HABIT-CHANGE

adaptive management for protected areas

HABIT-CHANGE

Priority matrix impacts per region and habitat

07/2011

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1. Introduction, objective and method

1.1. Introduction

The “priority matrix impacts per region and habitats” is defined as Output 3.2.5 in the project application of HABIT-CHANGE. Its goal is to identify pressures and climate change effects of potential habitat changes in protected areas. The Output should include actual and anticipated effects. In addition information on the location of effects should be included. The Output will generalize results from investigation areas which are already documented (Output 3.2.2). This will help to define general guidelines for the adaptation of management plans (Action 5.3) and decision support for conservation management (Action 5.2).

Output 3.2.5 is presented as report including a priority matrix as table.

1.2. Objectives

Output 3.2.5 should provide a comprehensive overview on climate change impacts reported from investigation areas for habitats. Main aim is to:

- group habitats in a comprehensive way according to reported sensitivity,
- summarise and list actual as well as future impacts per habitat group reported from investigation areas and
- describe the most important impacts reported from investigation areas.

1.3. Method

Different sources have been used to compile the information for this report. Chapter 2 and 3 are based on a literature review (see Output 3.1.1). They will give a broader overview on the topic and allow for a comparison of the data from investigation areas with information provided on a more general scale.

The information on impacts per investigation area in chapter 4 is based on expert knowledge. It has been obtained by two queries from local experts. The first query was focused on existing problems and activities with negative effect on conservation status. These problems have already been reported in Output 3.2.2. Most of the existing problems are related to local land use or economic conditions, but there are also 60 problems that could clearly be linked to climate conditions. The later have been extracted from Output 3.2.2 for the compilation of the priority matrix impacts per region and habitats.

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The information has been obtained from:

- Balaton Upland National Park,
- Biebrza National Park,
- Danube Delta Biosphere Reserve,
- Flusslandschaft Elbe – Brandenburg Biosphere Reserve,
- Köros-Maros National Park,
- Natural Park Bucegi,
- Rieserferner Ahrn Nature Park,
- Secovlje Saline Nature Park,
- Triglav National Park and
- Vessertal Thuringian Forest Biosphere Reserve.

The second inquiry focused on potential future effects of climate change. These impacts have been presented as posters and discussed at the 3.HABIT-CHANGE Partner Meeting in April 2011. The posters identified the most important existing conflicts and problems as well as potential future pressures and impacts of climate change for each Natura2000 habitat type in the investigation areas. This way, more than 100 potential future impacts have been individually reported.

Posters have been provided for:

- Balaton Upland National Park,
- Danube Delta Biosphere Reserve,
- Flusslandschaft Elbe – Brandenburg Biosphere Reserve,
- Natural Park Bucegi,
- Rieserferner Ahrn Nature Park,
- Secovlje Saline Nature Park,
- Triglav National Park and
- Vessertal Thuringian Forest Biosphere Reserve.

For the analysis of impacts per habitats the information was processed in three steps:

1. The current problems and potential future impacts reported from investigation areas were listed per Natura2000 habitat type. The different information from investigation areas regarding habitat types was homogenized and the impacts were classified. More than 160 problems and potential future impacts have been individually reported. This information was grouped in 7 impact classes: seasonality, sea level rise, hydrology, soil, extreme events, CO^2 Concentration and Cumulative Effects. The impact classes are linking impacts to climate change exposure. The impacts classes are described in chapter 5.

2. The reported Natura2000 habitat types from investigation areas were aggregated to habitat groups according to their sensitivity and eco-physiological background. The system of Natura2000 habitat types was used for the classification (see Interpretation manual of European Union Habitats, European Commission – DG EUR27 2007). Due to the differences in sensitivity, the classification in this report is using different levels of the Natura2000 systematics (e.g. 01 COASTAL AND HALOPHYTIC HABITATS, but 31 Standing water and 32 Running water, see Table 1).

3. The final matrix was compiled showing impact classes per habitat group. The impacts could be prioritized using the number of habitat groups affected. In addition, also the most affected habitat groups could be identified by the number of relevant impacts per group.

According to the application form it was also planned to map potential habitat changes in protected areas in Output 3.2.5. This intention was not considered feasible in this analysis. There are other Outputs in HABIT-CHANGE directly concerned with spatial explicit analysis in the investigation areas (e.g. Output 4.3.5, 4.6.1). Therefore, Output 3.2.5 was deliberately focused on the aggregation of results from case studies.

The results for HABIT-CHANGE investigation areas are based on expert knowledge. Modelling results for future climate scenarios are analysed in Action 4.4 - 4.6. and will be available in due course. This analysis will most probably provide new insights in impacts of climate change not yet considered in investigation areas. Hence, the priority matrix only shows a fraction of potential impacts on habitats. To provide a broader basis and enable a scientific discussion literature data were used to generate an overall perspective for future climate changes in Europe.

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2. Overview on habitats groups

The habitat types from investigation areas were aggregated into 14 habitat groups (see Table 1) using the classification scheme according to the Interpretation manual of European Union Habitats (European Commission – DG EUR27 2007).

Table 1: Habitat Groups used for the analysis (incl. Number of habitat types listed for this group in EEA-Database of Natura2000 sites in Europe and in the investigation areas)

(Source: own preparation, 2011)

Habitat Group	EEA-Database	HABIT-CHANGE Investigation areas	
	No. habitat types	No. habitat types	Count of habitats
01 COASTAL AND HALOPHYTIC HABITATS	28	12	18
21 Sea dunes of the Atlantic, North Sea and Baltic coasts (+ Black Sea)	10	4	4
23 Inland dunes, old and decalcified	4	2	3
31 Standing water	10	4	29
32 Running water	9	5	23
40 TEMPERATE HEATH AND SCRUB	12	7	17
61 Natural grasslands	9	5	16
62 Semi-natural dry grasslands and scrubland facies	12	6	34
64 Semi-natural tall-herb humid meadows	6	6	39
65 Mesophile grasslands	3	2	33
70 RAISED BOGS AND MIRES AND FENS	12	6	40
80 ROCKY HABITATS AND CAVES	14	11	42
91 Forests of Temperate Europe	37	17	91
94 Temperate mountainous coniferous forests	3	2	12
Total	**169**	**89**	**401**

Habitats are complex entities because of their dynamic nature. Modelling future distribution of habitat types should not be exclusively based on their current definitions and mapped distributions, but also based on their characteristic plant species (Bittner et al. 2011). Therefore, existing species distribution modelling literature (Normand et al. 2007; Bittner et al. 2011; Milad et al. 2011; Pompe et al. 2010) was assessed to gain an overall perspective of the impact of different habitat groups to the expected 21st century climate change at European level (see Table 2). The most widely used prediction method of species diversity is to model species niches from point observations and project this models forward using future climate scenarios like the IPCC B2 and A2 scenarios. The resulting changes in individual species ranges than can be summed to predict diversity changes in habitat groups (Algar et al. 2009).

Table 2: Habitat groups under IPCC B2 and A2 scenarios

(Source: modified after Normand et. al 2007; B2/A2: calculated values (after Normand et.al 2007) ranging from -100% to infinity; Impact: magnitude to which a species within the habitat groups are affected (either adversely or beneficially) by climate change at an European scale)

Habitat groups	B2	A2	Impact
01 COASTAL AND HALOPHYTIC HABITATS	-1	-5	low
21 Sea dunes of the Atlantic, North Sea and Baltic coasts 23 Inland dunes, old and decalcified	-21	-34	medium
31 Standing water 32 Running water	-16	-36	medium
40 TEMPERATE HEATH AND SCRUB	-	-	
61 Natural grasslands 62 Semi-natural dry grasslands and scrubland facies 64 Semi-natural tall-herb humid meadows 65 Mesophile grasslands	-16	-32	medium
70 RAISED BOGS AND MIRES AND FENS	-48	-65	high
80 ROCKY HABITATS AND CAVES	-12	-24	low
91 Forests of Temperate Europe 94 Temperate mountainous coniferous forests	-26	-48	high

Various characteristic species for the European habitats were predicted to be negatively affected by climate change across Europe, although the species responses vary among the different habitat groups (Normand et al. 2007). The number of endangered species and projected range loss in habitat groups induce a higher impact on the habitats (Table 2). Thus, habitat specific management and the possibilities for migration through the landscape can decline the impact of climate change on the conservational status of habitats (Normand et al. 2007; Pompe et al. 2010).

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3. Overview on impacts classes

The identification of impacts of climate change on the different habitats have been prepared based on extensive literature review of previous outputs within the HABIT-CHANGE project (Output 3.1.5, Output 4.3.3 and the work prepared by Sándor Csete on the impacts of climate change in Hungary).

In general, altering environmental conditions leads to

- Decreasing diversity and increasing vulnerability
- Effects on ecosystem values and services
- Changing species community structures (increasing abundance of generalist species, extinction of species, development of new biocoenosis)
- Habitat fragmentation
- Changes in macro-climate
- Changes in timing of life history events or phenology
- Changes in species distribution areas

The following tables are grouped according to their main impact class and give an overview on impacts to flora (1) and fauna (2), general impacts at the landscape level (3), special impacts related to wetlands and aquatic dominated landscapes (4) and finally impacts on habitats, ecosystems or the overall biodiversity (5).

Table 3: Seasonal Impacts

(Source: own preparation, 2011)

Pressure	Flora [1]	Fauna [2]	Terrestrial [3]	Aquatic [4]	Ecosystem [5]
Increasing annual mean temperature	- Change of species' distribution range - Increasing NPP (grasslands, forests etc.) - Deteriorating water balance of forests	- Changes species' distribution area - Increase of pests	- Damage to crops / cultural landscapes (cereals)	- Increasing net primary production (NPP) - Water bodies' temperatures increase - Loss of wetlands	- Higher evapotranspiration rate - Species' extinction - Alterations in ecosystems structure and functions
Increasing winter temperature	- Changes of species' distribution area	- Changes of species' distribution area - Increasing winter survival of insect species and pests	- Decline of glaciers - Less snow cover in winter	- Greater chance of persistence of alien or migration species	
Increasing summer temperature	- Increasing relative drought stress	- Increasing abundance of pest insect species - Increasing range and abundance of insect species		- Change in species dominance, also related to water level influence	- Decline in typical soil natural communities
Decreasing frequency of frosty days in autumn and in the spring	- Deteriorating water balance of forests		- Erosion	- Higher persistence of alien propagules	
Increasing number of frosty days / Longer frosty periods in winter	- Increased frequency of ice-break - Desiccation of winter active plant species	- Decreasing winter survival of insect species hibernated in imago stage			
Early / late frost	- Increasing mortality of plant species due to frosts - Destruction of shoots and flowers (in a less severe form, it can prevent flowers to set)		- Damage to fruit trees / plantations		
Number of sunny hours / Decreasing cloud cover (stronger radiation – higher evapotranspiration)	- Deteriorating water balance of forests		- Changes in water- and energy balance of lands covered by vegetation	- Increased evaporation - dangerous decrease of water level	

Pressure	Flora [1]	Fauna [2]	Terrestrial [3]	Aquatic [4]	Ecosystem [5]
Increasing length of vegetation period	- Altering phenology (budding starts earlier) - Inappropriate pollination by insect vectors - Increasing vulnerability by early frosts	- Increasing number of generation of insects - Increasing abundance of insects		- easier establishment of thermophilous species	
Altering annual rain distribution	- Decreasing fitness of summer flowering plants - Disappearing intolerant species to water cover - Altering phenology of plant species	- Altering phenology of insect species		- Higher and long lasting seasonal high water table in spring	

Table 4: Hydrological Impacts

(Source: own preparation, 2011)

Pressure	Flora [1]	Fauna [2]	Terrestrial [3]	Aquatic [4]	Ecosystem [5]
Low water table	- Appearance of drought tolerant plant species - Invasion of alien species & weeds - Canopy closure	- Decreasing mortality rate in insect populations hibernated in the soil		- Eutrophication - Alteration in groundwater levels	- Habitat desiccation
Decreasing mean precipitation	- Increase in annual and biannual plant species - Decrease in perennial grasses - Drying out process of cool-climate tree species (e.g. spruce, beech, sessile oak) - Deteriorating water balance of forests	- Increasing range of xerophilous insect species - Decreasing mortality rate due to fungi infection of insects - Pressure on amphibian species	- Increasing probability of wildfires	- Loss of wetlands - Loss of aquatic species - Decrease in surface water bodies flow regimes - Increase in concentrations of pollutants - Alteration of groundwater cycles	- Decreasing volume of nutrient cycle - Decreasing litter decomposition
Increasing mean precipitation	- Disappearing plant species intolerant of long lasting water cover	- Structural changes of insect assemblages (disappearing species laying eggs in the soil)		- Seasonal high water table	

Pressure	Flora [1]	Fauna [2]	Terrestrial [3]	Aquatic [4]	Ecosystem [5]
Decreasing snowfall / snow cover			- Decline of glaciers - Less winter snow cover		
Thick snow layers	- Decreasing negative effects of extreme frosts Altering phenology of plant species Increasing ice-break damage	- Altering phenology of insect species		- Long lasting snow cover	
Longer rainless periods	- Disappearing plant species sensitive to the lack of precipitation - Increasing abundance of tolerant species to the lack of precipitation	- Pressure on amphibian species		-increased dominance of species adapted to low water levels or with amphiphytic character -decrease of typical hydrophytic species	

Table 5: Impacts of extreme events

(Source: own preparation, 2011)

Pressure	Flora [1]	Fauna [2]	Terrestrial [3]	Aquatic [4]	Ecosystem [5]
Frequent meteorological anomalies and extremities	- Increasing mortality/damage to reproductive organs of plant species due to frosts - Disappearing plant species sensitive to low mean temperature	- Decreasing winter survival of insect species hibernated in imago stage - Altering phenology of insect species		- Higher and long lasting seasonal high water table in spring	
Heavy rains			- Erosion	- Deteriorating surface water balance (contribution to floods) - Increased leakage of pollutants into groundwater	
Flooding events	- Disappearing plant species intolerant of long lasting water cover		- Increased river discharge causing landscape alteration	- Increased river discharge	

Pressure	Flora [1]	Fauna [2]	Terrestrial [3]	Aquatic [4]	Ecosystem [5]
Heat waves	- Severe damage on plants and vegetation - Leaf burning - Limited pollination resulting in imperfect set of fruit	- Severe damage on species unable to protect themselves from too high temperature - Increasing mortality of desiccation intolerant insect species (butterflies)			
Drought	- Appearance of drought tolerant species - Disappearing specialist species Invasion of weeds & alien species - Increasing inter-annual compositional variability - Reduction in NPP of tree species	- Increasing abundance of pests - Extinction of amphibian species	- Alteration of cultural landscapes - Erosion - Reduction of field moisture	- Loss of wetlands - Lowering water table - Less water retention - Eutrophication	- Habitat desiccation - Increasing NPP wetlands - Decreasing biomass in dry habitats - Changing trophic relations between plants and herbivores - Increasing fine-scale (compositional, structural, functional) heterogeneity of vegetation
Wildfires	- Facilitation of weed and alien species spread - Alteration of species composition - Long regeneration periods after wildfire	- Extinction of insect populations strongly related to vegetation	- (temporary) Landscape alteration - Erosion	- Excessive nutrients can run into wetlands increasing biomass production	- Modification of species composition, process of regeneration as well as material cycles, profoundly altering ecosystem conditions in the receptive habitat types
Strong wind blows	- Increasing wind damage in tree stands - Increasing probability of long-distance dispersal of species - Decreasing pollination success in case of insect pollinated flowers	- increasing probability of long-distance dispersal of insect species			

4. Matrix on impacts per habitat

The matrix on impacts per habitat is identifying actual climate related problems and expected impacts of future climate change in the investigation areas of HABIT-CHANGE. The matrix has been compiled for Natura 2000 habitat types represented in the HABIT-CHANGE investigation areas. To provide a comprehensive overview the habitat types have been grouped in classes based on an appraisal of their eco-physiological sensitivity (see Table 1).

The appraisal of impacts is based on expert knowledge from local experts. The effects are grouped in 7 categories. These categories are described in more detail in Chapter 5.

The information shown in Table 6 and 7 has been further aggregated to identify the most important impacts reported from investigation areas. This is geared towards an identification of the most important impacts of climate change on habitats in Central Europe. Even though the information is not representative for all habitat types, the matrix gives a first idea of the impacts considered as most important by conservation management at the moment. This is a valuable addition to model based assessments like Normand et al. (2007).

To prioritize climate change impacts the different effects have been counted and summarized. The impacts can be ranked according to their number (see Table 8).

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Table 6: Matrix on impacts per habitat in investigation areas (Part 1)

(Source: own preparation, 2011)

	01 COASTAL AND HALOPHYTIC HABITATS	21 Sea dunes of the Atlantic, North Sea and Baltic coasts (+Black Sea)	23 Inland dunes, old and decalcified	31 Standing water	32 Running water	40 TEMPERATE HEATH AND SCRUB	61 Natural grasslands
Seasonality				- changes in temperature regime influencing development pattern of aquatic organisms and related food-web relationships	- changes in temperature regime influencing development pattern of aquatic organisms and related food-web relationships	- temperature pattern changes - disappearance of species depending on vernalization and simplification of the biocenosis structure	- worm summers and drought - replacement of currently dominant species by a more thermophilous species; - changes in phenology: late successional plant communities, like Carex curvula alpine grasslands, may resist climatic changes for long periods due to clonal growth strategy (esp. 6110, 6170)
Hydrology	- drying out - changes in flooding regime (frequency and period of flooding) and salinity	-water level changes (decline of groundwater)		- change in water regime - fluctuation of water levels - drying out	- changes in flooding regime (frequency and period of flooding) -changes in frequency and period of drought - drying out		
Soil	- accumulation of organic material (favourable for the appearance of colonial plant species in dry seasons) - erosion of costal habitats			- accumulation of organic material		- torrents associated with erosion and ruptures	- erosion - increase the C/N ratio in the biomass, would lead to reduced food quality for herbivores and to alterations in decomposition processes
extreme events				-changes in frequency and period of drought - changes in shore ecotone conditions	-changes in frequency and period of drought or extreme floods - irreversible alteration in floodplain ecotonal systems and river bed modification	- Pinus mugo (mezo-mezohygrophyte and psichotermophyte) can be affected	
Sea Level Rise	- decrease of present abundance of habitat types (esp. 1140)						

	01 COASTAL AND HALOPHYTIC HABITATS	21 Sea dunes of the Atlantic, North Sea and Baltic coasts (+Black Sea)	23 Inland dunes, old and decalcified	31 Standing water	32 Running water	40 TEMPERATE HEATH AND SCRUB	61 Natural grasslands
	- decrease of present abundance of habitat types - decrease of present abundance of habitat types - Shift from 1420 to 1310 HT is possible						
CO_2 Concentration				Changes in pH-regime of still waters with acidic character	- aquatic plants relying primarily on CO_2 as inorganic carbon source will increase productivity		
cumulative effects		- dispersed habitation		- changes in aquatic biocoenoses, including the effects of invasive and– so far –alien species, both floral and faunal elements	- changes in aquatic biocoenoses, including the effects of invasive and– so far –alien species, both floral and faunal elements	- succession sequences	- disappearance of species sensitive to drought, high temperature and eutrophication - succession sequences - changes in species composition: increase scrub abundance, in particular expansion of Pinus mugo; many alpine species will lose major parts of their habitats (esp. 6110, 6150, 6170) - changing environmental conditions will favour invasion and expansion of alien species with a wider environmental tolerance, short juvenile periods, and long distance dispersal; - changes in species composition: migration corridors for climate warming-induced upward migrations of alpine grassland species will be restricted to "stepping stones" at stable and rocky ridges (esp. 6110, 6150, 6170)

Table 7: Matrix on impacts per habitat in investigation areas (Part 2)

(Source: own preparation, 2011)

	62 Semi-natural dry grasslands and scrubland facies	64 Semi-natural tall-herb humid meadows	65 Mesophile grasslands	70 RAISED BOGS AND MIRES AND FENS	80 ROCKY HABITATS AND CAVES	91 Forests of temperate Europe	94 Temperate mountainous coniferous forests
Seasonality	- increasing proportion of xerophytic insect species		- species shifts caused by temperature increase and changes in precipitation pattern	- species shifts caused by temperature increase and changes in precipitation pattern	- disappearance of species depending on vernalization - permafrost melting and glacier retreatment	- shifts and loss of species relevant for habitat status caused by temperature increase and changes in precipitation pattern	
Hydrology	- increasing frequency and abundance of drought tolerant plant species	- drying out - changes in flooding regime (frequency and period of flooding)	- changes in flooding regime (frequency and period of flooding) - changes of ground water levels	- changes of ground water levels		- drying out - water and drought stress - changes in groundwater level caused by temperature increase and changes in precipitation pattern - changes in flooding regime (frequency and period of flooding) -changes in frequency and period of drought	
Soil	- decreasing N mineralization	- mineralization of peat - accumulation of organic material	- erosion	- erosion - soil leaching - mineralization of peat - accumulation of organic material and litter (esp. 7210)	- permafrost melting - erosion	- mineralisation of peat (esp. 91E0)	
extreme events		- wildfire (peat fire)		- wildfire (peat fire)	- avalanches	- drought - loss of habitats because of flood protection (esp. 91E0, 91F0)	- damages by storm - damages by pests
Sea Level Rise							
CO^2 Concentration	- fertilization		- fertilization				

	62 Semi-natural dry grasslands and scrubland facies	64 Semi-natural tall-herb humid meadows	65 Mesophile grasslands	70 RAISED BOGS AND MIRES AND FENS	80 ROCKY HABITATS AND CAVES	91 Forests of temperate Europe	94 Temperate mountainous coniferous forests
cumulative effects	- diversity loss - succession sequences	- increasing net primary production - canopy closure - invasion of alien species - increasing abundance of generalist plant and animal species at the expense of specialists (disappearance of specialists) - spontaneous spread of shrubs and trees - spread of reed (esp. 6410) - disappearance of habitat type (esp. 6460)	- disappearance of habitat type (esp. (6510) - succession sequences - invasion of alien species	- succession sequences - increasing net primary production - canopy closure - invasion of alien species - increasing abundance of generalist plant and animal species at the expense of specialists (disappearance of specialists) - changes of plant communities by increasing tree cover which will diminish bryophyte cover (esp. 7140) - changes of plant communities by increasing tree cover which will diminish bryophyte cover (esp. 7110*, 7230) - spread of Cladium mariscus (esp. 7210) - spread of reed (esp. 7210)	- succession sequences - loss of the colder climatic zone at higher altitudes and linear shift of all remaining vegetation belts upslope because mountain tops are smaller than its bases, present vegetation belts in high elevations will occupy smaller areas, while corresponding species will suffer from population declines and thus may become more vulnerable to genetic and environmental pressure	- invasion of alien species - increasing abundance of generalist plant and animal species at the expense of specialists (disappearance of specialists) - canopy opening (esp. 91M0) - decreasing health condition of trees - more frequent gradation of pests - Carpinion forests (currently restricted to the colline altitudinal belt) will expand into areas which are currently occupied by submontane and low-montane Fagus forests changes in wood stock – Fagus: - 76 %; acceleration of succession will allow Fagus to establish and increase in higher altitudes (esp. 91K0) - loss of space for habitat type (esp. 9190, 91E0, 91F0)	- shifts and loss of species relevant for habitat status - Succession sequences

Table 8: Priority matrix of impacts per habitat groups

(Source: own preparation, 2011)

Habitat Group	Cumulative Effects	Hydrology	Soil	Seasonality	Extreme Events	Sea Level Rise	CO_2 Concentration	Impacts per Habitat
01 COASTAL AND HALOPHYTIC HABITATS		2	2			4		**8**
21 Sea dunes of the Atlantic, North Sea and Baltic coasts (+Black Sea)	1	1						**2**
23 Inland dunes, old and decalcified								**0**
31 Standing water	2	3	1		1		1	**8**
32 Running water	2	3		2	1		1	**9**
40 TEMPERATE HEATH AND SCRUB	1		1	2	1			**5**
61 Natural grasslands	5		2	3				**10**
62 Semi-natural dry grasslands and scrubland facies	2	1	1	1			1	**6**
64 Semi-natural tall-herb humid meadows	7	2	2		1			**12**
65 Mesophile grasslands	3	2	1	1			1	**8**
70 RAISED BOGS AND MIRES AND FENS	9	1	4	1	1			**16**
80 ROCKY HABITATS AND CAVES	2		2	2	1			**7**
91 Forests of temperate Europe	7	5	1	1	2			**16**
94 Temperate mountainous coniferous forests	2				2			**4**
Habitat Groups per Impact	**43**	**20**	**17**	**13**	**10**	**4**	**4**	

In the priority matrix the impacts are ranked as follows:

1. Cumulative Effects
2. Hydrology
3. Soil
4. Seasonality
5. Extreme Events
6. Sea Level Rise
7. CO_2 Concentration

In addition to the habitat groups per impact the number of impacts per habitat group can give an indication of the sensitivity of habitat groups (see Table 9).

Table 9: Ranking of habitat groups according to the number of effecting impacts

(Source: own preparation, 2011)

Habitat group	No. of impacts
70 RAISED BOGS AND MIRES AND FENS	16
91 Forests of temperate Europe	16
64 Semi-natural tall-herb humid meadows	12
61 Natural grasslands	10
32 Running water	9
31 Standing water	8
01 COASTAL AND HALOPHYTIC HABITATS	8
65 Mesophile grasslands	8
80 ROCKY HABITATS AND CAVES	7
62 Semi-natural dry grasslands and scrubland facies	6
40 TEMPERATE HEATH AND SCRUB	5
94 Temperate mountainous coniferous forests	4
21 Sea dunes of the Atlantic, North Sea and Baltic coasts (+Black Sea)	2
23 Inland dunes, old and decalcified	0

5. Details on impacts per habitats

The impact classes are linking impacts to climate change exposure and were grouped depending on the 160 individually reported problems and potential future impacts (see Output 3.2.2). The following chapter will give more detailed information on the described impacts in the priority matrix (see Table 6 and Table 7) and are listed according to their ranking in Table 8.

5.1. Cumulative Effects

An alternating climatic environment leads to complex interaction of abiotic and biotic pressures which are expressed as 21 different cumulative effects. These effects describe impacts like the shift in species composition and abundance, community structure, successional changes and land use changes.

Species composition and community structure

The species composition and its community structure form constituent elements of habitats. Therefore changes in species composition and community structure will also result in changing habitat structure and quality. However, the magnitude of impacts varies depending on the species ecological amplitude in combination with the species distribution range and dispersal mechanisms (Normand et al. 2007; Milad et al. 2011; Bittner et al. 2011). Highly specialized species with small ecological amplitudes and a wide distribution range, like “01 COASTAL AND HALOPHYTIC HABITATS” species are less affected by cumulative effects than forest species, where abiotic impacts like seasonality induce a shift in species composition and community structure. Overall, changes in community structure by means of succession sequences is one of the most named impact on the habitats in the HABIT-CHANGE investigation areas.

Invasion of aliens

In an altering climatic environment, species holding invasive potential could become more competitive due to their characteristics like short regeneration and high migration rates and a higher proportion of introduces species or species escaping from cultivation will be able to survive (Milad et al. 2011). Half of the habitat groups like forest or grassland, but also aquatic and semi-aquatic habitats, are facing the problem of invasive species mainly in combination with altering community structures.

Land use changes

Habitat types in cultural landscapes (like forest and grassland habitat types) are largely driven by their applied current and historical land use (Renetzeder et al. 2010). Changes in the land use pattern like intensification, extensification and abandonment are also changing species composition and community structure patterns (Berry et al. 2006). The loss of space for habitats in the “91 Forest of temperate Europe” group was noted in Table 7 but can be predicted for grassland habitats.

5.2. Hydrology

Hydrological processes of greatest relevance in climate change impacts are related to condensation, precipitation, runoff, evapotranspiration and transpiration. Topographic features of the landscape such as altitude, slope and aspect and as well as the characteristics of the soil also influence hydrological processes. For more details in hydrological processes see Output 4.4.2.

Changes in water regime

Changes in precipitation intensity and variability due to climate change are the most significant factors affecting the water regime, which can be noted as most important impact group in HABIT-CHANGE. The water regime is the prevailing pattern of water flow over a given time consisting of surface water, ground water inflow and precipitation and defines the flooding regime and water levels. Changes in flooding regime and water levels are the main impacts in all freshwater habitat groups, “70 RAISED BOGS and MIRES AND FENS” habitat types, “64 Mesophile grasslands” and in some forest habitat types.

Drying out

In addition to water level fluctuations, also the expected decrease of precipitation during vegetation period will have an impact on habitats, especially in areas characterised at present by semi-arid climate. Increasing mean temperatures will reinforce the effect, especially in grasslands and forests.

5.3. Soil

Impacts of climate change need to be considered on different time scales. Most changes are gradual and take considerable time to show effects while others are abrupt. Rapid changes of soil conditions like erosion or landslides are in most cases resulting from extreme weather events like heavy rains. In the context of this report such impacts are classified as extreme events (see Chapter 5.5). Effects on soil moisture and groundwater level are considered as impact on hydrology (see Chapter 5.2).

Most impacts reported by local experts are of gradual nature. These effects are not easy to detect but they are of considerable importance as they are not reversible once occurred. Changes in soil have further effect on plant cover, biomass production, water levels and quality as well as atmospheric CO_2 concentration.

The impacts considered in the HABIT-CHANGE investigation areas can be classified in changes on soil structure, nutrients and chemistry.

Impacts on soil structure

Especially increasing rates of decomposition and mineralization in peat land and hydromorphic soils (e.g. alluvial forest) are considered important in HABIT-CHANGE. Rising temperatures and drought situation in summer will be amongst the most important pressure for this impact.

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In coastal and halophytic habitats as well as freshwater habitats also the accumulation of organic material (e.g. leaf litter) has been reported. This is especially important for raw and nutrient pure soils (e.g. silt banks). Fauna and flora depending on these habitat conditions (e.g. for spawning) will be negatively affected. In this context also erosion of soils is considered a problem. This is true for alluvial areas were sediments are deposited as well as running and standing water where input of sediments will decrease water quality. But foremost this impact will decrease soil cover and hence primary production. Increasing intensity of rain and decomposition as well as decreasing plant cover and rising temperatures will add to this problem. All in all the resilience against physical and chemical soil degradation will be diminished. For coastal and halophytic habitats also the erosion of coastlines due to sea level rise is listed.

Especially in alpine climates of Central Europe the gradual disappearance of permafrost is reported as major impact. Melting of permafrost as well as increasing frequency and intensity of heavy rains, changes snow cover, freeze and thawing cycles as well as shrinking and swelling cycles will compromise the structural integrity of alpine and montane hillsides. This will change habitat conditions of rocky habitats and caves.

Impacts on soil nutrients

One of the very slow impacts is effecting nitrogen (N) mineralization of soils. Whilst mineralization of peat lands and hydromorphic soils is expected to increase the mineralization of N in in semi-natural dry grasslands and scrubland facies is expected to decrease. This is mostly related to drought situation and water shortage in summer, when biological decomposition will be reduced. In natural grasslands also the balance between carbon stocks and nitrogen (C/N ratio) are expected to change. This ratio is most important for decomposition processes and alterations would lead to reduced food quality for herbivores.

Impacts on soil chemistry

Increasing temperatures and changes in precipitation will affect chemical weathering of soils. The increase of hydrolysis, cheluviation and ferrolysis (Brinkman & Sombroek 1996) will result in soil leaching especially from raised bogs, mires and fens but also from other habitat types.

In addition to these impacts several other effects on soils are discussed in the literature and need to be considered for different habitats. Especially in arid conditions of the Pannonia basin soil salinization caused by increasing temperatures and evaporation can be expected.

In HABIT-CHANGE 17 different impacts on soil have been reported. They are relevant for 10 of 14 habitat groups. It needs to be considered one of the most important consequences of climate change on habitat level.

5.4. Seasonality

Changing pattern in means and maxima of temperature, precipitation, frost and snow days are leading to shifts in the vegetation period thus also in phenology. Especially trees are negatively

affected by changes in seasonality (Milad et al. 2011): Elevated winter temperatures can result in disproportionally high losses of stored carbohydrates due to increased respiration. The activation of metabolism processes during dormancy could lead to physiologically stressful conditions. Also late frost periods may cause severe damages to trees.

Zonal habitat types like forests, scrubs and grasslands are more vulnerable to seasonality impacts and are more likely to be negatively affected by climate change (Csete 2010). This consideration is also reflected in the noted impacts on terrestrial habitat groups in HABIT-CHANGE.

5.5. Extreme Events

Extreme weather events are considered as important pressure for many habitats in HABIT-CHANGE. They will result in direct and indirect impacts. These abrupt changes will profoundly disturb habitat conditions like species composition, habitat structure and material cycles of habitats.

Direct impacts of Extreme Events documented with relevance for habitat types in HABIT-CHANGE are:

Heavy Rains

Increasing frequency and severity of heavy rains will affect surface runoff and erosion. Diminished infiltration in soils (e.g. due to drought stress) will add to this problem and contribute to more frequent and severe flood events.

Floods

Floods are resulting from heavy and enduring rain. There is a considerable difference between flash floods and river floods. Flash floods are the result of relatively short and heavy rain events, causing severe damage near to the rainfall area, whereas river floods are consequences of long and enduring rains in catchment areas. River floods can produce damage to habitats far away from rainfall areas. The effects are related to duration and frequency of inundation as well as erosion and structural changes. In HABIT-CHANGE changes in frequency and period of flooding are projected for several habitat types. This impact is not only limited to aquatic and wetland habitats but will also affect forest and grassland habitats.

Drought

For a lot of areas in Central Europe climate models project a decrease of precipitation in spring and even more frequent in summer month. Prolonged periods of precipitation below average will effect river runoff, groundwater recharge as well as tables and cause deficiency in water supply. Increasing mean temperatures will increase evaporation and enhance this effect. Disturbance due to water stress and severe drought will impact especially forest habitats, but also shallow water bodies, e.g. in floodplains.

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Wildfire

“Heatwaves together with severe drought and increasing mean temperature can result in more frequent wildfires.

These fires will probably occur in xeric forest types more commonly than in mesic or hydric ones, especially those in transition climatic situation at the border of their distribution area, e.g. forest-steppe communities on the Great Hungarian Plain (Czucz et al. 2007). Wildfires can modify species composition, process of regeneration as well as material cycles, profoundly altering ecosystem conditions in the receptive habitat types. On peatland, wildfire can mobilize excessive amount of soluble mineral decomposing peat depositions and can facilitate weed and invasive species spread” (Csete 2010).

Storm

High wind velocities and strong wind blows are considered a problem for forest habitats. They will result in storm-felled timber and change habitat structure and species composition.

Indirect effects of Extreme Events documented with relevance for habitat types in HABIT-CHANGE are:

Pests

Diseases and insect pests like bark beetle are foremost considered a problem for forest habitats. They will be the result of drought and water stress situations as well as storm.

Extreme events are considered a problem for 8 of 14 habitat groups in HABIT-CHANGE.

5.6. Sea Level Rise

Global sea level variability due to changes in the water mass in the oceans and variations in its density as well as local and regional effects define the local sea level rise. The mean sea level variability around Europe is influenced by the North Atlantic Oscillation (Tsimplis & Shaw 2008). Increased flooding and permanent inundation of low-lying coastal areas, increased erosion of beaches and cliffs and degradation of costal habitats are the major impacts expected (Hinkel et al. 2010).

Habitat types in HABIT-CHANGE impacted by Sea Level Rise can be found on the costs of the Adriatic and Black Sea. The main impact is related to the decrease of suitable habitats for “01 COASTAL and HALOPHYTIC HABITATS”. Although, it has to be noted that sea level rise trends vary along the Adriatic coasts and local coastal flooding can be influenced by e.g. storms or other synoptic meteorological forcing (Juračić et al. 2009).

5.7. CO_2 Concentration

CO_2 concentration in the global atmosphere is considered a major driver of climate change. In addition, CO_2 concentration also has an effect on photosynthesis and biomass production. Increasing CO_2 concentrations are generally considered to have a fertilizing effect on plant growth. This is especially relevant for tree growth and agricultural production, even though the fertilizing effect could also be counteracted by other effects such as drought stress (e.g. Körner et al. 1992; Gedalof & Berg 2010).

In HABIT-CHANGE CO_2 concentration is considered especially relevant in relation to forests habitats in alpine environments of Central Europe. But there are also other effects that need to be taken into account in relation to soil. Rising CO_2 levels can interact with chemical weathering and soil leaching. Further effects like changes in pH of sea water have not been considered relevant for the project. However, possible changes in pH may influence less well buffered environments like lakes in silicate rock regions, and may influence the composition of aquatic organisms, e.g. those with a preference of CO_2 as a source of inorganic carbon for photosynthesis.

6. Conclusion

For this Output more than 110 current and future problems related to the effects of climate change have been reported from HABIT-CHANGE investigation areas. The impacts have been classified in 7 categories and related to 14 habitat groups. The habitat groups comprise Natura2000 habitat types on different levels of the Natura2000 systematics. Not all Natura2000 habitat types are covered in HABIT-CHANGE.

The results from his analysis are not representative, but will give an indication on major impacts relevant for HABIT-CHANGE and Natura2000 areas in Central Europe. The habitat group considered to be most affected by impacts of climate change are:

1. RAISED BOGS AND MIRES AND FENS followed by
2. Forests of temperate Europe and
3. Semi-natural tall-herb humid meadows.

This result reflects conclusions from various authors (e.g. Csete 2010, Renetzeder et al. 2010) that zonal habitat types like forests are more vulnerable to climate change impacts than highly specialized habitats like “01 COASTAL AND HALOPHYTIC HABITATS” or “80 ROCKY HABITATS AND CAVES”. The ranking differences (see Table 10) between the impact magnitude derived from species distribution models (see Chapter 2) and the impact analysis done in this report can be explained due to the fact that habitats are complex entities. The habitat types are not only characterized by their specific species compositions, community structures and local climatic conditions but are further influenced

by abiotic conditions like soil type. Therefore grassland habitats show the highest number of impacts, whereas the modelling indicates medium magnitude of climate change impacts.

Table 10: Comparisons of impact magnitude from literature vs. overall impacts in HABIT-CHANGE

(Source: own preparation, 2011)

Habitat groups	Impact Literature	Impact Analysis
91 Forests of Temperate Europe 94 Temperate mountainous coniferous forests	high	20
70 RAISED BOGS AND MIRES AND FENS	high	16
61 Natural grasslands 65 Mesophile grasslands 64 Semi-natural tall-herb humid meadows 62 Semi-natural dry grasslands and scrubland facies	medium	36
31 Standing water 32 Running water	medium	17
21 Sea dunes of the Atlantic, North Sea and Baltic coasts 23 Inland dunes, old and decalcified	medium	2
01 COASTAL AND HALOPHYTIC HABITATS	low	8
80 ROCKY HABITATS AND CAVES	low	7
40 TEMPERATE HEATH AND SCRUB		5

Due to the geographic distribution and the focus on terrestrial ecosystems in HABIT-CHANGE Sea dunes of the Atlantic, North Sea and Baltic coasts (+Black Sea) as well as old and decalcified inland dunes are reported as less affected.

Most habitat types are affected by cumulative effects of climate change. The complex interaction of abiotic pressures like climate change with biotic driving forces like intra- and interspecific competition will result in diverse changes. They can affect species composition, species abundances and community as well as habitat structure. Much is unknown about these changes and ecological thresholds for future impacts. There is a fair chance that new cumulative effects will show in the future course of climate change. Monitoring and projecting these changes will be a challenging task for habitat management and science alike. This is especially true for the diverse interactions of climate change and human land use.

The second and third most important impacts are related to hydrological and soil conditions of habitats. Changes in CO_2 concentration and sea level are considered as impacts of less importance for habitat types in HABIT-CHANGE.

In the course of HABIT-CHANGE further information on climate scenarios and modelling results will be produced. This analysis will most probably provide new insights in impacts of climate change not yet considered in investigation areas.

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