

Chapter 8

Assessment of Climate-Induced Impacts on Habitats

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8.1 Impacts Vary Between Biogeographical Regions

Climate change impacts biota from individual, population, species and community level to whole ecosystems or biogeographic regions. The biota's current distribution is a result of abiotic factors like climate conditions, topography, soil types or disturbance regimes and biotic factors like competition. If abiotic factors like regional climate conditions are changing, the individuals can be more prone to catastrophic disturbances like disease, insects or fires (Bergengren et al. 2011).

In parts of the world, including Europe, the species distribution is already influenced by climate change (Parmesan and Yohe 2003). Rising temperatures led to an increase in thermophilic plant species (Bakkenes et al. 2006). Especially in alpine areas, warm-adapted species become more frequent and the more cold-adapted plants are declining (Gottfried et al. 2012). This also shows that the impact of climate change on plant species communities varies between biogeographical

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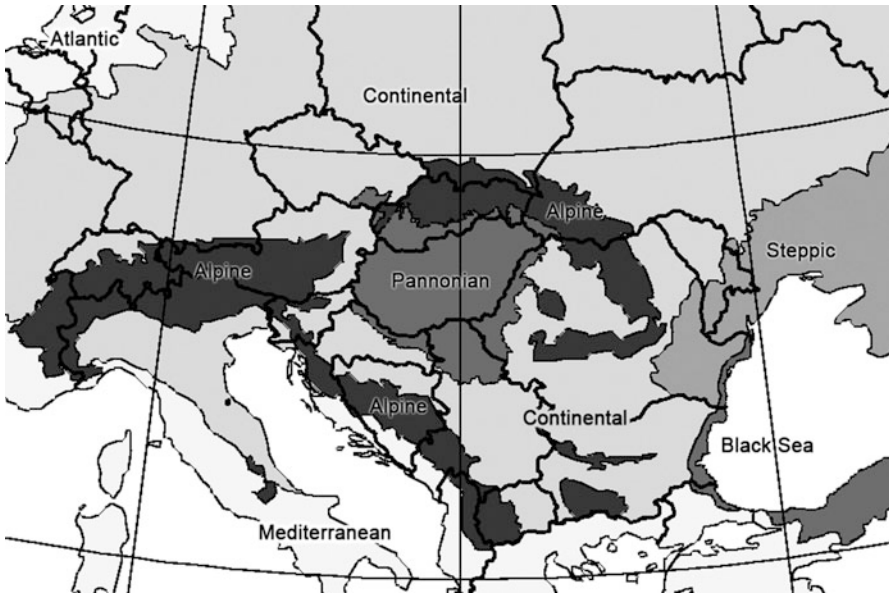


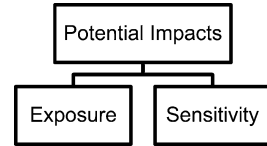
Fig. 8.1 The biogeographical regions of Central and Eastern Europe, modified after EEA (2011)

regions (Fig. 8.1) as stated by the EEA for the past and projected key impacts of climate change effects (2010): Alpine areas suffer from high temperature increase, whereas the lowlands of Central and Eastern Europe (incorporating the Continental, Pannonian and Steppic regions) have to face more temperature extremes and less summer precipitation (see Chaps. 2, 3, and 4).

In order to develop adapted management it is crucial to counteract against past and projected key impacts of climate change and their effects, and to understand the underlying processes and pattern. Biodiversity monitoring programmes can help to understand these processes and altered pattern of biota (Lepetz et al. 2009). Especially long-term monitoring programmes like the Global Observation Research Initiative in Alpine Environments (GLORIA, <http://www.gloria.ac.at>) help to understand key past changes since effects on plant species' composition are often only visible after decades (Gottfried et al. 2012). Future effects on biota are simulated in models so that predictions on climate change impacts can be made. Due to the fact that many abiotic and biotic parameters can be incorporated into the model they are able to simulate complex biological processes (Lepetz et al. 2009). Therefore, various species distribution models are used to project future species compositions of habitats depending on various climate scenarios (e.g. Dullinger et al. 2012; Lepetz et al. 2009; Bittner et al. 2011; Milad et al. 2011; Normand et al. 2007).

In HABIT-CHANGE the assessment of climate-induced impacts on habitats focuses on existing frameworks (e.g. Rannow et al. 2010; Renetzeder et al. 2010) to provide information about priorities for the climate change adapted management process in the protected areas. The framework consists of sensitivity and exposure, which are both leading to climate-induced impacts on habitats. Existing literature

Fig. 8.2 Framework for the assessment



about projected species compositions (e.g. Normand et al. 2007; Bakkenes et al. 2006; Milad et al. 2011), ecological envelope (Ellenberg 1992; Landolt et al. 2010; Borhidi 1995) and expert knowledge systems (Petermann et al. 2007) are used to assess the sensitivity of habitat types, whereas results from climate scenarios (see Chaps. 2 and 3) are used to describe the magnitude of the expected exposure to climate change.

The framework for the assessment (Fig. 8.2) follows the concept defined by the IPCC (2001): **sensitivity** is defined as “the degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g. change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea-level rise).” The term **exposure** specifies “the nature and degree to which a system is exposed to significant climatic variations”. **Potential impacts** describe “the consequences of climate change on natural and human systems [...] that may occur given a projected change in climate, without considering adaption”. Furthermore, in the application of the assessment framework the focus particularly was set on (I) the assessment: simple approach which is locally valid and can be transferred to other biogeographical regions; (II) the traceability: transfer expert knowledge into values based on defined criteria; (III) the scale: localised analysis for habitats within an investigation area and regionalised statement for a biogeographical region.

8.2 Framework for the Assessment

The climate-induced impact on habitats was assessed by the consideration of investigation areas within the Alpine, Continental and Pannonian biogeographical region (Table 8.1). The locally analysed data from those areas were used to derive sensitivity, exposure and potential impacts per biogeographical region.

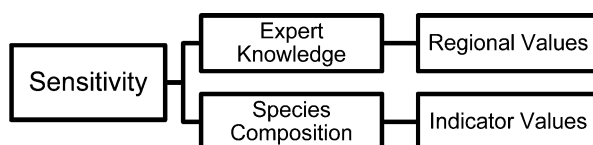
8.2.1 Sensitivity

In HABIT-CHANGE the sensitivity of a habitat is considered a result of its characteristics and existing or future pressures. The characteristics of habitats are the results of the effective abiotic factors like climate conditions, topography, soil type or disturbance regimes and biotic factors like species distributions, competition or regeneration rates. These characteristics describe the ecological envelope of

Table 8.1 Investigation areas used to assess the climate-induced impacts on habitats

Region	Investigation area	Cnt. HT
Alpine	Natural Park Bucegi, Romania	11
Alpine	Rieserferner-Ahrn Nature Park, Italy	13
Alpine	Triglav National Park, Slovenia	14
Continental	Biebrza National Park, Poland	11
Continental	Riverside landscape Elbe-Brandenburg Biosphere Reserve, Germany	21
Continental	Vessertal – Thuringian Forest Biosphere Reserve, Germany	20
Pannonian	Balaton Uplands National Park, Hungary	10
Pannonian	Körös-Maros National Park, Hungary	5
Pannonian	Lake Neusiedl/Fertő-Hanság National Park, Austria/Hungary	25

Cnt. HT amount of different habitat types stated as important by the investigation areas

Fig. 8.3 Framework for the sensitivity assessment

the habitats. However, existing non-climatic pressures like land use changes modify the resilience of habitats to climate change on the local level. The sensitivity of habitats was assessed by two approaches (Fig. 8.3). One is focusing on regional expert knowledge and the other incorporates the ecological envelope of the habitat by assessing the current plant community composition.

The framework for the **regional expert knowledge** was based on the approach developed during the sensitivity assessment of Natura 2000 habitats in Germany by Petermann et al. (2007). The resulting list of sensitivity values has the advantage of being regionally adapted to central Europe. It is based on a nomenclature familiar to conservation areas within the EU and simplistic enough to derive results with a minimum of input data. Moreover, the approach after Petermann et al. (2007) is not modelling specific key species. Other tools, like the NatureServe Climate Change Vulnerability Index (Master et al. 2012) or the approach by Preston et al. (2008) can supply more detailed results about the predicted spatial extend of species, but have the disadvantage of high data-requirements and low locally generalised adaptation of the method and the nomenclature.

The assessment after Petermann et al. (2007) was structured into seven sensitivity criteria (Table 8.2):

1. Average or reduced conservation status: habitats which are already marked as endangered are more sensitive;
2. Ability to regenerate: how long habitats need to recover after disturbance;
3. Horizontal distribution (range): species migrations due to climate change (e.g. from Northwest to East);
4. Altitudinal distribution (range): species are forced to migrate upwards (e.g. summit areas);

Table 8.2 Sensitivity criteria for the regional expert knowledge assessment (After Petermann et al. 2007)

Values	CONS	REGE	HORI	ALTI	COVER	NEOP	WATER
Low	≥ 3	Marginal	No limits, closed range	Planar collin	No change	No invasives	No
Medium	≥ 2	Difficult	No limit but fragmented	Montane	Medium decrease	One invasive species	Only for some forms
High	≥ 1	None, barely	Limits or disjoint habitats	Subalpine and alpine	Strong decrease	More than one invasive species	For most forms

Abbreviations: *CONS* Average or reduced conservation status, *REGE* Ability to regenerate, *HORI* Horizontal distribution, *ALTI* Altitudinal distribution, *COVER* Decrease of territorial coverage, *NEOP* Influence of neophytes, *WATER* Dependency on ground water and surface water in water balance

5. Decrease of territorial coverage: remnants of habitats which are already endangered;
6. Influence of neophytes: potential danger of neophytes due to new invasive species or changing territorial coverage;
7. Dependency on groundwater and surface water in water balance: sensitivity of habitats which depend on water to changing temperature and precipitation patterns.

For each habitat type each criteria was evaluated from the experts between the values “*low*” (1), “*medium*” (2), and “*high*” (3) sensitive. Afterwards, these values are summed and categorised to describe the overall sensitivity of a habitat type. Thereby, the categories were named similar to the evaluation values (Table 8.3). This evaluation was done from regional experts for the Alpine, Continental and Pannonian biogeographical region.

To get an overall impression of the status per region, the sensitivity values of each habitat type from each investigation area within HABIT-CHANGE were grouped using the statistical median according to their biogeographical region.

The variability of the ecological envelope of habitats was assessed by **indicator values** which were derived from the characteristic species composition of the habitats. As above, the biogeographical regions define the type of plant indicator scheme used for the assessment (Table 8.4). This differentiation was made because indicator schemes are based on the plant species response to climatic (e.g. temperature) and edaphic (e.g. moisture) habitat parameters, which are varying between the biogeographical regions (Englisch and Karrer 2001). Following Ellenberg (1992), different authors adapted the ecological preference of plants for their region. Each scheme categorises this ecological preference into ordinal scaled systems.

Temperature values as climatic parameter and **moisture** values as edaphic parameter were selected in the framework. The temperature describes the plants response to air temperature gradients during the vegetation period. Moisture values indicate the degree of soil moisture needed by the plant during the vegetation period. Since the approach should be locally valid and transferrable to other biogeographical regions, the indicator schemes were re-categorised into three values each (Tables 8.5 and 8.6). Thereafter, the categorised indicator values were used to calculate an overall indicator value based on the statistical median for each habitat type listed by the investigation area.

The frequency of the categorised indicator values per habitat, investigation area and biogeographical region was used in the sensitivity assessment. The proportion of the categories defined the main direction, therefore also the sensitivity of the habitat against changes in direction of the other category (Table 8.7). For instance, freshwater habitats are characterised in their moisture by moist to wet category and therefore are sensitive to drought periods.

Table 8.3 Sensitivity categories (after Petermann et al. 2007)

Sum	Value	Category
>14	3	High
14–16	2	Medium
<16	1	Low

Table 8.4 Indicator schemes per biogeographical region

Region	Indicator scheme	Ordinal scale	New scale
Alpine	Landolt et al.(2010)	1–5 (temperature, moisture)	1–3
Continental	Ellenberg (1992)	1–9 (temp.); 1–12 (moist.)	1–3
Pannonian	Borhidi (1995)	1–9 (temp.); 1–12 (moist.)	1–3

Table 8.5 Categories for the indicator temperature

Scale	Category	Description
1	Low	Species from high elevations, sustainable of low air temperature during the growth period
2	Medium	Species from the midlands, need average air temperature during the growth period
3	High	Species from low elevations, need higher air temperature during the growth period

Table 8.6 Categories for the indicator moisture

Scale	Category	Description
1	Dry	Species sustain low soil moisture during growth period
2	Moist	Species need average soil moisture during growth period
3	Wet	Species need high soil moisture during growth period

Table 8.7 Example sensitivity assessment of the indicator values for three habitat types

Habitat	Dry	Moist	Wet	Present	Sensitivity
Freshwater habitats	1	15	58	Moist/Wet	>Dry
Grassland formations	72	196	24	Dry/Moist	>Wet
Forests	14	174	43	Moist	Indifferent

8.2.2 Exposure

In HABIT-CHANGE exposure of a habitat is equivalent to the pressure “climate change”. The changes can be represented as long-term changes in climate conditions, changes in the climate variability or changes in the magnitude and frequency of extreme events.

The exposure was assessed (Fig. 8.4) by comparing climatic conditions of today with information from meteorological observations from the past (period between the years 1971–2000) and climate change projections for the future (period between

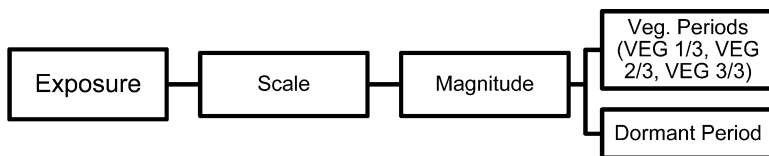


Fig. 8.4 Framework for the exposure assessment

Table 8.8 Exposure magnitude categories

Scaled value	Category	Magnitude
>0.90	3	High
0.90–0.30	2	Med
<0.30	1	Low

the years 2036–2065). Various exposure parameters are available when comparing climatic conditions from the past to the future (see Chaps. 2 and 3). This framework selected the two exposure parameters corresponding most with the two plant indicators which describe the ecological envelope of a habitat. The **mean temperature** (°C) indicates the changes in air temperature for each period and therefore can describe the indicator temperature. The **climatic water balance** (mm) combines precipitation and evapotranspiration and for that reason is one of the best parameter to explain the distribution of vegetation (Stephenson 1990). The climatic water balance indicates the changes in the water storage in the soil and therefore can be used to be compared with the indicator moisture.

The exposure values were calculated as annual ensembles (for more details see Chaps. 2 and 3). These values represented the climatic conditions during the course of the year for the past and projected future date periods from above. Instead of the usage of the length of the vegetation period, the productive time was divided into three time segments, which are further referred to as 1/3, 2/3 and 3/3 of the vegetation period. The non-productive time segment is referred as dormant period. The exposure values therefore were calculated separately for each period during the course of the year. First, the difference in the exposure values between the past and future date period was obtained to get the amount of change from the past to the future. This led to difference values ranging around zero (e.g. see Fig. 8.7 with temperature range between 6 and -6 °C). In a second step, the values were scaled by dividing them by the root mean square. Now, the values of the different exposure parameters (e.g. °C or mm) showed the same range around zero, which means that all values at least range between 1 and -1 . Finally, the scaled values were categorised into three magnitudes of exposure classes by making use of this fact. The statistical median was calculated for each period per parameter. Negative values were transformed into positive and afterwards assigned to one of the three magnitude classes (Table 8.8).

Fig. 8.5 Framework for the impact assessment

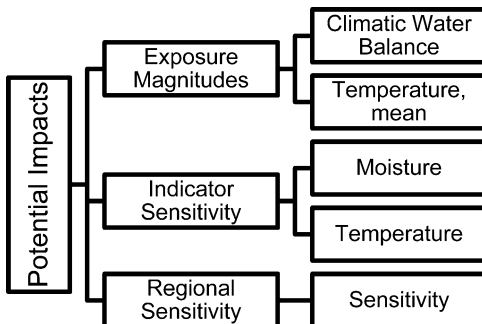


Table 8.9 Transformation rules of the temperature using the temperature sensitivity

Sensitivity	Rule
>High	If habitat is sensitive against raising temperatures, then leave all positive exposure values
>Low	If habitat is used to high temperatures and therefore sensitive against lower temperatures, then leave all negative exposure values
~	If habitat is indifferent because the frequency does not show any clear preference in one direction (either high or low), then remove all low values (1, -1)

8.2.3 Impact

In HABIT-CHANGE the term impact is considered as a change in the state of a system caused by pressures like climate change or land use. The focus is set on environmental impacts esp. on habitats. Climate impacts may be positive or negative. They can be the result of extreme events or more gradual changes in climate variables showing either direct or indirect effects. Examples for direct impacts are changed abiotic conditions (e.g. soil moisture) for protected habitats. Examples of indirect impacts are changes of agricultural practices due to increasing drought stress.

The framework for the assessment (Fig. 8.5) of climate-induced impacts on habitats results into overall impact magnitude values partitioned into the four time segment during the course of the year. The starting points in the impact assessment were the exposure values and the sensitivity derived from the indicator values. The parameter temperature (tas) and climatic water balance (cwb) were checked against the sensitivity of the indicators temperature and moisture. Subsequently, this resulted into the first impact values following the rules defined in Table 8.9 for Temperature and Table 8.10 for Moisture. In the example shown in Table 8.11, for the Temperature, the Indicator rules stated that all negative values should be ignored from further analysis. The Moisture was indifferent and therefore all low exposure values were removed. The sensitivity values from the regional expert knowledge assessment were used to weight the first impact values. This was done by summarising the values from temperature, moisture and regional sensitivity for

Table 8.10 Transformation rules of the climatic water balance using the moisture sensitivity

Sensitivity	Rule
>Wet	If habitat is sensitive against soil wetness, then remove all high positive values (3) (Extreme increase in the Climatic Water Balance)
>Dry	If habitat is sensitive against droughts, then leave all negative values (Climatic Water Balance is decreasing, which can cause water shortage)
~	If habitat is indifferent because the frequency does not show any clear preference in one direction (either dry or wet), then remove all low values (1, -1)

Table 8.11 Example of exposure values and their respective sensitivity derived from the indicator values of alpine grassland formations

Grassland formations	VEG1	VEG2	VEG3	DORM	Indicator
Temperature	-2	1	2	3	>High
Moisture	2	1	1	-3	Indifferent

Table 8.12 Example of an impact assessment for alpine grassland formations

Grassland formations	VEG1	VEG2	VEG3	DORM
Temperature		1	2	3
Moisture	2			3
Regional sensitivity	2	2	2	2
Sum	4	3	4	8
Impact category	2	1	2	3

Table 8.13 Impact magnitude categories

Sum	Category	Magnitude
<4	1	Low
4-6	2	Med
>6	3	High

each of the four time segments (see Table 8.12 for an example assessment). The sums were again categorised into three classes (Table 8.13) which resulted into the final impact magnitudes.

8.3 Assessment Results

The assessment of the habitats investigated in the project shows differences in the sensitivity values between the biogeographical regions. *Freshwater habitats, raised bogs and mires and fens* and *forest* are most sensitive, whereas the very specialised azonal *rocky habitats* show the lowest sensitivity against climate change pressures.

Table 8.14 Regional sensitivity values for the Alpine region

Habitat type	<i>Cnt.</i>	CONS	REGE	HORI	ALTI	WATER	COVER	NEOP	<i>Sum</i>	SEN
Freshwater habitats	2	3	2	3	3	1	1	1	14	2
Grassland formations	14	2	2	3	3	2	1	2	15	2
Bogs, mires and fens	5	3	3	3	1	3	1	3	17	3
Rocky habitats	7	2	1	3	3	1	1	1	12	1
Forests	4	3	3	3	2	2	2	2	17	3

Cnt. indicates number of habitat types within the region; *Sum* states the amount of values used to categorise the sensitivity (**SEN**)

Table 8.15 Alpine indicator values

Habitat type	<i>Cnt. Spec</i>	Temperature	Temp. SEN	Moisture	Moist. SEN
Freshwater habitats	35	Low–Med	>High	Dry–Moist	>Wet
Grassland formations	798	Low–Med	>High	Moist	~
Bogs, mires and fens	168	Med	~	Moist–Wet	>Dry
Rocky habitats	120	Low–Med	>High	Moist	~
Forests	441	Med	~	Moist	~

Cnt. Spec indicates the number of species; Temp. SEN, Moist. SEN sensitivity for changes in temperature and moisture

8.3.1 Alpine Region

The Alpine biogeographical region is characterised by species disjunct to mountain areas or endemic species. Beside the conservation status and other criteria, this is why the alpine region has a higher overall regional sensitivity (Table 8.14). The ecological envelope of the habitat types ranges from more or less lower temperatures during the vegetation period to overall moist soil conditions (Table 8.15, Fig. 8.6). Therefore, Alpine habitats are sensitive against raising temperatures and high moisture amplitudes (positive or negative), which is the case especially in the last 3/3 of the vegetation period and in the dormant period (Fig. 8.7). In sum, this sensitivity and exposure values show the highest potential impacts during the dormant period (Table 8.16).

8.3.2 Continental Region

The continental biogeographical region is characterised by species with large contiguous distribution areas, therefore also by a high amount of invasive species. The ability to regenerate is low due to mostly ‘climax’ status of the habitats. This

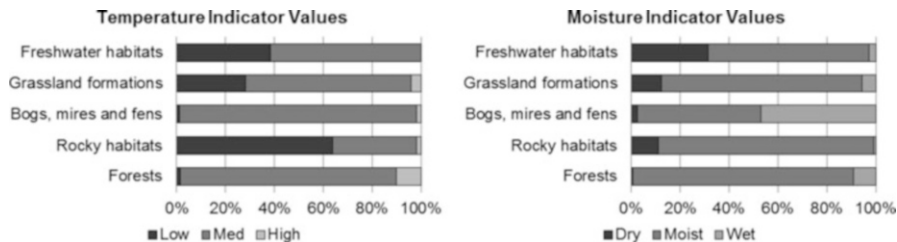


Fig. 8.6 Proportional distribution of the indicator values per habitats in the Alpine region

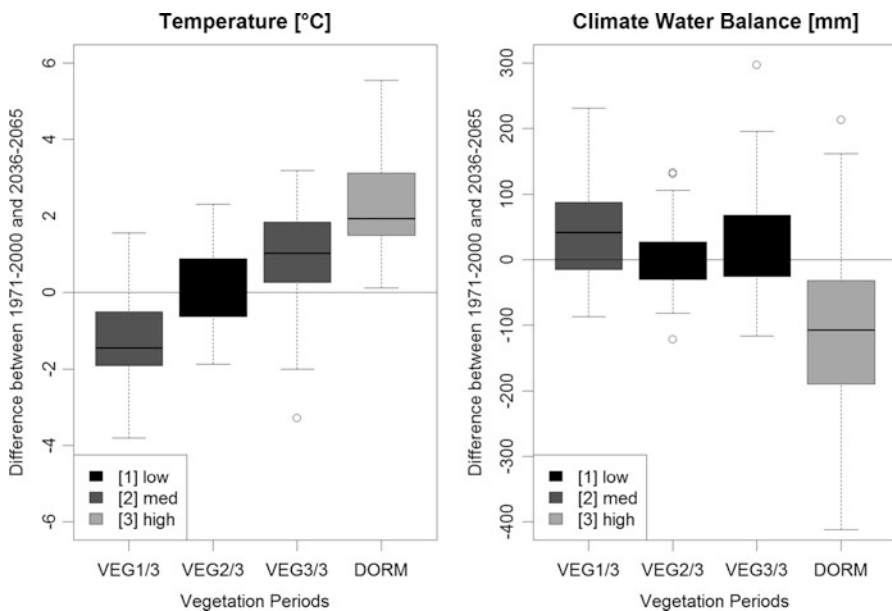


Fig. 8.7 Difference in exposure between periods 1971–2000 and 2036–2065 for parameters used in the Alpine impact assessment

Table 8.16 Potential impact magnitudes for the Alpine region

Habitat type	VEG 1/3	VEG 2/3	VEG 3/3	DORM
Freshwater habitats	2	2	2	3
Grassland formations	2	1	2	3
Bogs, mires and fens	2	1	2	3
Rocky habitats	1	1	1	3
Forests	3	1	2	3

(1) low, (2) medium, (3) high magnitude of potential impacts

Table 8.17 Regional sensitivity values for the Continental region

Habitat type	<i>Cnt.</i>	CONS	REGE	HORI	ALTI	WATER	COVER	NEOP	<i>Sum</i>	SEN
Freshwater habitats	5	3	3	2	2	3	2	3	18	3
Grassland formations	12	2	3	2	2	2	3	3	17	3
Bogs, mires and fens	10	3	3	3	2	3	2	3	19	3
Rocky habitats	3	3	2	3	3	1	1	2	15	2
Forests	17	3	3	2	2	3	3	3	19	3

Table 8.18 Continental indicator values

Habitat type	<i>Cnt. Spec</i>	Temperature	Temp. SEN	Moisture	Moist. SEN
Freshwater habitats	78	Med	~	Moist/Wet	>Dry
Grassland formations	313	Med	~	Dry/Moist	>Wet
Bogs, mires and fens	191	Med	~	Moist	~
Rocky habitats	42	Low/Med	>High	Dry/Moist	>Wet
Forests	287	Med	~	Moist	~

Cnt. Spec indicates the number of species; Temp. SEN, Moist. SEN sensitivity for changes in temperature and moisture

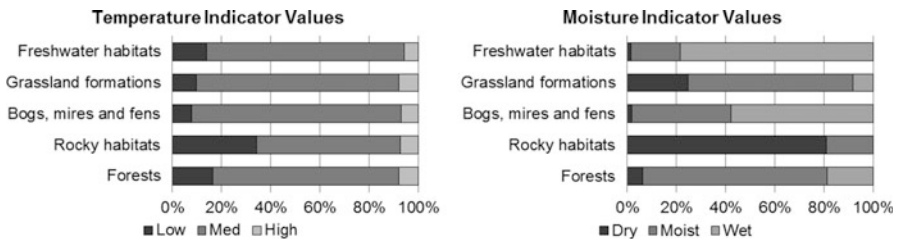


Fig. 8.8 Proportional distribution of the indicator values per habitats in the Continental region

results into an overall very high regional sensitivity (Table 8.17). Characteristic for lowland to midland vegetation types, the ecological envelope ranges from medium temperature values during the vegetation period to habitat specific soil moisture demands (Table 8.18, Fig. 8.8). Continental habitats are more or less indifferent in their sensitivity against changing temperatures, but sensitive when it comes to alterations in the soil moisture. However, the high magnitude changes of the exposure temperature, especially in the dormant period and first 1/3 of the vegetation period, will induce phenological shifts as already stated by many studies

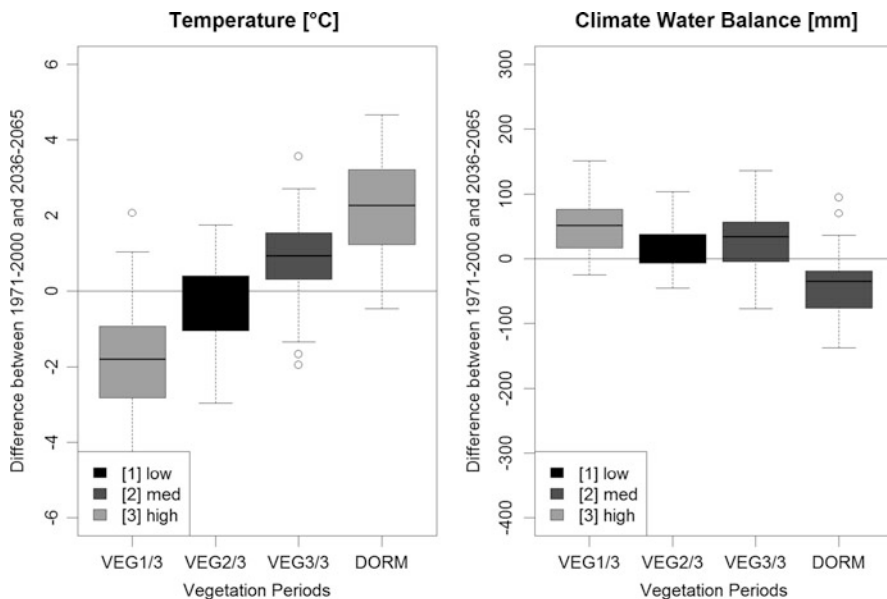


Fig. 8.9 Difference in exposure between periods 1971–2000 and 2036–2065 for parameters used in the Continental impact assessment

Table 8.19 Potential impact magnitude for the Continental region

Habitat type	VEG 1/3	VEG 2/3	VEG 3/3	DORM
Freshwater habitats	2	–	2	3
Grassland formations	2	2	3	3
Bogs, mires and fens	3	–	3	3
Rocky habitats	–	1	3	3
Forests	3	–	3	3

(1) low, (2) medium, (3) high magnitude of potential impacts

(see Milad et al. 2011 for a review on forest). High negative changes in the water balance will impair this situation (Fig. 8.9). Like in alpine habitats, the sensitivity and exposure values lead to the highest potential impacts during the dormant period (Table 8.19).

8.3.3 Pannonian Region

The Pannonian biogeographical region is characterised by species distributed more restrictively to the eastern lowland where low natural barriers hinder migration.

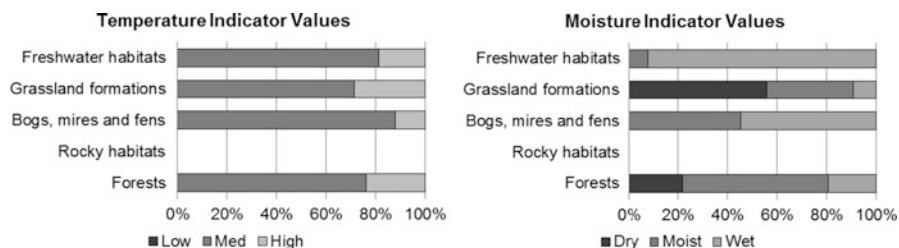
Table 8.20 Regional sensitivity values for the Pannonian region

Habitat type	<i>Cnt.</i>	CONS	REGE	HORI	ALTI	WATER	COVER	NEOP	<i>Sum</i>	SEN
Freshwater habitats	8	3	3	2	2	3	2	3	18	3
Grassland formations	26	2	3	1	1	2	3	3	15	2
Bogs, mires and fens	4	2	2	1	2	3	1	2	13	1
Rocky habitats	–	–	–	–	–	–	–	–	–	–
Forests	13	2	2	1	1	3	2	2	13	1

Table 8.21 Pannonian indicator values

Habitat type	<i>Cnt. Spec</i>	Temperature	Temp. SEN	Moisture	Moist. SEN
Freshwater habitats	219	Med	~	Wet	>Dry
Grassland formations	649	Med–High	>Low	Dry–Moist	>Wet
Bogs, mires and fens	56	Med	~	Moist–Wet	>Dry
Rocky habitats	–	–	–	–	–
Forests	423	Med	~	Moist	~

Cnt. Spec indicates the number of species; Temp. SEN, Moist. SEN sensitivity for changes in temperature and moisture

**Fig. 8.10** Proportional distribution of the indicator values per habitats in the Pannonian region

This is also mirrored in the high number of invasive species. Overall, the regional sensitivity of the habitats is lower than in the two other biogeographical regions (Table 8.20). Like in the Continental region, the ecological envelope ranges from medium but also high temperatures to habitat specific soil moisture demands (Table 8.21, Fig. 8.10). The habitats are more or less indifferent in their sensitivity against changing temperatures, but sensitive when changes in the soil moisture occur during the vegetation period. The magnitude of the water balance, which is

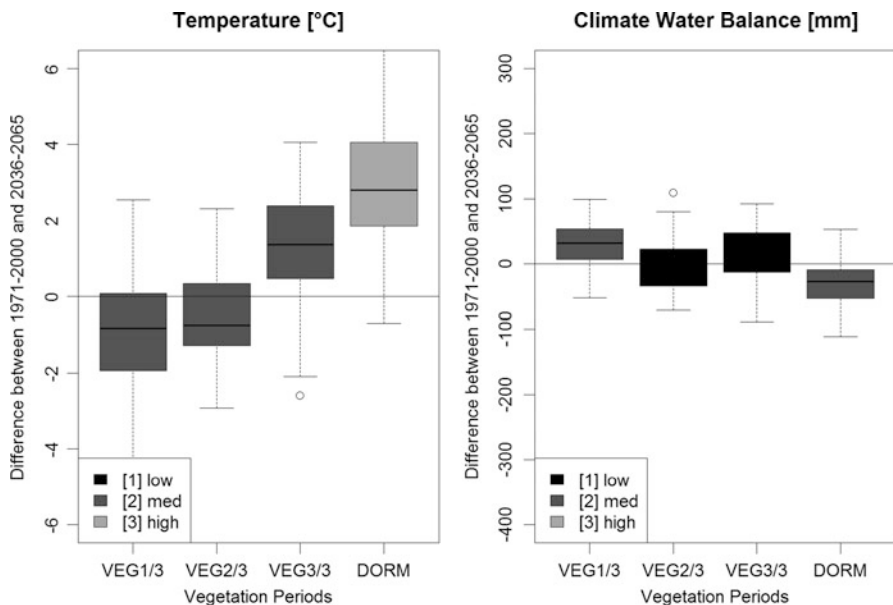


Fig. 8.11 Difference in exposure between periods 1971–2000 and 2036–2065 for parameters used in the Pannonian impact assessment

Table 8.22 Potential impact magnitude for the Pannonian region

Habitat type	VEG 1/3	VEG 2/3	VEG 3/3	DORM
Freshwater habitats	2	2	2	3
Grassland formations	2	2	1	2
Bogs, mires and fens	1	2	1	2
Rocky habitats	–	–	–	–
Forests	2	1	1	2

(1) low, (2) medium, (3) high magnitude of potential impacts

already low compared to the other regions, is notably increasing during the first 1/3 of the vegetation period and decreasing in the dormant period. The magnitude of the parameter temperature is knocking out to higher temperatures (Fig. 8.11). This leads to the highest overall potential impact magnitudes in the dormant period, whereas the other vegetation periods face lesser potential impact magnitudes (Table 8.22).

8.4 Conclusions

In HABIT-CHANGE the assessment of climate-induced impacts on habitats focused on a framework consisting of the sensitivity and the exposure which defined the potential impacts. The framework needs at least the following input data for the assessment of climate induced impacts on habitats:

- First of all, a list of all important **habitat types per biogeographical region** for which the assessment should be done. In the project the participating regional partners provided such lists of habitats.
- **Regional expert-knowledge** to evaluate the sensitivity criteria for the regional occurrence of the habitats. Within the project the evaluation was done by experts for the Alpine, Continental and Pannonian region covering all habitats occurring within the scope of the project.
- A **localised plant species list** to evaluate the ecological envelope for each habitat type which should be assessed. The participating investigation areas provided such species lists for their habitats.
- **Climate scenarios** to compare the conditions of the past with projected changes in the future subdivided into the four time segments (1/3, 2/3, 3/3 of the vegetation period and dormant period; see Chaps. 2 and 3).

The framework used categories and rules for the assessment instead of modelling approaches. This has the advantage of a simple framework that is transferrable to other biogeographical regions and can be understood and applied by regional partners. Moreover, just a minimum of local data (e.g. species list per habitat type) is required to yield a result representative to the supplying region or nature conservation area. With this minimum input information it is still possible to derive detailed maps of sensitivity and potential impact per season (see Fig. 8.12 for the example of the Biebrza National Park). Furthermore, studies concentrating on a broader range of habitats are less widespread. For example Renetzedler et al. (2010) used Ellenberg's indicator scheme to characterise the ecological envelope of habitats in a landscape and to compare them with climate scenarios using regression analysis. They concluded that natural habitats are more sensitive than strongly managed (e.g. agricultural) ones. Another example uses species distribution models to predict the sensitivity of habitats by using the range occupancy of the characteristic plant species (Normand et al. 2007). The authors project the highest sensitivity of *bogs, mires and fens* followed by *forests leaving rocky habitats* on the last position also indicated by the results of this chapter. However promising the results of the framework are, it does not incorporate the adaptive capacity of habitats into its approach like spatial planning studies try to do (e.g. Holsten and Kropp 2012; Rannow et al. 2010). Nevertheless, such studies focus on political boundaries in which habitats with high conservation values are only one part of the assessment. Therefore, it can be concluded that the presented approach can be a valuable tool by using this simple framework to assess the climate induced impacts on habitats.



Fig. 8.12 Exemplary set of maps for sensitivity and potential impact for the Biebrza National Park (Continental Region)

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