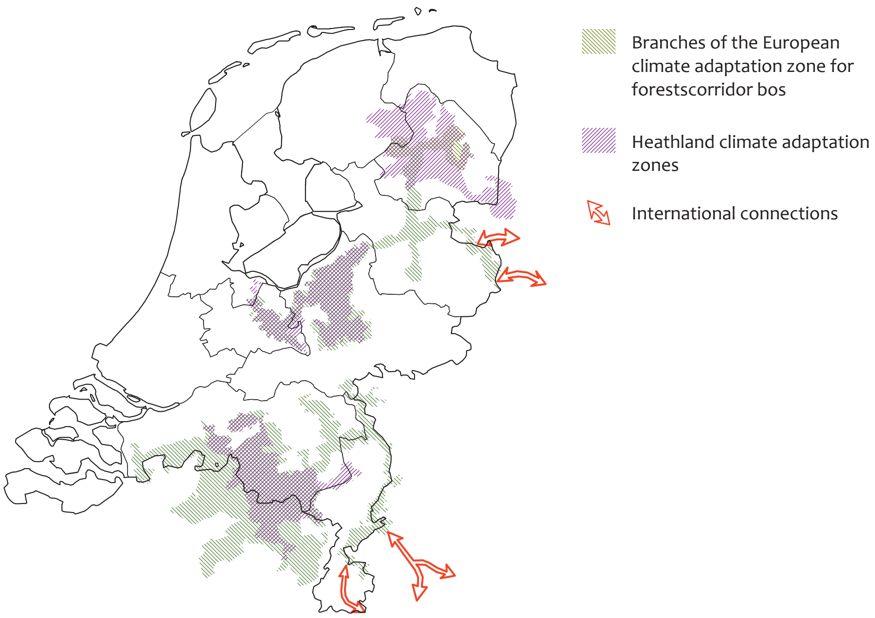
The adaptation strategy applies to the wetlands in the lower-lying western and northern areas of the Netherlands and along the rivers, such as mesotrophic grasslands, floodplain grasslands and floodplain shrublands.

Climate change is putting the future of wetlands in doubt. As a lowland delta, the Netherlands bears a relatively large responsibility for the conservation of wetland ecosystems, and for this reason an international strategy is proposed: the development of an international climate adaptation zone for wetlands which includes the Netherlands and contributes to the European adaptation strategy for wetlands (Figure 7). The wetland climate adaptation zone connects the core wetland areas in the Netherlands with each other and with wetlands elsewhere in Europe. The climate adaptation zone strategy concentrates adaptation measures largely within certain areas, which makes them more cost-effective: they are implemented in the best locations and clustering them reinforces their effects.

The climate adaptation zone functions as a search area within which measures can be taken to increase the adaptive capacity of wetland systems. The first pillar is the development of an international network of wetland ecosystems of sufficient size and coherence (Figure 6, pillar 1). Measures will also be taken to increase heterogeneity and gradients within protected areas and in the surrounding landscape (pillar 2). Finally, site conditions will be improved to enhance the capacity of the ecosystem to adapt, preferably by creating more space for the operation of landscape-forming processes, for example in the Rhine-Meuse floodplain (pillar 3). The measures will increase the adaptive capacity of the ecosystem locally, while at the same time offering species opportunities to migrate to suitable climate zones if the climate becomes unsuitable in their present locations.

Work on creating the climate adaptation zone for wetlands can be successfully combined with flood safety or other water

 **Figure 8**




*The national strategy for forests and heaths consists of two elements: concentrating the adaptation measures for heathlands within national and cross-border clusters of 'mosaic areas', and developing the Dutch forests into branches of a European climate adaptation zone for forests.*

management measures, especially where these facilitate wetland restoration (e.g. Hey & Philippi 1995; Acreman et al. 2007). The riverine areas in the lower-lying regions in the west and north of the country offer particularly good opportunities to create wetland habitat and facilitate dynamic natural processes. A good example of appropriate measures in the lowland areas is the designation of inundation areas in the deepest polders (Woestenburg 2009). Measures to improve flood protection in the Rhine-Meuse floodplain (Room for the River programme) also provide opportunities to take action for habitats and biodiversity (International Commission for the Protection of the Rhine Action Plan on Floods 2005).

Various options exist for connecting the national climate adaptation zone for wetlands into a European climate adaptation zone. A connection to the south via the Scheldt river basin is promising because the site conditions there are of good quality; moreover, there are already concrete plans for this area (e.g. Jungwirth et al. 2002). The river basins of the Rhine, Vecht, Reest and Ems link the Dutch climate adaptation zone for wetlands with sites in Germany.

## National adaptation strategy for heaths and forests

### Concentrate adaptation measures in four heathland clusters

Apart from a few clusters, the areas of heath in the Netherlands are highly fragmented. This is also true in the surrounding countries. Improving ecosystem connectivity at the international scale is therefore not a realistic option. Moreover, the expected changes in site conditions and species composition due to climate change are relatively large and appear to be unfavourable for dry heath.

We therefore propose a national strategy, its main objective being to strengthen the adaptive capacity of the four heathland clusters in the Netherlands that contain a high density of large heaths (see Figure 8). The continued existence of heathland species in the Netherlands depends heavily on these clusters, where measures can be taken to increase the adaptive capacity of the heathland ecosystem. The most important pillar of the adaptation strategy for heaths is the development of greater heterogeneity by managing wet heath, raised bog and dry heath as mosaics with gradual transitional zones (Figure 6, pillar 2). In addition, the spatial connectivity within the clusters can be improved by expanding the size of the areas and linking them together (pillar 1). Measures are also proposed for improving site conditions (pillar 3).

Measures like increasing the connectivity of heathland ecosystems may contain a cross-border component. The heathlands in Belgium, for example, could be expanded northwards towards the heathlands in the southern Netherlands. Linking into the heathlands in Central and South-West Europe is more difficult because these heaths are very isolated from the heathlands in the rest of Europe. Large-scale heathland restoration in France and Belgium or the active dispersal of seeds with herds of sheep or trimmings would be needed.

### Dutch forests as branches of the European climate adaptation zone for forests

The sustainability of Dutch forests is declining because the areas of forest may be too small to absorb the effects of extreme weather events and because the migration of species is hampered by spatial barriers. The changes in site conditions do not appear to be severe. The adaptation strategy for Dutch forests is geared primarily to increasing connectivity (Figure 6, pillar 1). There are large contiguous areas of forest to the east of the Netherlands, but these do not border on the Dutch forests. Including the Netherlands in a European climate adaptation zone for forests is not therefore an obvious option. Nevertheless, it is important for the climate resilience and adaptive capacity of the Dutch forests that they do have links to the international climate adaptation zone. As species for which the climate will become unsuitable will eventually disappear from the Netherlands, new species for which the climate will become suitable will be able to colonise the Dutch forests via the international network, thereby maintaining the level of functional biodiversity.

The proposed adaptation strategy, therefore, is to develop the Dutch forests as branches of a European climate adaptation zone for forests (see Figure 8). These branches are bordered by several areas, including the Veluwe, the Drents-Friese Wold and the Brabantse Wal, that make a significant contribution to the continued survival of forest species. Creating these connections with the larger European forests will require strenuous efforts. The most promising routes run through the province of Limburg towards Belgium and through the province of Overijssel towards Germany.

## Regional adaptation strategy for small habitat areas

Small habitat areas together make up a mosaic of different natural and semi-natural environments and communities in multifunctional landscapes. They often have considerable cultural and heritage value, as in the Achterhoek and Twente regions in the east of the Netherlands. A regional, multifunctional adaptation strategy in which biodiversity conservation is one of the functions of the landscape is therefore an obvious option. This strategy seeks to create synergy between nature conservation and other sectors like agriculture, water regulation, recreation and landscape management. Biodiversity adaptation measures do not then by definition have to involve the acquisition of more sites or the expansion of existing sites. For example, in Groningen biodiversity adaptation measures will be integrated into measures to adapt the water regulation regime, although adapting water storage to climate change will probably present a greater challenge. The water board can accommodate more than 10 per cent of the additional required water storage capacity due to climate change by creating a climate adaptation zone for wetlands and wet grasslands along the optimal routes for biodiversity (Roggema et al. 2009; van Rooij et al. 2009). Synergy benefits can also be obtained by combining water management and biodiversity adaptation measures in the western fen meadow areas. Developing wetland habitats in the areas most susceptible to land subsidence can help to combat land subsidence as well as building adaptive capacity into wetland ecosystems (Woestenburg 2009). Finally, the 'water/biodiversity combination' is self-evident for stream systems. Stream systems play a key role in regional multifunctional climate adaptation on the higher sandy soils in the south and east of the country (Verdonschot 2010). They consist of a stream and surrounding habitats and form a fine interlacing network of terrestrial and aquatic habitats, or a natural 'blue/green veining'. Stream systems have an important role to play in the regulation of regional water systems (Agricola et al. 2010) and the restoration of natural stream courses can help to prevent flooding during periods of peak discharge. A larger water retention capacity in the upper reaches of stream systems benefits regional water management by reducing water deficits during dry periods in summer, preventing drought damage to crops, and provides opportunities for habitat creation and restoration in the upper reaches of the stream system (Stuijfzand et al. 2008).

Measures around and between wildlife habitats in multifunctional zones can also be effective. Water management and nutrient management measures in areas that have an influence on wildlife habitats ('zones of influence', see PBL 2010) can make a considerable contribution to the conditions in the habitats themselves. These measures raise the effectiveness of nature policy and enhance the cultural and heritage values of the landscape in these 'zones of influence'.

## Consequences for nature policy

The proposed adaptation strategy does not represent a radical change in the objectives of the National Ecological Network (NEN), including the robust corridors, and Natura 2000: protection, enlargement, connectivity, improving site conditions and management where necessary. However, the elaboration, prioritisation and evaluation of these objectives in the proposed strategy are different than in current policy. For example, the focus of policy is shifted from species to the adaptive capacity of ecosystems. Climate change also necessitates the making of choices in the international context. We therefore propose focusing efforts on international connections and to divide the strategy for biodiversity into three scales. What do these proposals mean for national nature policy?

Climate change is already happening, but is mainly a long-term phenomenon. However, the government can take measures in the short term and adjust nature policy to anticipate and respond to the potential impacts of climate change. Here we briefly describe the steps the government can take within the NEN and under the Birds and Habitats Directives (BHD), and how it can combine nature conservation objectives with other objectives.

### Towards sustainable ecosystem functioning with high adaptive capacity

Ecosystems are dynamic; there is a continuous development of successional stages. Climate change adds an extra dynamic to this: rising temperatures, rising sea levels and more frequent and intense extreme weather events. As a consequence of these changes, the population sizes of species will fluctuate more often, new species will appear in the Netherlands and some existing species will disappear. It is therefore not realistic for nature policy to focus on the sustainable conservation of specific species at specific locations.

Climate change implies the need to amend nature policy. It must be geared more than at present to creating the right

## Natura 2000, NEN and robust corridors inside and outside climate adaptation zones

Figure 9


*Most Natura 2000 sites, NEN areas and robust corridors fall within the climate adaptation zones subject to the national/international strategy. The regional strategy covers small habitat areas that support biodiversity in multi-functional landscapes (not indicated in the figure).*

conditions for the sustainable functioning of ecosystems or the ecological network as a whole. Policy should also reduce the risks associated with climate change by increasing the adaptive capacity of ecosystems and biodiversity. This amendment of policy objectives and instruments applies not only to national policy. The goals of Natura 2000 should also no longer be directed at the preservation of specific species at specific locations. Furthermore, it is important that the communities or species for which the current protected areas will in time no longer be suitable are able to disperse to new areas of habitat in the new suitable areas elsewhere in Europe.

### Concentrate measures in climate adaptation zones

The strategy involves the implementation of adaptation measures within climate adaptation zones. This makes them more effective (and cost-effective) because they are implemented in the best locations and because the clustering of measures reinforces their effects. In addition, climate adaptation zones have the advantage of being easy to integrate into the spatial planning system.

The spatial priorities proposed in the strategy deviate from current spatial priorities. This means also that the areas of land still to be acquired or restructured for inclusion in the NEN should preferably be within the proposed climate adaptation zones. Some of the existing NEN areas, robust corridors (or parts thereof) and a few Natura 2000 sites lie outside the climate adaptation zones in the adaptation strategy (Figure 9). The government should not necessarily have to formulate biodiversity goals for these areas; other national objectives can be formulated that benefit biodiversity, such as the development of recreational landscapes. However, these areas are also subject to regional objectives and regional climate-proofing policies. If these areas connect with the climate adaptation zones, the regional biodiversity will also be more climate-proof.

### Connect and expand ecosystems and habitats in climate adaptation zones

Climate change is an additional argument for expanding and connecting protected areas, which is already one of the goals of national (NEN) and international (BHD) policies. Depending on the rate of climate change, models predict a shift in suitable climate z ones by several hundred kilometres by 2100 (EEA 2008). Some species will therefore have to migrate and for successful migration there must be connectivity between habitats over long distances. The coordination and steering of nature policy must therefore be expanded from the national level to the level of North-West Europe. In concrete terms, this means that if EU nature policies are to succeed, it is necessary to create EU climate adaptation zones for the different ecosystems and species, and within them a coherent Natura 2000 network.

In its White Paper on Adapting to Climate Change (COM 2009) the European Commission states that 'the impact of climate change must also be factored into the management of Natura 2000 to ensure the diversity of and connectivity between natural areas and to allow for species migration and survival when climate conditions change. In future it may be necessary to consider establishing a permeable landscape in order to enhance the interconnectivity of natural areas.' The accompanying action plan lists various research topics to support the required policy changes. The EU is also examining the current state of biodiversity and is taking stock of the effectiveness of its biodiversity policy. At the end of 2010 the European Commission will present a biodiversity action plan to achieve its biodiversity targets. In the post-2010 thinking of the Commission, Natura 2000 and the underlying BHD continue to play an essential role, but supplemented by the key concept of 'green infrastructure'. This is a complex, new concept in EU policy which pulls together various aspects of its biodiversity policy and which in all probability will become a part of the post-2010 biodiversity policy.

The strategy of increasing ecosystem and habitat connectivity is supported by an international review of adaptation measures. This shows that connecting and enlarging natural areas is the most recommended measure (Heller & Zavatela 2009). Recommendations either focused on measures that facilitate dispersal e.g. design corridors and remove barriers for dispersal or measures that increase both connectivity and carrying capacity of ecological networks by increase the number of reserves, increase reserve size and by habitat restoration (e.g. Opdam & Wascher 2004; Hannah & Hansen 2005; Scott & Lemieux 2007). Brooker et al. (2007) particularly recommend an adaptation strategy where Natura 2000 areas function as core areas within a permeable landscape through which species are able to move freely.

### Facilitating natural processes, heterogeneity and improving conditions

Natural landscape-forming processes, such as erosion, sedimentation and sand drift, are important for the development of the adaptive capacity of ecosystems. They create opportunities for species to coexist in new combinations, which in turn generate new communities that may be better adapted to the new environmental conditions created by climate change. In addition, the internal heterogeneity of an area is a crucial factor in the recovery of species and communities following disturbance. Recovery begins in those parts of the area that were not affected and from which the affected areas can be recolonised. Internal heterogeneity or gradients arise in areas where there is room for transitional zones between wet and dry, open and closed vegetation, variations in elevation, etc.

In the strategy we propose continuing environmental and water policies in the climate adaptation zones. Eutrophication, and in many cases also water table drawdown, will have to be controlled and minimised to ensure that ecosystems and biodiversity are able to adapt to the consequences of climate change. Water management policy should focus more than at present on sustaining a natural water regime within larger, coherent hydrological units. The eutrophication targets may be more difficult to achieve with climate change than without climate change, while other water policy targets may be easier to achieve. These environmental and water targets and the management of sites will focus less on the maintenance of specific species and more on the whole ecosystem.

According to the latest scientific insights, under the warmest and driest scenario in the Netherlands (W+ scenario, KNMI 2006) the development of living raised bog in the Netherlands will probably not be possible (Witte et al. 2009a; Witte et al. 2009b). However, it remains unclear how fast and in what direction climate change will proceed and how raised bogs will develop in future. In the adaptation strategy we advise continuing for the time being with measures designed to improve the environmental conditions for raised bog. Nevertheless, it is advisable to manage dry heath, wet heath and raised bog systems as contiguous units more than at present to allow gradual transitional zones to develop. It is expected that if raised bogs and wet heaths then undergo a gradual process of drying out, species of dry heaths will be more able to disperse from one system to another. Species lost because the climate is no longer suitable can then be compensated to a certain extent by the arrival of new species, improving the chances of maintaining the level of functional biodiversity. In the raised bog ecosystem there will then be a gradual shift towards new combinations of species and conditions.

### Combining biodiversity goals with other goals

Climate change not only has consequences for the spatial aspects of nature policy, it already has an influence on spatial planning policies and their objectives. The cost-benefit balance of biodiversity measures will depend on the possibilities for combining biodiversity goals with other goals: the investment costs can then be shared and the benefits to society will be greater, because the measures will not only benefit biodiversity conservation, but other land uses as well. The government therefore seeks to obtain synergy benefits between policies.

Plans for climate adaptation to secure public safety and freshwater supplies are being given shape in the Delta programme and the Room for the River programme (International Commission for the Protection of the Rhine Action Plan on Floods 2005). Whether synergy will be achieved between these goals and the goals of biodiversity adaptation will depend on the detailed implementation of these programmes. These programmes are certainly capable of delivering solutions with added value for the adaptive capacity of ecosystems, such as creating room for the development of freshwater – saltwater gradients and for natural processes such as sedimentation and erosion, and for the connection and expansion of wildlife habitats through habitat creation and restoration along the main rivers.

Synergy is also possible in the wider countryside. An important aspect of the strategy is expanding and connecting habitats. While this can be achieved by purchasing sites for the sole purpose of nature conservation, it can also be achieved through the management of multifunctional landscapes around protected areas. These latter areas combine different land uses, such as water management, agriculture, recreation and counteracting land subsidence. Measures to make wildlife habitats climate-proof do not therefore by definition have to involve the acquisition of land for habitat creation or restoration and the expansion of existing protected areas; measures around and between wildlife habitats in multifunctional zones can also be effective.

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# Colophon

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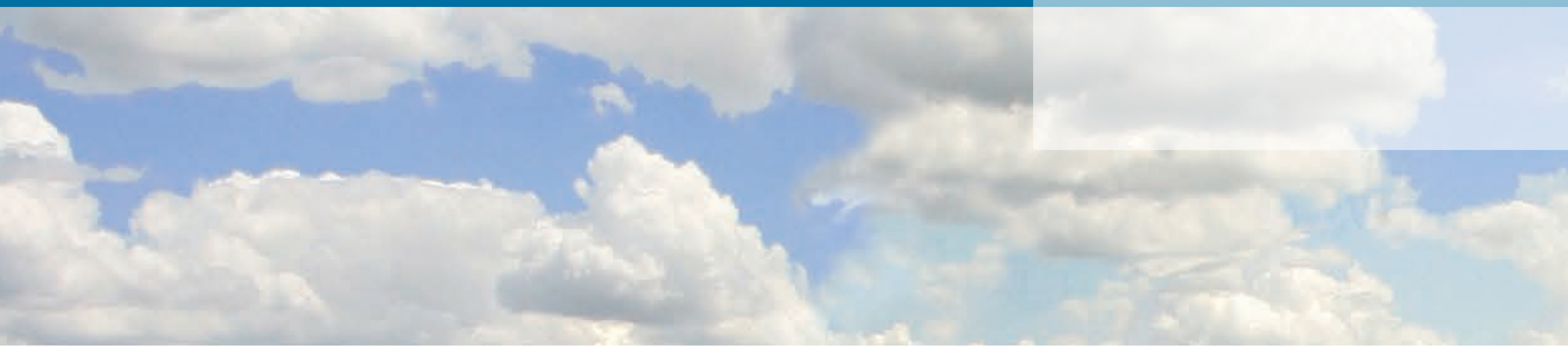
## Adaptation strategy for climate-proofing biodiversity

Over the last few decades the Netherlands has become warmer and wetter, with more extreme rainfall events. Climate scenarios indicate that these trends will continue, but the magnitude and rate of climate change remain uncertain. The impacts on ecosystems and biodiversity are already visible and are expected to increase. Some species will decline in number or possibly even disappear from the Netherlands; other species, though, will be able to become established. As the climate changes, biodiversity can be maintained if ecological systems have sufficient capacity to adapt to these changes.

The implementation of current policies will not remove the vulnerability of ecosystems and biodiversity to the consequences of climate change. The Netherlands Environmental Assessment Agency (PBL), in cooperation with Wageningen University and Research Centre, has therefore developed an adaptation strategy to increase the adaptive capacity of ecosystems, and by extension to make them climate-proof. Policies should be geared more towards ecosystem functioning and increasing the adaptive capacity of ecosystems and less than at present to the conservation of specific species in specific sites. Adaptive capacity can be strengthened by increasing the size of protected areas and the connections between them (both within the Netherlands and internationally), increasing habitat and landscape heterogeneity, and improving environmental and water conditions, thereby facilitating natural processes.



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