

Indicators for the 'Convention on Biodiversity 2010'

Influence of climate change on biodiversity

B.S.J. Nijhof
C.C. Vos
A.J. van Strien

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Wettelijke Onderzoekstaken Natuur & Milieu



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B.S.J. Nijhof

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Preface

This study was carried out as part of the MNP assessment on the 'Convention on Biological Diversity 2010' - CBD2010 - goals. The aim of this study was to develop indicators for the influence of climate change on biodiversity.

The 'Climate response database' was developed as part of BSIK (Besluit Subsidies Investeren Kennisinfrastructuur) 'Climate Changes Spatial Planning' Programme in the project 'Strategies for optimising the nature conservation potential of the Dutch National Ecological Network and the surrounding multifunctional farm landscape under predicted climate change scenarios'. It was also supported by the Policy Support Research Programme of the Ministry of Agriculture, Nature and Food Safety (LNV-BO).

Summary

The realization that human induced climate change has large impacts on biodiversity is relatively recent. The predicted climate change scenarios for the 21st century indicate that these impacts will further increase. Temperatures are rising, precipitation patterns are changing and weather extremes show an increasing frequency. The impacts of climate change on plant and animal species are wide-ranging, including changes in morphology, phenology and geographical distribution.

These responses will have important implications for the conservation of biodiversity, especially where the effects of climate change are aggravated by land cover changes.

As climate change is an ongoing process in the coming decades, even if human activities causing climate change would be drastically reduced, climate change will also impact biodiversity goals. For the achievement of biodiversity goals it is important to understand how species are influenced by climate change.

In this report we take the first steps for the development of a climate change indicator system, based on the different responses of species to climate change. We test the usefulness of several climate change indicators, by analysing the relation between indicators and population trends of target species.

We have restricted this study to terrestrial ecosystems.

Four indicator groups are defined:

- IA Cold preferent species: Climatological circumstances deteriorate at the southern edges of their distribution. Species run an increased risk to decrease or in due time to disappear from the Netherlands;
- IB Warmth preferent species: Climatological circumstances are improving on the northern edge of their distribution. Species have a chance to increase and expand their distribution. New species can in due time colonize the Netherlands;
- IC Neutral species: The shifting suitable climate conditions have no effect on these species. For neutral species the Netherlands are in the centre of their wider European distribution.
- II Species showing a forward shift in phenology. Temperature is important in timing of phenological processes in the lifecycle of species, e.g. start of activities in spring, start date of the reproductive season and flowering date.

One of the important attributes of an indicator is that species responses can be related to the achievement of policy goals, for instance whether the response has an impact on the sustainability of target species. Therefore we tested the usefulness of the indicators with a population trend analysis. Data were available through the newly developed 'Climate response database' and the NEM (Network Ecological Monitoring) database for a selection of the species groups. The preliminary development of indicators focuses on songbirds, butterflies and amphibians and additionally reptiles for the phenological analysis.

Indicators IA and IB react as hypothesized. Indicator IB, benefiting from the temperature increase, shows positive population trends, while for indicator IA the climatic conditions become unfavourable resulting in negative population trends. Both indicators have a causal link to climate change, are measurable and differentiate over space and time and therefore are suitable indicators. The reaction of Indicator IC, although significantly different from IA and IB, is unexpected. Instead of remaining stable it shows a decrease. There is no explanation for this result yet.

For warmth preferent species climate change might help to achieve policy goals while for cold preferent species the impact is expected to be negative. As for most species persistence is threatened by several factors, e.g. habitat fragmentation and/or eutrophication, it is relevant to know that part of the species performance which is caused by climate change.

The indicator should be further extended with other species groups and it should be tested whether all ecosystem types are sufficiently represented.

For indicator II no correlation was found between the amount of phenological change and population trends for birds and reptiles. However for butterflies a small positive trend was found. It could be possible that some species groups are more sensitive than others. Or perhaps a longer time series of data of more species are needed. This indicator is suitable regarding its causal relation with climate change, its measurability and its differentiation in time and space. However, as no clear correlation was found with species persistence, the usefulness of this indicator regarding policy goals is still unclear and should be further studied.

As for now no suitable indicator is available for another important aspect of climate change: the increase of weather extremes. The increasing occurrence of weather extremes will cause larger fluctuation in population numbers and may lead to (local) extinctions.

1 Introduction

The realization that human induced climate change has large impacts on biodiversity is relatively recent. The predicted climate change scenarios for the 21st century indicate that these impacts will further increase (IPPC, 2001). Temperatures are rising, precipitation patterns are changing and weather extremes show an increasing frequency (IPPC, 2001). Recently, studies showing species responses to climate change have been growing substantially (e.g. reviews by Hughes, 2000; Parmesan & Yohe, 2003; Root *et al.*, 2003). The impacts of climate change on plant and animal species are wide-ranging, including changes in morphology (Kanuscak *et al.*, 2004), phenology (Menzel *et al.*, 2006) and geographical distribution (Walther *et al.*, 2002). Range shifts of species have been noticed across a wide range of taxonomic groups and geographical locations during the 20th century (e.g. pole ward range expansions: plants Tamis *et al.*, 2001; butterflies Parmesan *et al.*, 1999; Warren *et al.*, 2001, birds Julliard *et al.*, 2004, expansion to higher elevations: mammals Green *et al.*, 2002, or decline at southern range margins Lesica & McCune, 2004). Although studies vary in the amount of evidence that human induced climate change is the dominant factor, several meta-analyses show convincing evidence that earlier phenology, pole ward range shifts and shifts to higher altitudes are in accordance with observed climate changes (e.g. Parmesan & Yohe, 2003; Root *et al.*, 2003).

These responses will have important implications for the conservation of biodiversity, especially where the effects of climate change are aggravated by land cover changes and habitat fragmentation (Foppen *et al.*, 1999; Warren *et al.*, 2001; Opdam & Wascher, 2004; Pearson & Dawson, 2005). A negative interaction between climate change and habitat fragmentation was shown for butterflies. Warren *et al.* (2001) found that only species with a large dispersal capacity or species whose suitable habitat is widespread across the countryside were able to expand their ranges northwards. While species with small dispersal capacity or species with specific habitat requirements that are rare (habitat specialists) were not able to expand their range. Hill *et al.* (1999) showed for the butterfly Speckled wood (*Pararge aegeria*) that habitat availability is an important determinant of the rate of expansion when species are responding to climate change.

Populations will eventually be lost in those parts of the distribution range where the climate becomes unsuitable. Otherwise, species may expand into regions where suitable climate conditions newly arise (the so-called 'new climate space').

Policy relevance

Only recently adaptation programmes to national and international policies are developed to adapt nature conservation policy to the impacts of climate change. Also the development of indicator systems to assess the impacts of climate change on biodiversity are still under construction (EEA, 2004).

Species respond differently to climate change. Some species will benefit, while others might become extinct. Differences in phenological responses and impacts on geographical distribution will also impact species interactions on the ecosystem level of food webs. These interactions are complex and to a large extend unpredictable.

This research

As climate change is an ongoing process in the coming decades, even if human activities causing climate change would be drastically reduced, it will have an impact on biodiversity goals. For the achievement of biodiversity goals it is important to understand how species are influenced by climate change. Obviously it is important to know how nature management can best be adapted, in order to improve the resilience of ecosystems and species to the impacts of climate change. This topic is however outside the scope of this report. In this report we take the first steps for the development of a climate change indicator system, based on the different responses of species to climate change. We test the usefulness of several climate change indicators, by analysing the relation between indicators and population trends of target species. We have restricted this study to terrestrial ecosystems.

2 Climate change

Since 1900 average world temperature rose with 0.8°C, of which 0.7°C occurred only in the past 20 years (Roos & Woudenberg, 2004). The top 10 warm years in the Netherlands is entirely composed of years from 1988 until present (KNMI, 2006; Table 2.1). The number of rain showers in the Netherlands increase yearly (Roos & Woudenberg, 2004). In summer a small increase in average precipitation can be seen, but at the same time evaporation increases. The net result is an increased risk on dehydration. Locally there is an increase in water inconvenience as a result of the increased risks on severe local rain showers. The most important processes of climate change in the Netherlands are summarized under 'Climate' in Figure 2.1 in paragraph 2.1.

Table 2.1. Changes in weather for the Netherlands (based on KNMI data)

Temperature	
Average	+1°C (since 1900)
Extreme, hot	3x increase in warm days (since 1900)
Extreme, cold	Decrease by half (since 1900)
Precipitation	
Average	Increase by ± 20% (since 1900)
Extreme drought	Probably more dry years, dry days
Evaporation	Proportional with increasing temperature
Water	
Sea level rising	+20 cm (since 1900). Locally amplified due to lowering of ground surface
River discharge	In winter on average high discharges In summer on average low discharges
Extreme weather	
Winter	More severe winters will become more rare and shorter
Storms	The Netherlands too small; monitoring period too short

2.1 Processes of climate change

Processes of climate change act on different levels within the natural system, e.g. species, community and ecosystem.

2.1.1 Species level

Four main effects of climate change on species can be identified (Figure 2.1 'Species').

The rising temperature as well as the increased concentration of CO₂ has a stimulating effect on several processes concerning growth and decomposition. These are the *physiological effects* of climate change.

Temperature is important for timing of *phenological processes* in the lifecycle of species, e.g. start of activities in spring, start date of the reproductive season and flowering date (Walther *et al.*, 2002). Phenological changes in the Netherlands are documented in the 'Natuurkalender'

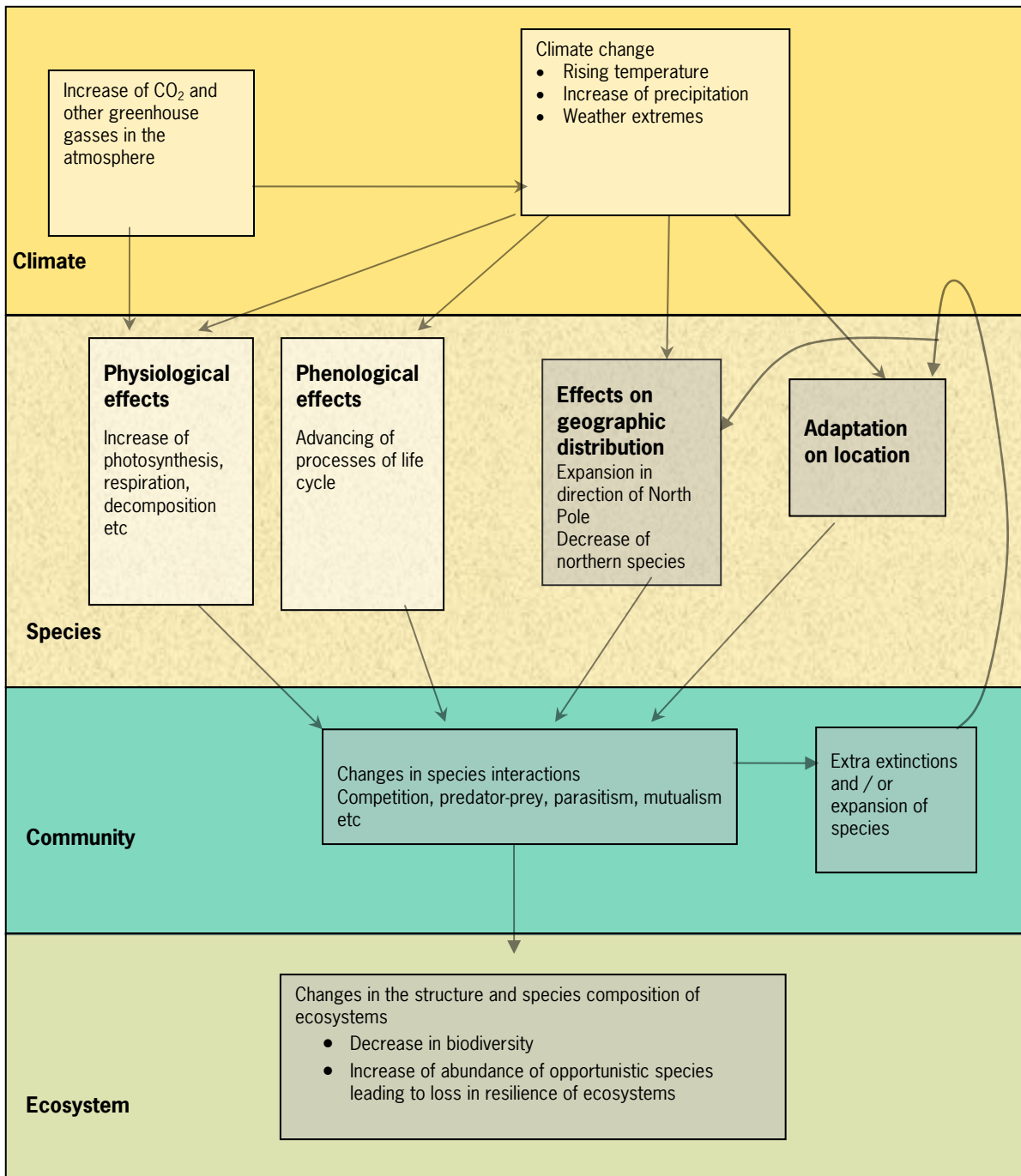


Figure 2.1. Schematic overview of the way processes of a changing climate directly and indirectly affect biodiversity (adapted after Hughes, 2000). On the top row the increase of CO₂ and other greenhouse gasses in the atmosphere leads to climate change. Furthermore the increasing concentration of CO₂ has a direct effect on several physiological processes. On the 2nd row are the four main effects of climate change on species: physiological effects, phenological effects, effects on the geographical distribution and adaptation on location. These main effects all lead to changes in species interaction. As a cause of species interactions further geographical shifts and extinctions of species will happen (3rd row). Finally the complex of direct and indirect effects on species will lead to changes in the structure and species composition of the ecosystem (4th row). The grey shading indicates those effects of the changing climate where an interaction with spatial coherence occurs.

(Nature Calendar; www.natuurkalender.nl). There are two constraints: 1) the time span over which these data have been collected is limited, from 2001 onwards; 2) the species selected are the ones the most sensitive to climate change. A more extensive list of species and stretching over a longer time span is collected by the NEM/CBS (Network Ecological Monitoring/ Statistics Netherlands).

Climate change also has effects on *the geographical distribution* of species. Changes in the climatological circumstances lead to shifts of potential suitable habitats. Climate conditions are an important abiotic factor in determining the potential suitable habitat for species. Species have a tolerance for maximum and minimum temperatures. If the 30°C boundary shifts northwards, species having this temperature as a maximum temperature must shift along. In the distribution of lichens the effect of shifting temperature is well seen (Table 2.2).

Table 2.2. Increase and decrease in number for Dutch lichen species (n=329). The species are divided in four classes: tropical, warm-moderate (sub-tropical), cold-moderate (the Dutch region) and northern (or high in the mountains). A shift towards more southern species has occurred (Source: Lichenologisch Onderzoeksbureau Nederland, Van Herk et al., (2002), adapted by CBS and MNP for Natuurcompendium).

Changes	Tropical	Warm-moderate	Cool-moderate	Northern	Total
Strong decrease	0	3	2	7	12
Less strong decrease	0	33	8	26	67
No change	2	56	3	24	113
Less strong increase	5	57	27	9	98
Strong increase	2	22	7	0	31
Very strong increase	3	4	1	0	8
Total	12	175	76	66	329

When the physical environment systematically changes, as with climate change, selection pressures will change and evolutionary responses are expected to take place (Thomas *et al.*, 2001). However, at present there is hardly any empirical evidence available. These are the *evolutionary or local genetic adaptations* to the changing local climatological circumstances.

2.1.2 Community level – interactions between species

The above mentioned effects on species result in alterations in interactions between species. Examples of alterations are changes in competition, in predator-prey relationships and in other mutual relationships (Figure 2.1 'Community').

Differences in *physiological relations* can lead to differences in growth rate. Faster growing species suppress slower growing species.

A difference in *phenological response* can lead to mismatching relations in the food chain. Time of giving birth does not coincide anymore with the moment when availability of food is highest. Research on Pedunculate oak (*Quercus robur*), Winter moth (*Operophtera brumata*) and Great tit (*Parus major*) illustrate how differences in phenological reactions to climate change lead to complex mismatches in the food chain (Visser & Rienks, 2003; Both *et al.*, 2006). The Winter moth hatches before the leaves of the Pedunculate oak have developed. The Great tit, a non-migratory bird, and to an even larger extent a migratory bird like the Pied flycatcher (*Ficedula Hypoleuca*) have moved their eggs laying period insufficiently forward to have their young's hatching at the shifted peak in food supply. For the Pied flycatcher this seems an important cause for the retreat in populations (Both *et al.*, 2006).

The *shift of habitat boundaries* has a direct link to species interactions through species disappearing and new species appearing. This can have consequences for competitive

relations, where a new species can suppress an existing one. Food chains can change, predator or prey species disappear, but also mutualistic relationships like those between plant and pollinator, can fall apart if the climate is no longer suitable for one of the two species.

2.1.3 Ecosystem level

Changes in interactions between species will alter the *structure and species composition of ecosystems* (Figure 2.1 'Ecosystem'). There is lack of literature on effects of climate change on the ecosystem level. This is because of the great complexity of responses, due to which it is not possible to translate the influences on individual species and their interactions to the ecosystem level (Thuiller, 2004).

Species within the same ecosystem can react differently on climate changes. Species can appear or disappear. This will indirectly influence the ecosystem. A direct influence can occur through abiotic conditions. An example is the change in the water balance. Too large fluctuations in precipitation and dehydration during summer are unfavourable for the Dutch wet ecosystems like brook and river systems, swamps, wet heath lands and peat areas. Sea level rising influences the coastal system by coastal erosion of the dunes, ecosystems behind dunes and dikes becoming brackish, and salt marshes will drown. This means a continuous process of changes in the coming century, which on the one hand can lead to a poorer species composition, but on the other hand could lead to an increase of opportunistic species.

2.2 Habitat fragmentation

Some effects of climate change are interacting with habitat fragmentation. These are indicated with a grey shading in Figure 2.1. The extent to which the habitat of a specific species is connected or not influences the final resulting effects the changing climate has on the sustainability of the species. It is expected that the effects of climate change are larger as the habitat of a species is more fragmented.

If climate change leads to a shift of potential habitat, species will try to follow this habitat shift by colonising new suitable habitat. However this is only possible if distances to the new habitat are small enough. Research indicated that species with a small dispersal capacity and species with a specific choice of habitat are not able to colonise new suitable habitat (Warren *et al.*, 2001). Also the recuperation capacity of populations after disturbance elapses slower in fragmented habitats (Foppen *et al.*, 1999). Due to the changing climate weather extremes will occur more often and these species will have a higher risk on regional extinction.

Example potential range expansion of warmth preferent species prevented by habitat fragmentation

Warren *et al.* (2001) investigated changes in habitat distribution of 46 butterflies. The distribution of the period 1970-1982 was compared with that of 1995-1999 (Fig. 2.2). Many species declined in numbers due to deterioration of the quality of their habitat because of various factors. However, the increasing temperature due to climate change is positive for many species and lead to a northward expansion. This expansion is limited to species having a good distribution capability or species of which the habitat is not fragmented (habitat generalists). Little mobile species and species with specific habitat demands hardly show expansion of their distribution. This is a clear illustration of the interaction between the response on climate change and spatial cohesion of the habitat. A species can only profit from the increasing temperature due to climate change if it can cover the distance to new suitable habitat.

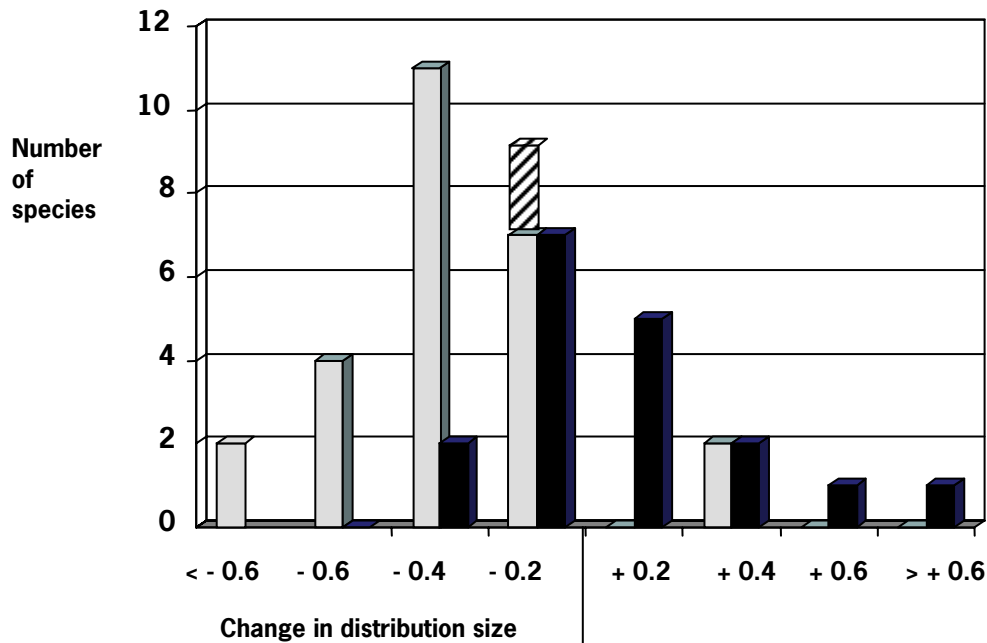


Figure 2.2. Proportional changes in distribution sizes of butterflies between 1970-82 and 1995-99. Habitat specialists with small dispersal capacity (grey), habitat specialists with large dispersal capacity (hatched) an habitat generalist with large dispersal capacity (black).

Example of interaction of habitat fragmentation with climate change: disturbance caused by weather extremes: Sedge warbler (*Acrocephalus schoenobaenus*)

From research on the Sedge warbler (Foppen *et al.*, 1999) it appears that in weak habitat networks, where habitat patches are small and isolated, the collapse of populations was much larger than in strong habitat networks. Moreover the recovery took much longer in weak networks compared to the networks where the spatial coherence was good (Fig. 2.3).

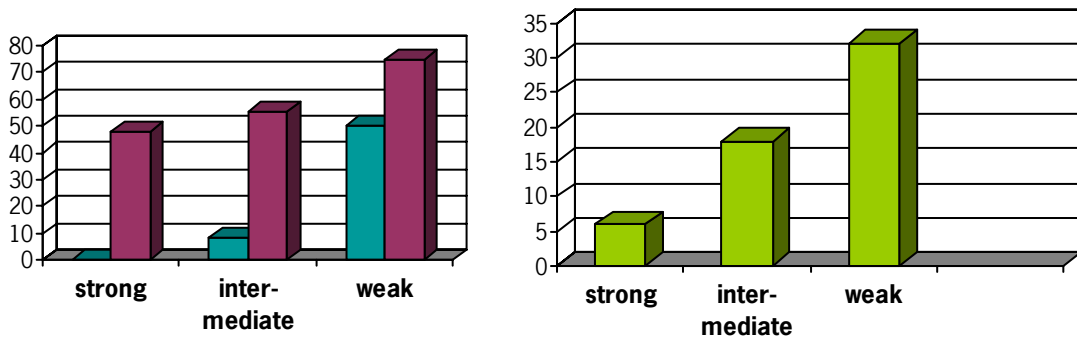


Figure 2.3

Blue are % extinct populations, purple are % populations with low densities in networks with a strong, average and weak spatial coherence (left).

Recovery time in years after a severe disturbance in networks with a strong, average and weak spatial coherence (right).

3 Indicator development

3.1 Conditions to be met by indicators

Indicators should preferably hold the following attributes (modified after EEA, 2003):

- 1) Does the indicator(s) incorporate all main responses of species to climate change?
- 2) Does the indicator(s) have a causal link to climate change?
- 3) Does the indicator differentiate in space and time?
- 4) Is the indicator relevant regarding policy goals, for instance population trends of target species?
- 5) Is the indicator measurable and preferably already available in historical data?
- 6) Does the indicator represent all relevant ecosystems and species groups?

3.2 Indicators

Looking at the list of preferred attributes for indicators we need species responses that have a causal link to climate change, are measurable and differentiate over time and space. Perhaps even more important is whether species responses are relevant regarding policy goals. For some species climate change helps to achieve policy goals, while for the others the impact is negative. As for most species persistence is threatened by several factors, e.g. habitat fragmentation and/or eutrophication, etc, it is relevant to know that part of the species performance is caused by climate change.

Therefore we come to the following responses:

- 1) Changes in the potential geographical distribution as a consequence of the increasing *temperature and precipitation*. This concerns both species profiting from climate change, species that expand their distribution as well as species having to deal with contracting ranges as their habitat becomes unsuitable because of climate change.
- 2) Increasing fluctuations in population numbers because of *more frequent occurring weather extremes*. These are species which are vulnerable to weather extremes because they have a small buffer against environmental variation. Furthermore it also concerns species with a small potential growth rate, which means a slower recovery capacity after disturbance.

In addition we have conducted an analysis of phenological reactions of species to climate change. Many species show an earlier start of the growing season. This response has a causal relation with climate change, is well measurable and differentiates over space and time. In addition it is well documented in historical data. However the relevance for policy goals is still unclear, because so far no clear relation between the phenological responses and the persistence of the species has been documented.

Figure 3.1 shows in a schematic way the relation between climate change and the responses of species.

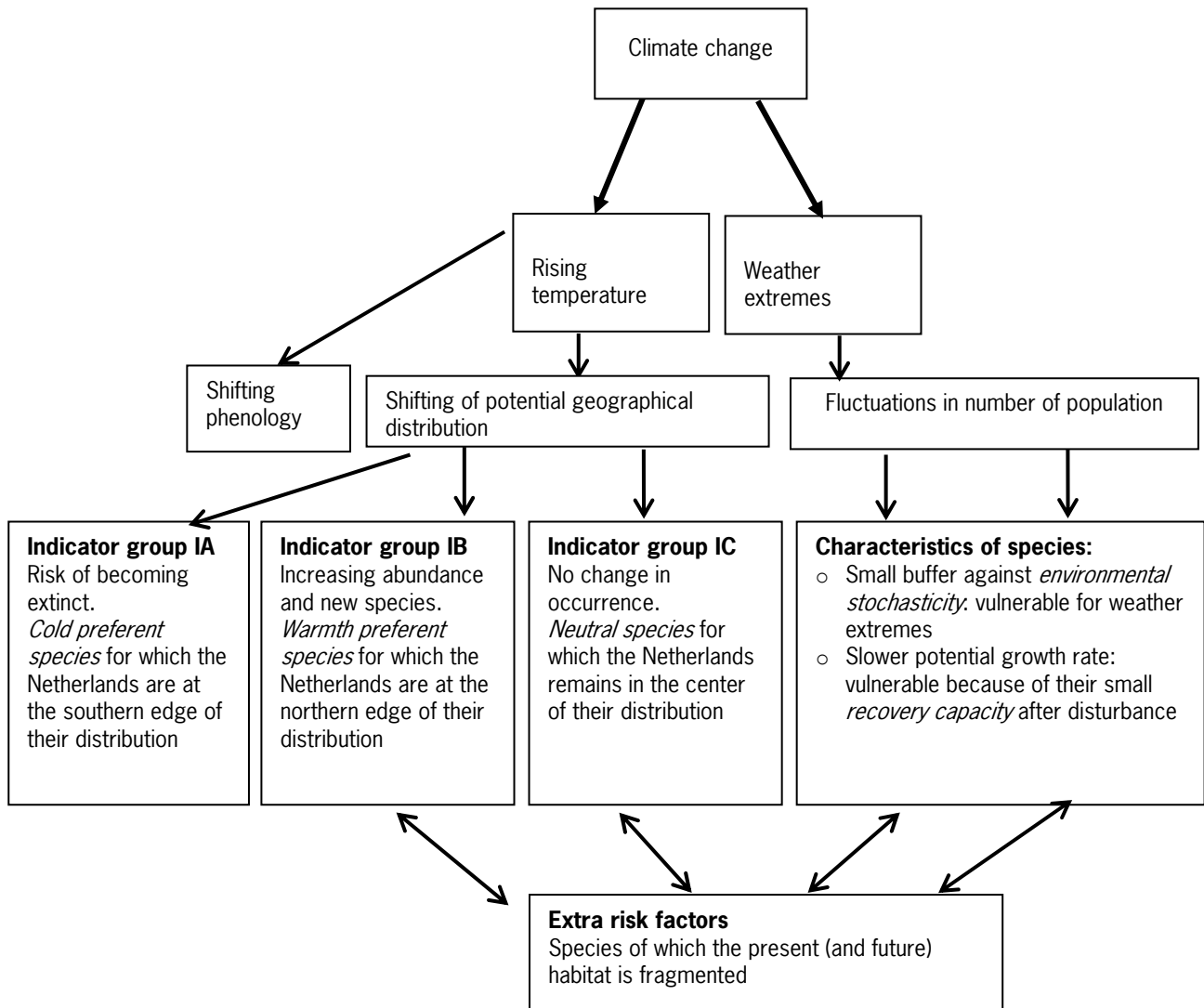


Figure 3.1. Schematic overview of how, as a result of the most important processes of climate change, species running a higher risk can be identified. Two main axes are distinguished. The response of species to the raising temperature has a direct relation with the present distribution of species and the position of the Netherlands in relation to that distribution. Temperature also influences shifts in phenological characteristics of species. A more frequent occurrence of weather extremes mainly influences species which are sensitive to fluctuations in numbers within the population, and species with a lesser recover capacity. All processes are subsequently influenced by the degree of fragmentation of the present and future suitable habitat.

Responses to temperature increase: Shifting of potential geographical distribution

A rising temperature as well as changes in precipitation due to climate change, result in changes in potential suitable habitat for many species. Some species will profit from the rising temperature and spread to formerly colder regions. Other species encounter a shrinking of their potential habitat (Parmesan *et al.*, 1999; Bakkenes *et al.*, 2002). The response of species to the rising temperature has a direct relation with the climatological tolerance of a species. A *cold preferent* species will have a relatively northern distribution, while a *warmth preferent* species has a more southern distribution. The location of the present distribution is therefore an important factor in the expected response to climate change (Hill *et al.*, 2002).

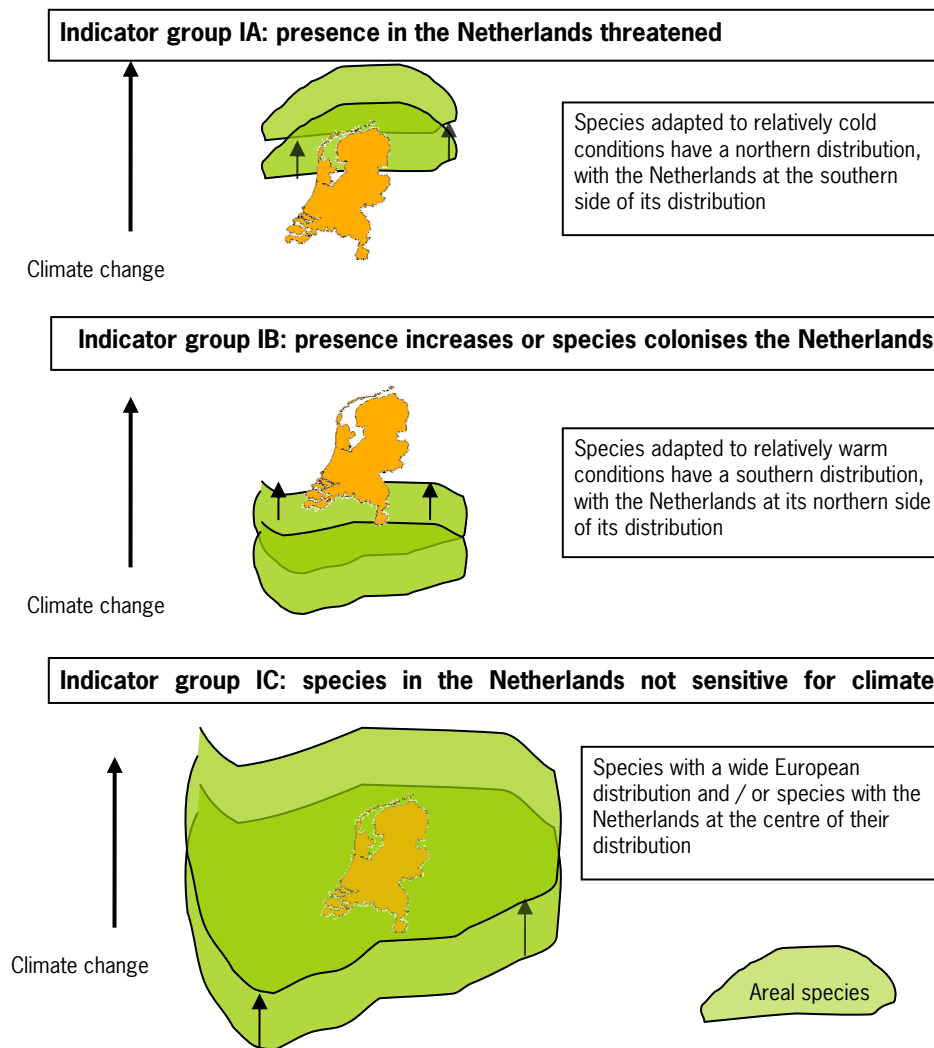


Figure 3.2. Indicator group IA: Cold preferent species. Species with a northern distribution in Europe run the risk to, in time, disappear from the Netherlands. Indicator group IB: Warmth preferent species. Species with a southern distribution in Europe can expand northwards in the Netherlands. Indicator group IC: Species with a wide European distribution, with the Netherlands in the centre of their distribution, no effects of climate change are expected.

Species will primarily react on climate changes on the edges of their distribution. Looking at the Netherlands the expected response of species depends on the position of the Netherlands in the geographical distribution of the species as a whole. If the Netherlands are on the northern or southern edge of the distribution, responses to climate change are expected (Figure 3.2). Where the Netherlands are located in the centre of a species distribution, no effects of temperature rise are expected.

Indicator group IA: Cold preferent species

Cold preferent species see their climatological circumstances deteriorate at the southern edges of their distribution. These species run an increased risk to decrease or in due time to disappear from the Netherlands.

Indicator group IB: Warmth preferent species

For warmth preferent species the climatological circumstances improve at the northern border of their distribution. These species have a chance to increase and expand their distribution. New species can in due time colonise the Netherlands.

Indicator group IC: Neutral species

For neutral species the Netherlands are in the centre of their wider European distribution. No effects of shifting suitable climate conditions are expected.

In literature there is a lot of information available on range shifts of species. From analysis of time series of distribution data a correlation has been found between expanding or contracting of species distribution and certain climate changes in the same period (e.g. Tamis *et al.*, 2001; Warren *et al.*, 2001; Parmesan *et al.*, 1999). Furthermore, so-called 'climate envelop models' predict how the climatic suitability of the habitat of species will shift as a consequence of climate change (e.g. Pearson *et al.*, 2002; Bakkenes *et al.*, 2002; Thuiller, 2004).

Reactions to weather extremes

The increasing occurrence of weather extremes will cause a larger fluctuation in numbers of populations. Extreme weather events like for example a cold spring, a long hot period during summer, or a very soft winter can lead to direct death of individuals or to failing of reproduction. As a consequence species which are vulnerable to fluctuations in numbers run a higher risk when weather extremes occur. Species with a smaller buffer against environmental variation, like cold blooded species, are relatively vulnerable to fluctuations in numbers. The same is true for species with a small potential growth rate, such as species with a long generation time and/or a small number of offspring. These species are sensitive to increased population fluctuation, due to their slow recovery after an unfavourable period (Foppen *et al.* 1999).

At present, there is insufficient information available on which species are most sensitive to weather extremes. Therefore this is not a useful indicator, as for now.

Responses to temperature increase: phenology

Advancing of life cycle processes is well documented and has a clear link to rising temperatures. Temperature is important in timing of phenological processes in the lifecycle of species, such as the start of activities in spring, starting date of the reproductive season and the flowering date (Walther *et al.*, 2002; see review Both *et al.*, 2002). However it is unclear what is the impact of this response on the viability of species.

Phenology becomes important for biodiversity when this results in a mismatch of processes in the food chain. In paragraph 2.1 the research on Pedunculate oak (*Quercus robur*), Winter moth (*Operophtera brumata*) and Great tit (*Parus major*) illustrates how differences in phenological reactions to climate change lead to complex mismatches in the food chain (Visser & Rienks, 2003; Both *et al.*, 2006).

One might expect that lengthening of the growing season has a positive effect on population trends. On the other hand mismatches in the food chain, caused by differences in phenological responses, might counterbalance positive effects.

Indicator group II: Species showing a forward shift in phenology

Species showing changes in phenological processes in their lifecycle due to increasing temperature

3.3 Indicator analysis

This study was done for the Netherlands. The focus with regard to species was therefore on those species already present in or in close range to the Netherlands. We selected a balanced representation of species sensitive and not sensitive to climate change (Figure 3.3). Three preliminary indicator groups were defined: cold, warmth preferent and neutral species (IA+IB+IC) and species showing a forward shift in phenology (II).

One of the important attributes of an indicator is that species responses can directly be related to the achievement of policy goals, for instance do they impact the sustainability of target species? Therefore we tested the usefulness of the indicators with a population trend analysis. In this respect cold preferent species are expected to show a declining population trend, while warmth preferent species are expected to profit from climate change and show an increasing population trend. For the phenology indicator we hypothesize that the larger the advancement of the response, the more species will benefit and thus show a positive population trend.

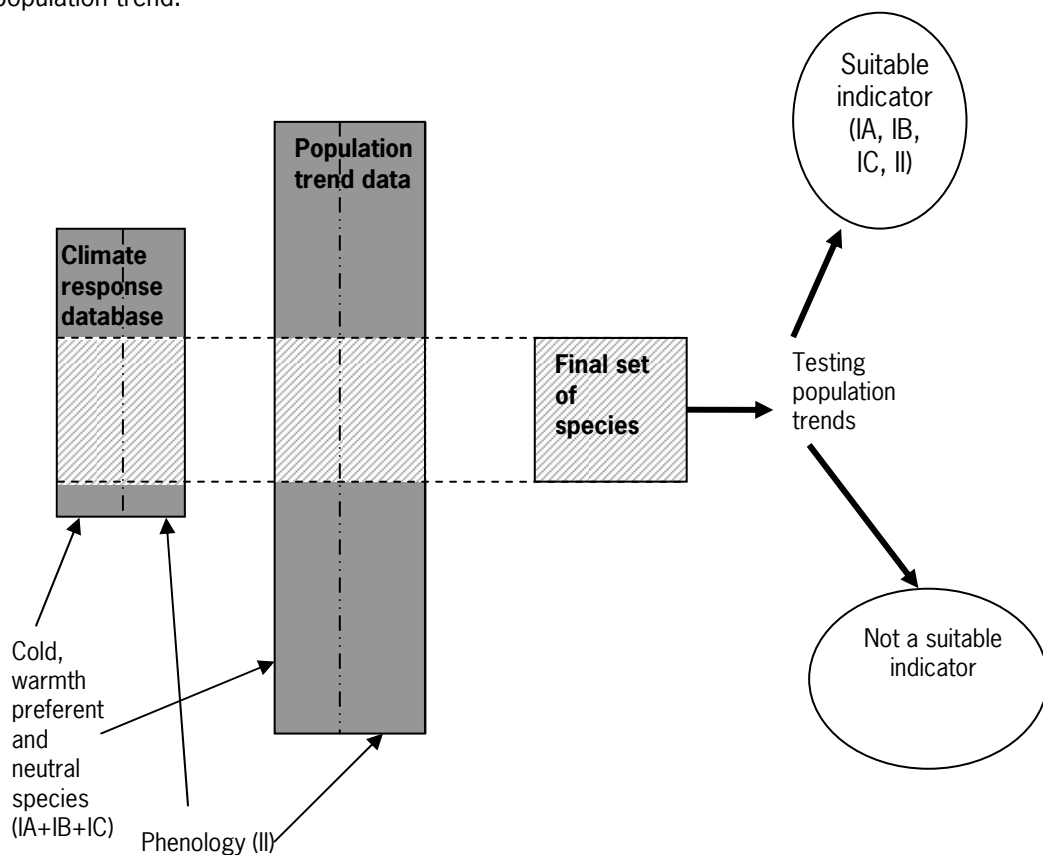


Figure 3.3. Indicator analysis

Data sources for defining and testing indicator groups

For the continuing development of indicators a so called 'Climate Response Database' was set up. Data on a species characteristics in relation to climate change driven processes are included. Also, information on the (preliminary) indicator group a species belongs to is included (Figure 3.3). Information was derived from several sources: publications and expert judgement. The publications were either descriptive, empirical or simulation models were used (climate envelope models).

Information on phenology and population trends was provided by the NEM (Network Ecological Monitoring). This is a cooperation between governmental and non-governmental - PGO's (Private Governmental Organisations). This monitoring started in 1995. NEM has also documented phenological responses for several species groups, among which are reptiles, amphibians, birds, butterflies, lichens and flora.

The preliminary development of indicators focuses on songbirds, butterflies and amphibians and additionally reptiles for the phenological analysis. The data for butterflies are taken from the NEM-measuring sequence of butterflies. With regard to butterfly species the day of the year (1st of January = day 1 etcetera) at which the first 10% of butterflies to be seen in the whole year is observed was determined for each year from 1992 to 2004. The data for the songbirds originates from the time series of nest records measured by the NEM. Breeding data for numerous bird species throughout the Netherlands are registered. An estimation of the day on which the first eggs are laid can be made (PGO's & CBS) and averaged for all nests.

Final set of species used

The combination of (1) the species from the Climate Response Database with (2) indicator groups information per species and (3) data on population trends resulted in a total of 60 species. To come to a balanced distribution of species for every indicator group, a selection of species was made such that within a species group the number of species per indicator group was similar. The selection has an equal distribution of nature types. The origin of the data was preferably from model simulations, which is seen as the most secure source, followed by empirical studies, experimental studies, describing studies and expert judgement. This resulted in total in 20 species per indicator group IA, IB and IC: birds (n=16), butterflies (n=3) and amphibians (n=1).

In the analysis for indicator group II the numbers of species are: butterflies (n=42), songbirds (n=42) and reptiles (n=7). The final selection of species is purely based on availability of data. Data related to the effects of climate change on species might cause a focus on species vulnerable to climate change, but the data from the NEM are solely selected through availability and are not based on sensitivity of species; therefore they reflect a more neutral representation of reality.

Assigning species to the cold, warmth preferent and neutral indicator groups

Species were assigned to indicator group IA, IB or IC using the following sources: climate envelope models, empirical and descriptive studies and expert judgment. Whenever possible expert judgment was replaced with the other sources.

Climate envelope models project the potential future distribution area of a species based on a set of climate and soil parameters in the present distribution area and a prediction of the future climate.

In an empirical analysis a correlation is sought for between changes in distribution of a species in a determined time period and weather conditions in the same period. Examples are the investigations from Warren et al. (2001) for early butterflies and Tamis et al. (2001) for plant species.

Species were assigned to indicator group II whenever phenological data were available.

Testing indicators

By using population trends the suitability of the indicator groups for indicating climate change was tested. Population trends were assessed by Poisson regression, using the program TRIM (Pannekoek & Van Strien, 2001). For the analysis of the phenological data the population trends were plotted against the date of appearance and a trend was calculated.

4 Result of indicator analysis

4.1 Indicator groups

4.1.1 Indicator group I – Cold, warmth preferent and neutral species

Table 4.2 (p. 25) indicates the references based on which species were assigned to a specific indicator group.

IA – Cold preferent species

Indicator group IA consists of 20 species from the species groups butterflies (n=3), birds (n=16) and amphibians (n=1).

IB - Warmth preferent species

Indicator group IB consists of 20 species from the species groups butterflies (n=3), birds (n=16) and amphibians (n=1).

IC - Neutral species

Indicator group IC consists of 20 species from the species groups butterflies (n=3), birds (n=16) and amphibians (n=1).

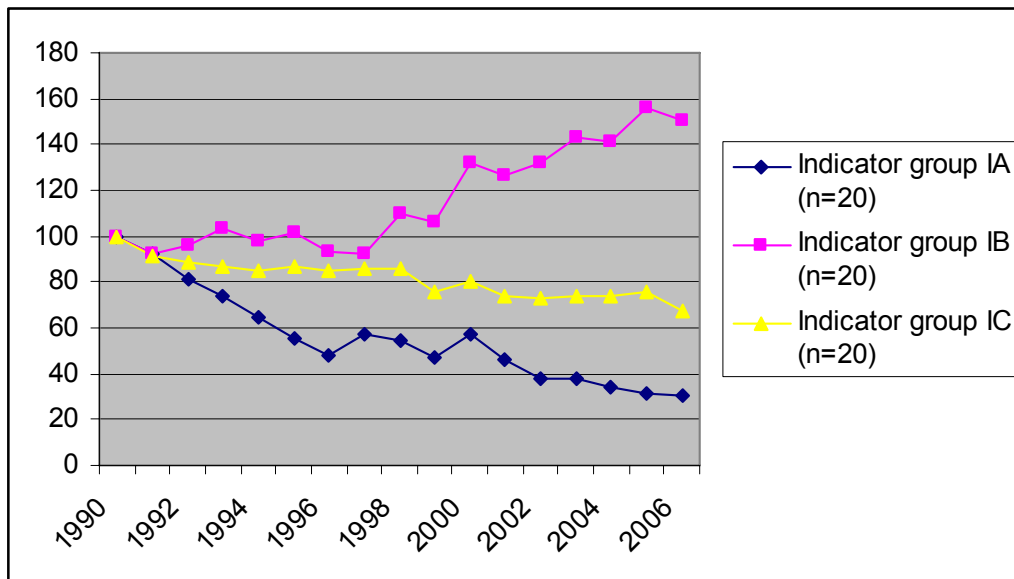


Figure 4.1. The average population trend per year for indicator groups IA (cold preferent species), IB (warmth preferent species) and IC (neutral species). The differences between the three indicator groups IA, IB and IC are significant. Source: NEM (PGO's & CBS)

Indicator group IA: species adapted to relatively cold conditions: disappearing from the Netherlands;

Indicator group IB: species adapted to relatively warm conditions: increasing or appearing in the Netherlands;

Indicator group IC: species reacting neutral to the climatic conditions in the Netherlands

Indicator groups IA and IC show a significant average population decrease, while indicator group IB shows a significant average population increase (Figure 4.1). All indicator groups differ significantly from one another ($p < 0.001$).

These results are partly in accordance with the expected response, where the warmth preferent species of indicator group IB benefit from the temperature increase and for the cold preferent species of indicator group IA the climatic conditions become unfavourable. The reaction of the neutral species of indicator group IC is unexpected. It was expected that the neutral species would remain stable, but they show a decrease. The decrease of the cold preferent species however is significantly stronger.

We have no explanation for this result. It could be possible that the neutral group is not really neutral: the number of 'expert judgements' for indicator group IC is relatively large (e.g. IA=2; IB=1; IC=8; Table 4.2). Next to that a question could be what is the influence of other pressure factors, like fragmentation, on the different indicator groups? Are these the largest on the neutral species?

A temporary positive population trend is seen for indicator group IA in the years 1997, 1998 and 2000. This trend exists, but is much less clear for indicator groups IB and IC. However looking at the average temperature, number of sun hours and precipitation in the preceding years, we see no clear explanation (Table 4.1).

Table 4.1 Weather conditions (total precipitation, average temperature and total number of sun hours per year) from 1995 until 2007 (KNMI-website)

	Precipitation (mm)	Temperature (°C)	Sun hours
1995	730	10.4	1814
1996	576	8.6	1607
1997	744	10.3	1693
1998	1240	10.4	1429
1999	902	10.9	1720
2000	932	10.9	1515
2001	1039	10.4	1623
2002	924	10.8	1688
2003	613	10.3	2022
2004	859	10.3	1623
2005	873	10.7	1789
2006	807	11.2	1725
2007	951	11.2	1690

Table 4.2 References according to which the species were assigned to the indicator groups cold, warmth preferent and neutral (IA, IB and IC).

Group	Species group	Species name (NL)	Scientific name	Species name (UK)	References
IA	Amphibians	Heikikker	<i>Rana arvalis</i>	Moor Frog	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IA	Butterflies	Veenbesblauwtje	<i>Plebeius optilete</i>	Cranberry Blue	Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829
IA	Butterflies	Veenbesparelmoervlinder	<i>Boloria aquilonaris</i>	Cranberry Fritillary	<ul style="list-style-type: none"> • Opdam, P. & J. Klijn, 2003. Klimaatverandering in de 21ste eeuw: consequenties voor het natuurbeleid. Rapport 813. Alterra, Wageningen • Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK • Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829
IA	Butterflies	Veenhooibeestje	<i>Coenonympha tullia</i>	Large heath	<ul style="list-style-type: none"> • Opdam, P. & J. Klijn, 2003. Klimaatverandering in de 21ste eeuw: consequenties voor het natuurbeleid. Rapport 813. Alterra, Wageningen • Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK • Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829
IA	Birds	Bonte Vliegenvanger	<i>Ficedula hypoleuca</i>	Pied Flycatcher	<ul style="list-style-type: none"> • Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829 • Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK

Group	Species group	Species name (NL)	Scientific name	Species name (UK)	References
IA	Birds	Bosrietzanger	<i>Acrocephalus palustris</i>	Marsh Warbler	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IA	Birds	Fitis	<i>Phylloscopus trochilus</i>	Willow Warbler	Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829
IA	Birds	Graspieper	<i>Anthus pratensis</i>	Meadow Pipit	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IA	Birds	Grutto	<i>Limosa limosa</i>	Black-tailed Godwit	expert judgment Alterra
IA	Birds	Spotvogel	<i>Hippolais icterina</i>	Icterine Warbler	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IA	Birds	Kemphaan	<i>Philomachus pugnax</i>	Ruff	Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829
IA	Birds	Klapekster	<i>Lanius excubitor</i>	Great Grey Shrike	Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829
IA	Birds	Kramsvogel	<i>Turdus pilaris</i>	Fieldfare	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IA	Birds	Kwartelkoning	<i>Crex crex</i>	Corncrake	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IA	Birds	Paapje	<i>Saxicola rubetra</i>	Whinchat	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK

Group	Species group	Species name (NL)	Scientific name	Species name (UK)	References
IA	Birds	Rietgors	<i>Emberiza schoeniclus</i>	Reed Bunting	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IA	Birds	Tapuit	<i>Oenanthe oenanthe</i>	Wheatear	Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829 Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IA	Birds	Velduil	<i>Asio flammeus</i>	Short-eared Owl	Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829 Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IA	Birds	Zilvermeeuw	<i>Larus argentatus</i>	Herring Gull	expert judgment SOVON
IA	Birds	Zwarte Specht	<i>Dryocopus martius</i>	Black Woodpecker	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IB	Amphibians	Boomkikker	<i>Hyla arborea</i>	European Tree Frog	Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829
IB	Butterflies	Bont zandoogje	<i>Pararge aegeria</i>	Speckled Wood	Opdam, P. & J. Klijn, 2003. Klimaatverandering in de 21ste eeuw: consequenties voor het natuurbeleid. Rapport 813. Alterra, Wageningen;
IB	Butterflies	Gehakkelde aurelia	<i>Polygonia c-album</i>	Comma	Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829

Group	Species group	Species name (NL)	Scientific name	Species name (UK)	References
IB	Butterflies	Koninginnepage	<i>Papilio machaon</i>	Swallowtail	<ul style="list-style-type: none"> Opdam, P. & J. Klijn, 2003. Klimaatverandering in de 21ste eeuw: consequenties voor het natuurbeleid. Rapport 813. Alterra, Wageningen; Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829
IB	Birds	Appelvink	<i>Coccothraustes coccothraustes</i>	Hawfinch	Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829
IB	Birds	Blauwe Reiger	<i>Ardea cinerea</i>	Grey Heron	Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829
IB	Birds	Boomklever	<i>Sitta europaea</i>	Nuthatch	Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829
IB	Birds	Boomkruiper	<i>Certhia brachydactyla</i>	Short-toed Tree Creeper	expert judgment SOVON
IB	Birds	Boompieper	<i>Anthus trivialis</i>	Tree Pipit	Julliard, R., F. Jiguet & D. Couvet, 2004. Common birds facing global changes: what makes a species at risk? Global Change Biology 10, 1: 148-154
IB	Birds	Draaihals	<i>Jynx torquilla</i>	Wryneck	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IB	Birds	Grasmus	<i>Sylvia communis</i>	Whitethroat	Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829

Group	Species group	Species name (NL)	Scientific name	Species name (UK)	References
IB	Birds	Ijsvogel	<i>Alcedo atthis</i>	Kingfisher	Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829
IB	Birds	Kuifmees	<i>Parus cristatus</i>	Crested Tit	Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829
IB	Birds	Nachtzwaluw	<i>Caprimulgus europaeus</i>	Nightjar	<ul style="list-style-type: none"> Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829 Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IB	Birds	Nijlgans	<i>Aloochen aegyptiacus</i>	Egyptian Goose	Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829
IB	Birds	Scholekster	<i>Haematopus ostralegus</i>	Oystercatcher	Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829
IB	Birds	Vink	<i>Fringilla coelebs</i>	Chaffinch	Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829
IB	Birds	Wielewaal	<i>Oriolus oriolus</i>	Golden Oriole	Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829
IB	Birds	Winterkoning	<i>Troglodytes troglodytes</i>	Wren	Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829

Group	Species group	Species name (NL)	Scientific name	Species name (UK)	References
IB	Birds	Wulp	<i>Numenius arquata</i>	Curlew	Roos, Rolf & Saskia Woudenberg (eds.), 2004. Opgewarmd Nederland. Stichting Natuurmedia, Uitgeverij Jan van Arkel en Stichting Natuur en Milieu. ISBN: 9080815829
IC	Amphibians	Rugstreeppad	<i>Bufo calamita</i>	Natterjack	expert judgment Alterra
IC	Butterflies	Klein geaderd witje	<i>Pieris napi</i>	Green-veined White	expert judgment Vlinderstichting
IC	Butterflies	Icarusblauwtje	<i>Polyommatus icarus</i>	Common Blue	expert judgment Vlinderstichting
IC	Butterflies	Bruin zandoogje	<i>Maniola jurtina</i>	Meadow Brown	expert judgment Vlinderstichting
IC	Birds	Boomleeuwerik	<i>Lullula arborea</i>	Wood Lark	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IC	Birds	Goudvink	<i>Pyrrhula pyrrhula</i>	Bullfinch	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IC	Birds	Grauwe Gors	<i>Miliaria calandra</i>	Corn Bunting	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IC	Birds	Grauwe Klauwier	<i>Lanius collurio</i>	Red-backed Shrike	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IC	Birds	Grauwe Vliegenvanger	<i>Muscicapa striata</i>	Spotted Flycatcher	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IC	Birds	Havik	<i>Accipiter gentilis</i>	Goshawk	expert judgment Alterra

Group	Species group	Species name (NL)	Scientific name	Species name (UK)	References
IC	Birds	Kneu	<i>Carduelis cannabina</i>	Linnet	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IC	Birds	Nachtegaal	<i>Luscinia megarhynchos</i>	Nightingale	expert judgment Alterra
IC	Birds	Patrijs	<i>Perdix perdix</i>	Partridge	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IC	Birds	Ringmus	<i>Passer montanus</i>	Tree Sparrow	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IC	Birds	Roerdomp	<i>Botaurus stellaris</i>	Bittern	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IC	Birds	Veldleeuwerik	<i>Alauda arvensis</i>	Sky Lark	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IC	Birds	Wespendief	<i>Pernis apivorus</i>	Honey Buzzard	expert judgment Alterra
IC	Birds	Zanglijster	<i>Turdus philomelos</i>	Song Thrush	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IC	Birds	Zomertortel	<i>Streptopelia turtur</i>	Turtle Dove	Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.), 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate – BRANCH project Final Report. Natural England, UK
IC	Birds	Zwarte Roodstaart	<i>Phoenicurus ochruros</i>	Black Redstart	expert judgment Alterra

4.1.2 Indicator group II – Phenology

Indicator group II consists of 42 butterfly species, 42 songbirds and 7 reptiles. For butterflies a weak but significant relationship, which is much dependent on two extreme values, between the population trend and an earlier appearance is found ($P < 0.01$). This significant relationship is mainly due to the group of early butterflies (butterflies flying early in the year; $n=19$) within the group of all butterfly species (Figure 4.2a).

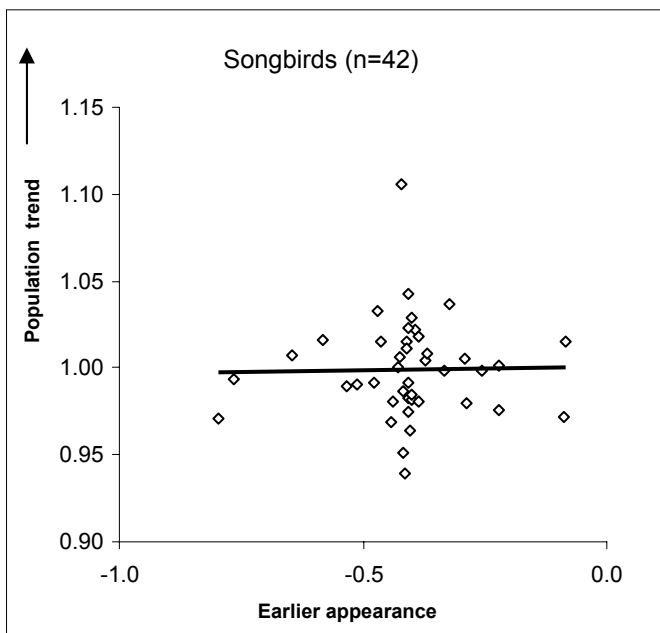
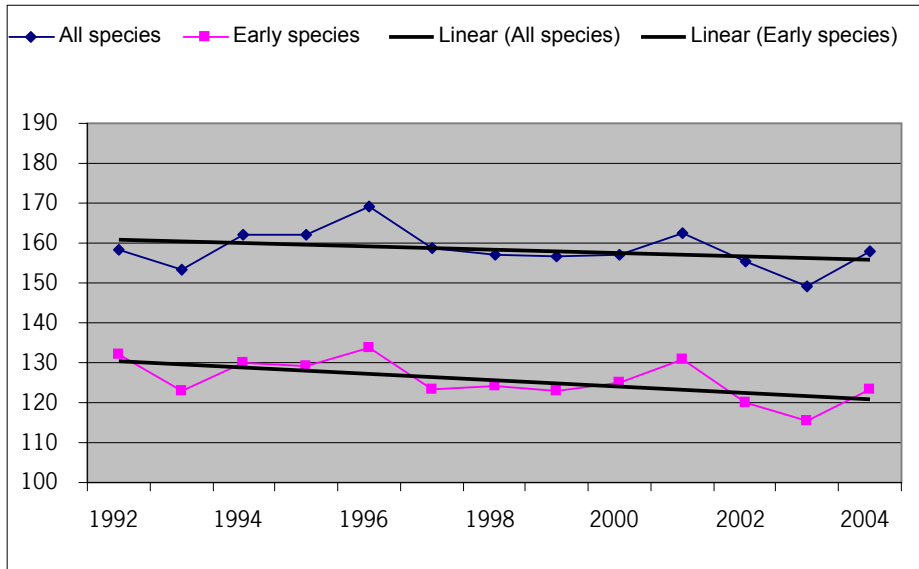


Figure 4.2a Advancing of the average appearance date of 42 butterfly species (uppermost line) and 19 early butterfly species and b) Advancing of the average egg laying date in relation to the population trend for 42 monitored songbirds. Y-axis: population trend is stable when $Y=1.00$. The trend is expressed as yearly multiplicative slope ('growth factor'). Earlier appearance here stands for the trend in the day of the year, expressed as regression coefficient.; X-axis: time of appearance remains the same when $X=0.0$. Source: NEM (PGO's & CBS)

Species showing the largest forward shift in their phenology show an increasing population trend compared to species which do not show an earlier appearance or appear even later (Figure 4.3). For birds and reptiles no relationship is found (Figure 4.2 b & Figure 4.4.).

An earlier appearance of butterflies seems to increase their chances for survival. The warmer spring of the last years is probably the cause of this earlier appearance (CBS web magazine).

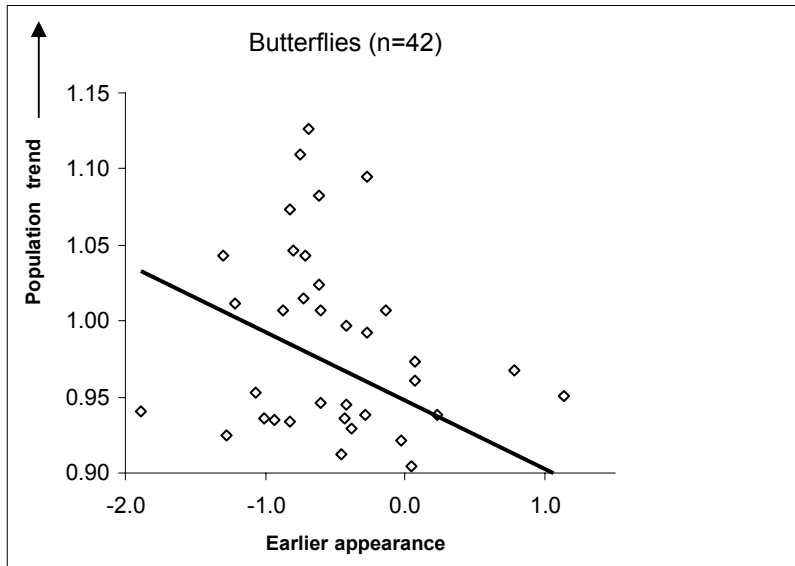


Figure 4.3. Advancing of the average appearance date in relation to the population trend for 42 monitored butterfly species. Y-axis: population trend is stable when $Y=1.00$. The trend is expressed as yearly multiplicative slope ('growth factor'). Earlier appearance stands for the trend in the day of the year, expressed as regression coefficient. X-axis: time of appearance remains the same when $X=0.0$. Source: NEM (PGO's & CBS).

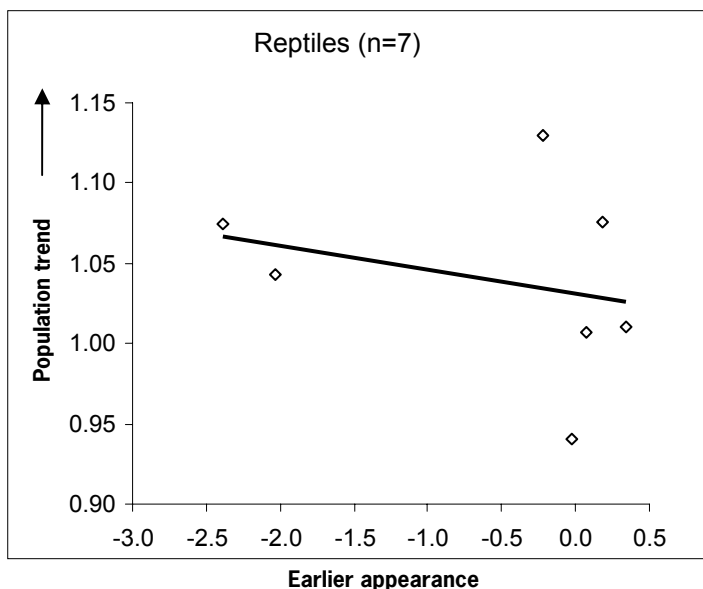


Figure 4.4. Advancing of the average date of appearance in relation to the population trend for 7 monitored reptiles. Y-axis: population trend is stable when $Y=1.00$. The trend is expressed as yearly multiplicative slope ('growth factor'). Earlier appearance here stands for the trend in the day of the year, expressed as regression coefficient. X-axis: time of appearance remains the same when $X=0.0$. Source: NEM (PGO's & CBS)

4.2 Population trends found in climate change indicators

Indicator group IA cold preferent species and indicator group IB warmth preferent species are suitable indicators, since a significant correlation with population trends was found. The two indicators have a causal link to climate change, are measurable and differentiate over time and space. In addition their response is relevant regarding policy goals, as it has an impact on population trends of target species.

The reaction of indicator IC neutral species is not as expected and requires further study.

The phenological response of species shows only a slight correlation with population trends for butterflies, but no correlation for songbirds and reptiles. The indicator is suitable regarding its causal relation with climate change, its measurability and its differentiation in time and space. However as no clear relation was found with species persistence the usefulness of the indicator regarding policy goals is still unclear.

4.3 Indicators used elsewhere in Europe

The European Environmental Agency (EEA) has developed an indicator system for the assessment of climate change (EEA, 2004). They have chosen the following indicators for terrestrial ecosystems and biodiversity:

1) Changes in plant species composition for warmth and cold preferent species

This indicator measures the changes in frequencies of groups of plant species adapted to 'warm' and 'cold' conditions. In a study by Tamis *et al* (2001) based on Ellenberg values it was shown that species adapted to warm conditions showed an increase in abundance, while cold adapted species showed a decrease.

This correlates well with our indicator groups IA (cold preferent species) and IB (warmth preferent species), where we studied different species groups.

2) Plant phenology and growing season

Growing season change is closely related to climate change and well documented. On a European level the International Phenological Gardens of Europe have extensive historic datasets (Menzel *et al*, 2006). Although these data show clear changes closely related to climate change, a drawback of this indicator is that it is not clear how a change in phenology impacts species persistence. It has been shown that differences in *phenological response* between species can lead to mismatches in the food chain (see Fig. 2.1). However this is a measure relative to other species. It would be relevant if a relationship was found between the amount of phenological change and the probability of becoming part a food chain mismatch. Our findings for the phenology indicator (II) are comparable

3) Bird survival

The survival rate of bird species wintering in Europe has increased over the past few decades (Frederiksen, 2002). This could have an impact on the level of populations, as adult survival and reproductive success are two key factors in population dynamics.

This indicator is restricted to birds and therefore limited as an indicator, which is the reason we suggest it should not be used.

5 Discussion: further indicator development

5.1 Cold, warmth preferent and neutral indicator groups (IA, IB and IC)

The responses of the Cold tolerant (IA) and Warmth tolerant (IB) species are in accordance with the expected responses to climate change. Therefore they seem to be suitable indicators for climate change. However the negative trend of the neutral species group is not in accordance to the expected and requires further study. Thus the indicators are still under construction and need further improvement on several aspects. How do the cold, warmth preferent and neutral response groups 'score' regarding the list of preferred indicator attributes?

1) *Does the indicator(s) incorporate all main responses of species to climate change?*

The indicator groups for cold/warm/neutral species are linked to the response to temperature increase caused by climate change. However they are not related to the other important aspect of climate change: the increase of weather extremes.

Recommendation: Further research is needed to find suitable indicators for the response to weather extremes.

2) *Does the indicator(s) have a causal link to climate change?*

Parmesan and Yohe (2003) conducted a meta-analysis for 460 species in which they showed that 81% of the species displayed a shift in range in the direction predicted according to climate change (temperature). Also species envelope models, which predict range shifts based on climate change scenarios predict range shifts towards the poles and to higher altitudes (Pearson *et al.* 2002; Bakkenes *et al.* 2002; Thuiller, 2003). Thus it is clear that climatic conditions have a large impact on the potential distribution of species.

For cold preferent species the following responses to increasing in temperature at the 'warm border' of their distribution have been recorded:

- a) A negative population trend;
- b) Extinction of local populations outnumbers local colonisations;
- c) The species disappear at the 'warm border' of their distribution – a so called contracting distribution.

For warmth preferent species the opposite responses to increasing temperature at the 'cold border' of their distribution have been recorded:

- a) A positive population trend;
- b) Colonisations outnumber local extinctions;
- c) The species shows an expanding pole wards distribution and expansion towards higher altitudes – a so called expanding distribution.

3) *Does the indicator differentiate in space and time?*

The response of the cold and warmth preferent species clearly differentiates in space and time. The potential distribution of species is shifting pole wards and to higher altitudes as a response to increasing temperatures. Thus the response is differentiated in space and depends on the location of a target area (for instance a country) compared to the distribution

of the species (Figure 4.1). Climate change induced rise of temperatures have been increasing in the last century and this will continue, according to the different climate models.

4) *Is the indicator relevant regarding policy goals, for instance population trends of target species?*

We have shown in chapter 4 that the cold preferent species show a negative population trend in the Netherlands, while the warmth preferent species show a positive trend. As the analysis was based on a sample of policy target species (a selection of butterflies, birds and amphibians) these trends are relevant regarding the achievement of policy goals. However the unexpected response of the neutral group needs to be further explored. For some species climate change helps to achieve policy goals, while for the others the impact is negative. As for most species persistence is threatened by several factors, e.g. habitat fragmentation and/or eutrophication, etc, it is relevant to know that part of the species performance is caused by climate change. Obviously the tested sample was only small and should be extended. The analysis on climate change response of plant species (Tamis *et al.*, 2001; EEA, 2004) showed similar results. In this study based on Ellenberg numbers it was shown that species adapted to warm conditions showed an increase in abundance, while cold adapted species showed a decrease. However a similar analysis on plants is not possible, as no population trend data are available.

Recommendation: Further research is needed to understand the unexpected response of the neutral species group (indicator group IC). Many additional climate envelope models projections are being developed at the moment, for instance for all European breeding birds (Huntley *et al.*, 2007). With this additional information the cold, warmth preferent and neutral species groups can be further improved and extended.

5) *Is the indicator measurable and preferably already available in historical data?*

Our indicator requires two sources of input. First we need information to put a species in indicator group I or indicator group II. This selection was based on literature:

- a) Climate enveloping models that predict future distributions under different climate change scenario's, where one of the distribution borders expands or contracts in the Netherlands;
- b) Empirical data: statistical analysis of historical distribution data where a correlation was found between changes in distribution and climate changes.

Second we need time series of population trends. For these trend data we depend on the NEM data. The NEM consist of 14 monitoring networks, which vary in time span. For the species groups used in this research reliable population trends are available. The data are tested for errors and statistically corrected to adjust for oversampling and undersampling of particular regions and habitat types (Van Swaay *et al.*, 2002)

6) *Does the indicator represent all relevant ecosystems and species groups?*

When selecting species for analysis of the indicator groups an equal distribution of ecosystems within the indicator groups was taken into account. It should be tested however whether all relevant ecosystems are present. Furthermore the cold, warmth preferent and neutral indicator groups should be tested on whether policy target species are equally well represented.

The NEM data are representative for the characteristic ecosystems in the Netherlands. It should be further tested whether the species of cold, warmth preferent and neutral indicator groups are sufficiently represented in the NEM species selection.

5.2 Phenological indicator (II)

The phenological response is a suitable indicator regarding most preferred attributes:

- a) There exists a causal relationship with temperature increase, caused by climate change (attribute 1,2);
- b) The indicator differentiates in time and space (attribute 3).
- c) It is well documented on a national (www.natuurkalender.nl) and an European level: the International Phenological Gardens of Europe have long historic datasets (Menzel *et al.*, 2006) (attribute 4) ;
- d) The indicator could be balanced for ecosystem types and species groups (attribute 6).

However, for now, a disadvantage of the phenological response is that it is unclear how a change in phenology impacts species persistence (attribute 5). In our analysis no correlation was found between the amount of phenological change and population trends for birds and reptiles. However for butterflies a small positive trend was found ($P < 0.01$). It could be possible that some species groups are more sensitive than others. Or perhaps a longer time series of data of more species are needed. Thus as for now it is not clear how to link the phenological response to policy targets. This can be explained by the fact that the phenological response becomes especially important for species persistence when this causes a mismatch of processes in the food chain (Visser & Rienks, 2003; Both *et al.*, 2006). Thus one needs to analyse phenological responses not for single species but for food chains. Although this type of research is very important for the understanding of the impacts of climate change, the analysis of food chain mismatches does not seem feasible as an indicator.

Recommendation. More research effort is needed to look for links between the phenological response of species and their persistence. An option would be for instance to analyse whether a correlation exists between the warmth and cold preferent response groups and the rate of the phenological response.

5.3 Indicator for weather extremes

The Temperature indicator and the Phenological indicator are both related to the aspect of climate change related rising temperatures. However they are not related to the other important aspect of climate change: the increase of weather extremes. The increasing occurrence of weather extremes will cause larger fluctuation in population numbers and may lead to (local) extinctions (Easterling *et al.*, 2000). Extreme weather events like for example a cold spring, a long hot period during summer, or a very soft winter can lead to direct death of individuals or to failing of reproduction. As a consequence species which are vulnerable to fluctuations in numbers run a higher risk when weather extremes occur. So do species with a slower potential growth rate.

At present, there is insufficient information about the effects of weather extremes. This can be explained by the fact that extreme weather events are rare and therefore it is difficult to link them to population performance. However the general impression is that weather extremes are important factors for ecological processes. For now, this is not a useful indicator. Further research is needed to link particular species traits to sensitivity for weather extremes during certain periods of their life cycle.

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