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Sven Rannow
Marco Neubert *Editors*

Managing Protected Areas in Central and Eastern Europe Under Climate Change

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Managing Protected Areas in Central and Eastern Europe Under Climate Change

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Photographer: Marco Neubert, 2009
Caption: Dried clay illustrating climate change impacts

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Preface

The idea to investigate the impacts of climate change on nature protection sites supported by a remote sensing-based monitoring tool – inspired by Lovejoy and Hannah's book *Climate Change and Biodiversity* – was the starting point of the project "Adaptive Management of Climate-Induced Changes of Habitat Diversity in Protected Areas" (HABIT-CHANGE). This first idea was further developed and extended during several meetings with a growing number of interested partners. After two years of preparation, the project proposal was submitted to the European transnational funding programme INTERREG IV B Central Europe and later on approved for a three-year runtime. We chose this funding opportunity since climate change does not stop at national borders and the programme supports science-practice-policy cooperation and implementation, which is especially needed for this topic. Since the Central European area is expected to be especially affected by climate change impacts, it is an appropriate investigation region. Furthermore, by choosing European investigation areas it was possible to evaluate the concept and regulations of the EU Habitats Directive – the most important pillar of European wildlife and nature conservation that forms a network of protected sites across the European Union called Natura 2000.

In March 2010, a consortium of 17 great and well-respected partners from nature protection site administrations, scientific institutions, and nature conservation authorities started researching. However, several of the institutions interested in joining the partnership were unable due to financial or administrative reasons. Thus, we additionally had a large number of highly interested associated institutions.

During the project runtime, a lot of public recognition was gained: The HABIT-CHANGE project was selected as:

- One of 28 good practice examples worldwide for the UNESCO-MAB Conference "For life, for the future. Biosphere reserves and climate change" in 2011
- A project of strategic importance of the INTERREG Central Europe funding programme combined with additional funding for capitalisation activities

- A so-called lighthouse project of the German INTERREG/transnational cooperation office by the Federal Institute for Research on Building, Urban Affairs and Spatial Development

The results achieved by the project are part of the book content. Extended and more detailed technical reports are available on the project's website.

Dresden, June 2013 Marco Neubert and Sven Rannow

Acknowledgements

This book was compiled within the project "Adaptive Management of Climate-induced Changes of Habitat Diversity in Protected Areas" (HABIT-CHANGE). We thank the European transnational funding programme INTERREG IV B Central Europe for co-funding this project (reference number 2CE168P3).

A project would not work without the support of a functioning partnership. Thus, we thank all our project partners and their respective teams, including their administrations, the whole lead partner team, all the cooperating associated partners as well as our advisory board members with special thanks to Jochen Schumacher.

We thank all participants of the numerous project events as well as the "International Conference on Managing Protected Areas under Climate Change" (IMPACT) for their fruitful discussions and various inputs to the project. Together with various interested and cooperating experts they contributed to the project's success and helped to gain a high level of attention.

Writing and publishing this book took a lot of effort and could not have been done without the following people. We would like to express our gratitude to:

- All authors including the contributing external experts
- The internal and external reviewers, especially Stefan Lang, Jochen Schumacher and Rene Griesbach, as well as
- The editor team of the Springer series "Advances in Global Change Research"

Dresden, June 2013 Marco Neubert and Sven Rannow

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Part I
Introduction

Chapter 1
Natural Heritage at Risk by Climate Change

Sven Rannow, Marco Neubert, and Lars Stratmann

1.1 Climate Change as a Threat to Habitat Diversity

The Fourth Assessment Report of the Inter governmental Panel on Climate Change (IPCC 2007a) clearly underlined the existing trend of climate change. It projected future developments with dramatic impacts, such as increasing temperature, changes in both amount and distribution of precipitation, change of the climatic water balance, and the increasing occurrences of extreme events.

These changes will have serious impacts on nature (IPCC 2007b) and endanger the natural heritage that is protected within nature reserves, national parks, biosphere reserves or other protection categories. These facts are already recognised on a European policy level: "Climate change has the potential, over a period of a few decades, to undermine our efforts for the conservation and sustainable use of biodiversity" (European Commission 2006, p. 13).

Current discussions connected to climate change often focus on the prevention or mitigation of greenhouse gas emissions. Even though mitigation of climate change is of utmost importance, protected area administrations as well as nature protection authorities also need support on the political (administration) as well as on the practical level (management) in order to cope with climate change and their adaptation to it. To preserve ecosystems, habitats, and species, as well as their goods and services, for society under changing climatic conditions it is recommended to:

- identify potential climate change and land use-induced threats;
- model regional climate change effects and their potential impacts on protected areas (see Chaps. 2 and 3);
- evaluate existing management practices;

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- derive a set of indicators reflecting local-scale effects of climate change (see Chap. 6);
- establish monitoring concepts based on earth observation data and ground truthing (see Chap. 7);
- assess habitat sensitivity to potential impacts (see Chap. 8);
- analyse existing legal framework for adapted management in protected areas (see Chap. 9);
- adapt management plans, strategies, and measures of protected areas to climate change effects (see Chap. 10);
- implement the findings on a practical level with the help of local experts, as well as fostering public awareness of the policy and stakeholders, and also the demand for adaptive management (see Chaps. 11, 12, 13, 14, 15, 16, 17, 18, and 19);
- provide guidelines for climate change adaptation of protected areas on national and transnational (e.g. EU) level.

These issues were part of the project objectives of "Adaptive Management of Climate-induced Changes of Habitat Diversity in Protected Areas" (HABIT-CHANGE) and will be presented and discussed in this book. Thus, the information about existing problems and solutions on local and regional levels and the experiences of implementing adaptation strategies with all its facets shall be shared. This volume should support other conservation managers in coping with the challenges of climate adapted management.

1.2 The Need for Adaptation and Obstacles for Application

The diversity of species and habitats is one of the foundations of life on earth (Barnosky et al. 2012; Cardinale et al. 2012). Therefore, it seems advisable to safeguard biodiversity on Earth from substantial threats like climate change (e.g. McLaughlin et al. 2002; Carvalho et al. 2010; Bellard et al. 2012). Its first effects are already apparent (Parmesan et al. 1999; Root et al. 2003) and the speed of change is increasing (Chen et al. 2011). The impacts of climate change will put additional pressure on the majority of endangered species and habitats. The adaptation of conservation management in the face of such extensive transformations is a pressing need and an ambitious target. Changing climate conditions as well as global transformations are challenging nature protection in general and conservation management on site. To address these challenges new and adapted concepts, tools, and practices are necessary (Dawson et al. 2011; Hobbs et al. 2010). Most methods and tools are already available but need to be used with a new perspective of climate change adaptation in mind (Hansen and Hoffman 2011; Lawler 2009). This could be achieved, for instance, by:

- incorporating climate change in national or regional biodiversity conservation plans (e.g. Groves et al. 2012);
- reflecting potential effects of climate change in the design of wildlife corridors and adapting existing area networks (e.g. Vos et al. 2008);

- including vulnerability to climate change effects as a factor in the development of endangered species lists;
- considering potential effects of climate change in protected area management plans (e.g. March et al. 2011);
- considering potential effects of climate change like shifting distributions within species action plans (Singh and Milner-Gulland 2011);
- assessing the effect of climate-induced changes in carrying capacity in population viability analysis;
- considering potential effects of climate change on habitat restoration plans (e.g. Battin et al. 2007);
- developing habitat restoration plans for habitats that are endangered by climate change effects like sea level rise.

The following chapters exemplify the adaptation of concepts, methods and tools for conservation management. This is illustrated for protected areas located in Central and Eastern Europe.

This book focuses on protected areas because they are a prominent element of conservation schemes worldwide. They safeguard the most treasured biodiversity hotspots and focus conservation action at the local and regional level. Even though climate change is considered a global problem and changes, e.g. in species distribution, become only apparent when analysed on the global or regional scale, it is the individual sites that are the first to feel the effects on endangered species and habitats. During the last years a growing number of parks and conservation sites have made individual adaptation efforts (e.g. March et al. 2011; Littell et al. 2011). These efforts are challenged by the fact that climate change rarely is the only pressure to consider. This is especially true for large conservation sites, such as biosphere reserves, which are characterised by cultural landscapes and influenced by existing land use.

At most Central and Eastern European conservation sites climate change adds to a myriad of existing problems and interacts, either directly or indirectly, with them. Changes in temperature, precipitation, seasonality, or the frequency and severity of extreme events, have direct effects on species and habitats. Indirect effects, however, need to be considered, too. For instance changes in abiotic conditions, like changing river runoff and groundwater regimes or changing phenology, and biotic interactions, have impacts on local biodiversity. In addition, autonomous adaptations of local stakeholders show potential for increasing existing or creating new conflicts. Changing practices in agriculture, forestry, fisheries, or tourism have ripple effects on protected sites and surrounding areas. Improvement of conservation management at site level is needed to handle these new problems.

Projections of future climatic trajectories are accompanied with notorious uncertainties and ecosystem responses are complex due to their non-linear and often unclear relationships between causes and effects of changes, like feedback loops, substantial temporal and spatial lags, and frequent discontinuities (Prato 2008). Most local conservation experts are uncertain when to react and how to adapt to the impacts of climate change. There is still a lack of transfer from existing scientific knowledge into conservation strategies and measures. Especially, the social effects of climate change and their impact on conservation management are not well addressed, even though they frame its decision context (Heller and Zavaleta 2009).

Most of the available concepts and guidelines for the adaptation of conservation management are lacking connection to local strategies and actions. There is an urgent need for more science-practice partnerships to identify strategies that are robust to uncertainty deriving from climate projections and their ecological consequences. In addition, easy applicable tools are needed that provide no-regret options for adaptation, based on available scientific information.

The adaptation of conservation management is a huge task and has to overcome multiple challenges on local level:

- The lack of resources: local conservation management is chronically scarce of resources like budget and manpower. New challenges like climate change are therefore hard to tackle.
- The lack of expertise in adaptation issues: on a local level there might be several experts trained to identifying effects of climate change, but only few are trained in adaptation issues.
- The lack of guidance to find suitable data and methods: in the last years an overwhelming amount of data and information on climate change and its effects has become available. A plethora of approaches and data has been published making it hard to identify relevant information and useful methods.
- The lack of suitable monitoring methods: signals of local climate change and its effects are hard to distinguish from the noise of natural dynamics. Robust methods helping to disentangle the web of pressures like land use and climate change are still rare.
- The lack of management methods: conservation experts in the field need simple, applicable tools and guidance for decision support in everyday management of conservation sites. They need methods to identify climate change related conflicts, to identify robust adaptation strategies, to choose suitable management measures, and to prioritise action.
- The lack of tools for communication and awareness raising: effective adaptation of conservation management needs to build public, as well as political, support for local adaptation activities. Tools for communication and participation are needed to foster environmental education, to illustrate effects of climate change, to show the relevance of adaptation measures, to guide autonomous adaptation of other land users, and to include stakeholders and the wider public in the adaptation process.

Despite the existing gaps and challenges, local conservation management cannot hesitate to take action and must proceed in the face of considerable uncertainty (Conroy et al. 2011).

1.3 Recognition and Adaptation on Higher Spatial and Administrative Levels

The protection of biodiversity and ecosystem services from adverse impacts of climate change is of importance on local and regional levels worldwide (Pérez et al. 2010). Systematic support and guidance by higher policy levels is needed (SCBD 2007). The European Commission adopted an EU strategy on adaptation to climate change in 2013.

Adaptation to climate change is addressed in several recent regulations as well as strategies on EU levels – but it is not yet mainstreamed into all EU policies. Biodiversity, and therewith, the diversity of habitats is one of the focus areas of adaptation. “Biodiversity and climate change” is one of four key policy areas within the EU Action Plan for “Halting the Loss of biodiversity by 2010 – and Beyond”. The Action Plan states that “policies will also be needed to help biodiversity adapt to changing temperature and water regimes” (European Commission 2006, p. 13).

Subsequently, a White Paper on climate change adaptation was issued (European Commission 2009). It emphasises the importance of maintaining and restoring ecosystem integrity and names as actions: “increasing the resilience of biodiversity, ecosystems and water”; the need to “improve policies and develop measures which address biodiversity loss and climate change in an integrated manner to fully exploit co-benefits and avoid ecosystem feedbacks that accelerate global warming”; and, to “draft guidelines by 2010 on dealing with the impact of climate change on the management of Natura 2000[1] sites”. This draft guideline (European Commission 2012) points out the requirement to “review [. . .] other policies and strategic frameworks in terms of how they could be developed and utilised as part of the integrated solutions that will be increasingly required for climate change management”. It also gives core advices to site managers, e.g. “to develop adaptive management plans” (p. 96).

The EU Biodiversity Strategy to 2020 (European Commission 2011) underlines the importance of addressing climate change in the EU. In order to improve the exchange of information on climate change and measures for adaptation, a European clearing-house for climate change was developed.[2]

Beside the activities of the European Commission other international policy declarations were made. UNESCO’s “Dresden Declaration” acknowledges that climate change mitigation, adaptation to climate change, and the conservation of biological diversity are among today’s key environmental challenges (UNESCO, German Commission 2011). Therefore, biosphere reserves serve as model regions for adaptation to the impacts of this change. Ensuring sustainable land use and

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[1] “Network Natura 2000” according to Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (OJ L 206, 22.7.1992, p. 7) and to Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds.

[2] http://climate-adapt.eea.europa.eu

safeguarding ecosystem services are important actions. The declaration demands to "place greater focus on the capacities of the MAB [Man and Biosphere] Programme and biosphere reserves for mitigating and adapting to the impacts of climate change, and [to] improve integrating their contributions into national and international climate strategies and policies". It also calls for the establishment of "adequate legislative, administrative and institutional frameworks at national and/or local level for biosphere reserves". At practical level, climate change adapted management plans shall be drawn up and implemented (UNESCO, German Commission 2011).

Further policy documents for adaptation were published by the Secretariat of the Convention on Biological Diversity (SCBD 2003, 2006, 2007, 2009). They: (a) show the connections between biodiversity and climate change mitigation and adaptation; (b) give guidance for promoting synergies among activities that address biological diversity, desertification, land degradation, and climate change; (c) give advice on the integration of biodiversity considerations into the implementation of the United Nations Framework Convention on Climate Change and its Kyoto Protocol; (d) state that maintaining biodiversity should be part of all national policies, programmes, and plans for adaptation to climate change to allow ecosystems to continue providing goods and services.

The interconnections between climate change and biodiversity are considered in many other conventions as well. The United Nations Framework Convention on Climate Change recognises the need to tackle climate change and calls upon the parties to act within a certain time frame that allows ecosystems to adapt to climate change. The World Heritage Committee elaborated a strategy to assist state parties to implement appropriate management responses to climate change. The Conference of the Parties to the Convention on the Conservation of Migratory Species requested their scientific council to afford climate change high priority in its future programme of activities and called on parties to implement, as appropriate, adaptation measures. The Conference of the Contracting Parties of the Ramsar Convention on Wetlands called upon contracting parties to manage wetlands so as to increase their resilience to climate change by promoting wetland and watershed protection and restoration (SCBD 2007).

Finally, guiding principles for adaptation to climate change in Europe were given (ETCACC 2010) and guidelines for protected area legislation were provided, which include "adaptive management" and "managing for climate change" (Lausche 2011).

1.4 Investigation Areas

HABIT-CHANGE focused on those habitats of community interest defined by annex 1 of the Habitats Directive (92/43/EEC), which are mainly affected by climate change and land-use pressures. Thus, the project included protected sites consisting of wetland, forest, grassland, alpine, and coastal ecosystems located in Central and Eastern Europe. The administrations of several suitable national parks, biosphere reserves, and natural parks cooperated as project partners (Fig. 1.1) or supported the work as associated institutions.

Fig. 1.1 Location of the investigation areas within Central and Eastern Europe

At site-level, climate change will lead to different conditions for the remaining habitats. Especially affected are water-based ecosystems, such as wetlands and rivers, but also the composition of forested areas and grasslands. Climate change-related impacts can be manifold (Table 1.1). Generally, all areas will be affected by more frequent extreme weather events, warming, changes in species composition and pattern (loss of habitats in the extreme case), migration of species, and expansion of invasive species. These impacts are usually accompanied and partly intensified by anthropogenic influences caused by land use.

1.5 Contents of the Book and Case Studies

This book sets out to meet the growing need for sharing knowledge and experiences in the area of biodiversity conservation and climate change. It builds on the results of the transdisciplinary HABIT-CHANGE project. Similar to the project, the book consists of a theoretical/methodical and a case study/practice-based part. It provides an overview on data, methods, models, and plans used within the project sharing the experiences of putting adaptation strategies, management measures, as well as monitoring into conservation action.

The first part of the book provides necessary background information on climate trends in Central and Eastern Europe and their effects on abiotic and biotic components. It discusses climate change-adapted management issues with an

Table 1.1 Overview of investigation areas, their main ecosystem type as well as climate change-related problems

Investigation area	Ecosystem type	Climate change-related challenge
Balaton Uplands National Park, Hungary	Grassland, wetland, forest	Droughts, water shortage
Biebrza National Park, Poland	Wetland, grassland, forest	Flooding
Danube Delta Biosphere Reserve, Romania	Wetland, forest, grassland	Changed water regime, sea level rise, droughts
Hainich National Park, Germany	Forest, grassland, bog	Forest composition, extreme events (storm)
Körös-Maros National Park, Hungary	Wetland, steppic grassland, forest	Droughts, eutrophication, flooding
Lake Neusiedl/Fertö-Hanság National Park, Austria/Hungary	Wetland (shallow steppic lake), grassland	Droughts, higher water temperatures, growth of algae, loss of ecosystem
Natural Park Bucegi, Romania	Alpine grassland, forest, rocky habitat, wetland	Shifting vegetation zones, changing snow cover
Rieserferner-Ahrn Nature Park, Italy	Alpine grassland, forest, rocky habitat, wetland, glacier	Shifting vegetation zones, glacier retreat, changing snow cover and permafrost
Riverside Landscape Elbe-Brandenburg Biosphere Reserve, Germany	Wetland, grassland, forest	Droughts, flooding
Sečovlje Salina Nature Park, Slovenia	Wetland, coastal area, grassland	Sea level rise, changed hydrological river regime, changes in salinity
Shatsk National Natural Park, Ukraine	Forest, wetland, bog	Changed climatic water balance
Škocjanski Zatok Nature Reserve, Slovenia	Wetland, coastal area, grassland	Sea level rise
Triglav National Park, Slovenia	Alpine forest, grassland, rocky habitat, wetland	Shifting vegetation zones, changing snow cover and permafrost
Vessertal-Thuringian Forest Biosphere Reserve, Germany	Forest, grassland, bog	Shifting woodland vegetation zones, extreme events (storm)

emphasis on topics like “Benefits and limitations of modelling approaches for nature conservation planning”, “Monitoring”, “Legal options and limits for adapted management” and a “Methodological approach to climate change adapted management plans”. The second part introduces case studies from investigation areas in Central and Eastern Europe focusing on habitats most vulnerable to changes of climatic conditions, namely alpine areas, wetlands, forests, lowland grasslands, and coastal areas. The case studies illustrate local impacts of climate change and the application of adaptation strategies and measures in protected areas. Potential benefits, as well as existing obstacles, for national parks, biosphere reserves, and natural parks are presented.

Valuable experiences were gained within the project and are presented in the lessons learned section of this book; existing methods were tested in new context and developed further. To preview a few of the issues that were overcome, three of them are highlighted in the following: (1) remote sensing approaches require a highly site and context specific design of fitting indicators to derive useful results. Short-term indicators can be used, e.g. to monitor the percentage of natural tree types at Natura 2000 sites, and long-term indicators can be utilised, for instance, to monitor the immigration of beech in a spruce dominated region. (2) Legal objectives need to be shifted from preservation and restoration to improving resilience and adaptive capacity. In principle, Natura 2000 law has got a high adaptive capacity. Resilience improvement, however, is not explicitly regulated and will remain the main subject of legal controversy. (3) Adaptation processes need cooperation beyond the protected area administration. The identification of relevant parameters for climate modelling, modelling of sensitivity, and assessments of climate change impacts can only be done with the help of scientific partners. Also, many elements of adaptation strategies and measures cannot be implemented by the protected area management alone. This can only be done in close collaboration with local stakeholders and land users, as well as regional and national institutions and administrations.

1.6 Target Audience

First and foremost, this book is targeted at administrations, managers, and practitioners of protected areas. They can benefit from the theoretical and conceptual information about climate change, its impacts, monitoring and modelling, as well as adapted area management and legal issues.

The contents of this book are addressed to nature protection administrations on international, European, national and regional levels; to NGO's working in the field of nature protection and environmental education; and to umbrella organisations focusing on nature protection. These include national authorities and organisations responsible for European regulations regarding Natura 2000 and monitoring in the context of the Water Framework Directive.[3]

Applied research institutions and scientists working on biodiversity, protected area management or climate change are addressed as well.

Finally, stakeholders within proximity of protected areas in Central and Eastern Europe and worldwide are another potential target group. Forest and water authorities, land development boards, and farmers' associations from national to local levels, for instance, can gain practical experience and background knowledge for their activities that affect the environment within protected areas.

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[3] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (OJ L 327, 22.12.2000, p. 1).

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Part II
Climate Change and Potential Impacts in Central and Eastern Europe

Chapter 2
Climate Change in Central and Eastern Europe

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2.1 Preface and Definitions

Along with the increasing world population and the technological advancement during the last centuries both energy consumption and the demand for land have increased simultaneously. Climate change at its estimated pace poses serious challenges for society, policy, and the economy. In order to develop suitable strategies for adaptation, fundamental knowledge about the climate in the past, present, and potentially in the future is required on a global and a regional scale. Thus, a scientific assessment of observed and projected changes of climate variables and indices is an inevitable precondition for appropriate adaptation and mitigation measures.

Because the terms "weather" and "climate" are often misunderstood, a few general definitions have to be explained first. While "weather" means the state of the atmosphere in a certain moment, hour, day, or week, "climate" is defined as the statistical description of weather, including averages and variability as well as the return intervals of extremes over a period of at least 30 years [defined by the World Meteorological Organisation (WMO)] (WMO 2011). The most relevant climate parameters characterising this period are surface variables- air temperature, precipitation, radiation, humidity, cloud cover and wind. Closely related to this definition

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is the term "climate change" as used by the Intergovernmental Panel on Climate Change (IPCC). Climate change is defined as a statistically significant change in the mean state or the temporal variability of the climate due to natural variation of external forcing, anthropogenic changes in the atmosphere's composition, or changes in land use (IPCC 2007). In this chapter possible sources of climate information are summarised including an overview of uncertainties. The main focus is on climate change signal in Central and Eastern Europe.

2.2 Measurements, Climate Models and Sources of Uncertainties

2.2.1 *Observations*

One traditional way to observe past climate change is through measurement and analysis of instrumental climate series, as currently performed by national weather services. The first international measurement network was built in 1781 and included 39 stations from North America to the Urals, with most in Europe (Schönwiese 2003). Based on these observations institutes like the Met Office Hadley Centre,[1] the Climatic Research Unit,[2] and others have calculated the global temperature since 1850. For periods before 1850, scientists use climate reconstructions based on natural archives. They extract data from ice cores, tree rings, speleothems, varved sediments, and subsurface temperature profiles which are obtained from boreholes or proxy data like historical references, harvest numbers, phenological phases, icing and flooding information, conclusions about the prehistoric climate, or to past states of the atmosphere (Esper et al. 2002; Luterbacher et al. 2004; Wanner et al. 2008). Figure 2.1 shows on the left a slice of a stalagmite which has been used to reconstruct precipitation. The tree ring on the right could be dated back to 1746 and gives information about environmental conditions in each year of the tree's life.

A historical monthly precipitation data set since 1900 for global land areas has been constructed by the Climatic Research Unit, gridded at two different resolutions (2.5° latitude by 3.75° longitude and 5° latitude/longitude). For Central and Eastern Europe a number of regional data sets have been developed for manifold applications. A sufficient length of time, sufficient spatial density, and high data quality without any inhomogeneities are the requirements of the data used for climate variability studies. Inhomogeneities are artificial breaks or trends in time series caused by manifold non-climatic perturbations like station relocations, changes of instruments or observation hours, altering of regulations for means calculations,

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[1] http://www.metoffice.gov.uk/hadobs/hadcrut3/diagnostics/comparison.html

[2] http://www.cru.uea.ac.uk/

Fig. 2.1 *Left*: Slice of a stalagmite from a cave in Austria; *Right*: Horizontal cross section of a tree (Larix decidua) in Savoyen grown in 1746, cut in 1999

urban trends and many other disturbances (Aguilar et al. 2003). Different tests and correction procedures have been developed to remove inhomogeneities; however these tests concentrate mainly on monthly temperature and precipitation data. Daily data requires more sophisticated methods, taking not only the mean but the whole frequency distribution of an element into account (cf. Della-Marta and Wanner 2006; Mestre et al. 2009).

Nevertheless, some groups have expended great efforts to create and analyse regional long-term data sets. For the southern part of Central Europe [called the Greater Alpine Region (GAR)] the Historical Instrumental Time Series for the Greater Alpine Region (HISTALP) database[3] has been developed. Its temperature and air pressure series date back to 1760, precipitation to 1800, cloudiness to the 1840s and sunshine to the 1880s. In those earlier times the network density was rather sparse; only since national weather services have been founded in the mid-nineteenth century the number of stations has been steadily increasing. This growth allows for extensive climate information during the twentieth century.

Not all measured or observed climatological data has been made available for research or practical applications. Some of the data has been lost forever destroyed during wars or other misfortunes, some other data is still left in archives, libraries or other locations in its original paper sheets, some data has been printed in yearbooks or newspapers that have not been digitised until now. That is why a number of countries and institutions have started data recovery/rescue activities to make as much data available as possible. Such efforts have recently begun in 2011 for the Carpathian region; Hungary, Poland, Romania, Serbia, Slovakia and Ukraine have made great efforts to improve their database over the last 50 years. However, particularly in Eastern European countries, there has been a decline in the number of meteorological observation stations after the political changes of the early 90s. In some cases, the number decreased to the same level as during the 60s. For the Mediterranean Region the initiative WMO-MEDARE[4] was born under the auspice

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[3] http://www.zamg.ac.at/histalp

[4] http://www.omm.urv.cat/MEDARE/index.html

of the World Meteorological Organisation in order to develop climate data and metadata rescue activities across the Greater Mediterranean Region.

2.2.2 Models

Measurements provide information on the past and recent climate. To estimate possible changes of climate parameters, perspective climate models can be applied. These models can be divided into two main approaches- dynamical and statistical climate models. Dynamical climate models can be grouped into Global Climate Models or Global Circulation Models (GCMs), Regional Climate Models (RCMs), Earth System Models (ESMs), Coupled Atmosphere Ocean Global Climate Models (AOGCMs), and others. GCMs and AOGCMs are strongly simplified but contain the most important physical processes describing our climate system. They are limited to the representation of large scale effects on the global climate due to changes in greenhouse gas concentration, eruptive volcanoes etc. Their spatial resolution for the whole globe is from 3° down to 1.2°. RCMs use model output from GCMs as forcing to simulate the climate at smaller scales for certain regions. They contain complex model physics and due to their high spatial resolution from 50 km down to 3 km (0.5°–0.025°) it is possible to reproduce regional and local effects through the integration of orography and land use. The second group of climate models follows a statistical approach. Statistical relationships between large scale processes and local measurements are extended to estimate future climate and possible changes can be derived very locally. Typical statistical models are a weather generator, Markov chains, linear regression, or principle component analysis. Dynamical and statistical models both have their advantages and disadvantages and the decision of what kind of climate model to use depends on the application and the specific question to be answered in relation to future climate change.

For the interpretation of climate change scenarios and a consequent impact assessment, the consideration of given uncertainties is a fundamental task. Uncertainties arise from imperfect knowledge of physical processes of the climate system as well as from model limitations due to the numerical approximation of the physical equations. Many physical processes which operate at scales below the model resolution are integrated into the climate and impact models as assumptions, simplifications and parameterisations. Furthermore the internal model variability is a reason for uncertainties in the simulation of climate responses to given forcings (Christensen et al. 2001). Moreover, uncertainties arise from the internal variability of the climate system, which is characterised by natural fluctuations in the absence of any radiative forcing (Hawkins and Sutton 2009). Additionally, a high level of uncertainty of the observed climate is implied due to measurement errors and sparse station networks as already described in the previous section. The development of climate scenarios involves uncertainties due to the estimation of future greenhouse gas and aerosol emissions, the conversion of emissions to concentrations, the conversion of concentrations to radiative forcing, the modelling of the climate response to a given forcing, and the conversation of model response into inputs for impact studies (Houghton et al. 2001).

Each step in the development of climate change scenarios leads to a range of probable results followed by a plenitude of uncertainty. The challenge is to assess and to quantify uncertainties about climate scenarios and their consideration in climate change and impact studies. The use of a range of emissions scenarios to force a number of different GCMs and to take into account the range of possible socio-economic futures for the development of regional climate change scenarios is recommended.

2.3 Temperature and Precipitation Change in the Past 50–150 Years

Because climate analyses are often carried out for specific regions or for specific countries, the following section summarises past climate change information based on given literature for each different region separately.

The climate of the twentieth century in Central and Eastern Europe is marked by an overall temperature increase, although more pronounced in the Alps and their surroundings than elsewhere in this region. Other climate elements, like precipitation have developed diversely with regional increases and decreases of smaller distances. For the HISTALP area (GAR) covering the ***southern part of Central Europe*** (4–19°E, 43–49°N, 0–3500 m asl) temperature increased significantly by about 1.2 °C during the twentieth century. This increase was similar in all of the subregions (Auer et al. 2007). Warming at the high mountain observatories in the Alps did not differentiate significantly from that in the lowlands. The respective numbers for the seasons are 1.1 °C for spring, 1.3 °C for summer, 1.2 °C for autumn and 1.3 °C for winter. The strongest warming occurred in the 1980s and 1990s. Thus, focusing on a shorter time period of the last 30 years, a much more severe warming can be found in the series. Together with the higher mean temperature level, a number of extremes derived from daily maximum and minimum temperature are expected to have increased as well.

For the Austrian territory Nemec et al. (2012) found a widespread warming trend in both maximum and minimum temperature meaning an increase of warm days and warm nights. Cold days and nights, on the other hand, have been decreasing during the past 40 years. Climate impacts are easy to detect in nature, shrinking glaciers, elongated growing season lengths, thawing of permafrost, etc. Frost has decreased, above all in the lowlands in spring and autumn. In the high mountains the summer season is affected most by frost reduction (cf. Fig. 2.2).

For precipitation no general trend was detected for the HISTALP region, but regional features have to be taken into account. An increase of about 9 % in the north-western part matches a decrease of the same magnitude in the south-eastern part. Some stations in the south of ***Austria*** recorded a reduction of up to 20 %. Extreme

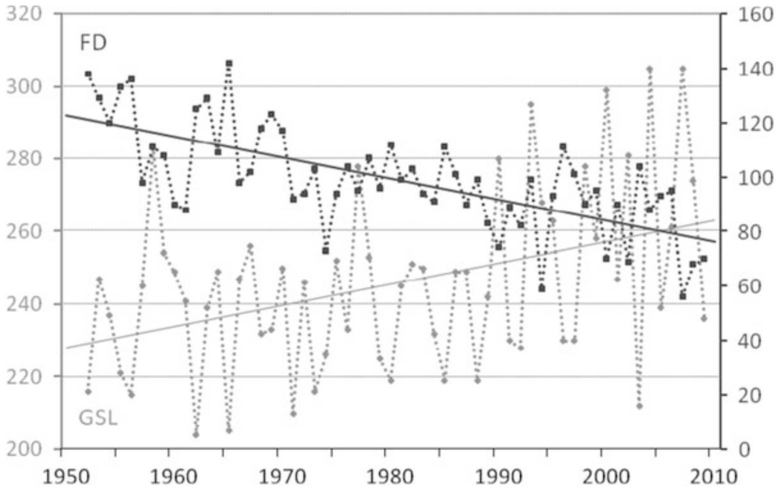

Fig. 2.2 Growing season length (*GSL*) and number of frost days (*FD*) in Laa an der Thaya, near the National park Thayatal in Austria for the time period 1952–2009. The prolongation of the growing season of approximately 1 month is documented as well as the reduction of frost days by about 45 days during the past 60 years (Data source: ZAMG, homogenised daily extreme temperatures of Laa an der Thaya)

precipitation events display an overwhelmingly heterogeneous picture. Only a statistical, not strongly significant tendency towards weaker 1-day and 5-day precipitation events is found in the south-eastern parts of Austria. In eastern and south-eastern Austria an intensification of precipitation events larger than 20 mm/day can be identified. On the other hand, consecutive dry days show a clear geographic pattern south of the alpine divide with a trend towards longer dry periods.

Warmer temperatures should result in a reduced amount of solid precipitation, which means less snow during the cold season in relation to the annual total precipitation amount. A pronounced difference between mountains and valleys can be expected due to the different temperature level. In the lowlands, winters have experienced more and more rain rather than snow, whereas core months of winter in the high Alps have not had much change. The snow deficit comes into effect in summer with negative consequences for Alpine glaciers.

Measurements of 51 stations evenly distributed, homogenised and averaged over the territory of ***Poland*** confirmed the rising of annual temperature for the second half of the twentieth century (Degirmendzic et al. 2004). It is obvious that not all months contributed to the annual temperature increase of approximately 1 °C; however, the most pronounced warming was found in spring. Extreme temperatures have been studied by Wibig and Glowicki (2002). Poland belongs to the group of countries in which a stronger increase of minimum temperature than maximum temperature caused a decrease of the daily temperature range (DTR) at most stations. This effect correlated with increasing cloudiness, however could not be found in the GAR. With rising minimum temperature, Poland experienced a prolongation of the frost-free season. At the same time warmer temperatures and the frequency of hot weather events in summer have been increasing. Wibig (2012) recorded a strong relationship between hot weather and lack of precipitation. Over the year no significant changes have been observed in the annual amounts of precipitation, but more interestingly, a decreasing summer precipitation trend has been found. March is the only month where a significant precipitation increase was detected.

In ***Hungary*** the general annual twentieth century warming of about 0.8 °C (most expressed in summer by increase of about 1 °C) initiated an extended calculation of extreme temperature and precipitation indices for the whole country using grids of the basic variables daily temperature and precipitation (Lakatos et al. 2011). Countrywide the grid point average of hot days (Tmax >= 30 °C) and warm nights (Tmin >= 20 °C) showed a remarkable increase beginning in the 1980s. Maps allow for a better identification of the most sensitive regions of the country. These maps coincide with the Austrian studies (Nemec et al. 2012) which state that warming does not necessarily cause more heavy precipitation. Changes of the annually greatest 1-day total rainfall between 1961 and 2009 vary from −15 to +10 mm. This increase could be detected mainly in the regions east of the Danube. Precipitation in general has decreased by 11 % in Hungary since 1901, especially since the 1970s. This decrease in precipitation is especially pronounced in spring. Although summer precipitation does not display a special negative trend drought events with dry and warm months are immanent in the climate of Hungary. The Hungarian plains are most affected, with drying occurring in late spring/early summer and during late autumn.

Romania has experienced a warming of about 0.5 °C in annual mean temperature since 1901, and in the south eastern region trends up to 1 °C have been estimated. Summer temperatures have been increasing since the 1970s with highest positive anomalies in the Northeast and Southwest of the country. During the hot summer of 2007 temperatures above 40 °C have been recorded during periods with maximum temperatures of 35 °C (Busuioc et al. 2007). Winter temperatures have been increasing more steadily during the last century leading to the warmest winter in 2006/2007 with an anomaly of about +6 °C. As stated previously, no uniform long-term precipitation change pattern was detected in Romania. There are some smaller regions with increases and decreases in other regions. Extreme precipitation events and their variability have been studied by Cazacioc (2007) for 1961–1996. On average, the daily maximum precipitation amount is highest in the south-western mountainous region (up to 68 mm) whereas in central Romania rather low rainfall of around 30 mm can be experienced. Maximum daily precipitation has mainly decreased during this period, most significantly more or less only in the south-western mountain region. On the other hand slight growing trends have been found partly in western and north-western regions of Romania.

2.3.1 Global and European Trends

For at least the last 500 years, European winters were generally colder than those of the twentieth century, except for two short periods around 1530 and 1730

(Luterbacher et al. 2004). The coldest winter periods occurred during the late sixteenth century, during the last decades of the seventeenth century, and at the end of the nineteenth century (Jones et al. 2001; Luterbacher et al. 2004).

Since the middle of the nineteenth century the annual average temperatures of the northern hemisphere have increased by 0.6 °C (Jones et al. 2001). Winters have warmed by nearly 0.8 °C and summers by only 0.4 °C in which the warming has occurred in two phases from about 1920–1945 and from 1975 to 2001 (Jones et al. 1999). On a global scale the minimum temperatures have increased more significantly than the maximum temperatures for the period of 1950–1993 (Jones et al. 1999). This leads to a decrease of the diurnal temperature range by 0.08 °C per decade.

A statistical trend analysis of temperature and precipitation of more than 600 stations across Europe shows a "warming band" of mean annual temperatures which extends from south-western to north-eastern Europe for the time period of 1951–2000 (Schönwiese and Janoschitz 2008). The seasonal examination of the data indicates that the temperature trends of the winter months are higher and clearer than the temperature trends of the summer months. Highest warming trends were found in the Baltic region with about 3 °C and in the western parts of Russia and the Alps with about 2 °C. For Eastern Europe (east of about 20°E) the summer temperature trends show small negative values (moderate cooling) and for Central Europe there are positive trends (warming).

The spatial precipitation pattern for Europe displays increasing annual trends for parts of North Europe, no trends for Central and Eastern Europe, and a clear negative trend for South Europe for the period of 1951–2000 (Schönwiese and Janoschitz 2008). In summer, precipitation increases in most parts of Europe, except areas east around 25°E and south around 60°N (East and Southeast Europe), in which a precipitation decline was observed. In winter months, the precipitation trends over Europe are divided into two parts. In the Mediterranean countries and in some countries of Eastern Europe precipitation has declined and in other parts of Europe precipitation has increased with observed maximum values of about 40 %.

2.4 Projected Climate Change in the Near and Far Future in Europe

2.4.1 Temperature

In Central and Eastern Europe the mean annual temperature is projected to increase between 1 and 3 °C until the middle of the century and up to 5 °C by the end of the century (Giorgi et al. 2004; Räisänen et al. 2004; Rowell 2005; Christensen et al. 2007; Déqué et al. 2007; Kjellström et al. 2007), if no policy measure is taken (IPCC 2007). Figure 2.3 illustrates the projected change in temperature as a result of a multi-model average for the middle of the twenty-first century.

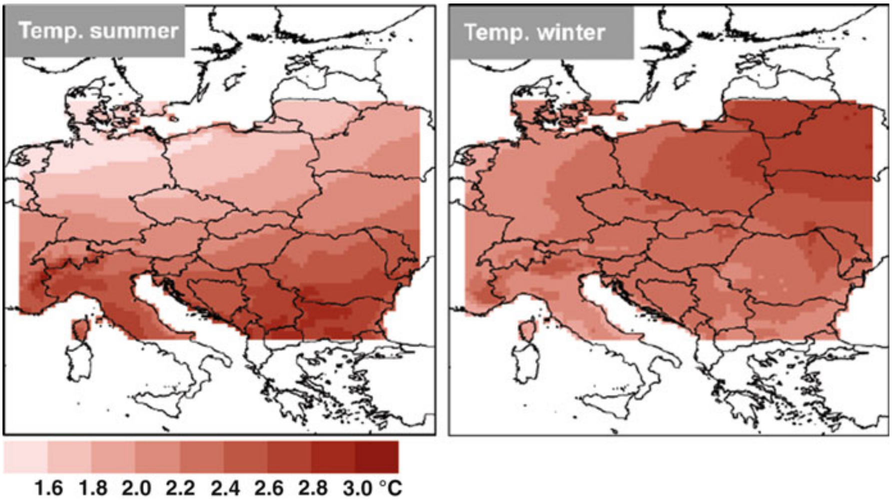

Fig. 2.3 Change of simulated mean temperature in Central and Eastern Europe in winter and summer as the multi-model mean 2036–2065 relative to 1971–2000 for the A1B greenhouse gas emission scenario

The model output is taken from various regional model simulations driven by different European Global Climate Models produced in the European project ENSEMBLES (van der Linden and Mitchell 2009). The projections up to 2100 use a common forcing under A1B greenhouse gas emission scenario. The European warming will be higher than the global mean temperature increase. As can be seen in Fig. 2.3 this temperature increase is different from region to region and season to season. In the autumn and winter months the temperature change in North and Eastern Europe will be higher (up to 3 °C) compared to South Europe (1–1.5 °C).

The warming in winter increases from the western coastal regions of Europe to the eastern continental interiors (Giorgi et al. 2004; Rowell 2005). This can be mainly explained through two mechanisms. The first is the influence of the rather modest warming of the ocean on the climate of the western parts of Europe (Rowell 2005), and the second is the snow albedo feedback mechanism. If the warming depletes the snow cover, the albedo decreases and more solar radiation reaches the surface, which in turn enhances the surface warming, accelerates the snow depletion, and sustains a positive feedback mechanism (Giorgi et al. 2004; Rowell 2005; Kjellström et al. 2007). Furthermore, the minimum temperatures have risen most, leading to decreased winter temperature variability (Räisänen et al. 2004). Adversely, in summer the increase in the south of up to 2.5 °C is larger than in the north with an increase of less than 2 °C.

The projected increase in daily mean temperature varies overall. The model projections show a clear warming trend for the future, although there are regional and seasonal differences in the magnitude of the projected temperature increase. The changes in temperature as multi-model mean for the period 2036–2065 relative to 1971–2000 show a steady rise of the summer temperature of 1.5 °C in the northern parts of Germany and Poland and up to 3 °C in Southeast Europe. For the winter months the projected increase is the highest in the north-eastern region (~3 °C) and lowest in the western parts of Central Europe (~1.8 °C). Thereby, the spread of the model projections for temperature is high in the summer months, especially in the southern parts of Central Europe with a coefficient of variation up to 50 % (not shown).

For all of Central and Eastern Europe a clear temperature rise is visible for the future which is projected to become more distinct at the end of the century. A general pattern is that the projected increase of temperature is highest during summer and lower during winter. For most areas, a comparison of the projections shows a high uncertainty range, especially during summer. The range of uncertainty results from different potential pathways of technological, economic, and demographic development leading to different emissions of greenhouse gases and the related response of the climate system.

2.4.2 Precipitation

The projections for precipitation show a more complex picture. The spatial heterogeneity of precipitation is generally larger than the special heterogeneity of temperature. The projected changes for precipitation vary seasonally and across regions in response to changes in large scale circulations and water vapour loadings. With regard to the nearer future the evaluation of various climate models does not show a distinct trend for precipitation in most of the area, especially due to the highest uncertainties in simulated precipitation trends existing for Eastern Europe. Nevertheless, trends on future precipitation become clearer for the end of the century, where a shift of precipitation from summer to winter becomes visible. A general assumption is that the summer precipitation all over Central Europe (except along the coast of the Baltic Sea) will decrease, while in most cases Central Europe will most likely become wetter in the winter season. Despite these precipitation increases, the amount of snow and area covered by snow are expected to decline due to warming. In contrast, the projections for the summer months show tendencies for a decrease in precipitation especially in the southern parts of Central Europe. The multi-model mean (cf. Fig. 2.4) shows a decrease up to 25 % in the summer months for southern Central Europe and an increase in the amount of precipitation up to 20 % for northern Central Europe in the winter months.

Due to the high spatial and temporal variability of precipitation and the complexity of its development processes, the changes in precipitation show more regional and seasonal differences than temperature shows. In spring and autumn the precipitation amount decreases in South and Southeast Europe. In North and Northeast Europe an increase can be detected. In winter Central and Southeast Europe show small changes in precipitation sums. Several climate change studies show a south-north contrast in precipitation, with an increase in North Europe

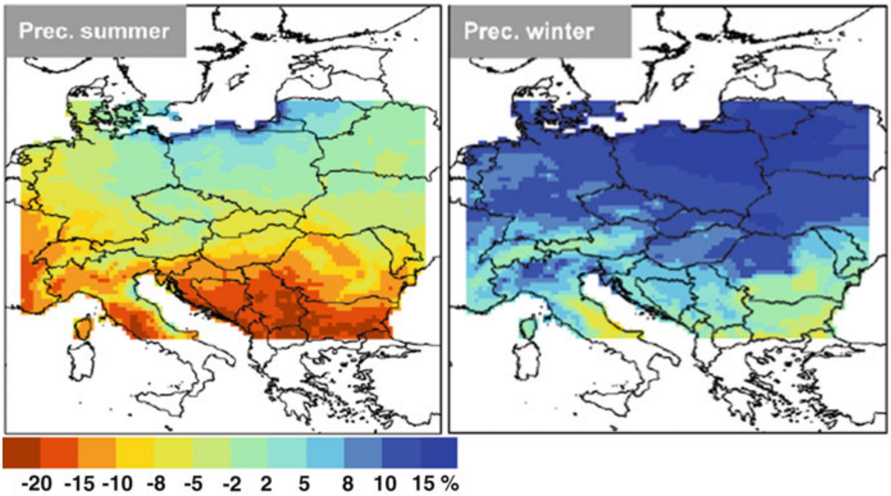

Fig. 2.4 Change of simulated mean precipitation in Central and Eastern Europe in winter and summer as the multi-model mean 2036–2065 relative to 1971–2000 for the A1B greenhouse gas emission scenario

and a decrease in South Europe. The border between increasing and decreasing precipitation moves with the season and shows a northwards shift in summer (Christensen and Christensen 2007; Christensen et al. 2007). This transition line extends from the Iberian, Italian, and Balkan peninsulas (Giorgi et al. 2004) and is located at about 40°N in winter, 45°N in spring, 60°N in summer, and 55°N in autumn (Rowell 2005). Missing precipitation in spring can increase the probability of the occurrence of heat waves in Central Europe (like e.g. in 2003) (Fischer and Schär 2009; Fischer et al. 2007).

2.5 Need for Research

Meteorological measurements provide essential information about past and present climate conditions. Data recovery initiatives contribute to a reduction of deficiencies and thus an enhanced knowledge of regional climate variability. To assess future changes in temperature, precipitation, and other climatic parameters, Global Circulation Models, Regional Climate Models, and statistical downscaling methods are utilised to simulate climate variations for the upcoming decades.

During the last century the global air temperature has increased by about 0.7 °C (IPCC 2007). Central and Eastern Europe have turned out to be more sensitive to climate change than other regions, facing a temperature rise of a little more than twice the global mean (Auer et al. 2007). The research community in Europe is very big and intensive investigations are carried out to assess climate change in mean and variability of common parameters, but also in their extreme values. Central Europe is located in a climatic transition zone of precipitation increase and decrease. Estimating the changes is difficult. This fact results in a high uncertainty in the expected future change. These uncertainties from observations and similarly from models need to be taken into account in all fields of climate change related decisions.

Climate researcher can give a hint of possible future changes but also have to communicate the range of uncertainty and the limitation of measures. The challenge in climate research tends to focus more and more to a very local scale. In all fields of applications strategies have to be developed that take a wide range of possible future developments into account and are adapted regularly by updated climate data.

Acknowledgements The analysis of the climate change signal in Central and Eastern Europe is based on regional climate model simulations for all of Europe, and the A1B emissions scenario is based on regional climate model simulations carried out in the European Union-funded Project ENSEMBLES (GOCE-CT-2003-505539). We are very grateful to Sorin Cheval, Joanna Wibig and Zita Bihari for supplying information on national observation systems and climate change information and to Michael Grabner and Bernhard Hynek for photos.

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Chapter 3
Effects of Climate Change on the Hydrological Cycle in Central and Eastern Europe

Judith Stagl, Elisabeth Mayr, Hagen Koch, Fred F. Hattermann, and Shaochun Huang

3.1 Introduction

Water is involved in all components of the climate system: the atmosphere, hydrosphere, cryosphere, land surface and biosphere. The dynamics of the water cycle are one of the key variables that determine the distribution and productivity of ecosystems. Changes in hydrology influence plant and animal species in various ways. Almost all land-dependent life, habitats and ecosystems depend of freshwater. Similarly, water plays a key role in the climatic system. The water cycle is a key process upon which other cycles of the climate system operate. It acts as an energy transfer and storage medium through the hydrological cycle. Globally, changes in water vapour content of the atmosphere, cloud cover and ice influence the radiation balance of the earth and thus play an important role in determining the climate response to increasing greenhouse gas emissions (Bates et al. 2008). Hence, changes in climate are intricately interlinked with changes to the hydrological cycle – the most important feedback cycle in the climate system.

For the management of protected areas knowledge about the water regime plays a very important role, in particular in areas with wetlands, marches or floodplains as well as lakes. The local hydrological conditions depend widely on temporal and spatial variations of the main components of the hydrologic cycle and the physiographic conditions on site. In many protected areas, especially those with existing

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conflicts of interests (e.g. agriculture) between stakeholders, water management measures are implemented since many years. Such measures mainly focus on the regulation of water levels in lakes, rivers and groundwater through the construction of slices, locks, drainage channels or artificial reservoirs, with high impacts to the local biodiversity. To preserve a favourable conservation status under changing climatic conditions park managers require information about potential impacts of climate change in their area. Climate change projections from regional climate models can provide such information, even though with a low spatial resolution (several km^2) concerning biodiversity. Hydrological models can downscale these information and investigate potential impacts of climate change or management measures to the local water regime like river runoff, lake levels or water availability in an area. The projected changes due to climate change vary significantly across Central and Eastern Europe. Hence, the following chapter provides an overview of how climate change affects the hydrological regimes in Central and Eastern Europe. It focuses on the underlying processes and which general hydrological impacts can be expected in the light of climate change. First of all, major processes of the water cycle on river catchment scale are explained. Furthermore, changes of the most important water cycle processes due to climate change, precipitation and evapotranspiration, as well as climatically indicator for the potential water availability the climatic water balance are summarised. This leads to the impacts on river flow regimes and changes the inter- and intra-annual variability, which are described in the following sub-section. The subsequent chapter shows the role of water resources management on stream flow and its availability to counterbalance effects of climate change. Finally, climate change impacts on the glaciers in the European Alps as important storage component are illustrated.

3.2 Overview About the Hydrological Cycle

The hydrological cycle describes the continuous circulation of water between ocean, atmosphere and land. Water is transferred through physical processes like evapotranspiration, precipitation, infiltration and river runoff. This circle from one reservoir to another involves energy exchange in terms of heat transfer, solar radiation and gravitational potential energy. During these processes water can change its aggregation state (liquid, vapour, or ice) various times. Hydrological processes encompass a variety of spatial and temporal scales. At the river catchment scale, the hydrological cycle comprises precipitation as major input, various transfer processes, different storages and outputs. They are referred to by hydrologists as components of the water balance.

Precipitation is condensed water vapour and mostly occurs as rain, but also includes snow, hail, drizzle, sleet and fog drip. Snow can accumulate and eventually

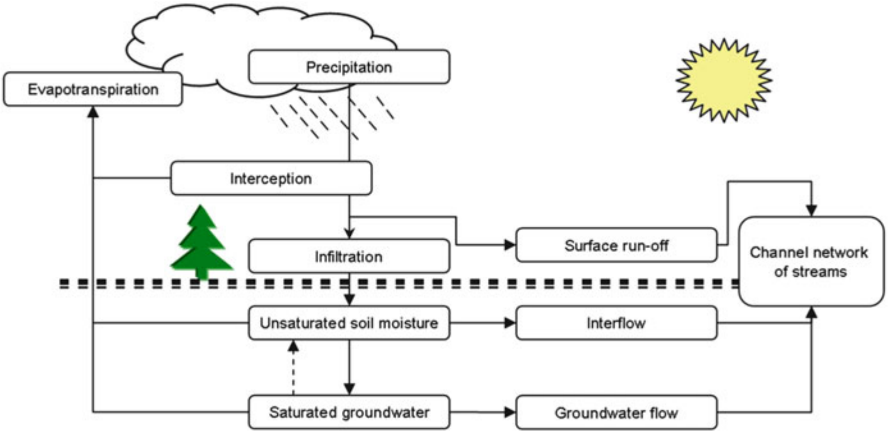

Fig. 3.1 Hydrological components on catchment scale

compact to form glaciers and ice caps. In case of ice and snow, the water stored is released to the cycle with delay as a function of temperature. Rainfall type, volume and intensity are a decisive factor for further processes in the catchment. Factors controlling evaporation are the amount of incident solar radiation, the vapour pressure of the air relative to saturation, air temperature, wind circulation and atmospheric pressure. About 600 calories of energy per gram of water is exchanged during the change from a liquid to a gaseous state. Transpiration accounts for loss of water vapour through plant stomata. Besides in snow and ice covers, water can be held on the canopy surface, which includes plant foliage, branches and stems. From this so called **interception** store, it eventually evaporates to the atmosphere without reaching the soil surface. If rainfall intensity exceeds the soil's infiltration capacity, **surface runoff** occurs. The respective **infiltration** rate depends mainly on the texture and structure as well as the initial moisture content of the soil. Water infiltrated can be held in the **unsaturated soil** dependent on the amount lost by plant uptake, evaporation, groundwater recharge, or interflow (see Fig. 3.1).

Interflow characterises the downslope transfer of water through the soil towards river channels. The **groundwater storage** is replenished slowly by deep percolation and can be a long-term reservoir of the water cycle (with residence time from days to millennia). **Groundwater flow** is the slow movement of water within the saturated zone of an aquifer under the influence of gravity or hydrostatic pressure. River runoff in streams is composed of surface runoff, interflow, groundwater flow and direct precipitation. The **flow process** that dominates on a slope are a function of several variables, including climate, vegetation, rainfall characteristics, soil thickness, slope morphology, and human interferences. The velocity of runoff in (river) **stream channels** is controlled by the gradient and shape of the channel, and its roughness caused by the presence of bed load, i.e. stones, and vegetation.

3.3 Climate Change Impacts on the Water Regime for Central Europe

3.3.1 Precipitation, Evaporation and Climatic Water Balance

In Central and Eastern Europe the mean temperature is projected to increase between 1 and 3 °C in the next decades and up to 5 °C until the end of the century (see Chap. 2). A general pattern is that the higher temperatures lead to an intensification of the water cycle (EEA 2008). Based on the Clausius-Clapeyron expression for saturation vapour pressure, the moisture holding capacity of air increases by about 7 % per 1-°C increase in air temperature (Baumgartner and Liebscher 1990). As a result, climate warming will lead to an increase of the evaporative demand in the air, or "potential evaporation". Generally a higher moisture potential in the atmosphere ultimately leads amongst others to changes in rainfall patterns.

Key changes to the hydrological cycle in Central Europe associated with an increased concentration of greenhouse gases in the atmosphere include (Goudie 2006):

Changes in the seasonal distribution and amount of precipitation. Generally, for all scenarios, the projected annual mean precipitation increases in northern Europe and decreases in the south of Europe. In doing so, the changes in precipitation patterns vary from season to season and across regions in response to changes in large-scale circulation and water vapour loading (Bates et al. 2008). A substantial decrease is projected in summer precipitation for most parts of Central Europe. Because precipitation comes primarily from moisture convergence, an increase in the atmospheric water holding capacity increases the potential for intense precipitation (Trenberth et al. 2003). At the same time this leads to a decrease in the frequency and duration of precipitation events, making way for longer dry periods between precipitation events (IPCC 2007).

Increased evapotranspiration and a reduction in soil moisture. As a result of higher temperature the water vapour deficit in the atmosphere increases. In areas with sufficient (surface) water availability this leads to an increase in actual evapotranspiration. With scarce precipitation, this enlarges the risk of drought as surface drying and hence, a reduction on soil moisture is forced up (Bates et al. 2008). Additionally, an increased atmospheric CO_2-concentration directly alters plant physiology and thus transpiration rates (especially C3 plants).

Changes in the balance between snow and rain. As temperature rises, the likelihood of precipitation falling as rain rather than snow increases, especially in areas where temperatures are near freezing point, and at the beginning and end of the snow season. Yet a warmer climate leads to a shorter snow season with more rains but reduced snow packs, earlier snowmelt and greater ablation. Such changes are already observed in many places, especially over land in high latitudes of the Northern Hemisphere (Bates et al. 2008). As for some areas in Central and Eastern Europe a general increase in winter precipitation is projected, this effect could partly compensate a reduction of the total amount of snow, even if the percentage of precipitation falling as snow is decreasing.

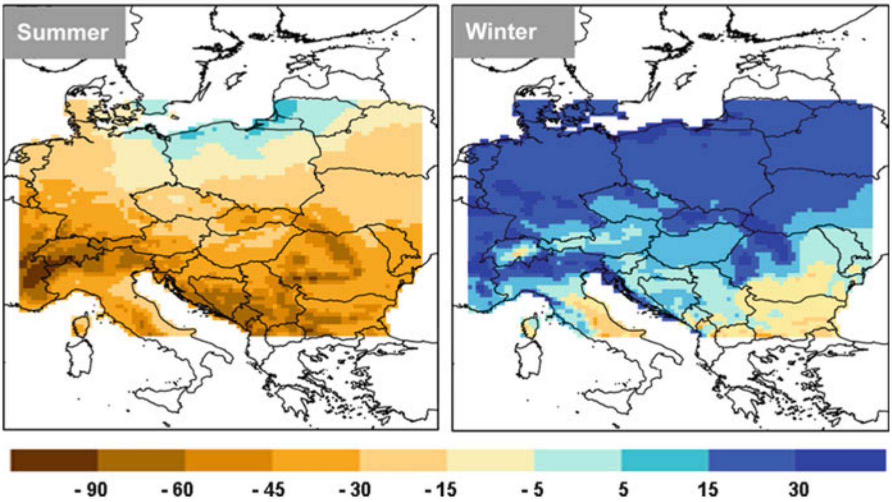

Fig. 3.2 Change of Climatic Water Balance in Central and Eastern Europe for winter (December–February) and summer (June–August) as the multi-model mean 2036–2065 relative to 1971–2000 [absolute differences in mm/3 months], for the A1B greenhouse gas emission scenario with 14 different GCM-RCM-combinations from the ENSEMBLES project (van der Linden and Mitchell 2009)

By the use of the Climatic Water Balance (CWB) expected changes on the potential water availability due to climate change can be illustrated. The CWB is defined as the amount of precipitation minus the potential evapotranspiration. It indicates the extent of the water yield in an area and provides an indication for the vegetation on-site.

If the potential evapotranspiration is higher than the amount of precipitation the CWB turns out to be negative and there is a climatic water deficit. A positive water balance indicates a climatic water surplus for the area. For the results shown in Fig. 3.2 the potential evapotranspiration is calculated with the TURC-IVANOV-method by DVWK (1996) and the monthly coefficients by Glugla and König (1989). For Central Europe an increase of the Climatic Water Balance is projected for the winter months with exception of the southern parts. In summer (June to August) the potential water availability tends to decrease in whole Central Europe (see Fig. 3.2).

3.3.2 Climate Change Impacts on River Runoff

River runoff consists of a portion of precipitation that is not evaporated, transpired or stored, e.g. by soils. Variations on river runoff are determined by climatic conditions like precipitation and temperature as well as catchment characteristics and watershed management practices. In numerous studies (e.g. Huang et al. 2012;

Hattermann et al. 2012) published in scientific journals potential effects of climate change in river flow regime have been examined. Most studies apply a hydrological catchment model which is driven by scenario climate data from regional climate models (dynamical or statistical) and adjusted for the investigation area (Bates et al. 2008). In the framework of the HABIT-CHANGE project the eco-hydrological watershed model SWIM (Soil and Water Integrated Model) (Krysanova et al. 1998) has been chosen to evaluate the impacts of climate change on eco-hydrological processes and water resources at a regional level provided by the Potsdam Institute for Climate Impact Research. SWIM is a continuous-time, semi-distributed watershed model, which combines hydrological processes, vegetation, erosion and nutrient dynamics at the meso- to macro-scale. After validation for the target areas, the model is used to transform changes in climate and land use into spatially distributed changes in hydrology and water resources under scenario conditions. Depending on the physiogeographical and hydrogeological characteristics, different river basins respond in different ways to the same change in climatic conditions. Uncertainties in projected changes in the hydrological system arise from internal variability of the climate system, uncertainties in future greenhouse gas and aerosol emissions, the translation of these emissions into climate change impacts by global climate models, regionalisation by regional climate models, hydrological model uncertainty and uncertainties in model input data (e.g. runoff, soil and land use data). Specific challenges in hydrological modelling are the scale difference between the climate and hydrological systems, data limitations and the effect of human interventions such as reservoir impoundment. However, modelling results can help to locate and assess possible future changes taking into account the range of uncertainty (different scenarios and models).

Changes in annual river runoff are projected to vary significantly across Europe, related to regional environmental settings and local changes in precipitation and temperature. Furthermore, changes in seasonal runoff regime and interannual runoff variability due to climate change depend primarily on changes in the amount and timing of precipitation, the evaporative demand and whether precipitation falls as snow or rain. Generally, annual river flows have been observed to slightly increase in the north and north-eastern part of Europe and to decrease in the south and south-eastern parts. Additionally, climate change leads to changes in the seasonality of river flows, particularly with a trend to lower flows in summer and higher flows in the winter months (EEA 2008, 2009).

A very robust finding of hydrological impact studies is that in snow-dominated watersheds warming would lead to changes in seasonality of river flows (Bates et al. 2008). Hence, spring flow tends to decrease in some areas as a result of reduced and earlier snowmelt and, in addition, winter flow increases by less winter precipitation falling as snow which can be stored. In some areas this effect could be diminished by a general increase in winter precipitation, even if the ratio of snow related to the total amount decreases. Summer flow in river basins with considerable groundwater contribution will change in accordance with changes in precipitation during the groundwater recharge period in winter. In regions with little or no

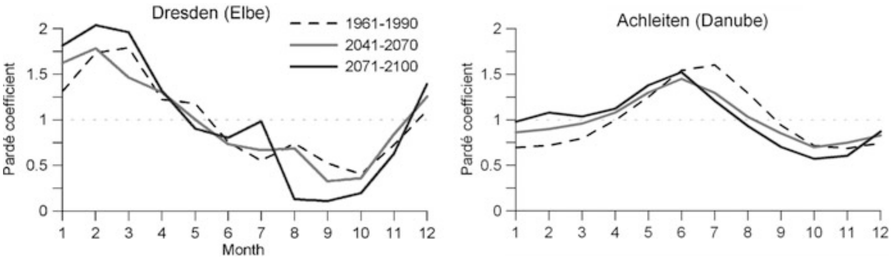

Fig. 3.3 Monthly Pardé-coefficients (PC = Q mean monthly/Q mean annual) simulated by the eco-hydrological model SWIM (Krysanova et al. 2000) driven by regional climate simulation from REMO for the A1B greenhouse gas emission scenario for gauge Achleiten at Danube river and gauge Dresden at Elbe river for three different time slices (long-term annual mean values for 1961–1990, 2041–2070 and 2071–2100)

snow fall, changes in river flow are much more dependent on changes in rainfall than on changes in temperature (Bates et al. 2008). Due to the non-linearity of response, the changes in river flow will always be considerably higher in percentage than the changes in the precipitation amount. Many studies in such regions project an increase in flow seasonality, often with higher flows in the peak flow season and lower flows during the low-flow season. Though, in most cases the timing of peak and low flows remains virtually unchanged (IPCC 2007).

River flow regimes can be described as the average seasonal behaviour of flow. Differences in the regularity of the seasonal patterns reflect different dimensionalities of the flow regimes, which can change due to changes in climate conditions. For Fig. 3.3 the non-dimensional monthly Pardé-coefficients are used to describe the annual distribution of discharge at two characteristic river gauges. The gauge Achleiten in the upper Danube catchment represents a mainly snow driven regime (nivo-pluvial), while the gauge Dresden in the upper Elbe catchment can be described as pluvial regime (rain-dominated). Figure 3.3 illustrates the expected shifts in the seasonality of river flows described above.

Future climate scenarios indicate a likelihood to more frequent floods in the next decades for many European regions, particularly in winter and spring (EEA 2008). Flood magnitudes are expected to increase where floods result from increasingly heavy rainfall events. Furthermore flood magnitudes are projected to decrease in regions where floods are generated by snowmelt (Kundzewicz et al. 2012). Despite the considerable rise in the number of reported major flood events over recent decades in Europe, no conclusively climate-related trend in extreme high river flows could be detected in observations up to now (EEA 2010; Pińskwar et al. 2012; Kundzewicz et al. 2012). River engineering and water management practices alter the river conveyance system over time which complicates the detection of climate change signals in observed river discharge data. Concurrently, the observed upward trend in flood damages can mostly be attributed to socio-economic factors and land use changes (Kundzewicz et al. 2012).

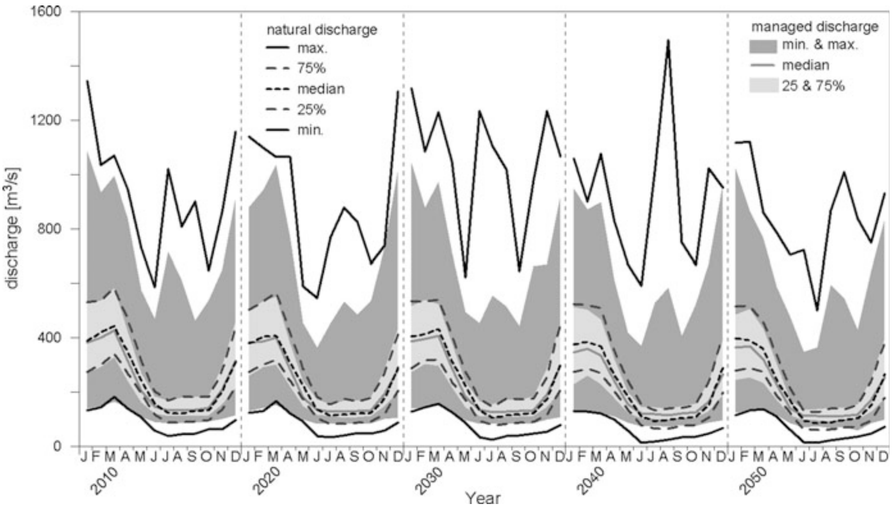

Fig. 3.4 Natural discharge (model SWIM) and managed streamflow (model WBalMo) at gauge Hrensko/Labe (Czech Republic) for the years 2010–2050 displayed as a 5-year average (e.g. "2010" stands for multi-year average of 2008–2012)

3.3.3 Water Resources Management Impacts on Streamflow

Besides climate change and land use change direct human interventions can affect natural runoff processes. When analysing the effects of such changes a clear differentiation between the natural discharge affected by climate change and land use change, and managed streamflow should be made. Therefore particularly in regions with large anthropogenic water use or water management effects, e.g. reservoir management or water transfers, natural runoff processes and the resulting natural discharge should be distinguished from measured (and managed) streamflow. In the project GLOWA-Elbe (Wechsung et al. 2011) an eco-hydrological model for the river Elbe basin was developed to simulate the effects of climate change and land use change on natural runoff. A water resources management model was used to simulate the effects of water management on streamflow and water availability. In the example presented in Fig. 3.4 climate change and land use change are considered in the simulation of the (unmanaged) natural runoff using the eco-hydrological model SWIM. From 100 realisations of future climate data, all assuming a temperature increase of approximately 1.8 °C by 2055, a corresponding number of realisations of natural discharge are generated (Conradt et al. 2012). This natural discharge is an important input for the water resources management model. Simulated in the water resources management model (WBalMo®[1] Elbe) are all relevant water users with their water demand and return flows, and the management of the water infrastructure, i.e. reservoirs and water transfers.

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[1] WBalMo is a registered trademark of DHI-WASY Ltd.

The river Elbe basin with a catchment area of approximately 150,000 km^2 is located in Central Europe (Czech Republic, Germany, Austria and Poland). Especially in the mountainous upper parts of the Czech Republic a number of large reservoirs are concentrated. These reservoirs are used to regulate the streamflow in the rivers Vltava/Moldau and Labe/Elbe, and to promote navigation and other water uses. As an example for the different quantities simulated by SWIM (natural discharge) and successive by WBalMo Elbe (managed streamflow) the flow at gauge Hrensko is displayed in the Fig. 3.4. The results are presented for the years 2010–2050, where 2010 stands for the time period 2008–2012 and so on. Since 100 realisations are used, 500 values (5 years * 100 realisations) are available for the statistical analysis for each time step of the respective time period.

Especially for dry periods in summer a decline of the natural low flows is simulated, e.g. "min" of natural discharges. The minimum managed streamflow in summer months is higher compared to the natural discharge, due to low flow augmentation by reservoirs and discharges from wastewater treatment plants etc. However, for mean conditions the differences between natural discharge and managed streamflow are rather small. During periods of high flows the managed streamflow is lower compared to the natural discharge, because water is used to refill the reservoirs. Overall the extremes caused by natural conditions are buffered by water resources management.

From Fig. 3.4 also the potential of water resources management to counterbalance effects of climate change and land use change on streamflow and water availability can be estimated. Not considered here are possibilities of adapting water management to changing conditions.

3.3.4 Climate Change Impacts on Glaciers

Glaciers are considered as key indicators for the early detection of global greenhouse gas related warming trends (IPCC 2007). Moreover, glaciers itself have considerable impact on the runoff regimes of rivers with glaciated areas within their catchments. Basic requirement for the formation and persistence of glaciers is the accumulation of snow which is not entirely melted in the following summer and remains as firn till the next winter. The firn of several years compacts to ice and finally starts to flow following gravity. In Central Europe, glaciers are located in the Alps as well the Caucasus with a total ice covered area of 3,778 km^2 (Zemp et al. 2008; WGMS and NSIDC 1989, updated 2012). Since their last maximum during the little ice age in the middle of the nineteenth century, most glaciers in these areas are shrinking.

In the twentieth century, annual temperature increased by 1.3 °C for the alpine region (Auer et al. 2007). Additionally, winters in the alpine areas became drier in the last 25 years and therefore reduced the amount of snow accumulation (Zemp et al. 2008). Both processes have negative effect on the existing glaciers.

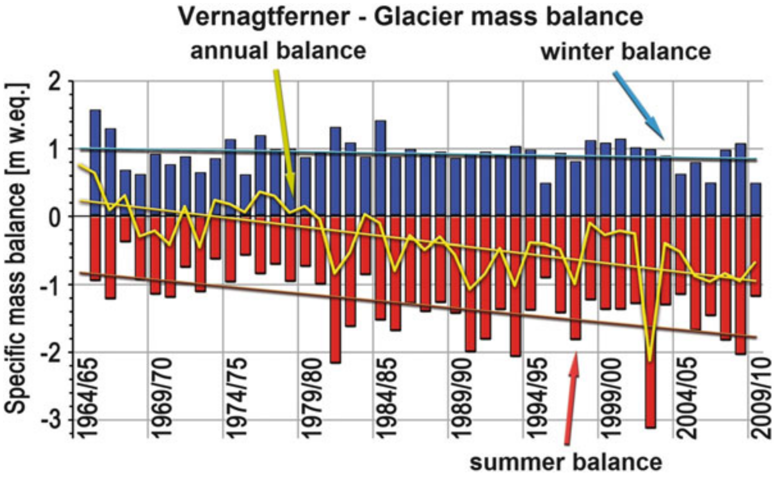

Fig. 3.5 Winter, summer and annual mass balance of the Vernagtferner in Austria for the period 1964/65 to 2009/10

In the Alps, glacier cover was shrinking by 35 % from 1850 to the 1970s and another 22 % by 2000 (Paul et al. 2004) and also in the Caucasus a severe mass loss is evident since the little ice age (Zemp et al. 2008). In Central Europe, front variations of glaciers are observed at 764 glaciers with an average time length of 65 years. But to determine the direct reaction of a glacier to climate change, ice volume changes – the so called glacier mass balance – have to be observed. In the mid latitudes, the mass balance of a glacier is mainly dependent on winter precipitation (accumulation) and summer temperature (ablation) which are measured separately in spring and autumn. In Central Europe, these measurements are available for 43 glaciers with an average number of observations of 20 years (Zemp et al. 2008). One of the longest time series of mass balance is measured at the Vernagtferner (46°52′N/10°49′E) in Tyrol, Austria (Fig. 3.5).

Direct measurements of both, winter and summer mass balance were initiated in 1964 (Reinwarth and Escher-Vetter 1999). Winter, summer and annual mass balance since then are presented Fig. 3.5. The annual mass balance trend is negative with some positive years in the 1980s and beginning 1990s and a prominent negative peak in 2003 where a heat wave in Europe heavily accelerated the icemelt. While the winter mass balance shows just a slight decreasing over the full period, ice losses in summer are increasing considerably in the same time.

The trend of negative mass balances is therefore mainly caused by enhanced melt in summer while changes in winter accumulation have only small influence. The time series of area changes at Vernagtferner is even longer and documents a glacier shrinking from 11.6 km^2 in 1889 to 7.9 km^2 in 2010.

The influence of glaciers on runoff and the effect of changing glaciation due to climate change are of high importance for the water availability in many regions.

A glacier in equilibrium state with stable ice volumes results in a glacial runoff regime with runoff maximums during the ablation period in summer. A shrinking glacier causes increased melt water supply and enforces the glacial regime (Lambrecht and Mayer 2009). Gradually shrinking glacier areas finally lead to decreasing amounts of ice melt and therefore finally to a shift from glacial to nival runoff regime with runoff maxima shifting from July and August to May and June (Huss et al. 2008). How big these impacts are for the river runoff and the water availability is highly dependent on the climate conditions. Melt water is most important in climates which are both warm and dry and gets even more important if the river flows into an arid area. In the mid latitudes of Central Europe, the share of glacier melt to total runoff is only moderate because of the high additional precipitation input (Kaser et al. 2010).

3.4 Conclusion

There is convincing evidence that increasing concentrations of greenhouse gases in the atmosphere are causing a substantial rise in global temperature (IPCC 2007). As integral component of the climate system, water is the primary medium through which climate change exhibits its impacts on earth’s ecosystem. Increases in temperature enhance the moisture holding capacity of the atmosphere and thus, lead to an intensification of the hydrological cycle. The hydrological impacts of climate change to the individual protected areas are area-specific and vary from region to region. Generally, key changes in the hydrological system for Central Europe include alterations in the seasonal distribution, magnitude and duration of precipitation, an increase in evapotranspiration in areas where water is available and a reduction of the snow season. This leads to variations in water storage and water fluxes at the land surface as well as in soil moisture and seasonal snow packs. Observations of central European glaciers, which are considered as key indicator for the early detection of climate change, show a severe mass loss in the last decades. Other indirect impacts of climate change include modifications in the intra- and interannual variability of river flows and an increase in the risk of flood and droughts. Through, water resources management can help to counter-balance effects of climate change on stream flow and water availability until a certain level. In general, climate-induced changes are projected to aggravate the impact of other stresses like land-use and socio-economic changes on water availability (EEA 2008).

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Chapter 4
Potential Impacts of Climate Change on Protected Habitats

Anca Sârbu, Georg Janauer, Ingolf Profft, Mitja Kaligarič, and Mihai Doroftei

4.1 Climate Change and the Protected Areas of Europe

Climate change is recognised as a major global threat (Stern 2007), which will have significant impacts on many aspects of biological diversity in the near future (Campbell et al. 2009).

Unfortunately, climate change is happening on a day-to-day basis and will continue to affect biodiversity and, thus, induce biodiversity loss with negative effects for human well-being and natural systems (EEA 2010).

According to the existing research, various protected areas and protected habitat types across Europe are predicted to be negatively affected by climatic change (Normand et al. 2007). Changes in climatic conditions will likely threaten the

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sustainability of existing protected plants and habitats in different ways and with different magnitude (Andrade et al. 2010). It is expected that climate change will affect the species composition, reduce the richness of taxa, and will substantially modify the functionality of many ecosystems (Andrade et al. 2010).

Some studies and projections (Araújo et al. 2011) claim that by 2080 about 58 % of European terrestrial plants and vertebrate species will no longer find climatic conditions suitable for survival within the current protected areas. The consequences of potential climate change will be illustrated by Natura 2000 sites.

The aim of this chapter is to provide some information on actual and anticipated impacts of climate change responsible for potential habitat changes in Natura 2000 sites, which comprise the most important protected areas for maintaining the natural heritage of Europe (Campbell et al. 2009; EEA 2010) and especially Central Europe. This chapter was prepared as part of the international project HABIT-CHANGE "*Adaptive management of climate induced changes of habitat diversity in protected areas*," consisting of partners from protected areas and scientific organisations from eight European countries.

4.2 Considered Habitats, Categories of Source and Taxonomic Nomenclature

To identify the potential effects of climate change on protected habitats, Natura 2000 habitat types selected for the HABIT-CHANGE project were considered. These types were grouped into 14 categories (groups) according to the Natura 2000 system of classification (Interpretation manual of European Union Habitats, European Commission – DG EUR 27 2007).[1]

Three categories of sources were used to compile the information of this chapter: expert knowledge, specialised literature, and the authors' expertise.

The information on impacts per habitat group was mainly based on expert knowledge and was obtained by an enquiry of local experts focussing on actual and potential future effects of climate change on Natura 2000 habitats. The basic information was provided by experts from ten protected areas within the frame of the HABIT-CHANGE project: Balaton Upland National Park, Biebrza National Park, Danube Delta Biosphere Reserve, Flusslandschaft Elbe – Brandenburg Biosphere Reserve, Köros-Marcos National Park, Bucegi Natural Park, Rieserferner Ahrn Nature Park, Secovlje Saline Nature Park, Triglav National Park and Vessetal Thuringian Forest Biosphere Reserve.

An additional source of information was specialised literature included in HABIT-CHANGE output 3.1.1. (HABIT-CHANGE 2010) as well as the personal expertise of the authors of this chapter. The nomenclature of species used in this chapter is in accordance with The Plant List (2010).

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[1] See HABIT-CHANGE output 3.2.5, 2011.

4.3 Impacts of Climate Change on Natura 2000 Habitats

Out of 169 habitat types described in the EEA Natura 2000 Database of Europe, 89 corresponded with those present in the protected areas studied for the HABIT-CHANGE project (see Table 4.1).

Seven potential impact classes of climate change on habitats in protected areas were identified: seasonality (changes of mean and maximum temperature, precipitation, frost and snow days), hydrology (decrease of precipitation during vegetation period, change in precipitation intensity and variability), soil (change of soil structure, nutrients and chemistry), sea-level rise (local coastal flooding), extreme events (heavy rains, floods, drought, wildfire, storm), CO_2 concentration (increasing concentration), and cumulative effects (the shift in species composition and abundance, the invasion of aliens, pest development, land use changes).

For **coastal and halophytic habitats**, the major impact of climate change can be considered sea-level rise, which induces erosion of coastlines followed by impacts on soil structure. Regarding sea-level rise, the Black Sea shows an increasing trend with an average rate of 2.11 ± 0.2 cm/year (Gâştescu and Ştiucă 2008). For the Mediterranean Sea it is estimated that the sea-level will increase between 12 and 30 cm by 2100 (Strojan and Robic 2009).

Seacoast habitats with vulnerable halophyte vegetation could be flooded in the near future. In this context, the annual vegetation of drift lines (Natura 2000 code 1210) from the Danube Delta Biosphere Reserve, which occupies only small areas (1.968,70 ha) on marine sand deposits (Gafta and Mountford 2008) along the Black Sea shore, could be lost (Fig. 4.1).

Table 4.1 Habitat groups (classes of habitats in capital letters, subclasses of habitats in lower case letters) including the number of habitat types relevant for the HABIT-CHANGE investigation sites, listed for these groups in EEA Database of Natura 2000 sites in Europe and recorded in the investigation sites (HABIT-CHANGE 2011)

	Number of habitat types	
Habitat group	EEA database	HABIT-CHANGE investigation areas
01 COASTAL AND HALOPHYTIC HABITATS	28	12
21 Sea dunes of the Atlantic, North Sea and Baltic coasts (+ Black Sea)	10	4
23 Inland dunes, old and decalcified	4	2
31 Standing water	10	4
32 Running water	9	5
40 TEMPERATE HEATH AND SCRUB	12	7
61 Natural grasslands	9	5
62 Semi-natural dry grasslands and scrubland facies	12	6
64 Semi-natural tall-herb humid meadows	6	6
65 Mesophyll grasslands	3	2
70 RAISED BOGS AND MIRES AND FENMS	12	6
80 ROCKY HABITATS AND CAVES	14	11
91 Forests of Temperate Europe	37	17
94 Temperate coniferous forests	3	2

Fig. 4.1 Annual vegetation of drift lines viewed from the strictly protected area in the Danube Delta Biosphere reserve (Photo: Mihai Doroftei)

Other significant examples can be found along the Slovenian seacoast of the Mediterranean Sea (Sečovlje Salina and Škocjan Inlet) where four different coastal wetland habitat types are affected by sea-level rise: rush salt marches dominated by *Juncus maritimus* Lam. and/or *Juncus acutus* L. (Natura 2000 code: 1410) (Kaligarič and Škornik 2007), *Spartina* sp. Schreb. swards (Natura 2000 code: 1320), *Salicornia* sp. L., and other annuals colonising mud and sand (Natura 2000 code: 1310, see Fig. 4.2) and Mediterranean and thermo-Atlantic halophilic scrub (Natura 2000 code: 1420).

The main threat to these four coastal habitat types is the rising sea-level. The long-term trend of this process was 1 mm p.a., but in the past 25 years this trend changed to 5 mm p.a. (Kaligarič and Škornik 2007). Considering this development it is possible that many Mediterranean seacoast habitats will be flooded or changed in the near future. The problem is that the enlargement of coastal habitats in case of sea-level rise is impossible since they are surrounded by urban or industrial zones, agricultural areas, or infrastructure. Buffer zones for potential migration usually do not exist.

For **sea dunes of the Atlantic, North Sea and Baltic coasts** (plus Black Sea), the major impact of climate change will be the decline of groundwater level.

The **old and decalcified inland dunes** are complex habitats including pioneer communities of terophytes and lichen communities growing on barren lands (Gafta and Mountford 2008). Hydrological changes and changes of soil structure can be considered as significant impacts.

Fig. 4.2 Slovenian shallow coasts colonised with *Salicornia* sp. and other halophytes are frequently bordered with ports, urban areas, or infrastructure, with no possibilities to migrate in case of further sea-level rise (Photo: Mitja Kaligarič)

For **standing water** as well as for **running water** habitats, the most significant impacts are hydrological changes affecting water regime and water level.

For running waters these factors can induce an irreversible alteration of flood plain areas, river bed modification, or drying out of the river. Other relevant impacts are changes in temperature regime, which influence the development pattern of aquatic organisms and changes in bank ecotone conditions. Higher water temperature will cause water quality to deteriorate with a negative effect on microorganisms, benthic invertebrate, plankton species, and for different categories of aquatic macrophytes (Campbell et al. 2009).

The majority of aquatic macrophytes in the Lower Danube river system belongs to the mesothermophyte group (*Elodea canadensis* Michx., *Ceratophyllum demersum* L., *Potamogeton crispus* L., *P. nodosus* Poir., *P. pectinatus* L., *Vallisneria spiralis* L. s.o.) (Popescu and Sanda 1998). In contrast some adventive aquatic macrophytes as *Elodea nuttallii* (Planch.) H.St. John (Fig. 4.3) and *Lemna minuta* Kunth (Fig. 4.4) prefer warmer water temperatures and can develop an invasive behaviour in conditions of climate change. In this respect *Elodea nuttallii*, a short-time adventive species in Romania (Ciocârlan et al. 1998) was found in the majority of the Romanian Danube river corridors 8 years after its first discovery (Sârbu et al. 2006). *Lemna minuta* was first discovered in Romania within the Danube Delta in 2011 (Ciocârlan 2011).

As cumulative effects changes regarding the structure of aquatic biocoenosis and the expansion of alien species, especially more thermophylic organisms, must be expected.

Fig. 4.3 *Elodea nuttallii*, Danube Delta Biosphere reserve, June 2005 (Photo: Anca Sârbu)

Fig. 4.4 *Lemna minuta* (the small one) and *Lemna gibba* L., Kis-Balaton area, Hungary (Photo: Marco Neubert)

Fig. 4.5 Bushes with *Pinus mugo* and *Rhododendron myrtifolium* at the Bucegi mountains affected by erosion and fragmentation (Photo: Anca Sârbu)

Significant impacts with periodic variations are expected for **temperate heaths and scrubs** in alpine climate. Changes will occur in the temperature and precipitation regime, frost and snow days. Also, extreme events like torrents and storms associated with erosion, ruptures, and habitat fragmentation will occur more often. The expected cumulative effect could lead to the potential loss of plant species strongly depending on humidity and low temperature, as well as to degradation and potential loss of some types of habitats dominated by mesophytes or mesohygrophytes and psichro-thermophytes, like bushlands with *Pinus mugo* Turra and *Rhododendron myrtifolium* Schott & Kotschy (Natura 2000 code: 4070, Fig. 4.5).

An assessment of this habitat type carried out in June and July 2010 at Bucegi mountain shows that 90 % of the recorded plant species are depending on humidity (mesophytes and mesohygrophytes) and 70 % on low temperature (hekistotermophytes, psichrotermophytes and microthermophytes).

Climate changes expressed in terms of temperature rise and humidity decrease affect the dominant species (*Pinus mugo*), significantly reduce its diversity, and endanger the quality and integrity of this habitat type. Erosion and human activities, such as tourism, construction works, transportation, or eutrophication are all factors intensifying this development.

Alpine **natural grasslands** will feel significant climate change impacts through increasing temperatures (mild winters, warm spring and summer), decreasing precipitation (droughts in summers, less snow in winter), and more frequent extreme events like torrents and heavy rains associated with soil erosion. It is suggested that changes in composition of grasslands are likely in response to climate change (Campbell et al. 2009). Changing environmental conditions in the alpine zone will determine the disappearance of plant species sensitive to drought,

Fig. 4.6 Silicious alpine and boreal grasslands (Natura 2000 code: 6150) from Bucegi Natural Park; in front the rare and threatened plant *Nigritella nigra* (Photo: Anca Sârbu)

high temperature, and eutrophication, and will favour the expansion of drought tolerant ones, the increase of scrub abundance, and will modify succession sequences.

The alpine natural grasslands from Carpathian mountains, e.g. the silicious alpine and boreal grasslands (Natura 2000 code: 6150, see Fig. 4.6), accommodate many plants with high conservation value that strongly depend on low temperature, snow and humidity, such as the endemic *Dianthus glacialis* subsp. *gelidus* (Schott, Nyman & Kotschy) Tutin and the rare *Nigritella nigra* (L.) Rchb. f., which can be considered threatened by changing climate conditions.

For **semi-natural tall-herb humid meadows** the frequency, duration, and period of flooding are significant hydrological preconditions for sustenance. Severe drought and increasing mean temperature interfere with this necessary environmental setting and are often associated with a significant frequency of wildfires. Other effects like mineralisation of peat and accumulation of organic material address impacts on soil structure and nutrients.

For **mesophyll grasslands** (see Fig. 4.7) significant impacts are related to hydrology, e.g. changes in flooding regime and of groundwater level, rising temperature, change in precipitation pattern, or extreme weather events like heavy rains associated with soil erosion. Cumulative effects consist of changes in succession sequences, expansion of alien species, degradation of the habitat, and possible loss of species with high conservation value like the endangered plant *Gentiana lutea* L., and the rare plant *Trollius europaeus* L.

For **raised bogs, mires and fens** many different impacts can be considered: changes of groundwater level, changes of precipitation pattern, temperature

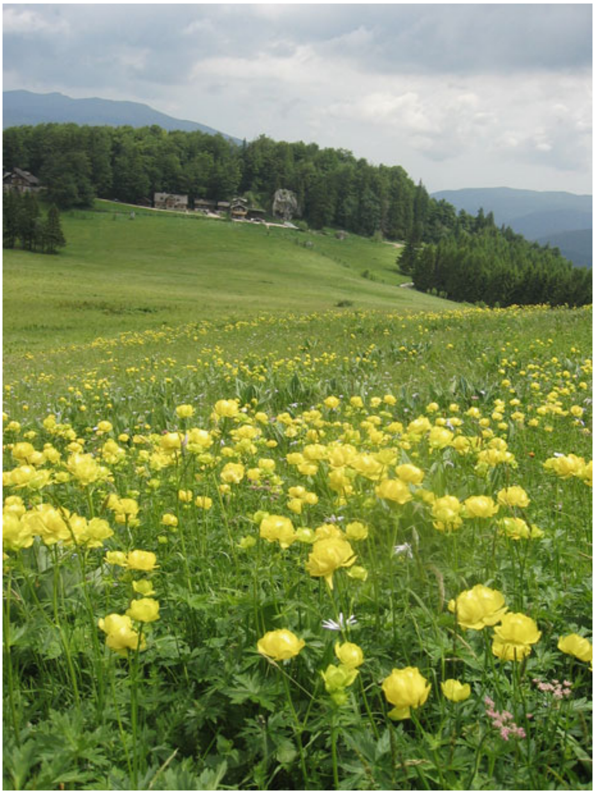

Fig. 4.7 Mountain hay meadows (Natura 2000 code: 6520) with a significant population of the rare plant *Trollius europaeus* L. within Bucegi Natural Park (Photo: Anca Sârbu)

increase and drought, wildfires, or changes in soil quality, such erosion, soil leaching, mineralisation of peat, and accumulation of organic material. Cumulative effects can consist of changes in succession sequences, increasing tree cover and spread of reed and alien plants, which affects bryophytes and other specialised plants.

For **rocky habitats and caves** (Fig. 4.8) significant impacts are related to temperature increases and precipitation decreases associated with permafrost melting and glacier retreat. Soil erosion and the frequency of avalanches as extreme events also need to be considered. Among cumulative impacts the loss of the colder climatic zone at high altitudes and a significant loss of plant species strongly depending on vernalisation can be expected.

In this respect many plants found within Natura 2000 habitat type 8210 at Bucegi Natural Park like the endemic *Achillea oxyloba* subsp. *schurii* (Sch.Bip.), Heimerl, and the rare plants *Androsace chamaejasme* Wulfen, *Asplenium adulterinum* Milde, *Campanula carpatica* Jacq. *Saxifraga oppositifolia* L., and *Viola dacica* Borbás s.o can be considered under threat (Ciocârlan 2009).

Forest of temperate Europe vegetation type will experience seasonal hydrological impacts on soils and related extreme events. Trees are especially negatively

Fig. 4.8 Calcareous rocky slopes with chasmophytic vegetation (Natura 2000 code: 8210) with *Achillea oxyloba* subsps. *schurii* within Bucegi Natural Park (Photo: Anca Sârbu)

affected by changes in seasonality (Milad et al. 2011; Profft and Frischbier 2009), temperature increase, and changes in precipitation pattern. They are also sensitive to increased drought stress associated with fluctuation in frequency, amplitude and moment of a drought's appearance, and to changes in groundwater level and in flooding regime. Torrents, storms, and heavy rains can all be ranked as heavy impacts. Cumulative impacts could lead to the loss of relevant and sensitive species, changes in the structure of the forest community, drying out of forest areas, an increased advantage of the propagation of pests, and improved conditions for the development of alien plants. Monitoring data show a significant relation between warmer growing conditions and the distribution and abundance of pest insects, such as bark beetles on spruce or larch (e.g. *Ips typographus* Linné), as well as oak processionary (*Thaumetopoea processionea* Linné) or horse chestnut leaf miner (*Cameraria ohridella* Deschka and Dimic).

Temperate coniferous forests dominated by trees depending on water supply (mesophytes, mesohygrophytes) and low temperatures (microthermophytes) are

Fig. 4.9 Spruce forest ecosystem of the Thuringian Forest, Germany, damaged by storm "Kyrill" on January 17, 2007. In total, about 2.7 % of the forest area was damaged. According to the German Weather Service (Deutscher Wetterdienst, DWD), the likelihood of the occurrence of such an extreme weather event is every 10–20 years (Photo: Karina Kahlert)

affected by changes in temperature and precipitation pattern as well as in groundwater level. Heavy rains, storms, and torrents need to be considered as significant impacts for forest life as well. They can have a great impact on stand stability and can cause sudden and dramatic ecological and economic losses (Fig. 4.9).

Some tree species might benefit from warmer growing conditions and longer vegetation period, but if the speed of increasing temperature is higher than the natural drifting speed for tree species (Bolte et al. 2009) the growing potential of some trees, e.g. *Picea abies* L., will be affected. Decreasing precipitation during the growing season is predicted for many parts of Europe (IPCC 2007) by various climate scenarios. This could diminish growing conditions for present tree species, too (Fig. 4.10).

4.4 Which Trends Can Be Predicted for Natura 2000 Habitats?

Climate change impacts on ecosystems and species living within these add more and more to the global challenge of biodiversity conservation (Campbell et al. 2009; Pompe et al. 2010).

In this respect the Intergovernmental Panel on Climate Change (IPCC 2007) has pointed out several types of major changes to ecosystems as a result of climate

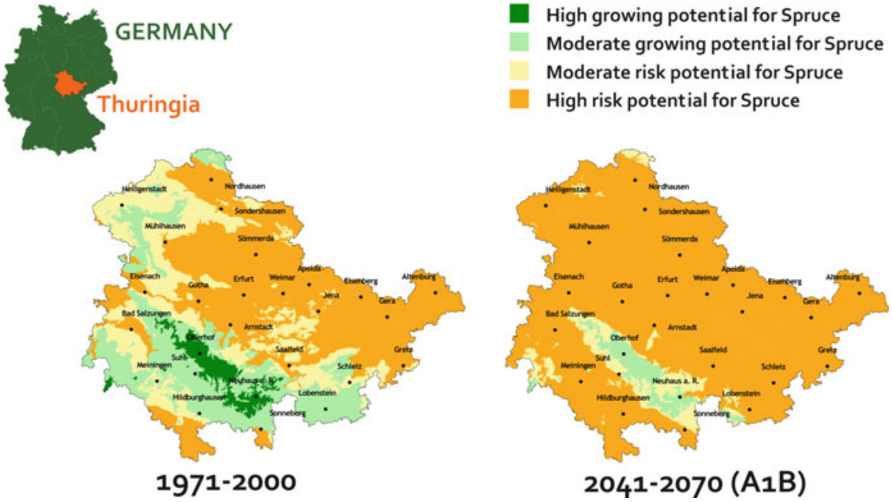

Fig. 4.10 Assessment of present and future growing potential for Norway Spruce (*Picea abies* L.) according to a combination of four climate thresholds for Spruce (Source: ThüringenForst, Service and Competence Centre)

change: changes in the distribution, composition, structure and functions, as well as changes in successional processes and in the value and services they provide.

There is also increasing evidence for ecological responses to recent climate changes and for the need of more information concerning the different possible climate change impacts and the linkages between them (Walther 2007).

Based on the climate change effects reported from the ten protected investigation areas of the HABIT-CHANGE project, seven impact classes related to 14 habitat groups were identified: seasonality, hydrology, soil, sea-level rise, extreme events, CO_2 concentration, and cumulative effects.

The 14 groups of Natura 2000 habitats taken into consideration in this chapter are simultaneously subjected to various categories of climate change impacts. All of them are being affected to different degrees by cumulative effects of climate change.

It is quite difficult to estimate which of these groups of habitats will be more profoundly affected by climate change impact in the future. The magnitude of impacts varies depending on the ecological requirements of plant species, in combination with their distribution range and dispersal ability (Normand et al. 2007).

However, some assertions can be made. The extent and rate of climate change puts forest ecosystems at high risk. Forestry in general faces particular difficulties, such as strong dependency on existing site conditions that cannot be modified, existing stand conditions exposed to nitrogen deposition and acidification, and multiple demands and expectations by society that have a direct influence on management strategies. A positive effect on forest growths can be expected on the short- and medium-term due to changes in mean climatic variables, but on the long term increasing drought and extreme weather events will become great risk factors for forest sustainability (Lindner et al. 2010).

A series of evaluations on the ecological spectrum of sub-alpine and alpine habitats of Bucegi mountains, made within the HABIT-CHANGE project, support the fact that they show significant vulnerability (related to 50–70 % of the species) with regards to projected temperature and humidity changes. If we add the fact that alpine plants may only be able to migrate horizontally (and this is by no means a certainty) we can conclude that alpine habitats are also very vulnerable. In this respect some studies addressed to alpine grasslands, underline the acute vulnerability of many dominant grasses and rare species to warming and drought and predict significant shifts in plant composition (Erschbamer et al. 2009).

Taking into account the inevitable prognosis of rising sea-levels, we can conclude that halophyte and coastal habitats may be lost in the near future. Such habitat types are more often near urban, industrial, or tourist areas, which diminish the chance even more that they could avoid effects of sea-level rise by migrating into other areas. The sustainability of coastal habitats will be especially problematic where there are limited options for landward migration (Gilman et al. 2008; Strojan and Robic 2009). Coastal habitats and their species that are of community interest are at risk in Europe and many of them have an unfavourable conservation status (EEA 2010).

Unfortunately, climate change effects will become noticeable everywhere and the vegetation, the basis on which biodiversity is established, will react according to the vital requirements of species it is composed of. This reaction to projected climate change impacts will be at a slower or faster rate, but nonetheless vegetation will react in a non-favourable direction.

In this respect some effects which also address Natura 2000 habitats were already observed (Campbell et al. 2009) and are expected to increase: the shifts in location of those ecosystems that can migrate (Salazar et al. 2007), changes in species composition and richness (Moritz et al. 2008), the loss of plant species with small ranges (Pompe et al. 2008) or strongly depending on special edaphic conditions (Colwell et al. 2008), the spread of invasive species (Rahel and Olden 2008), or the opportunity for native species to become invasive (van der Wal et al. 2008).

Climate change is already affecting ecosystems and the species of Natura 2000 sites. The understanding and documentation of this ongoing process will become increasingly important for the development of adaptation in the conservation sector.

4.5 Conclusions

The results of our analysis are not representative for all Natura 2000 habitats but they give an indication on major impacts relevant for protected areas included in the HABIT-CHANGE project located in Central Europe.

The information for approximately 50 % of the habitats listed in the Natura 2000 database enabled the identification of seven potential impact categories that are determined by climate change and that these habitats are confronted with now and in the future.

Each of the 14 Natura 2000 habitat categories taken into consideration is faced with a number of climate change impacts leading to a wide variety of effects: from the reduction of biodiversity and degradation of habitat quality to the potential loss of certain habitat types strongly depending on actual climatic conditions.

Even though there are several opinions regarding the level of potential vulnerability of different habitat categories, it is difficult to pinpoint which will ultimately be more profoundly affected by climate change impacts.

A significant uncertainty still exists regarding the level of performance of Natura 2000 habitats in the future, as the multitude of plant species and of environmental parameters and their interaction make more detailed projections nearly impossible at present. Therefore, a deeper insight in the complex network of species' reaction and climate change aspects need to be made available to scientists and practitioners as to provide more focused solutions for mitigation measures and possible re-orientation of conservation practices.

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Part III
Tools and Concepts for Climate Change Adapted Management

Chapter 5
Climate Change Impact Modelling Cascade – Benefits and Limitations for Conservation Management

Katrin Vohland, Sven Rannow, and Judith Stagl

5.1 Introduction

Even if all political targets are met, climate change is expected to increase temperatures within the next decades globally and to change climate regimes locally, resulting in shifting water regimes and extreme weather events. In Central Europe temperatures are expected to increase and the climatic water balance, especially in summer, to decrease (see Sect. 3.3.1). Consequently, adaptation to climate change will become a necessity. Thus, it is crucial to overcome the notion that accepting the need for adaptation implies admitting the failure of climate policy. In fact, there are some instruments which provide high synergies between adaptation and mitigation, for example, in the area of forest conservation or ecosystem based adaptation as defined by the Convention on Biological Diversity (CBD). In short, adaptation to climate change is becoming increasingly important for nature conservation management. But adaptation to which specific climate change impacts?

One answer is expected to come from the area of modelling. Modelling is increasingly important for understanding and projecting climate change impacts. Hence, model results can serve as a basis for adaptation. However, there is a gap

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between the kind of information models can provide and what managers of natural areas need. The perception of models differs between disciplines and between science and practice. Models range from semantic descriptions of assumed interrelations to computer based mathematical models; the term 'model' is often used for computer based models only.

During recent decades, model-based prediction of biological responses to climate change has become a very active field of research. In the field of climate change modelling, models primarily enable understanding of global climate cycles. The development of models could demonstrate the impact of human activities on the earth climate system. Models serve to structure knowledge, to formulate hypotheses and to illustrate future developments. In the field of nature conservation management, the development of alternative scenarios is of special interest. Different management options may lead to different futures. Ex-ante assessment of the outcome of specific management measures in conjunction with different climate change impact scenarios may support management – but may also lead to deep frustration because of the high degree of uncertainty about future developments. Especially the necessary combination of different model types, such as climate models, vegetation models, and hydrological models, including all their underlying assumptions and uncertainties, renders it difficult for managers to identify useful options for decision making.

Even though there have been extensive studies to model the impacts of climate change on biodiversity, the results are still sobering. In 2002 the IPCC found that "most models of ecosystem changes are not well suited to projecting changes in regional biodiversity" (IPCC 2002: 15). More and more authors have picked up this critical attitude towards the modelling of climate effects (e.g. Biesbroek et al. 2009; Opdam et al. 2009; Pyke et al. 2007). After a far-reaching survey of literature on conservation issues, Heller and Zavaleta (2009) concluded that "many articles based on concrete modeling work or empirical studies of species responses to climate change tended either to not elaborate their results to management directives, or to present recommendations in vague terms such as, 'restoration should be considered'" (Heller and Zavaleta 2009: 17). Therefore, Heller and Zavaleta highlighted the need to pay more attention of transferring modelling results into the decision context of management issues (Heller and Zavaleta 2009). This problem is not only limited to conservation management but to adaptation to climate change in general (Millner 2012).

In this chapter we are describing concrete model approaches used to support decision-making within the HABIT-CHANGE project context. Facing climate change, climate impact models are currently seen as a big support for the development of alternative management scenarios. Handling uncertainties and understanding the 'model cascade' will help in judging where models will supply useful information. A short overview of model approaches and their assumptions is presented as a basis for adaptive management and their benefits as well as limitations are discussed.

5.2 The Long Model Cascade

A major problem in communicating model results is the long 'model cascade' with partly hidden assumptions about future development. Results from one model are fed into the next one, which itself relies on assumptions or hypotheses. This results in a chain or cascade of models that starts with projections of the global greenhouse gas emissions, moves on to the impact of the global climate system and on to regional or local impacts on flora and fauna (Fig. 5.1). The relevance and reliability of the final outcome might, thus, be difficult to judge with regard to modelling uncertainties. To have an impression of the usefulness of the specific contribution

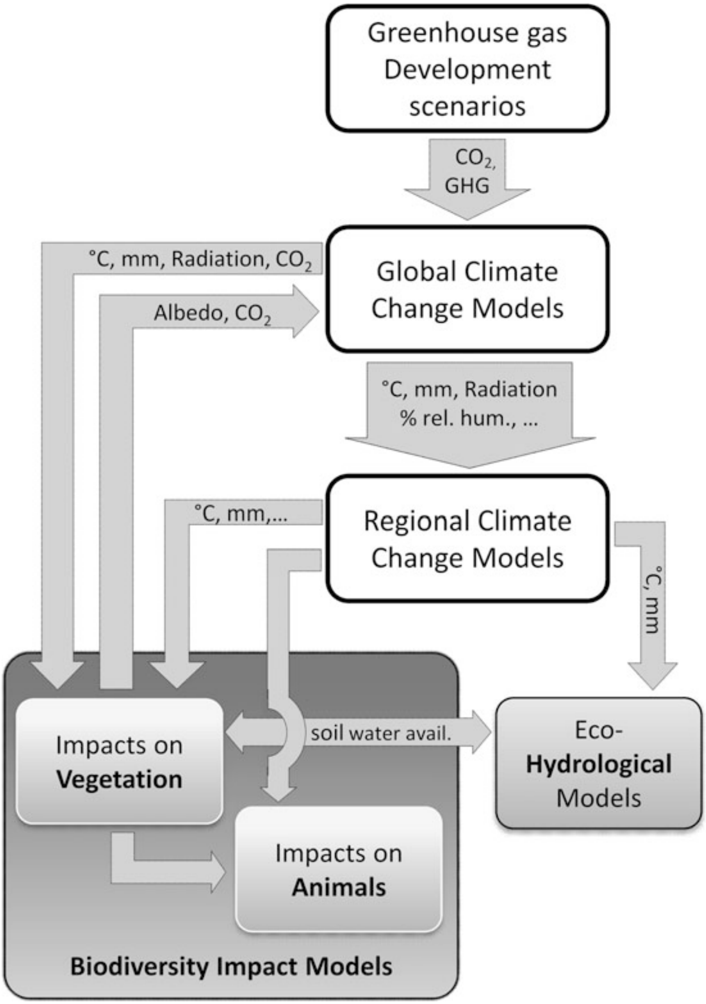

Fig. 5.1 The chain/cascade from emission scenarios to regional climate impact models

of models to adapt the management of protected areas with regard to climate change, we follow the course of this model cascade and make various underlying assumptions and models transparent.

5.2.1 Climate Models

Some prior steps are necessary for regional climate change impact projections. A big challenge for earth system analysis was to understand the interplay between human activities, greenhouse gases, and the climate system of the earth (IPCC 2007). The higher the concentration of greenhouse gases, the higher the energy of the atmosphere is. This results in higher global mean temperatures and subsequently increased global evaporation. Here, the model cascade starts (Fig. 5.1). Each model type builds at least partly on physically based assumptions, hypotheses and input data from prior cascade results (Table 5.1). In the Special Emission Scenarios (SRES; Nakićenović and Swart 2000) projections about the future development of earth's population with regard to population numbers, economic development, energy sources etc. were developed. According to these scenarios (e.g. B1, A2 etc.) concentrations of greenhouse gases are projected. This provides input for global circulation or climate models (GCMs). These global models normally work on a global grid (e.g. at the resolution of 50×50 km^2).

For a park manager, a 50×50 km^2 resolution is far from being useful for management adaptation. For example, in mountainous regions with climate variables differing at a small scale a resolution of several hundred metres is required to be helpful. Currently, there are two alternative model approaches to derive more regional and local resolutions. It is possible to downscale the results from global models dynamically to a resolution of 10×10 km (0,08°), an option chosen by the Max Planck Institute for Meteorology in Hamburg with the climate model REMO (Jacob and Podzun 1997). Alternatively, statistical regional climate models scale down trends from global climate models based on data from local weather stations and only include the global temperature trend as a parameter. This is how regional climate models such as STAR or WettReg work (Orlowsky et al. 2008). While the latter reflect the local conditions more precisely, the former has the advantage of also including new climatic conditions and long-term developments.

However, most park managers focus on living organisms, mainly plants, where temperature and precipitation alone are not sufficient parameters to identify climate change impacts. A more useful integrated indicator is the climatic water balance (CWB). The CWB expresses the difference between precipitation and potential evaporation. In the framework of the HABIT-CHANGE project, climate change projections have been provided for all the investigation areas (Stagl et al. submitted). In Fig. 5.2 the results are displayed via boxplots for two selected investigation areas for three time periods: (a) For the Natural Park Bucegi (Romania) the climate models indicate, despite the existing inter-model uncertainties, a clear trend towards a reduction of potential water availability for the

Table 5.1 Model assumptions, hypothesis and data along the model cascade

Model type/ focus	Greenhouse gas development	Global climate change	Regional climate change	Hydrological climate change impacts	Climate change impacts on vegetation	Climate change impacts on animals
Assumption/ hypothesis/ mechanism	Population growth, economic growth, use and consumption of fossil fuels, deforestation	Increasing green house gases	Regional modification of global trends by land surface	Climate, soil, and vegetation impacts the water cycle	Distribution and physiology of plants determined mainly by solar energy, temperature and moisture	Distribution of animals determined mainly by temperature and moisture
Model/tool	(Extrapolation of greenhouse gases)	Global Circulation Models (GCMs)	Regional Climate Models (RCMs)	Hydrological models	Statistical models (e.g. bioclimatic envelope modelling (BEM)), artificial neural networks (ANN); dynamic models	Statistical models (e.g. bioclimatic envelope modelling (BEM); artificial neural networks (ANN); distribution (absolute, relative) of species
Data	Greenhouse gas concentration	Global temperature, precipitation etc. mainly at 50 × 50 km grid	Regional temperature, precipitation etc. down to 1 × 1 km	Soil water, run-off, groundwater recharge at the catchment scale	Distribution (absolute, relative) of plant functional groups and/or species	Distribution, abundance
Examples	SRES-Scenarios	ECHAM, NCAR PCM, CSIRO, Hadley	REMO, STAR, WettReg	SWIM, SWAT	BIOMOD; LPJ GUESS	BIOMOD
Literature	IPCC 2000 Special Report on Emission Scenarios (SRES)	Wilby and Wigley (1997) and Gleckler et al. (2008)	Christensen and Christensen (2010)	Krysanova et al. (2000)	Kühn et al. (2009)	Lawler et al. (2009)

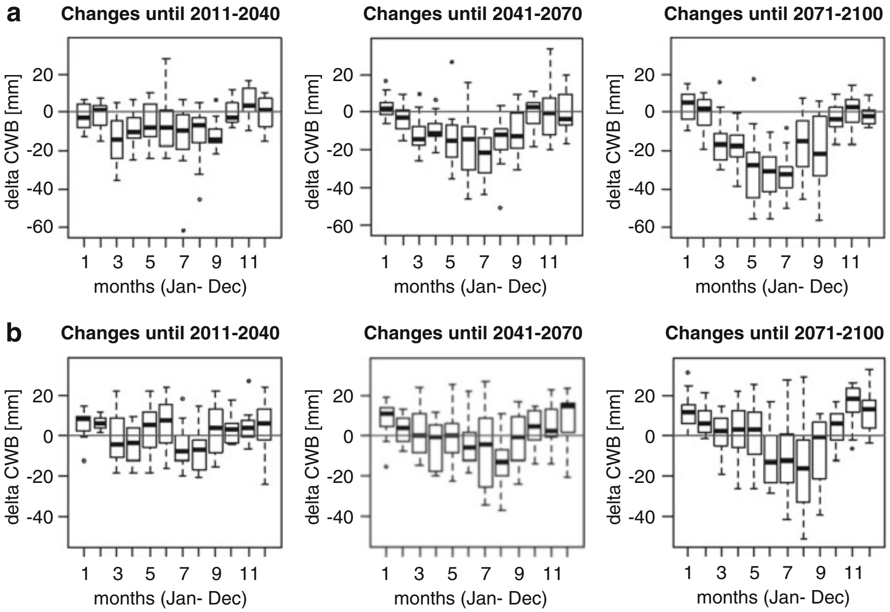

Fig. 5.2 Changes of Climatic Water Balance (*CWB*) as integrated climate change indicator for the area (**a**) Natural Park Bucegi (Romania) and (**b**) Vessertal – Thuringian Forest Biosphere Reserve (Germany). The graphs show the projected changes in the CWB as a multi-model box-whiskers plot for the years 2011–2040, 2041–2070 and 2071–2100, in each case relative to 1961–1990 (absolute differences in mm), for the A1B greenhouse gas emission scenario. The boxplots show the changes simulated from an ensemble of 14 different GCM-RCMs combinations (provided by ENSEMBLES project (van der Linden and Mitchell 2009)) and the variation between the model results. For each month the box depicts the lower and the upper quartile (25th to 75th percentile) of the spread and the *thick black line* stands for the median value. The whiskers show the maximum and minimum value of the model spread (except outliners (*black dots*)). The Climatic Water Balance is calculated by the method described in Sect. 3.3

months March to September, but particularly in summer. (b) For the area of the Vessertal – Thuringian Forest Biosphere Reserve (Germany) the model results spread is more pronounced, as indicated by longer boxes and higher variance. More than 50 % of the RCM-GCMs results indicate a trend for a CWB decrease in summer and a slight increase of the CWB in the winter months. The figures do not only show the directions of changes which should be considered but also indicate the uncertainty assigned to the choice of a model.

5.2.2 Hydrological Models

The CWB is an indicator which is directly calculated from climatic data; it does not consider local physio-geographical parameters like soil conditions or the influence of the vegetation. To consider supplementary parameters, hydrological process-based models support understanding of the behaviour of hydrologic systems as a response to climate change. Such models include evapotranspiration, surface run-off, subsurface and interflow, and river channel flow. For HABIT-CHANGE the hydro-ecological model SWIM (Krysanova et al. 2000; Hattermann et al. 2008) was applied. SWIM is a hydrological model at the scale of a catchment area (for details refer to Chap. 3). It integrates relevant hydrological processes to investigate the impacts of climate changes, such as water percolation, groundwater recharge, plant water uptake, soil evaporation, and river routing. SWIM allows the development of scenarios, for example, with a focus on the habitat type, and it provides information relevant to vegetation dynamics, i.e. the available soil water (Holsten et al. 2009). However, model results rely strongly on the quality and the resolution of the input data (like observed runoff, soil and land use data) for the specific investigation area.

5.2.3 Modelling Distribution and Occurrence of Plants and Animals

While the projection of potential impacts of climate change on water resources is very helpful and can be linked to specific management options, many protected areas aim to conserve specific plants or animals. Most modelling work to assess the potential impact of climate change on biodiversity relies on habitat modelling of plants and animals, and provides risk assessments for specific species or habitats (Normand et al. 2007; Hickler et al. 2012). Most of these approaches use statistical approaches, such as Bioclimatic Envelopes (BEM), and do not consider functional relationships, as, for example, with dynamic vegetation models (DVMs). Although DVMs are able to analyse changing patterns of competition their disadvantage is that they are resolved either at the basis of plant functional types or selected (tree) species (Kühn et al. 2009; Bellard et al. 2012). An additional uncertainty arises from other model shortcomings, e.g. the adaptive capacity of single species or species associations possibly being underestimated (Thuiller et al. 2008; Fordham et al. 2012).

When focusing on nature conservation issues the impact of climate change alone would not be so extensive if habitat destruction and fragmentation were not so widely advanced permitting species to adapt their distribution area (Opdam and Wascher 2004). The inclusion of land use parameters improves model results significantly.

So far, the major outputs of modelling the impacts on plants and animals (fungi are not yet a focus) are limited to projected changes in probabilities of occurrence. Furthermore, plants, animals, and fungi represent only a specific hierarchy or scale of biodiversity and nature conservation goals. Climate change affects biodiversity on different scales from changing mutation rates of genes and phenology to energy fluxes and ecosystem services (Vohland 2008; Bellard et al. 2012).

5.3 Reflection About the Role of Modelling in Conservation Management

Models are by definition simplified descriptions of reality. They have to neglect information and processes that are considered irrelevant for the modelling purpose. It is critical to realise "that model output is not the same as empirical data, and that modelled projections of the future contain significant uncertainties" (Hansen and Hoffmann 2011). These uncertainties derive from lacking or unsuitable data, measurement errors, or systematic mistakes in the data acquisition (Price and Neville 2003; Willis and Birks 2006). But even the simplified structure of models may result in uncertainties of results that have to be illustrated by the modellers. Modelling the complexity of biological systems and their interaction with management is a challenging task (McKenzie et al. 2004). Natural systems are characterised by system inherent variation. This makes it hard to identify signals of relevant effects from background noise of usual fluctuations (Hakonson 2003). An additional source of uncertainty derives from subjective interpretations. In an impressive selection of models developed and applied for environmental management, Pilkey and Pilkey-Jarvis (2007) prove how the selection of input data and interpretation of thresholds, system behaviour, as well as modelling results corrupts their usability in management. In this context transparency of modelling work is a prerequisite for the use of results in the decision-making context.

In consequence, modelling results can include a wide range of sources of uncertainty. This is especially true when results are built on a cascade of coupled models in a 'model chain' since all models add their own uncertainty to the overall results.

An important approach to handling uncertainty in model output is the quantification of uncertainty levels in results (see Ayala 1996; Bugmann 2003; Oreskes et al. 1994; Sarewitz and Pielke 1999). Yet, practical work with modelling results shows that quantification of uncertainty is no easy task. This is even more so as the validation of modelling results for complex systems, particularly with regard to predictions about long term future developments, involves major theoretical problems (Harris et al. 2003; Oreskes et al. 1994; Oreskes 2003; Sarewitz and Pielke 1999). Even if models have successfully simulated past or present changes this does not guarantee that they are also able to predict future changes, e.g. if the earth climate system and its biodiversity are pushed into unprecedented conditions in the context of climate change (Hansen and Hoffmann 2011).

As a first consequence, a cautious use of modelling results for decision-making is recommended (Millner 2012). Uncertainty must be considered when using modelling results for management decisions.

The gap between modelling and management issues is attributed to the different objectives of (natural) sciences and decision-oriented management. According to Opdam et al., the analytical and reductionist approach of scientific work is able to provide clues on driving forces and key elements, but lacks the ability to provide solutions and foster decisions if they are not especially tailored to do so (Koomen et al. 2012; Opdam et al. 2009). Further problems arise from the usual procedures of modelling and the integration of stakeholders and decision-makers. Relevance, legitimacy, and transparency are considered key aspects for the acceptance and implementation of scientific results (Meinke et al. 2006). Before modelling efforts are started, existing knowledge should be examined to determine whether it is sufficient to support decisions and how the existing information can be translated to the relevant decision-making context.

Modelling efforts use a lot of valuable resources for data acquisition, processing, model development, calibration, and validation. Usually these resources can be acquired in relation to research projects, but the limitation of resources must be considered if modelling approaches and procedures are transferred to a permanent task like conservation management. In the field of conservation management resources, whether manpower or budget, are chronically scarce and their use must yield the best possible output. Consequently, it is crucial to move modelling work beyond pure prediction (Dawson et al. 2011) and strengthen its integration in risk assessment, protocols of screening and monitoring, and integrated management in protected areas (Bellard et al. 2012). If modelling is to be integrated in management it must be based on an evaluation of the information need in protected areas. An assessment of its use in the management process must be done in order to guarantee maximum usability. The discussion of modelling goals and expected results will also guarantee the relevance and legitimacy of modelling endeavours. There is no doubt that modelling can provide various benefits for conservation management; however, the objectives of nature conservation need to be considered in modelling design, development, and presentation of results. Modelling for conservation management can be useful to:

- Structure the discussion about problems at hand and help develop hypotheses on consequences.
- Identify driving forces and hot spots where action is needed.
- Provide efficient and effective indicators to identify and monitor changes.
- Identify critical changes and thresholds to trigger action.
- Illustrate consequences of management options.

5.4 Developments for the Future

Understanding the interrelation between management measures and the impact of climate change is an important task for modelling in conservation management. This should allow the testing of hypotheses and the identification of alternatives in management. As a result, modelling that can be effectively used in the management of protected areas should take management options into account and provide possibility to project different future developments with regard to conservation strategies.

Model development needs to be done in cooperation with local management and stakeholders to guarantee transparency of models and their results. One possibility is a formalised co-production of knowledge. Experiences from visualisations of climate change effects have shown that stakeholder involvement should be considered at least (Pond et al. 2010):

1. when goals and objectives of modelling are discussed;
2. when alternatives are identified that need to be considered and
3. when results are assessed and discussed to derive consequences for management.

This general concept could also give guidance for the use of modelling in conservation management.

5.4.1 The Use of Models for Scenarios

Peterson et al. (2003) have suggested different methods to handle uncertainty in decision-making. To make decisions and plan for uncontrollable situations characterised by high uncertainty, the use of scenarios is often suggested (Peterson et al. 2003). Consequently, models in earth sciences are often used to simulate scenario results (e.g. GCMs). Several authors have also suggested using scenario approaches to handle uncertainty in conservation management and provide robust adaptation strategies (e.g. Julius and West 2008).

Scenarios as such are meant to project potential alternative developments. They should help managers identifying potential future situations and answer the question ‘What do we do if this event, trend, or change happens?’ Hence, scenarios are not meant to represent the most likely or even preferred development (Sträter 1988). They should prepare managers for a multitude of future situations. In most cases rare and unlikely extreme scenarios can help foster preparation for the unexpected better than mainstream scenarios or business-as-usual projections. In the context of scenario work models can be used to project system behaviour in response to different developments (e.g. increase or decrease of annual precipitation). Identifying relevant developments and transferring them to projections is of high importance for the process. A good scenario needs to be “carefully researched, full of relevant detail, oriented towards real-life decisions, and designed (one hopes) to bring forward surprises and unexpected leaps of understanding” (Schwartz 1992: XIIV).

Godet (2000) has suggested five criteria for a good scenario:

- It needs to be oriented to the problem at hand.
- It needs to be relevant for the questions of decision-makers.
- It needs to be coherent in itself.
- It needs to build on plausible assumptions.
- It needs to be transparent to the users.

Scenario development is regarded as supporting decision-making in situations with high uncertainty. Nevertheless, scenarios rarely provide sufficient decision support in complex situations. Decision makers are trained neither to analyse the different outcomes of climate impact modelling nor to develop management scenarios under the conditions of climate change. Hence, the adaptation of management needs to be included in a broader assessment framework to be useful in a decision-making context. This framework should comprise methods to compare scenario results as well as methods to evaluate options and prioritise actions. Risk management is suggested as one tool to provide this framework (e.g. Rannow 2011, 2013; Lorenzoni et al. 2005; Willows and Connell 2003). 'Stress tests' that help to identify critical changes and thresholds for resilience of ecosystems might be another tool (Brown and Wilby 2012).

5.5 Conclusion – How to Deal with Models?

Including the results from modelling climate change impacts can be important and provide a useful instrument to highlight possible negative impacts of climate change, especially when analysed in combination with land use change and degradation, as well as assessing the consequences of different management options. However, modelling results can only support the decision-making process in combination with other methods. Models cannot be better than their input data. If the density of climate stations and temporal resolution is very low or if the functional relationships are unknown, models might show up with numbers but they cannot be interpreted properly. At the local scale the identification of key parameters is complicated and should be done in cooperation with protected area managers as well as local experts. A special challenge in modelling is reflecting user needs and ensuring the applicability of results for decision-making and adaptation of management.

Consequently, modelling results on local to regional scales are accompanied by high uncertainties. These uncertainties must be taken into account and treated accordingly when management decisions are based on modelling results. This is best done through the joint development of management scenarios that include the whole spectrum of climate change impacts. The definition of relevant scales for decision-making and the acceptable limits of uncertainty must be considered a prerequisite for this. Uncertainty of facts should not corrupt decisions and needs to be separated from uncertainty of decisions. Models should be included in a wider framework to make them useful for the decision-making process in conservation management. Risk management, no-regret measures, and adaptive management have great potential to foster the profitable application of modelling results in conservation management. However, it should be emphasised that projections based on computer models are not the only option to prepare for climate change and support decisions for adaptation actions. Analysing and mapping sensitivity might be a useful method to identify driving factors, thresholds for resilience and management options even when results from climate models or detailed model based analysis are missing, as illustrated in Chap. 8.

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Chapter 6
Indicators for Monitoring Climate Change-Induced Effects on Habitats – A Wetlands Perspective

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6.1 Introduction

Climate change is expected to become a major threat to biodiversity by influencing the quality of landscapes and habitats. Thus monitoring techniques need to be adapted to provide information on climate change induced impacts in habitat conditions in the long run in order to be able to adapt management strategies in respective protected areas. Climate change may affect many ecosystem functions; consequently, specific indicators of symptoms of ecosystem degradation shall address various ecosystem properties and effects due to different pressures

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including climate change. Climate change-driven impacts overlap and interfere with other environmental pressures of various origins, and their effects may be observed as multifaceted changes in ecosystems. For the purpose of management decisions, the extent of these changes shall be evaluated using ecological indicators as measures providing insight into the state of the environment by quantifying habitat conditions.

An ecological indicator is a numerical value derived from measurements of selected ecosystem/habitat properties, used for detecting and describing environmental changes over space and time (Duelli and Obrist 2003; Maxim 2012; Bauler 2012; Heink and Kowarik 2010a; Dziock et al. 2006). Indicators are usually designed to reflect the achievement of specific goals. Moldan et al. (2012) specify two approaches of goal setting:

- Perspective oriented – established in the course of political debates; policy relevant indicators can be used to assess the effectiveness of legal regulations adopted in order to reach definite goals, such as to limit CO_2 emission to the atmosphere;
- Long and short term – adopted at regional or local level and defining the needs to measure and monitor ecosystem conditions and trends including the impacts of climate change; in the latter case, the environmental properties which are particularly sensitive to pressures of climate change would be of best indicatory value.

There are several systems of indicator typology (Maxim and Spangenberg 2006). The EEA classification of indicators distinguishes four simple groups including descriptive, performance, efficiency and welfare indicators within the system of the “DPSIR” or “drivers, pressures, state, impact, response” indicators (EEA 2007). Drivers and pressures embrace indicators of anthropogenic pressures on the environment, such as land pollution or relief changes while the state and impact indicators measure the resulting environmental effects, including habitat sensitivity to stresses. Climate change-relevant indicators for habitat monitoring belong, according to EEA, to the subsets of descriptive impact and state indicators. In contrast, the Millennium Ecosystem Assessment (MEA) proposes that drivers can be both anthropogenic and natural factors that directly or indirectly cause a change in an ecosystem, thus climate change indicators can be assigned to the driver class also (Maxim and Spangenberg 2006).

In this chapter we focus on long and short term ecological indicators which can be used for tracking and monitoring climate induced changes in habitat quality, especially in wetland habitats. Consequently, they can be used for adaptation of conservation planning. The assessment of habitat changes with the use of indicators requires the values measured (metrics) to be validated (Bockstaller and Girardin 2003). Not many ecological indicators have so far been empirically tested to determine if they meet the criteria by which they were purportedly chosen.

The validation of indicator reliability may be made using reference standards, normative values and limit numbers as well as by referring to iterative measurements performed in selected habitat compartments. Under the HABIT-CHANGE project, some indicators of habitat sensitivity to climate change were experimentally validated in wetlands (in the Biebrza National Park). An attempt was made to determine which impact indicators are most sensitive and valid for monitoring climate change effects in wetland areas and how these indicators may be applied in monitoring (short and long term) for management purposes (Ostrowska 2010; Heink and Kowarik 2010b; Ostrowska and Sienkiewicz 2011). It was found that changes in peat soils, including, in particular, changes in the contents of carbon and nitrogen and their water soluble forms as well as in soil solution concentrations, are correlated with the dynamics of precipitation and temperature over several decades.

6.2 Criteria to Select Indicators for Monitoring Climate Change Effects on Habitats

Climate change leads to a variety of effects in habitats including changes in water and nutrient circulation, soil quality and community structure and functions. This diversity of effects results in a diversity of assessment situations and requires many procedures and indicators whose performance can be directly associated with climate change over time. Over the last several years a variety of ecological indicators have been developed to document the status and changes in environmental quality. Ecological indicators include both site-specific, field-derived metrics and landscape-level properties (Tiner 2004; Stratmann et al. 2011). An extensive literature review made under the HABIT-CHANGE project yielded comprehensive lists of selected applicable indicators addressing climate change-induced effects in various habitats, based on hydrological, soil, botanical, plant sociological, zoological and climatologic metrics (Förster et al. 2010; Vohland et al. 2011; Stratmann et al. 2011).

The indicators vary from simple ones indicating changes in climate such as temperature, water balance, snow cover and water deficit, to indices of land cover derived from remote sensing at landscape and regional scales to the site specific indicators of climate change effects which have been developed based on field study and measurements. Remote sensing detection tools for natural resource managers in the context of climate change are discussed in Chap. 7. Here we focus on site-specific indicators that rely on environmental properties which are most sensitive to climate change and are helpful in qualifying and simplifying the complex phenomena of habitat changes. These changes are typically due to multiple stresses; therefore the effect of an individual stressor such as climate change cannot be easily separated from that of other pressures. The difficulty in selecting such purpose-oriented indicators arises from the dynamics of natural processes and of local environmental conditions (Dahl 2012).

The practical criteria for selecting appropriate indicators should be related to such qualities as their capacity to inform about complex changes in habitats and landscapes, to supply reliable information on the status and trends and, at the same time, to allow for quantification of the intensity of changes. As indicators have double function: to supply information and to support management decisions, they also need validation against their utility to the end-users. Management decisions in protected areas concern mainly the maintenance of favourable status of specific habitats and species by controlling pressures which change environmental quality. Thus, indicators should allow for monitoring the efficiency of measures applied to mitigate pressures on habitats. Therefore, we concentrate on indicators that, being relatively simple, reflect collective response of target habitats, and respond in an integrative way to environmental stresses (relevant and efficient), providing an overall ecosystem performance which can further be used as reference for predicting habitat sensitivity to climate changes. It is important to note that notwithstanding the fact that the extant typologies divide ecological indicators referring to such criteria as assessment methods and spatial scales at which they are applied (global, landscape, local, site), the indicators on various levels are complementary in evaluation and prediction of habitat changes and should be considered jointly in order to provide effective help to the managers in protected areas (EEA 2012).

6.3 Indicators for Monitoring Climate Change at Landscape and Habitat Levels Focusing on Wetlands in Biebrza National Park

The Biebrza National Park (BNP) embraces about 60,000 hectares of wetlands on peat soils in the Biebrza Valley. The distribution of local wetland habitats reflects both site hydrology and management intensity showing typical zonation of the river valley (Oświt 1991). In the BNP there prevails mainly extensive agricultural management, but socio-economic changes over the last three decades resulted in partial depopulation of the countryside and abandonment of traditional agricultural practices. This initiated forest succession and led to disappearance of semi-natural landscapes and habitats of many species as is the case with abandoned meadows in BNP. The indicators of effects of these driving forces include changes in land use pattern, landscape patchiness and richness of landscape elements which may be traced with indices based on analysis of land coverage. It is generally acknowledged that climate-induced alterations in landscapes may best be evaluated by structural analysis including the assessment of land use pattern, complexity, shifts in ecosystem boundaries and their fragmentation (Watts and Handley 2010). The indicators at landscape level suggested and partially tested in the BNP are given in Table 6.1.

As mentioned above, schemes of land cover-based indicators rely on visual scales using various data sources including remote sensing, aerial and landscape photographs (EEA 2006; Ode et al. 2010b). Visual scales allow for the determination of such features of landscape visual structure as land use pattern, complexity, disturbance and naturalness. Complexity refers to the diversity and richness of landscape elements and features and the interspersion of patterns in the landscape using e.g. LDI and EMS indices (Ode et al. 2010b). The quality of data obtained in visual analysis varies depending on image resolution, period when it was taken and accurateness of its interpretation. In the Biebrza National Park, the assessment of richness of landscape elements (complexity), i.e. the presence of patches of forest and shrubs,

Table 6.1 Landscape level indicators of habitat change in support of land management at BNP (Stratmann et al. 2010)

No.	Indicator	Interpretation of measure
1	Diversity of land cover categories	% share of open habitats per area unit, % share of shrub and forest habitats per area unit
2	Presence of water	% share of water bodies per area unit
3	Richness of landscape components/ elements	Number of various elements
4	Landscape diversity index (LDI)	Evaluation of diversity of land cover types in a given area, based on land-use maps, remote sensing and calculation of land-use classes within a defined area
5	Effective mesh size (EMS)	The effective mesh size measures landscape fragmentation due to linear elements such as technical infrastructure; the indicator measures landscape fragmentation in ha, ranging from 0 ha (totally fragmented) to the area size of the largest patch investigated for the region (the procedure is described by Moser et al. 2007)
6	Land cover diversity based on data from remote sensing and interpretation of imagery	NDVI (Normalised Difference Vegetation Index) – the index calculated from light reflectances measured in the visible and near infrared channels as the normalised difference between the near infrared and red reflectance values; NDVI is related to the fraction of photosynthetically active radiation absorbed by chlorophyll; NDVI has been correlated with a variety of vegetation parameters such as abundance, productivity and biomass LAI (Leaf Area Index) – a dimensionless variable defined as the maximal projected leaf area per unit ground surface area. LAI is used in remote sensing to quantify many biological and physical processes such as primary productivity, plant respiration, transpiration, photosynthesis and nutrient cycles VM (Vegetation Moisture) – the vegetation water content is defined as water volume per leaf or ground area of the amount of water per dry vegetation mass and is applied to assess e.g. water deficit or drought stress in vegetation
7	Edge density/spatial configuration/variation of element shape	Expressed as ratio: length per area unit; e.g. m/ha
8	Habitat fragmentation/patchiness	Number of patches per area unit; e.g. 1 = one large open area; 2 = split open area; 3 = patchy open area
9	Area visually affected by disturbance	% of area classified as visually disturbed per area unit
10	Agricultural intensity index	Agricultural intensity index measures the proportion of intensively used agricultural area in the total agricultural area; constitutes a common indicator to measure intensification of agriculture
11	Changes in ranges of plant communities	Observation of changes based on field measurements and mapping/ study of archival data
12	Wind and water erosion/physical degradation of land cover/denudation	Number of sand dunes, erosion gullies, etc. features per area unit; change in soil and water coloration according to Munsell scale

may best be done using aerial photographs taken in October, while the assessment of meadow cover diversity with those taken in July (Tomaszewska 1988). This author found that complexity of landscape attributes in the Biebrza Valley has considerably increased over the preceding three decades due to encroachment of shrubby and woodland vegetation onto the open landscape. This was also corroborated by Piórkowski and Rycharski (1999). The accurateness of image interpretation is largely dependent upon the indices which result from the comparison of image readouts and data obtained in the course of in-situ survey or ground truthing (Tomaszewska 1988). The evaluation of changes in the land cover diversity of Biebrza Valley may also be interpreted from aerial photographs with the use of such indices as NDVI – Normalised Difference Vegetation Index, LAI (Leaf Area Index) and VM (Vegetation Moisture). In the latter case, the images need to be taken at the peak of vegetation season (Tomaszewska 1988). Other important indicators rely on erosion phenomena – transportation of soil material and physical deformation of soil surface as well as on biodiversity in terms of changes in the flora and fauna species richness. The latter attributes depend largely on climate changes both in the long term and as short term disturbances. Temporal resolution for evaluations of changes at landscape level based on remote sensing imagery was defined for several year (3–5) intervals (Tomaszewska 1988). The changes in wetland landscapes in BNP are conditioned to a great extent by the changes in the local hydrological systems – water cycle, inflow and outflow (Kucharski 2010; Schmidt et al. 2000).

According to Jones-Walters (2008), biodiversity may be used as an indicator for assessing changes at landscape scale (contribution of individual ecosystems – assessment of landscape patchiness) and for the estimation of changes in individual ecosystems, especially to evaluate their fragmentation. Changes in the behaviour and distribution of birds as a group and individual species provide metrics for indicators of climate change at national, regional and global levels. The same is valid for amphibian species and populations which are extremely sensitive to changes in climatic and site parameters. Being comparatively easy to monitor with standard methods, they may be applied as indicators at various spatial scales, e.g. metrics built on species composition and population size at biotope or habitat level, and those built on data of species assemblages (composition, species richness, diversity) at the protected area level.

Changes in air, soil and water temperature, in precipitation, humidity and radiation affect animal and plant life cycles, in particular wetland plant communities and amphibian populations are highly dependent on climate changes. Observations of amphibian behaviour (migration time/e.g. earlier or later, reproduction time), reproduction success (number and size of clutches, developmental time/metamorphose rates, sex ratio) and habitat quality (spawning water temperature, presence of winter habitats for hibernation) provide bases for indicating changes at habitat level (Table 6.2).

Plant cover, phenology and species composition provide for one of the best indicators for monitoring climate-induced changes in habitats on condition that the observations are repeated over a long time period since e.g. “community structure” and “species composition” show net assignment to fluctuations in abiotic parameters such as light, temperature and water availability. Soil organic matter (SOM) is

Table 6.2 Habitat level indicators of climate change induced habitat changes

No.	Indicator	Interpretation of measure
1	Changes in local water balance (inflow/outflow)	Depicts local hydrological conditions; water balance deficit expressed as difference between precipitation and runoff; defines the degree of plant community vulnerability versus water shortage
2	Soil water – maximum water holding capacity (MWHC), field water capacity (FWC)	Evaluates soil porosity and general water storage capacity
3	Water availability to plants (WAP)	Provides information on the water accessibility to plants
4	River discharge	Provides information on the rate of water loss from wetlands
5	Depth of groundwater table	Provides information on water availability/water deficit for plant communities
6	Nitrogen load in water	Provides information on local water pollution and on the rate of peat soil mineralisation
7	Soil nitrogen, including changes in: $N\text{-}NO_3/N\text{-}NH_4$ rate; $N\text{-}NO_3$ content, with limit ranges of 5–10 mg/dm^3 of soil which denotes low level mineralisation, and >40 mg/dm^3 of soil denoting high intensity of peat mineralisation	Provides information on the rate of peat soil mineralisation, peat decay and moorsh formation
8	Mineral element content in soils	Provides information on peat soil mineralisation, peat decay and moorsh formation
9	Quantitative and qualitative changes of Soil Organic Matter (SOM mineralisation) including changes in: Soil Organic Carbon and Dissolved Organic Carbon; Soil Organic Nitrogen and Dissolved Organic Nitrogen; C/N rate; CO_2 diffusion from soil	Carbon storage and balance in soils provide information on the rate of soil organic matter decomposition and mineralisation
10	Biodiversity: species richness in communities listed in Annex 1 of the Habitat Directive: Total No. of species at a site Shannon-Wiener diversity index (H′); Evenness H′; Species richness versus boreal/glacial relics plant richness; No. of boreal plants in herbaceous layer; % of boreal/glacial relics plants, including: *Betula humilis, Calamagrostis stricta, Carex chordorrhiza, Carex secalina, Empetrum nigrum, Pedicularis sceptrum-carolinum, Pinguicula vulgaris, Polemonium caeruleum, Salix lapponum and Saxifraga hirculus*; Ratio: (No. of boreal/total No. of plants) × 100	Indices based on species richness provide insight into the degree of community transformation and general decline in native species diversity and losses of valuable elements targeted by the Habitat Directive

(continued)

Table 6.2 (continued)

No.	Indicator	Interpretation of measure
11	Changes in ranges of mesotrophic tree and shrub species (e.g. *Corylus avellana* in alder woods)	Provide information on community function and structure in wetland forests
12	Non-native species richness No. of non-native species (excluding ambiguous genera); % of non-native species; No. of non-native species/total No. of plants (excluding ambiguous genera) × 100; % cover of non-native species; % cover of non-native species/No. of plots; % of dominant plants that are non-native; No. of non-native plants with cover >5 %/total No. of plants with cover >5 %	Indices provide information on change and transformation in wetland plant communities structure and functions and on the increase in community hemeroby
13	Numbers of moisture loving diurnal butterflies including: Umbrella species of Lepidoptera found in peatlands: *Vacciniina optilete, Boloria aquilonaris*; and on meadows: *Lycaena dispar, Maculinea alcon, M. teleius, M. nausithous, Melitaea diamina, Euphydryas aurina* and *Heteropterus morpheus*; No. of moisture loving butterflies per transect; No. of warm loving and xerophilic diurnal butterflies per transect or observation plot	Indices provide information on the loss of umbrella species typical of wetlands, changes in species composition of biocoenoses of diurnal butterflies and change in species composition
14	Number, abundance and occurrence frequency of selected species of fauna such as birds and herpetofauna (amphibians), including: changes in population numbers; changes in survival rate of adults (birds, amphibians); timing of reproduction period (end of hibernation); migrations; arrival time; calling (males); rates of reproduction; changes in hatching time, clutch numbers, larvae survival	Indices provide information on changes in valuable fauna cenoses due to site desiccation and habitat loss, and inform on the loss of species targeted by the Habitat Directive

related to several other soil properties (Ostrowska et al. 2006). LAI and VM show correlation with soil moisture content, while NDVI is correlated with vegetation productivity, biomass and the intensity of vegetation cover development (Adegoke and Carleton 2002; Dąbrowska-Zielińska et al. 2003, 2009; Sienkiewicz and Ostrowska 2010).

6.4 Integrative Indicators

Ecological indicators may be broadly divided into two categories, i.e. simple which reflect the status of an indicated habitat attribute, and integrative indicators that summarise the ecological response of habitats to stress (Girardin et al. 1999). The latter category also includes those indicators that reflect the status of the habitat property which is significantly correlated with various other habitat attributes. Indicators built on metrics provided by measurements and observations of species and populations are regarded as integrative indicators of chronic changes in ecosystems. Integrative indicators represent summary responses reflecting ecosystem stress (ecosystem sensitivity) due to climate change and other pressures and, at the same time, may be simple and easy to apply. The summary response of habitats to climatic stress can be assessed, among others, by quantifying changes in community biodiversity and in soil properties and as well as in water, carbon and nutrient cycles. To this end, integrative indicators derived from metrics build on community biodiversity and soil properties are of special significance.

Soil properties can be used for constructing a variety of climate change sensitive indicators, and particularly the properties of peat soils built of organic matter (Ostrowska et al. 2006). Progressing climate warming is detrimental to hydrological regime of peat soils and results in disturbance of production and accumulation of organic matter and its decomposition, shifting the balance towards the latter process. The loss of organic matter is accompanied by the release of CO_2 and leaching of mineral elements, especially of nitrogen to groundwater. All the properties of peat soils are predefined by the content and quality of soil organic matter (SOM) and SOM decomposition is a highly sensitive indicator of temperature changes (Ostrowska et al. 2006). SOM mineralisation and CO_2 emission show a high assignment to climate change at habitat level. Therefore, carbon content of soil may be applied as basic metric of long-term processes of SOM decomposition as changes in this content will reflect, in an integrative way, the changes in peat soil quality. Accelerated SOM mineralisation results also in an increased migration of nitrogen to the soil environment. Likewise, a change in the content of soil nitrogen, and particularly of its mineral form, constitutes an integrative basic indicator of the above process. The indicator evaluates the rate of SOM mineralisation at a given moment of time; therefore it may be applied as a short term indicator (Ostrowska and Sienkiewicz 2011).

Wetland habitat sensitivity to climate change may be estimated using integrative indicators based on changes in plant communities. Accelerated SOM mineralisation causes a “quasi eutrophication” of soils due to an increase in plant nutrient availability. The increase in the pool of available nutrients leads to the expansion of species which have a high nutrient demand and are not typical of respective wetland communities (invasive species).

6.5 Validation of Climate Change-Related Indicators – The Case Study of Biebrza National Park

An attempt was made to validate integrative indicators derived from vegetation study and soil metrics which may be used to predict habitat sensitivity to climate change and applied for short and long term monitoring in wetland areas. Wetland habitats in the BNP were developed as a result of an interplay of correlations between river flooding, depth of groundwater table, climate pressure and vegetation development within the three topographically distinct basins, i.e. northern (upper), central and southern (lower) along the 60 km stretch of the Biebrza River (Oświt 1991). The Park area is located in three climatic zones which conform more or less to the three basins of the river (Liszewska 2011). The three zones vary significantly in climatic conditions, and especially, in temperature and precipitation distribution. The northern basin is cooler and moister than the southern one, while the central basin has transitional climatic conditions. For these three climatic zones changes in basic climatic parameters (precipitation, temperatures) were determined for the period of the last 50 years (1951–2000) and climate forecast until the year 2100 was made. Soil properties and plant communities were also studied within the above zones along the established transects. The results obtained along with the literature data concerning sensitivity of soil and vegetation parameters to climate change were used as a basis for selecting characteristics which are most sensitive to climate change driven pressures and for determining variability scales for every property within the area examined. In this way, indicators most sensitive to climate change, could be established and validated with respect to their suitability for management support.

In the BNP there dominate peat soils mineralised to various degrees. The peat mineralisation degree may be determined using the soil carbon content as a metric. It was found that soil carbon content fluctuates from 50 to 40 % in natural peats in the northern park zone, to less than 20 % in degraded peat soils which occur mainly in the southern climatic zone. In the transitional zone there occur peat soils of various degree of mineralisation where carbon content constitutes 40–30 % in decaying marshy peats and about 30–30 % in marsh soils. Taking into account the results of study in the BNP as well as the literature data on SOM sensitivity to climate change and the threat of CO_2 release to the atmosphere we adopted that it is the carbon accumulation in organic soils that provides for a most sensitive characteristics of the effects of climate change and a good indicator of climate change-induced changes in wetland habitats. To assess the indicatory strength of the soil carbon content, the correlational and functional relationships were statistically determined between this content and the remaining soil attributes such as Soil Organic Carbon (SOC), Soil Organic Nitrogen (SON), SOM, Dissolved Organic Nitrogen (DON), Cation Exchange Capacity (CEC), Bulk Density (BD), Soil Water Content (SWC), Maximal Water Holding Capacity (MWHC) and Field Water Capacity (FWC) (Tables 6.3 and 6.4).

Close relationships were found between all these properties what is evidenced by the high values of correlation coefficients, though the most significant correlation was determined between the soil carbon content and the remaining soil properties. The significance of correlation was corroborated by calculating Pearson's correlation coefficients between each of the soil properties analysed (Table 6.5).

A more detailed description of the relationships between the soil properties was provided on the basis of regression equations. The values of determination coefficients (R^2) > 0.7 were characteristic of the relationships between the contents of

Table 6.3 Mean values and standard deviations (mean ± SD) of the examined variables for four groups of SOC content in soils

	SOC	SON	SOM	DOC	DON	CEC
C content (%) groups	(%)	(%)	(%)	(mg/kg)	(mg/kg)	(mg/kg)
0.1–3	1.24a ± 0.94	0.05a ± 0.04	2.91a ± 3.27	146.1a ± 137.5	4.06a ± 2.51	30.0a ± 13.5
3.1–16	7.96b ± 3.07	0.55b ± 0.24	14.32b ± 5.79	497.8ab ± 383.4	31.04a ± 16.26	225.1a ± 148.3
16.1–35.9	28.61c ± 6.05	1.73c ± 0.63	50.54c ± 16.3	1266.1bc ± 831.7	109.05b ± 63.32	595.2b ± 258.5
36–56	44.65d ± 5.98	2.2d ± 0.61	78.68d ± 9.28	1741.1c ± 1469.6	115.23b ± 56.32	634.7b ± 341.8

All means of SOC, SON and SOM are significantly different between the groups. The lowest mean values of these three variables were observed for group 0.1–3 and the highest for group 36–56. The differences for DON and CEC were significantly different between the groups 0.1–3; 3.1–16 and the two other groups, i.e. 16.1–35.9; 36–56

Table 6.4 Mean values and standard deviations (mean ± SD) of the examined variables for four groups of SOC content in soils

C content (%) groups	BD (g/cm^3)	SWC (%)	MWHC (%)	FWC (%)	SOC (%)	SON (%)
0.1–3	1.39 ± 0.18	18.95 ± 10.31	38.67 ± 6.06	19.72 ± 5.96	1.4 ± 0.92	0.05 ± 0.04
3.1–16	0.81 ± 0.32	57.08 ± 14.51	62.06 ± 12.27	43.73 ± 12.1	8.42 ± 3.36	0.46 ± 0.25
16.1–35.9	0.31 ± 0.11	68.11 ± 21.8	75.22 ± 7.02	55.68 ± 11.76	28.98 ± 5.52	1.55 ± 0.4
36–56	0.14 ± 0.06	47.9 ± 28.84	74.09 ± 11.65	42.9 ± 20.52	48.84 ± 5.17	1.95 ± 0.53

Analyses performed on limited ($n = 44$) number of observations i.e. the datasets with additional variables

Table 6.5 Data for all groups of soil carbon content

–	SOC	SON	SOM	DOC	DON
SOC	–	0.85	0.98	0.61	0.72
SON	0.85	–	0.90	0.34	0.70
SOM	0.98	0.90	–	0.57	0.72
DOC	0.61	0.34	0.57	–	0.72
DON	0.72	0.70	0.72	0.72	–

Pearson's correlation coefficients between each of the soil properties analysed ($n = 100$) (all correlations are significant at $P < 0.05$ probability level)

carbon, organic matter and nitrogen. The interrelationships between the remaining soil properties were also significant (determination coefficients (R^2) = 0.4–0.5) (Ostrowska and Sienkiewicz 2011). It was determined that the loss of soil carbon of a range of 1 % results in changes in the remaining soil properties, e.g. the peat soil MWHC is lowered by about 2 %, while the N content and CEC – by more than 1 %. Consequently, it can be assumed that soil carbon content is an integrative indicator of climate change, validated against the remaining soil properties and thus, indirectly, against other habitat properties such as vegetation type, species composition, presence of invasive species etc. Likewise, the changes in the contents of carbon and nitrogen and their water soluble forms as well as those of soil solution concentrations were found to correlate with the dynamics of precipitation and temperature over several last decades (Ostrowska and Sienkiewicz 2011). Therefore, the soil carbon content may be applied as basic metric providing information on long-term changes in peat soils in an integrative way. In addition, accelerated SOM mineralisation results in the increased migration of nitrogen to the soil environment. Change in the content of soil nitrogen, and of its mineral form in particular, constitutes the basic indicator of the above process. This indicator evaluates the rate of SOM mineralisation process at a given moment of time, thus it may be applied as a short term indicator. In addition, the concentration and composition of soil solutions reflect both the rate of SOM mineralisation and the vulnerability of wetland habitat to the invasion of plant species having a high nutrient demand, especially of expansive and alien invasive species (Ostrowska and Sienkiewicz 2011).

Long-term effects of climate change in the vegetation of wetlands can be assessed with the use of indicators derived from the increased presence (numbers and abundances) of species which are not typical of the original natural community and of nitrophytes which are associated with eutrophic habitats and have a higher nutrient demand. In the study made in the BNP this group of species included e.g.: common nettle *Urtica dioica*, herb Robert *Geranium robertianum*, cleavers *Galium aparine*, wood avens *Geum urbanum*, cow parsley *Anthriscus silvestris*, hairy hempnettle *Galeopsis pubescens* and broad-leaved dock *Rumex obtusifolius* as well as touch-me-not balsam *Impatiens noli-tangere* and ground elder *Aegopodium podgararia*. These species were found to enter and replace the typical species composition of the drying riparian alder-ash woods on decaying peat soils in the BNP.

6.6 Suggestions for Using Indicators in Management Practice

Management adaptation to climate change in a protected area must be based on the recognition of the status of target habitats (habitat sensitivity/resilience to stress factors), conservation objectives and the existing conflicts which arise from various anthropogenic and natural pressures. Effective management measures should be built upon recognition of pressures to increase the resilience of target habitats to the ongoing and future climate change. Informed management decisions may be taken after consulting updated maps which provide the information on the vulnerability of protected habitats to changing climatic conditions considering other existing pressures (e.g. land use, drainage). To this end, expert knowledge is needed to provide information in the form of indicators for evaluating habitat sensitivity and potential response of protected habitats to pressures. The indicators shall be regarded as tools for updating the environmental information.

Management adaptation to changing environmental conditions requires a two track approach: first – the evaluation of effectiveness of measures undertaken, and second – the search for the information needed to undertake new actions. Both tasks shall be implemented with the use of indicators. Therefore, the focus was on the construction of indicators which are multidimensional, integrative, strongly assigned to climate change, i.e. evaluate climate change-related effects and impacts within the habitat/ecosystem. At the same time these indicators are relatively easy to apply for habitat monitoring and have a standardised methodology available. They also allow for updating the information contained in the maps.

Climate change is indicated by climatic scenarios, covering both a short (a decade) and longer periods based upon climatic parameters (temperature and precipitation) measured at local meteorological stations. The response of wetland habitats is to be seen in the changes of water balance, soil and vegetation properties and in the changes of biodiversity of plant communities.

The change in soil organic matter (SOM) in peat soils is a highly sensitive indicator of climate warming. SOM mineralisation and CO_2 emission are very strongly assigned to climate change. Therefore soil carbon content (SCC) may be applied as basic indicator of SOM stability as changes in its content will integratively reflect changes in peat soil quality. These changes shall be determined in longer periods (a decade) thus SCC may be used as the indicator of long term habitat changes due to climate change. SOM mineralisation results mainly in the release of carbon (CO_2) to the atmosphere and nitrogen to the soil environment. A basic indicator of the above process, in addition to CO_2 content, is the content of soil nitrogen, in particular, of its mineral form. This indicator evaluates the rate of the SOM mineralisation process as it is here and now, so it may be applied as a short term indicator. The concentration and composition of soil solution reflects both the rate of SOM mineralisation and the opportunity for wetland habitat to be invaded by plant species having high nutrient demand, especially by expansive and/or alien invasive species. This is also an integrative indicator of short term changes due to climate change. The following integrated indicators may be applied in habitat monitoring in the BNP and other wetlands:

1. Soil carbon content (SCC) is the best integrated indicator of long term effects of climate change-induced changes in organic soils. SCC shall be determined in the 40 cm-thick soil layer, on the established permanent plots, once a decade.
2. Soil nitrogen content (SNC) provides for the best assessment of climate change-induced changes in the soil environment for determining the short term effects; the effects may be assessed by determining either the SNC or the contents of elements in soils solutions, every 2–3 years.
3. Long-term effects of climate change in the vegetation of wetlands can be assessed with the use of indicators such as the increased presence (numbers and abundance) of nitrophytes which have higher nutrient demand. These indicators may be used for the evaluation of effectiveness of the implemented climate change mitigation and adaptation measures. At the same time, these indicators are relatively easy to apply for habitat monitoring.

6.7 Summary

Climate change effect on ecosystems constitutes a relatively new pressure as regards its intensity and interactions with other anthropogenic and natural pressures. The assessment of impacts relies mostly on the use of indicators based on metrics established by measurements of habitat properties that are particularly sensitive to climate change. Indicators of climate change impacts are required to evaluate and compare the behaviour of ecological systems at reference conditions and those subject to climate and management pressures.

Methods for developing integrative indicators vary between simple ones, as in case of land cover-based indicators, to more elaborate procedures requiring field measurements to develop indicators addressing soil and vegetation properties.

Schemes of land cover-based indicators rely mostly on remote sensing, aerial and landscape photographs (EEA 2006; Ode et al. 2010a). Remote sensing derived indicators allow for the determination of changes at landscape level such as land use pattern, complexity of landscape patterns, landscape disturbances and naturalness. At a habitat level, stress responses of main ecosystem compartments such as plant communities and soils may be measured using indicative parameters, including biomass production and soil carbon stock, biologically bound nitrogen and phosphorus, organic matter production and decomposition, species number and habitat composition, habitat extent and habitat structure, changes in biodiversity, dynamics of selected populations and changes in competitive behaviour of functionally important species.

Monitoring of changes in biodiversity using indicators based on changes in the flora and fauna species richness including amphibian populations reflects summary responses at habitat level. It was found that in wetland ecosystems the indicators built on metrics such as soil organic matter decomposition, soil CO_2 emission, soil carbon content, changes in the content of soil nitrogen and its mineral form, concentration and composition of soil solutions as well as on the presence and numbers of nitrophytes are strongly assigned to climate change. Collectively, the above indicators represent a habitat-level assessment which should serve for the complex bioindication of climate change effects on protected areas.

The complex bioindicatory information resulting from habitat monitoring shall be processed and visualised in the form of maps and models to render it available to the end users the site managers. The maps shall be informative as to the vulnerability of protected area and habitats to changing climatic conditions, considering their basic characteristics and other existing pressures (land use, drainage). The information processed, simplified and constantly updated constitutes an important aid to the management decision makers.

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Chapter 7
Remote Sensing-Based Monitoring of Potential Climate-Induced Impacts on Habitats

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7.1 Introduction

Climate change is likely to be a strong driver of changes in habitat conditions and, subsequently, species composition. Sensitive and accurate monitoring techniques are required to reveal changes in protected areas and habitats. Remote sensing bears the potential to fulfil these requirements because it provides a broad view of landscapes and offers the opportunity to acquire data in a systematic, repeatable, and spatially explicit manner. It is an important tool for monitoring and managing habitats and protected areas as it allows the acquisition of data in remote and inaccessible areas. This is important since traditional field-based biodiversity assessment methods (although far more detailed and often more accurate) are sometimes subjective and usually spatially restrained due to constraints in time, finance, or habitat accessibility. Remote sensing can provide indicators for different spatial and

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temporal scales ranging from the individual habitat level to entire landscapes and involving varying temporal revisit frequencies up to daily observations.

Habitat mapping is developing at a fast rate within the two basic approaches of field mapping and remote sensing. The latest technologies are quickly incorporated into habitat monitoring (Lengyel et al. 2008; Turner et al. 2003). Field mapping, for example, is facilitated by the use of object-oriented methods or wireless sensor systems (e.g. Polastre et al. 2004; Bock et al. 2005). Additionally, advances in remote sensing methods have resulted in the widespread production and use of spatial information on biodiversity (Duro et al. 2007; Papastergiadou et al. 2007; Förster et al. 2008). In fact, earth observation data is becoming more and more accepted as an appropriate data source to supplement, and in some cases even replace, field-based surveys in biodiversity science and conservation, as well as in ecology. Objectivity and transparency in the process of integrity assessments of Natura 2000 sites can be supported by quantitative methods, if applied cautiously (Lang and Langanke 2005). However, it should be kept in mind that there are various sources of uncertainty in remote sensing-based monitoring of vegetation (Rocchini et al. 2013).

Despite all the advantages mentioned above, the monitoring of habitats using field-based and remote sensing approaches has a very short history. Landsat-4, the first non-military optical sensor with the potential to monitor habitats at a suitable spatial resolution, was initiated only in 1982. Even within this time period the story of image acquisition and interpretation is not free of interruptions due to sensor faults and a lack of financial support for continuity missions (Wulder et al. 2011). Recently, the sensor series RapidEye and the planned mission Sentinel-2, which employ a constellation of multiple identical satellites, have been supplying data with a higher temporal frequency (Berger et al. 2012). However, this time-span is still not long enough to allow reliable statements about modifications of habitats dependent on climate change.

This study focuses on the potential of remote sensing to detect indicators related to climate change in three focus areas. The case studies presented use the Natura 2000 habitat nomenclature and descriptions of the conservation status of the protected habitats as a basis for their evaluation. For all studies within this chapter, RapidEye products acquired between 2009 and 2011 were used as basic imagery for the subsequent investigations due to their frequent availability and suitable spectral as well as spatial resolution. The acquired images were always used in combination for a single mapping step. The necessary time-frame for monitoring with repeated image acquisition (e.g. a 6-year cycle as proposed in the EC Habitats Directive) was not available within the HABIT-CHANGE project.

Within the general framework described (Natura 2000-related indicators, RapidEye data from 2009 to 2011), methods for various habitats in three different biogeographic regions (Continental, Alpine, Pannonian) were applied. The techniques, which are described in the following subchapters, are intended to demonstrate their potential for indicating likely climate change impacts. In the Vessertal, a forested area in Germany, the immigration of beech into a spruce dominated region – a potential effect of climate change – was investigated (Sect. 7.2). In the Lake Neusiedl area in Austria potential climate-induced changes in Pannonic inland marshes are shown (Sect. 7.3). In Rieserferner Ahrn, an Alpine region in Italy, the potential of detecting shrub encroachment – an indicator for climate-related change to the treeline – was explored (Sect. 7.4).

7.2 Case Study Forest Habitats: Vessertal, Germany

A detailed description of the study area Vessertal is found in Sect. 16.2. In Chap. 16, climate change related sensitivity of forests in general and the Vessertal specifically is also described. This section, therefore, provides only a summary of the main facts of the region. With 88 % forest cover, the Biosphere Reserve Vessertal can be characterised as a landscape almost completely covered by woodland. The main tree types are spruce and beech. In terms of protected habitats *Luzulo-Fagetum* beech forests (habitat code 9110) and *Asperulo-Fagetum* beech forests (habitat code 9130) are of major importance (see Table 16.1).

As already mentioned above, only a long-term study can provide facts about the immigration of beeches into spruce dominated areas as may be occurring in the Vessertal region. However, the multi-temporal based short-term habitat quality indicator presented here can be used to detect the actual status of tree species compositions within the protected areas. Using this approach a detailed and accurate differentiation of tree species can be obtained. Knowledge about the current status of the tree population is important information for decision makers, helping them plan further management measures for conservation of the Natura 2000 habitat types.

7.2.1 Data and Methods

For this study a multi-temporal series of RapidEye data (Level 3A) for the study area Biosphere Reserve Vessertal (Table 7.1) was obtained in 2011. Four images with the acquisition dates 24-04-2011, 08-05-2011, 26-08-2011, and 23-10-2011 were available. The RapidEye mission represents a constellation of five satellites and provides high spatial resolution multi-temporal imagery. Five optical bands cover a range of 400–850 nm, whereby the first three bands represent the visible spectral range (400–685 nm). Band 4 covers the red-edge wavelength (690–730 nm), which is very sensitive for vegetation chlorophyll, and band 5 covers the near-infrared (760–850 nm). The spatial resolution is 6.5 m for level 1B data and resampled to 5 m for orthorectified level 3A data (Schuster et al. 2012).

Table 7.1 Percentage of the share of natural tree types as an example indicator for the determination of conservation status for *Luzulo Fagetum* beech forests and *Asperulo Fagetum* beech forests ($\geq$90 % beech = favourable; between 80 and 90 % beech = unfavourable – inadequate; below 80 % beech = unfavourable – bad). The areas reported as *Asperulo Fagetum* beech forests show a higher share of favourable conservation status than *Luzulo Fagetum* beech forests

Conservation status	*Luzulo Fagetum* (9110)	*Asperulo Fagetum* (9130)
Favourable	14.19 %	57.68 %
Unfavourable – inadequate	30.61 %	37.73 %
Unfavourable – bad	55.19 %	4.58 %

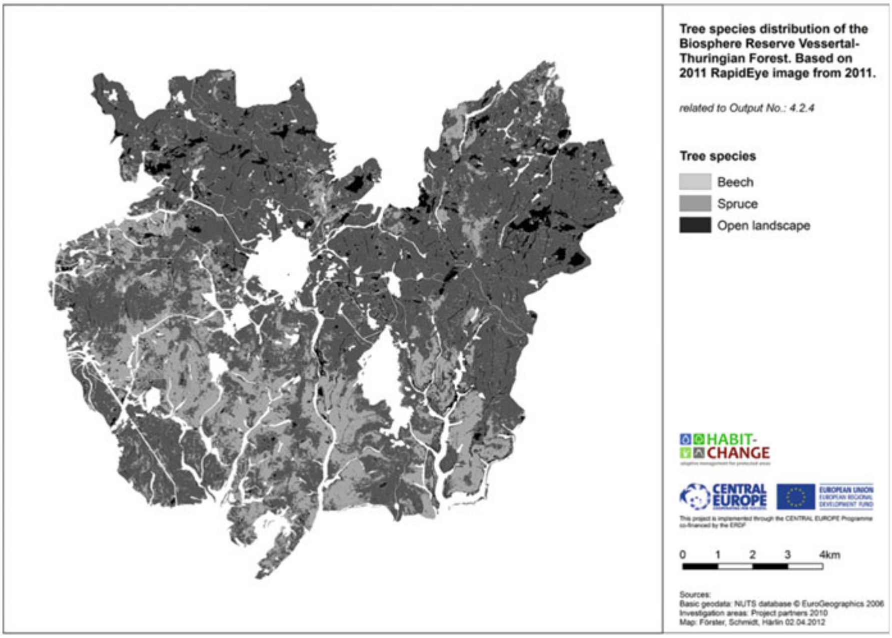

Fig. 7.1 Tree species distribution of the Biosphere Reserve Vessertal based on RapidEye satellite images from 2011

The pre-processing of the images included geometric correction (image-to-image) and radiometric normalisation to a cloud-free reference image in the middle of the vegetation period with a high radiometric quality (RapidEye image from 26-08-2011) to adjust the spectral variability. The IR-MAD algorithm implemented in ENVI/IDL was used for the radiometric normalisation. This algorithm automatically detects no-change pixels based on a no-change probability threshold and performs a relative radiometric normalisation of the images (Canty and Nielsen 2008).

Since the spatial accuracy of additionally available forest inventory data was insufficient to generate training samples for a supervised tree species classification, an unsupervised Isodata classification was performed in order to allocate spectral homogeneous clusters. These clusters were visually interpreted using aerial photographs and attributed to the classes beech, spruce, or open landscape. Subsequently, for each class, 1,000 random sample points were generated based on these spectral homogeneous areas. From these extracted sample points, a supervised classification, based on multi-temporal data using the Support Vector Machine (SVM) algorithm (Karatzoglou et al. 2005), was performed to generate a thematic tree species map (Fig. 7.1). For this process the samples were portioned into 70 % for the training of the SVM and 30 % for the validation. Thereafter, the tree species map was intersected with each of the existing Natura 2000 habitat type boundaries, which were available as a field-based mapping GIS-layer for reporting purposes from the Vessertal Biosphere Reserve. The tree species compositions (beech/spruce) per polygon were computed based on this independent data source.

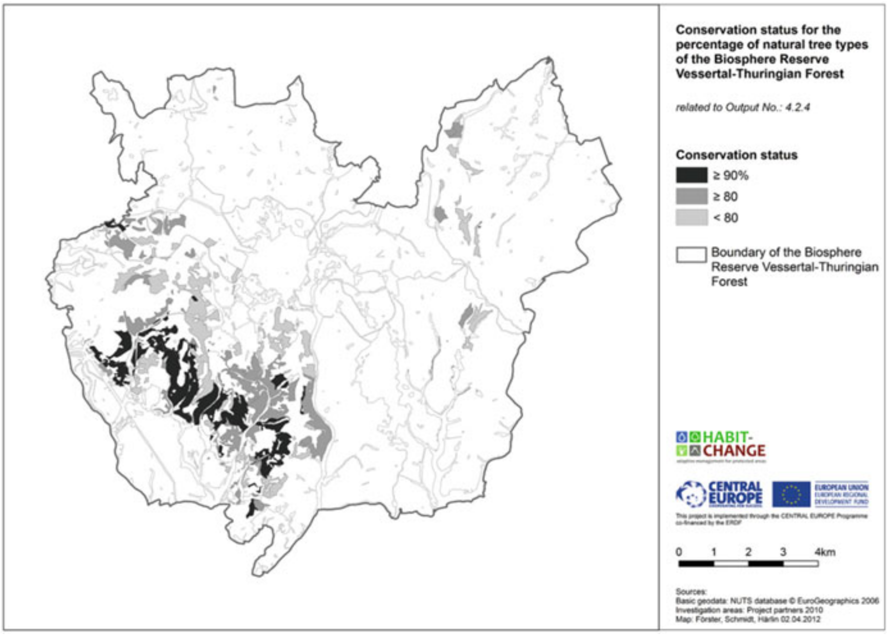

Fig. 7.2 Map of the percentage of natural tree types as an example indicator for the determination of conservation status (≥90 % beech = favourable; ≥80 % = between 80 and 90 % beech = unfavourable – inadequate; below 80 % beech = unfavourable – bad)

This approach enables detailed monitoring of habitat quality related to the tree species compositions. In terms of Natura 2000 in Germany, objective mapping guidelines with defined rules are available to determine the conservation status of a forest habitat (Burkhardt et al. 2004). These parameters define the status of a specific Natura 2000 site (e.g. favourable, unfavourable – inadequate, or unfavourable – bad). One indicator, suitable for remote sensing applications, is the percentage of natural forest types in terms of the abundance of specific species (Förster and Kleinschmit 2008). For this indicator, the tree species composition per polygon was calculated.

7.2.2 Results

The classification of the RapidEye images provides a detailed distribution of the tree species in the Biosphere Reserve Vessertal (Fig. 7.1). Spruce covers approximately 62 %, beech 30 %, and open landscape 8 % of the study site. The overall accuracy of the result is 88 %, so it was accepted as accurate enough to derive the indicator "percentage of natural forest types" for the Natura 2000 conservation status. The results of the percentage of tree species within the boundaries of the field-based delineated habitat types are depicted in Fig. 7.2.

In an exemplary evaluation of the conservation status for *Luzulo Fagetum* beech forests and *Asperulo Fagetum* beech forests, relying just on this single indicator, it can be shown that the conservation status of *Asperulo Fagetum* is more often favourable than for *Luzulo Fagetum* (Table 7.1), which corresponds with the findings of the field-based mapping presented in Chap. 16.

7.2.3 Conclusions

The results of the case study Vessertal illustrate the successful evaluation of an indicator of the conservation status of continental forest habitats (percentage of natural tree types). However, not all indicators defined for the conservation status of woodlands in Germany are detectable with RapidEye imagery. The differentiation of habitat types often relies on the understorey vegetation, which is not detectable using earth observation techniques. Within forest habitats a combination with LiDAR (Light Detection and Ranging) techniques has proven to be relatively helpful (Vehmas et al. 2009). However, the exploration of a set of indicators detectable by remote sensing that may complement the field-based data-set remains under discussion. In terms of climate change, the indicator evaluated here, percentage of natural tree types, can be utilised to monitor the immigration of beech into a spruce dominated region of the Thuringian Forest.

7.3 Case Study Wetland Habitats: Lake Neusiedl, Austria

7.3.1 Study Area

The transboundary Lake Neusiedl/Fertő-Hangság National Park was founded in 1993. It is situated at the Austrian and Hungarian border (see Fig. 1.1). Lake Neusiedl itself is – in hydrological terms – a steppe lake, the westernmost of a series of steppe lakes extending throughout Eurasia. It is especially sensitive to climate variations due to its extreme shallowness and small catchment area. Historical records indicate that large variations of the lake area have occurred naturally. However, today a constant water level is maintained by water engineering measures. Considering future climate scenarios, the main risk for Lake Neusiedl is significant water losses that could enhance eutrophication and algal growth (Soja et al. 2013).

East of the lake approximately 80 shallow saline ponds can be found. Nowadays, this area is determined by the spread of reed stands, smaller ponds created by the interconnection of the former bay-type formations, and smaller bays. Furthermore, reed in general is the most characteristic habitat in the region, covering more than 70 % of the protected area. Its structure ranges from very dense and impassable to sparse stands mixed with stretches of open water. In addition to reed, inland marshes (habitat code: 1530* – the star indicates a priority habitat) and calcareous fens (habitat codes: 7210 & 7230*) can be found in this region. In contrast to the larger patches of reed, these habitats are considered to be of European importance in terms of the EC Habitats Directive.

7.3.2 Data and Methods

For this case study two RapidEye images from 2009 (April and August, Level 3A), a Digital Elevation Model (DEM) to detect small altitude differences, and CORINE Land Cover data were used.

Within the European Union inland marshes are found solely in the region of Lake Neusiedl. They are greatly disturbed by increased nutrition input, changes in hydrology, regrowth of atypical plant types, and a decrease of land-use or degradation through intensive land-use. Some of these disturbances can be related to climate-induced impacts (e.g. change in moisture conditions). The Environmental Agency Austria uses an indicator-based approach to evaluate the quality of these habitats. The indicators employed are area, species composition, hydrology, completeness of typical habitat structures, and presence of disturbance indicator plant species. Here, a similar approach is used to develop potential habitat maps to support the monitoring process and consequently to detect areas not known to be covered by inland marshes. Because most of these indicators cannot be derived from satellite data, moisture and biomass were used for this investigation.

Moisture can be measured with the Normalised Difference Water Index (NDWI – Eq. 7.1) adapted for multi-spectral sensors (Gao 1996). This index allows the detection of water bodies and wet surfaces by utilising the spectral reflectance of the visible green wavelength and the near infrared (NIR). The requirements of inland marshes regarding water availability vary significantly. The amplitude ranges from temporary very dry periods (for alkali steppe) to periodic flooding (for salt steppes or salt marshes). Therefore, the NDWI is used to detect areas with periodically changing moisture conditions and permanently flooded or dry areas.

$$\mathrm{NDWI} = (\mathrm{Green} - \mathrm{NIR})/(\mathrm{Green} + \mathrm{NIR}) \tag{7.1}$$

Biomass can be approximated with the Normalised Difference Vegetation Index (NDVI – Eq. 7.2: Tucker 1979). This index is the common vegetation index for the detection of active biomass in remote sensing applications. In this study, the NDVI is used for detecting species which indicate a disturbance of inland marshes. Especially relevant here is reed, which has considerably high biomass production and replaces the common vegetation composition of inland marshes.

$$\mathrm{NDVI} = (\mathrm{Red} - \mathrm{NIR})/(\mathrm{Red} + \mathrm{NIR}) \tag{7.2}$$

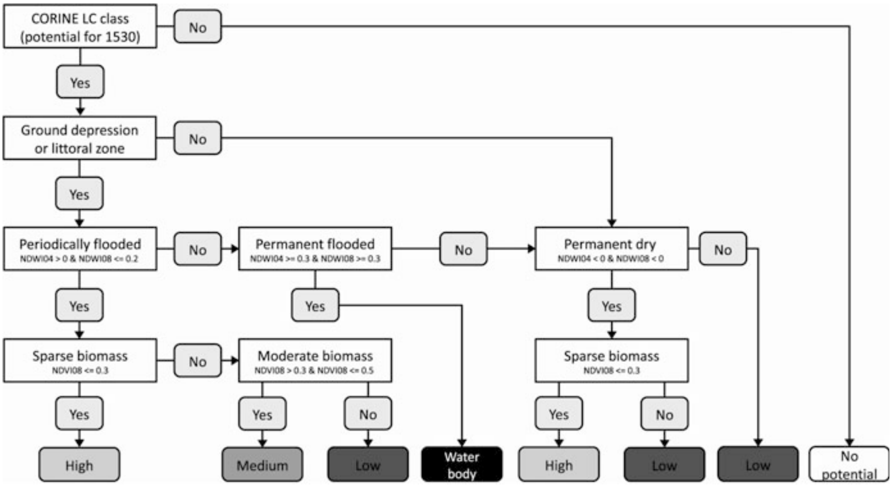

Fig. 7.3 Hierarchical classification approach for mapping of potential occurrence of inland marshes

Additionally, a DEM with a spatial resolution of 5 m and a ground depression detection map were used. Since especially salt steppes and salt marshes are closely related to the ground or sea water level, it can be assumed that ground depressions provide a high potential for this habitat type. The same applies to littoral zones beside the lake. However, littoral zones are not detected as ground depressions, since the entire littoral zone is already depressed. To determine these waterside areas, all areas between the lake's average surface of 115.45 m and 116 m ground elevation are taken as littoral zones.

Thresholds were applied to estimate three probability levels of inland marshes (Fig. 7.3). These thresholds are derived from reference habitats to deduce high, medium, and low habitat occurrence probabilities. Only land-cover types with a realistic potential for inland marshes were considered for the application of the rule set. CORINE land-cover data were used to mask out land-cover classes with little potential (e.g. urban areas).

7.3.3 Results

The results depicted in a habitat probability map (Fig. 7.4) show a transition from Lake Neusiedl in the western part to small probability patterns approximately 10 km from the main water body.

As expected, areas with the highest probability of occurrence can be found close to the lake. However, because of the low overall variation in altitude the possibility of detecting small depressions is a key feature for salt marshes. Therefore,

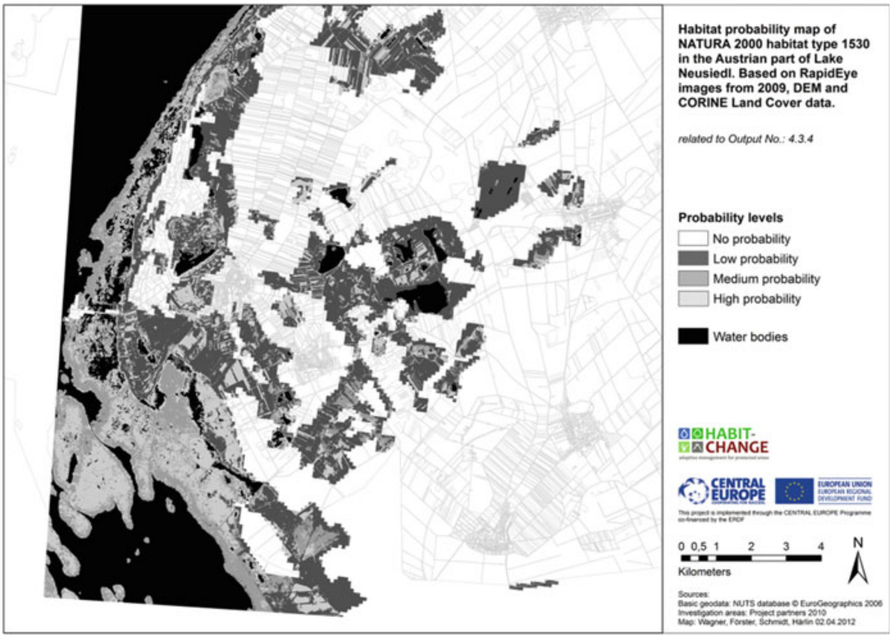

Fig. 7.4 Habitat probability map for the potential occurrence of inland marshes

RapidEye imagery can only be applied in combination with a high resolution DEM. The distribution of the inland marshes shows a realistic pattern which can be found in the area. Due to the difficult accessibility and limited personal resources, insufficient ground-truth data was available to evaluate the results statistically. The derived map could be compared to future probability maps in order to identify changes in the distribution of inland marshes and, thus, to potentially relate the changes to the impacts of climate change and other factors.

7.4 Case Study Alpine Habitats: Rieserferner-Ahrn, Italy

7.4.1 Study Area

The Nature Park Rieserferner-Ahrn is situated in the eastern Alps, in the north-eastern part of the Autonomous Province of Bolzano, Italy (see Fig. 1.1). It encompasses 313 km^2 and is characterised by Alpine landscapes and forest zones. Glaciers cover around 5 % of the area and are important water resources. The area is shaped by numerous streams, rivers, waterfalls, and fens.

Table 7.2 Natura 2000 habitats in the study site

Natura 2000 habitat code	Class definition
3150	Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*
4060	Alpine and boreal heaths
6150	Siliceous Alpine and boreal grassland
6230	Species-rich *Nardus* grasslands, on silicious substrates in mountain areas (and submountain areas in Continental Europe)
6520	Mountain hay meadows
7140	Transition mires and quaking bogs
8110	Siliceous scree of the montane to snow levels (*Androsacetalia alpinae and Galeopsietalia ladani*)
8220	Siliceous rocky slopes with chasmophytic vegetation
9420	Alpine *Larix decidua* and/or *Pinus cembra* forests

The location in the inner Alps south of the Alpine divide renders the climate moderately dry. The study area covers an elevation range from 890 to 3,480 m above mean sea-level. The vegetation reflects the mountainous character of the nature park. Spruce forests dominate while the timber line is made up of larch and Swiss pine. Increasing in altitude, the vegetation is composed of Alpine meadows and sub-Alpine and Alpine small shrubs and heath. Extreme habitats for plants and animals can be found here. The vegetation above the tree line is very heterogeneous and varies within small areas (Table 7.2).

Agriculture in the study site consists mainly of livestock farming and is characterised by the contrasts of intensification and abandonment. The nature park is managed by representatives of the municipalities, the department of forestry and agriculture, the farmers' association and experts from conservation organisations. The Nature Park is part of the Natura 2000 network of the European Union.

7.4.2 Climate Change Impact in Alpine Areas

The Alpine region has seen an exceptionally large increase in temperature of around +2 °C between the late nineteenth and early twenty-first century, more than twice the average warming of the northern hemisphere. Regarding precipitation, a slight trend towards an increase in the northern Alpine region and a decrease in the southern region has been recorded (EEA 2009; Auer et al. 2007).

Climate projections for the Autonomous Province of Bolzano show a clear warming trend in all seasons. Until 2050 temperatures are projected to increase between +1 °C and +2 °C (up to +2.9 °C in summer). Future precipitation projections are more heterogeneous and do not show a clear trend. Furthermore, a prolonged growing season, i.e. the period of the year with a daily mean temperature of over 5 °C, is projected. The meteorological water balance, which can be used as an indicator to estimate the requirement of irrigation water, does not show a clear trend in the models. However, local extremes of variations can be expected in future changes of climate (Zebisch et al. 2010).

The largest pressure on habitats in Alpine areas is land-use. This is true despite land-use activities being limited within the Nature Park due to conservation restrictions. Pressures arise mostly from extensive forestry, agriculture (grasslands with livestock breeding and pasture farming), tourism, and traffic. In this study we investigated the following potential impacts for the study area Rieserferner Ahrn:

- increase in dwarf shrub cover,
- change in tree line,
- new vegetation on rocks and the glacier forefields,
- changes in water regime and intra-annual and inter-annual dynamics,
- changes in phenology and its intra-annual and inter-annual dynamics (Zebisch et al. 2010).

7.4.3 Data and Methods

For the study area four RapidEye images (Level 1B) with the acquisition dates 22-07-2009, 29-07-2009, 03-10-2009 and 31-07-2010 were available. The following auxiliary data sets were used:

- a colour aerial orthophoto acquired in 2006 with a spatial resolution of 0.5 m,
- a Digital Elevation Model (DEM) with a spatial resolution of 2.5 m,
- solar radiation layers – from RapidEye images using metadata and DEM,
- texture layers: texture features (Haralick et al. 1973) such as mean, variance, homogeneity, contrast, dissimilarity, entropy, second angular moment and correlation features were generated from the orthophoto,
- detailed habitat thematic map: field mapping 2006 as well as photointerpretation and digitalisation of orthophotos by experts.

Initially the RapidEye images were orthorectified (Toutin 2003) and the pixel values converted to reflectance at top of the atmosphere (TOA). In the latter step only distance to the sun and the geometry of the incoming solar radiation was considered. Next we masked out clouds and shadowed areas in the images using object-based image analysis. Using Definiens eCognition software the images were first segmented and classified into two levels to map clouds and shadows based on object statistics, topological and shape object's features. The mapping results of the two classification levels were then merged. The classification was further improved by modifications of the object's shapes using appropriate features of classified objects. Subsequently, training as well as validation samples of the different vegetation types were derived following a random stratified sampling approach based on thematically homogeneous areas. A minimum of 50 samples were taken from twelve vegetation types present in the study area. The SVM classification

Table 7.3 Vegetation types classified in the study area and their corresponding habitat types according to the Natura 2000 habitat codes

Vegetation type	Corresponding habitat type
Water bodies	3150
Alpine heathland	4060
Alnus (Grünerle)	
Pinus mugo	4060
Natural grassland	6150
Extensive grassland	6230
Intensive grassland	6520
Wetlands	7410
Pioneer formations	8110

algorithm was then used to classify vegetation cover. Vegetation classes that can be distinguished in the study area and their corresponding habitat-types are listed in Table 7.3.

In a subsequent step, the classification results were validated using independent reference points. The summarised output is transferred into a confusion matrix for calculating overall accuracy and kappa value. Finally, we reclassified the vegetation classes from the supervised classification into habitat types applying a knowledge-based approach. We defined thresholds for each habitat type including the minimum and maximum percentages of vegetation types, the minimum area and the elevation range. The criteria are taken from the literature, in particular from Ellmauer (2005). Additionally, we included the expertise of biologists at the EURAC Institute of Alpine Environment. We applied a spatial kernel method to calculate the frequency of a class within a given filter window. Both the frequency and the spatial arrangement of class labels within the window are recorded. With this spatial reclassification kernel an adjacency matrix is produced for each pixel and habitat classes are assigned accordingly (Barnsley and Barr 1996). For those pixels where no rule or more than one rule is true the relevant pixel remains undefined. In order to classify such pixels we used a minimum distance classifier. An additional effect is that the reclassification also corrects misclassified data and thus improves the salt and pepper noise of the pixel-based classification (Schmidt 2012).

We assessed the accuracy of the resulting habitat type map (Fig. 7.5) using reference samples carefully selected from the orthophoto and labelled by an independent expert. In order to determine the conservation status of a habitat type we utilised two assessment schemes: that of the German working group of the Federal States and the Federal Government on nature conservation (Länderarbeitsgemeinschaft Naturschutz = LANA) and the Austrian scheme (BMULF). From these schemes we derived disturbance indicators that can be detected on satellite images, the most prominent being shrub encroachment, which can occur in different habitat types, most prominently in grassland types. For each habitat type the schemes give percentages of the area of a habitat which is covered by shrubs and consequently fall in a certain conservation status category. We implemented the LANA definitions of shrub encroachment and the subsequent conservation status in a rule set (result see Fig. 7.6).

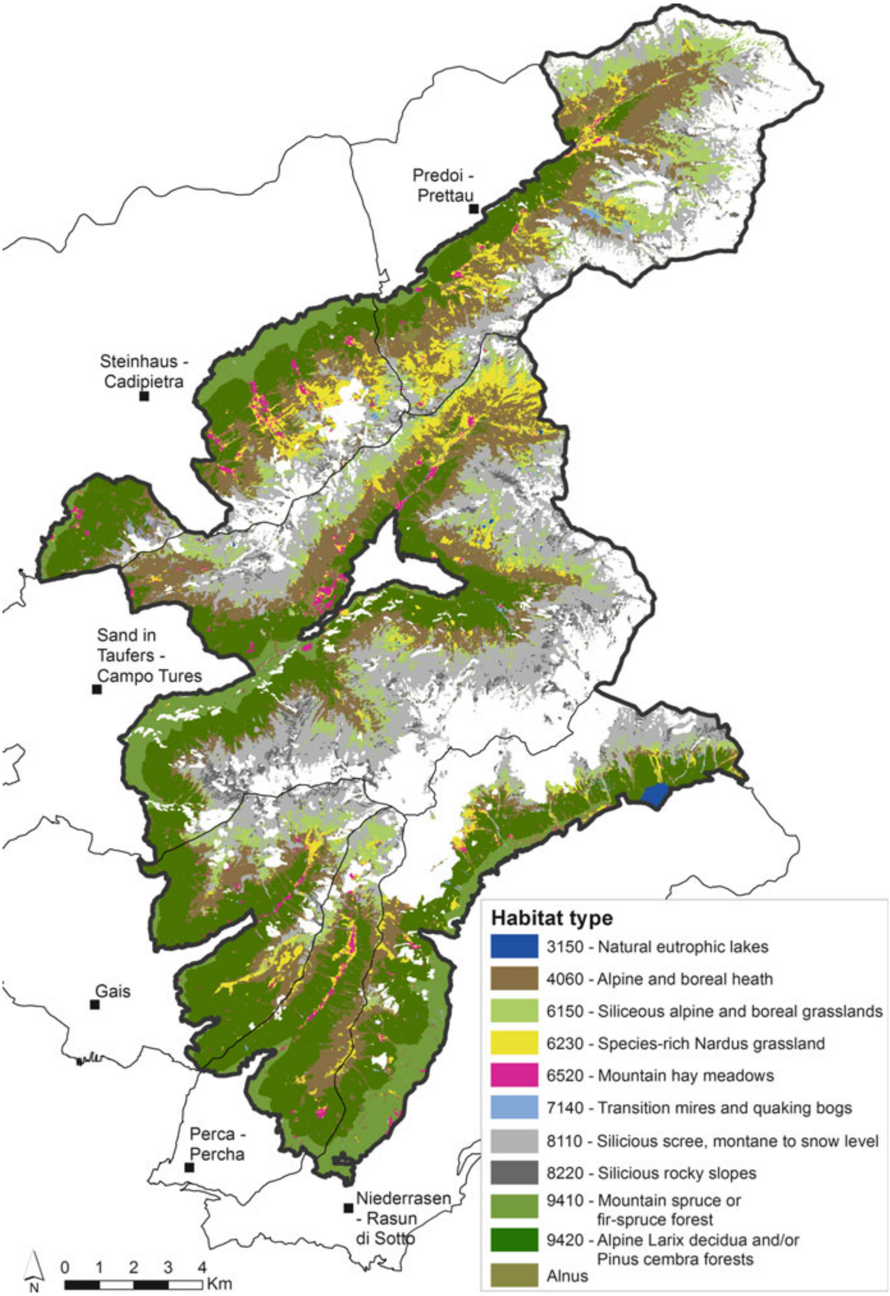

Fig. 7.5 Final habitat map Rieserferner-Ahrn Nature Park according to the Natura 2000 habitat codes

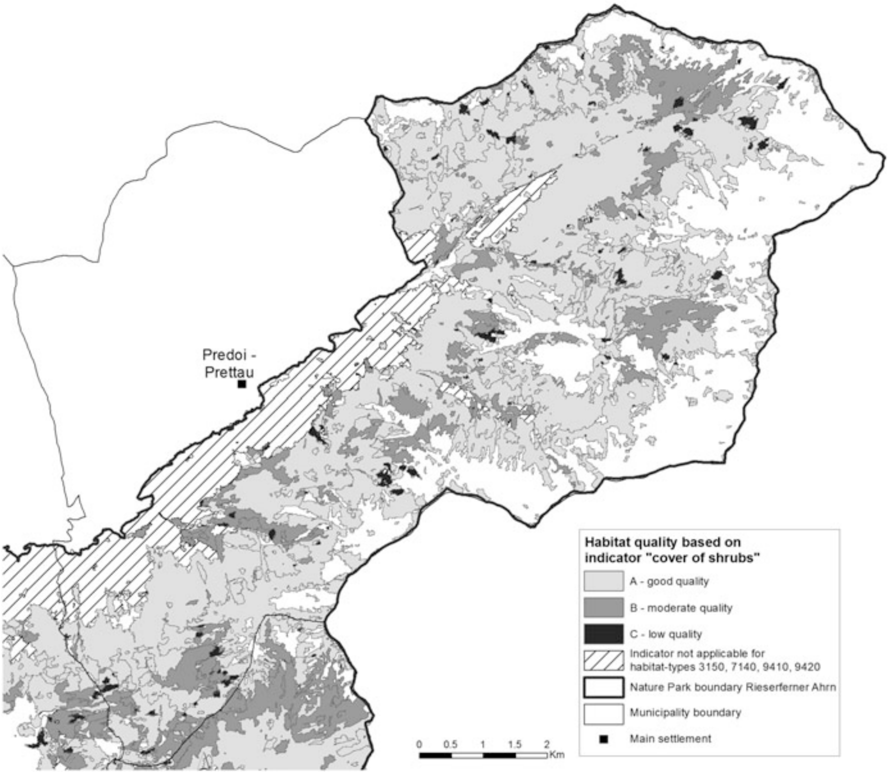

Fig. 7.6 Example for an evaluation of conservation status for the disturbance indicator "shrub encroachment" (for the north-eastern part of the Rieserferner-Ahrn Nature Park)

7.4.4 Results

In conclusion, we developed and applied a method to detect habitat types on satellite images that produced results of a quality to be used in regional habitat monitoring (see Fig. 7.5).

The resulting habitat map is 87 % accurate and can be processed further to determine the conservation status of a habitat. Provided that the necessary input data and adequate ground truth data for calibration and validation are available our approach can be replicated in other Alpine areas and for different time periods. The output habitat map could be reproduced regularly for a Natura 2000 site to detect changes and to evaluate the conservation status by means of a disturbance indicator such as shrub encroachment.

7.4.5 Conclusions

Multi-temporal high resolution satellite data have high potential for mapping and monitoring habitats in Alpine areas. The shortcomings from the technical side are mainly data gaps due to cloud cover, which is a relevant problem particularly in the Alps. The overall accuracy of 87 % is high, taking into account the large number of classes (12). However, while a remote sensing-based classification can hardly reach the accuracy of a field-based survey it can compete with the widely used approach of the photointerpretation of orthophotos. In particular the multi-temporal approach allows classes to be separated based on phenological differences or differences in management (mowing) that cannot be separated using a mono-temporal approach like an orthotophoto. Furthermore, the higher number of spectral bands with a better radiometric resolution and robustness of satellite data compared to orthophotos allow a semi-automatic classification which saves costs and labour. Key factors for a high quality classification result are sufficient samples in terms of amount and quality, which should be verified in the field. Moreover, the combination of automatic classification approaches with expert classification rules, which are based on profound knowledge of the habitats in the region, are required for a successful application of the proposed method. The possibility to also analyse some aspects of the conservation status of habitats adds further value to the approach. Regarding the potential impacts of climate change, the most obvious impact, which is a shift in vegetation zones to higher altitudes (shrubs, treeline, glacier foreland), can be effectively monitored with remote sensing.

7.5 General Conclusion and Discussion

In this chapter the possibility of using remote sensing information for monitoring climate-induced impacts on habitats has been demonstrated for three test cases in the Continental, Alpine, and Pannonian biogeographic regions. Moreover, habitats from the land-cover types forest, wetland, and Alpine environment were evaluated to assess the feasibility of supporting the monitoring of climate change impacts.

In those test cases with a validation of the classification results, the accuracy is higher than 80 %. Given the complexity of the target classes, this result can be accepted as a basis for the further derivation of the conservation status of classes. Generally, comparison with future image acquisitions for the evaluation of changes is possible. However, these changes might have causes other than pure (and often very gradually occurring) climate change. Variations in market prices of timber or crops may influence usage intensity, as may the subsidy schemes of the European Union or the changing touristic utilisation of an area. It is not possible to distinguish anthropogenic land-use changes from those induced by climate change by means of the methods discussed.

The results were achieved using multi-temporal RapidEye imagery. At least two scenes per year were available for the presented studies. The advantage of utilising several pieces of information from the phenological cycle was stated in all studies, as well as the necessity of working with very high spatial resolution imagery (below 10 m).

However, the compatibility and transferability of such classification results depends on a variety of factors, including:

- comparable and high sampling intensity in space (all necessary classes equally covered) and time (seasonally and/or according to phenological changes of the habitat types),
- comparable sensors and spectral resolution, similar conditions for input imagery (acquisition date/frequency, cloud cover etc.),
- comparable mapping scale or spatial precision: the minimum mapping unit (for vector maps) or the spatial resolution (for raster maps) should be similar,
- comparable mapping accuracy, consisting of thematic accuracy (percentage of correctly classified habitats), and spatial accuracy (habitat delineation errors),
- compatibility of habitat nomenclatures (habitat classification systems).

Summarising the experiences from the HABIT-CHANGE project, a set of key points has to be kept in mind when considering remote sensing techniques for habitat monitoring. In order to fulfil the goal of a focused habitat monitoring integrating remote sensing technique, a clear vision of the outcome (objective) has to be defined. A selection of possible questions is compiled in Table 7.4 for consideration in further studies, for service providers as well as (or together with) users and practitioners of the mapping or monitoring of results.

Table 7.4 List of key issues to be considered for remote sensing-based habitat monitoring (Adapted from Förster et al. 2010). Note that this list is not exhaustive and can be extended (e.g. use of additional data or post-processing)

Objective(s)	
Which is/are your objective(s)?	Mapping, indicator assessment, monitoring, change detection, phenology, others
Image data	
Which imagery should be acquired?	Multispectral, imaging spectroscopy, very high spatial resolution data, LiDAR, others
What is the image size or path width?	Spatial coverage (geographic extent of the image)
Which spatial resolution is necessary to fulfil the objective?	The ground sampling distance (GSD) of an image
What is the number of bands and wavelengths necessary to fulfil the objective?	Specific wavelengths (e.g. short wave infrared, thermal)
Which frequency of image acquisition is necessary to fulfil the objective?	Mono vs. multi-temporal images (indicate required acquisition time(s))
Sampling	
What is the sampling strategy?	Selected (non-random selection of representative plots of predefined classes) Systematic (e.g. regular grid) Simple random Stratified random
Which type of ground-truth data should be collected?	Plant species relevés Vegetation structure relevés Natura 2000 habitat type Spectral signature

(continued)

Table 7.4 (continued)

What is the season for acquisition?	Month or season
Which sample size is required?	No. of samples, depending e.g. on required minimum samples of classification algorithm
Remote sensing derived information	
Which information should be derived?	Map, change, phenology, others
Which classification approaches are used?	Pixel-based analysis or object-based analysis Classification or derivation of gradual vegetation composition Hard classification or soft (fuzzy) classification Supervised or unsupervised classification Spectral or spatial
Validation	
How should the result be validated?	Based on dependent or independent samples Automatic validation or visual interpretation Pixel or polygon based By confusion matrix or other techniques

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Chapter 8
Assessment of Climate-Induced Impacts on Habitats

Iris Wagner-Lücker, Michael Förster, and Georg Janauer

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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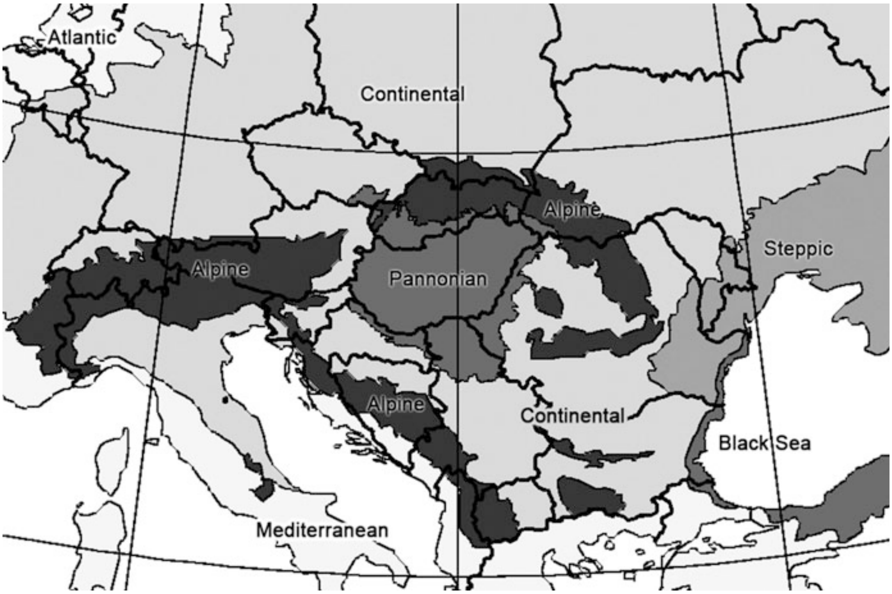

Fig. 8.1 The biogeographical regions of Central and Eastern Europe, modified after EEA (2011)

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

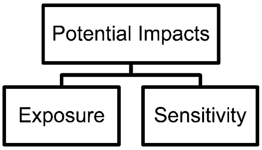

Fig. 8.2 Framework for the assessment

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/Fertö-Hanság National Park, Austria/Hungary	25

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

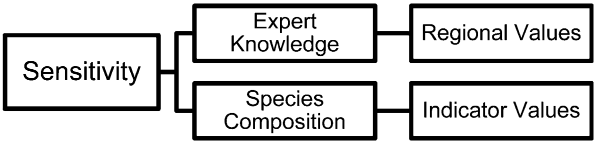

Fig. 8.3 Framework for the sensitivity assessment

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

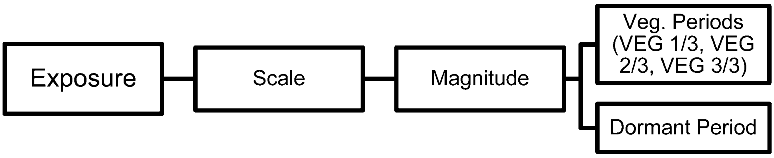

Fig. 8.4 Framework for the exposure assessment

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).

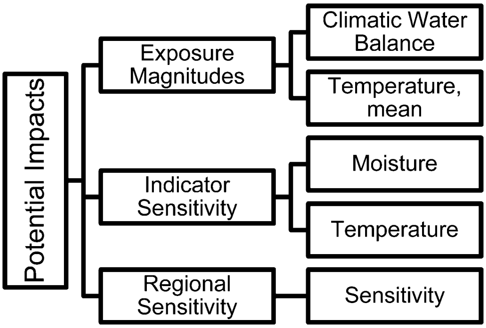

Fig. 8.5 Framework for the impact assessment

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, than 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	*Cnt.*	CONS	REGE	HORI	ALTI	WATER	COVER	NEOP	*Sum*	**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	*Cnt. Spec*	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

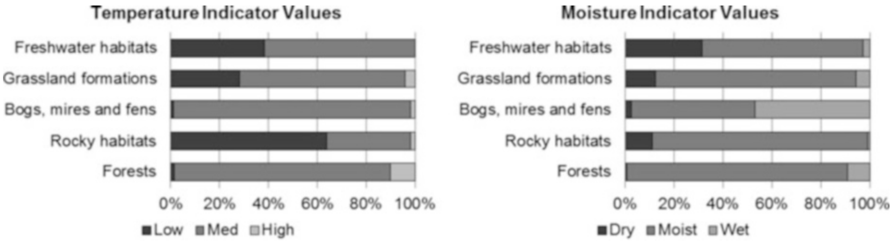

Fig. 8.6 Proportional distribution of the indicator values per habitats in the Alpine region

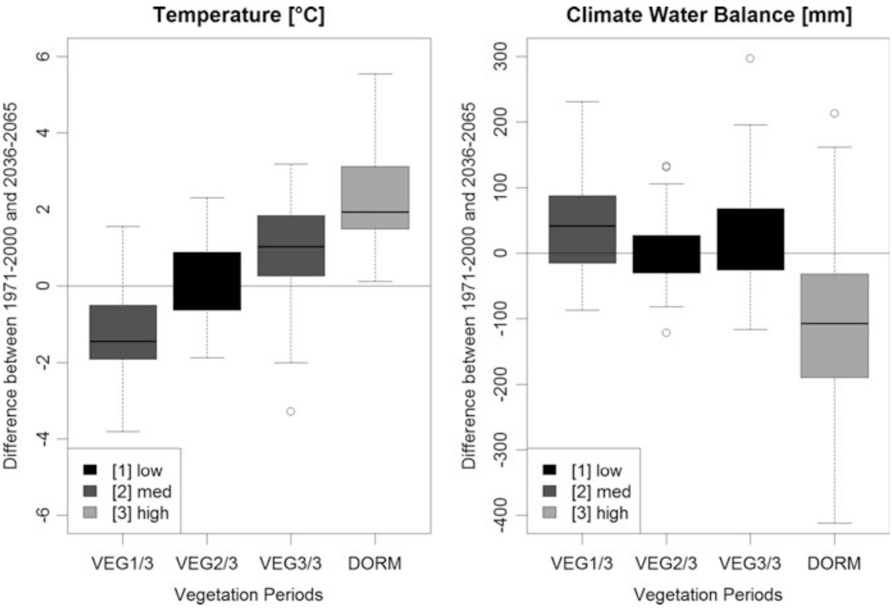

Fig. 8.7 Difference in exposure between periods 1971–2000 and 2036–2065 for parameters used in the Alpine impact assessment

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	*Cnt.*	CONS	REGE	HORI	ALTI	WATER	COVER	NEOP	*Sum*	**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	*Cnt. Spec*	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

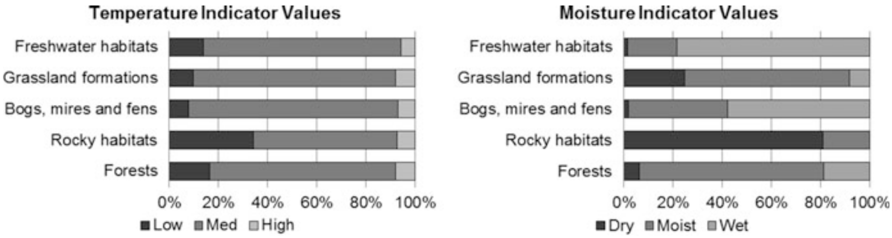

Fig. 8.8 Proportional distribution of the indicator values per habitats in the Continental region

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

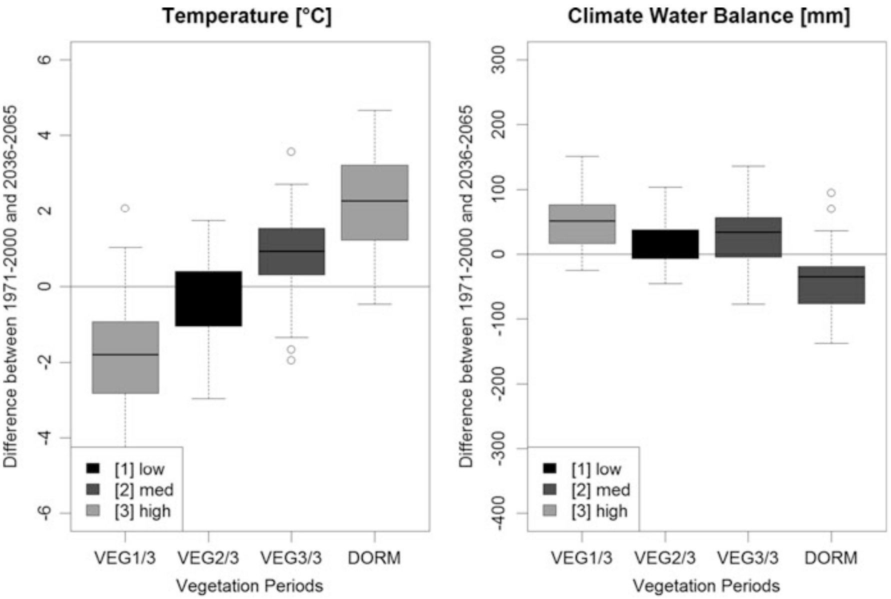

Fig. 8.9 Difference in exposure between periods 1971–2000 and 2036–2065 for parameters used in the Continental impact assessment

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	*Cnt.*	CONS	REGE	HORI	ALTI	WATER	COVER	NEOP	*Sum*	**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	*Cnt. Spec*	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

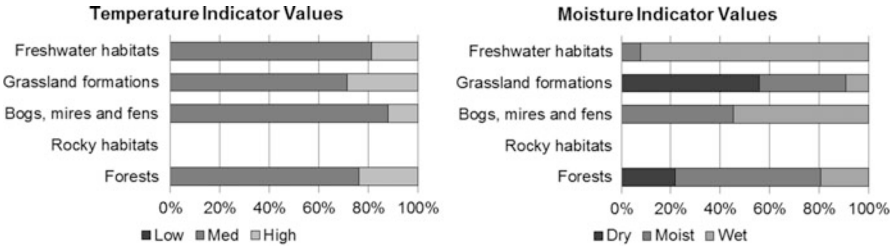

Fig. 8.10 Proportional distribution of the indicator values per habitats in the Pannonian region

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

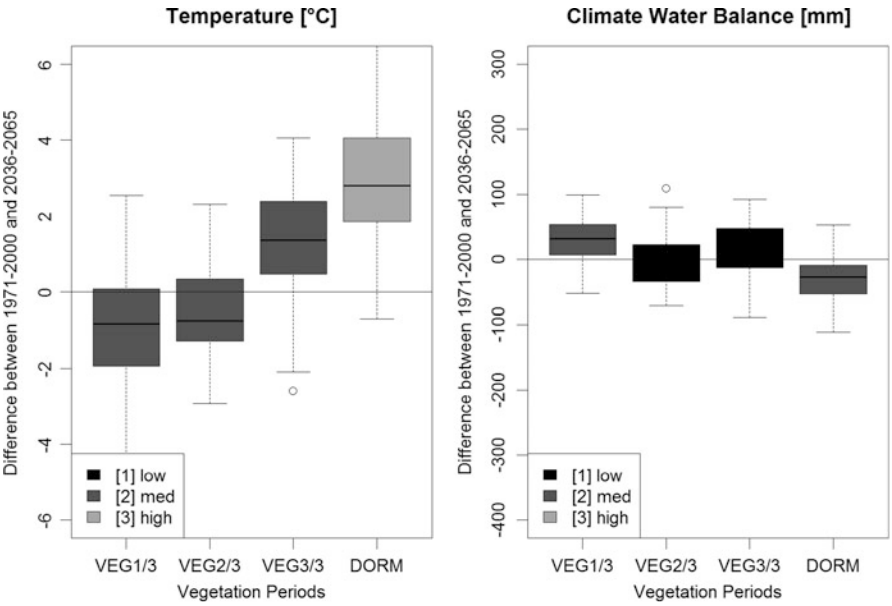

Fig. 8.11 Difference in exposure between periods 1971–2000 and 2036–2065 for parameters used in the Pannonian impact assessment

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 Renetzeder 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.

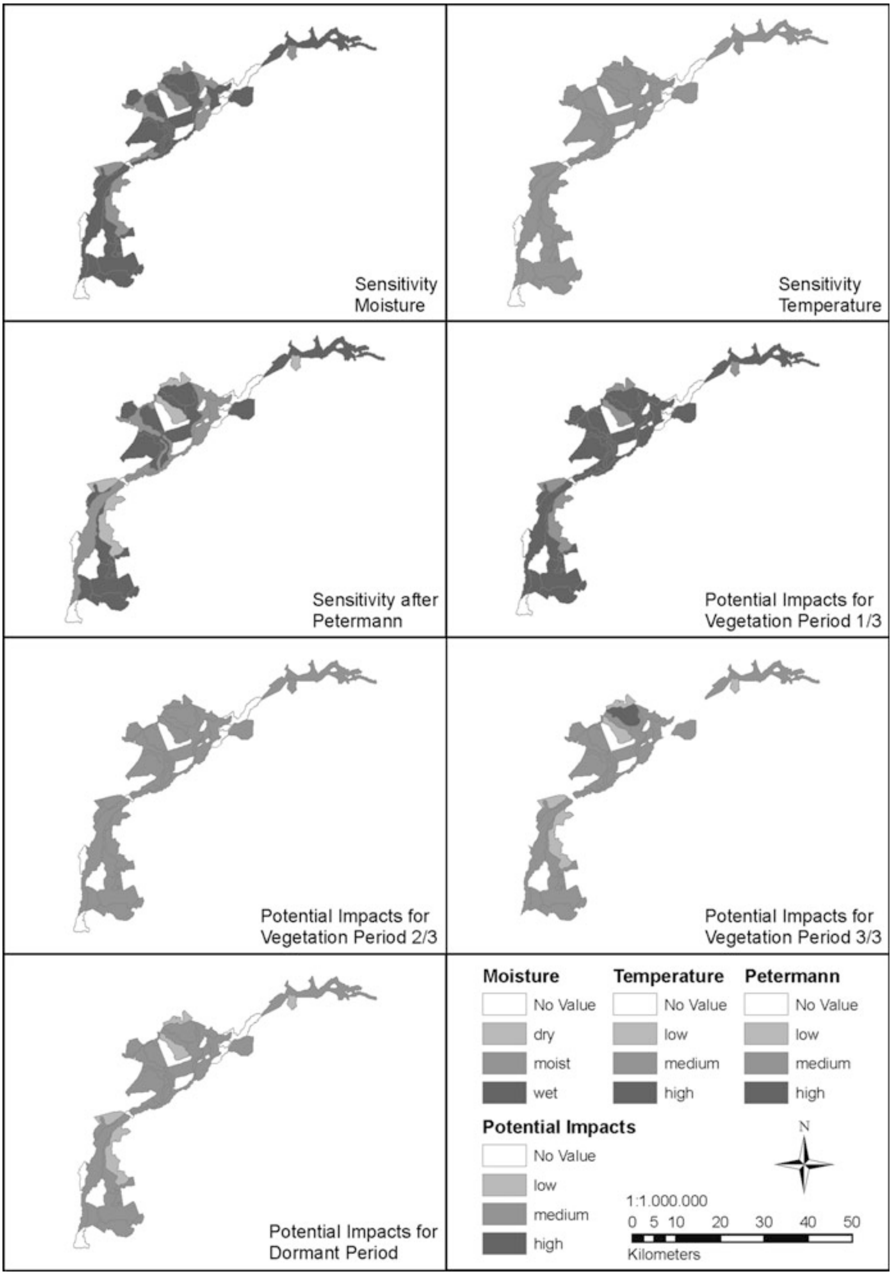

Fig. 8.12 Exemplary set of maps for sensitivity and potential impact for the Biebrza National Park (Continental Region)

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Chapter 9
Legal Aspects of Climate Change Adaptation

Moritz Gies, Juliane Albrecht, and Jadwiga Sienkiewicz

9.1 Introduction

As climate change and anthropogenic activities are putting European habitats and their management under pressure, measures are needed to reduce impacts and to prepare for and react to future developments of protected areas. These measures are subject to legal regulations, especially those of nature protection and water law, but also of spatial planning and the law of economic land and natural resources use. Adaptation for nature protection areas can cause conflicts with other legal interests of a public or private rights origin. Thus a stricter regime of nature protection adapted to higher habitat sensitivity can interfere with, e.g. a growing need for public infrastructures or private agricultural land use, which themselves could be intensified under changing climate conditions.

These legal issues of climate change adaptation are ideally dealt with in a comprehensive political and legislative process spanning from the international and European level down to national strategies and regional planning, in order to adapt the law as necessary to ensure a higher adaptive capacity of the legal framework for nature protection areas and water resource management. In this chapter, the policy making in the European Union for climate change adaptation and biodiversity protection and the possibilities and constraints of the legal framework for nature protection and water management are analysed in order to highlight the chances and shortcomings of adaptation in the political and legal field.

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First, the European policy framework for climate adaptation in the field of nature conservation is discussed. Second, the adaptability of European Nature Conservation and Water Law is evaluated. Third, the implementation of these provisions in central European member states is compared. On this basis, fourth, the legal options and the need for amendments are identified. Finally, the scope of future policy making and legislation will be assessed.

9.2 Nature Protection in European Climate Change Adaptation Policies

The European political context for adapting nature conservation to climate change emerges from legislative initiatives and documents produced by the European Council and the European Commission as well as from the literature on the effects of climate change on biodiversity and on recommended means and approaches for adaptation and mitigation (EC White paper on Adapting to Climate Change 2009,[1] EC Impact Assessment 2009,[2] EU Ad Hoc Working Group on Biodiversity and Climate Change 2009,[3] Draft Guidelines on dealing with the impact of climate change 2012,[4] EC Communication 'Our life insurance, our natural capital' 2011,[5] Biesbroek et al. 2010; Cliquet et al. 2009; Trouwborst 2009, 2011; Naumann et al. 2011). Within this context the EU appears to have a solid biodiversity conservation policy framework supported by such key instruments as the Birds and Habitats Directives with the Natura 2000 Network, the EU Green Infrastructure Strategy and the Water Framework Directive, in addition to other relevant regulations and documents reviewed, among others, by Trouwborst and Naumann (op. cit.). Put in a worldwide context, the recent European regulations on biodiversity and climate stem from comprehensive guidance provided by the Secretariat of the Convention on Biological Diversity (CBD): Connecting Biodiversity and Climate Change Mitigation and Adaptation and the CBD COP decision X/33[6] on

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[1] Commission of the European Communities, White Paper – Adapting to climate change: Towards a European framework for action COM(2009) 147 final.

[2] EC Impact Assessment Guidelines SEC(2009) 92.

[3] Report of the Second Meeting of the Ad Hoc Technical Expert Group on Biodiversity and Climate Change 18–22 April 2009 – Helsinki, Finland.

[4] Draft Guidelines on Climate Change and Natura 2000 – Dealing with the impact of climate change on the management of the Natura 2000 Network. The document was prepared under contract to the European Commission (contract N° (ENV B.3./SER/2010/0015r) by Alterra and Eurosite; supplemented 2012: "Managing climate change for the Natura 2000 network – assessment of the vulnerability of species and habitats of Community Interest to climate change").

[5] Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions – Our life insurance, our natural capital: an EU biodiversity strategy to 2020 COM(2011) 244 final.

[6] Conference of the Parties to the Convention on Biological Diversity, Tenth meeting, Nagoya, Japan, 18–29 October 2010, decision adopted by the conference of the parties to the convention on biological diversity at its tenth meeting X/33 – Biodiversity and climate change (UNEP/CBD/COP/DEC/X/33).

biodiversity and climate change. The CBD COP has resolved to "take measures to manage ecosystems so as to maintain their resilience to extreme climate events and to help mitigate and adapt to climate change" and to "integrate climate change adaptation measures in protected area planning, management strategies, and in the design of protected area systems." The EU's existing commitments including the Biodiversity Action Plan have already been instrumental in achieving some progress in the implementation of policies and practical measures for nature conservation in the face of climate change.

The European process of adapting nature conservation to climate change is already progressing in both political and practical dimensions, though adaptation options and approaches may be of a piecemeal character and vary between countries. Thus there is a need for an integrated strategic approach to be applied at regional and national levels to ensure that timely and effective adaptation of management measures is taken, safeguarding coherency across different sectors and levels of governance (Draft Guidelines 2012).[7]

The White Paper sets out a framework for the European policies which aim to reduce environmental vulnerability to the impacts of climate change by identifying main directions of activities to be taken. The document highlights the necessity for a more integrated effort to mitigate and adapt to climate change, as this is a prerequisite for preserving both the natural values and the socio-economic interests of Europe. The White Paper makes it clear that adaptation needs to be urgently mainstreamed into EU sector policies, and that in each sector further work needs to be done to improve understanding of the impact of climate change, assess appropriate responses and secure the necessary funding, while adaptation policies receive support and are strengthened by an integrated and coordinated approach at EU level. Also the new EU biodiversity strategy 'Our life insurance, our natural capital' of 2011 underlines the urgency of addressing climate change in sector policies in order to increase the resilience of European biodiversity.

The 'Draft Guidelines on dealing with the impact of climate change on the management of Natura 2000' implement one of the actions of the White Paper.[8] The document provides opportunities for adaptive planning and managing climate change impacts and presents practical options (strategies and measures) for management adaptation to reduce non-climatic stresses in habitats. At the same time, the Guidelines lay down principles for generating new activities to increase the effectiveness of responses to climate change with the aim of preserving Europe's biodiversity. The principles for conservation and management strategies that maintain biodiversity can be summarised as follows: integrate biodiversity into wider seascape and landscape management; restore degraded ecosystems and ecosystem functions; and facilitate adaptive management by strengthening monitoring and

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[7] Draft Guidelines on Climate Change and Natura 2000, European Commission, 2012 (op. cit. fn. 4).

[8] Commission of the European Communities, White Paper – Adapting to climate change: Towards a European framework for action COM(2009) 147 final.

evaluation systems.[9] In line with the Guidelines, the adaptation of protected area management shall focus on eliminating and/or limiting the pressures that have been proven to render target habitats especially prone to climate change, thus reducing their natural resilience. Another important issue is to include socio-economic aspects within the context of protected area adaptation to climate change.

9.3 Adaptability of the European Nature Conservation and Water Law

9.3.1 Natura 2000 Law: Aims, Measures, and the Relevance of Climate Change

The Natura 2000 law serves the purpose of conserving European natural heritage. It consists of both the Birds Directive[10] (BD) and the Habitats Directive[11] (HD), as Art. 3 (together with Art. 7) HD states that the birds protection measures are integrated in the system created by the Habitats Directive, which is characterised as a "coherent European ecological network of special areas of conservation [that] shall be set up under the title Natura 2000". The European directive law has to be implemented by the member states, however on the other hand it itself implements international law agreements that the EU is bound to, above all the Bern Convention (Trouwborst 2011, p. 73). Therefore, the aims of Natura 2000 are mainly based upon the provisions of the Biodiversity Convention as well as on the Bern Convention. This means that the protection of biodiversity is realised by means of both an in-situ system of specially managed protected areas for habitats of species and by general ex-situ protection measures for species. The Bern Convention thus provides for international coordination and for a combination of both species and habitats protection (Dodd et al. 2010, p. 144). It is aimed at "take[ing] requisite measures to maintain the population of wild flora and fauna at, or adapt[ing] it to, a level which corresponds in particular to ecological, scientific and cultural requirements, while taking account of economic and recreational requirements."[12] This is reflected in Art. 2 HD, which sets the task "to maintain or restore, at favourable conservation status, natural habitats and species of wild fauna and flora." That means that the Natura 2000 system is a conserving rather than a highly dynamic nature protection strategy.

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[9] Cf. Draft Guidelines on Climate Change and Natura 2000, European Commission, 2012 (op. cit. fn. 4), pp. 72–99.

[10] Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds (codified version, OJ L 20, 26.1.2010, p. 7, repealing in its Art. 18 the older Directive 79/409/EEC).

[11] Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (OJ L 206, 22.7.1992, p. 7).

[12] Art. 2 Bern Convention (Convention on the Conservation of European Wildlife and Natural Habitats, Bern, 19.9.1979, Council of Europe, European Treaty Series No. 104.)

The measures to achieve these aims are threefold, according to Art. 6 HD. First, management and development planning provisions have to ensure that conservation status can be maintained (Art. 6 (1) HD). Second, the deterioration prohibition (Art. 6 (2) HD) demands that the protected habitats are shielded from all kinds of external influences, according to the European Court of Justice[13] even those of a natural origin (Schumacher et al. 2013, Sec. 5.4.2), although the applicability of this jurisdiction to global natural changes such as climate change remains uncertain (Cliquet et al. 2009, p. 169; Möckel and Köck 2009, p. 320 et seq.; Trouwborst 2011, p. 74). And third, external influences arising from anthropogenic activities in the form of plans or projects have to be restricted to an admissible level, which is ensured by means of an impact assessment for those plans and projects that could affect protected areas (Art. 6 (3) HD). This system allows exceptions only for reasons of overriding public interest (Art. 6 (4) HD).

The Natura 2000 law focuses not only on ubiquitous species, but also on protecting area-based habitats, which are highly vulnerable to climate change impacts and therefore subject to considerable changes (Möckel and Köck 2009, p. 320; Schumacher et al. 2013, Sec. 3.2.1). The conservation aims on the other hand – especially in connection with the deterioration prohibition – do not allow a more flexible, dynamic approach (Cliquet et al. 2009, p. 163; Haber et al. 2010, p. 382; Hendler et al. 2010, p. 689; dissenting: Dodd et al. 2010, p. 141). Therefore, with increasing climatic influences on the ecological composition within protected areas, a more and more demanding protective effort has to be made in order to maintain or even restore the favourable conservation status that the Habitats and similarly the Birds Directive require in their respective Art. 2 (cf. Trouwborst 2011, p. 70, fn. 86; Dodd et al. 2010, p. 144 et seq.).

9.3.2 Water Law: River Basin Management Planning Under Climate Change

A lot of areas of high conservation value are wetlands. Therefore, as well as the Natura 2000 law, the European Water Framework Directive (WFD) plays an important role for the protection of areas of high ecological value.

Art. 4 para. 1 WFD obliges the member states to prevent deterioration and to achieve a good ecological status and a good chemical status by 2015 (with possible extensions to 2021 or 2027). While the good status of surface water bodies requires a good ecological status[14] (or potential) and a good chemical status,[15] for ground

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[13] ECJ 20.10.2005, Case C-6/04 “Gibraltar”, [2005] ECR I-9017, para. 34.

[14] Good ecological status is the status classified in accordance with the biological, hydromorphological, chemical and physico-chemical elements of Annex V WFD (Art. 2 No. 22 WFD).

[15] The chemical state of a surface water body is considered “good” if concentrations of pollutants do not exceed the environmental quality standards established in the Directive 2008/105/EC on environmental quality standards in the field of water policy (OJ 2008 L 348/84) and under other relevant Community legislation setting environmental quality standards at Community level, such as the Nitrates Directive (OJ 1991 L 375/1) (Art. 2 No. 24 WFD).

water bodies a good chemical and quantitative status is necessary. Due to its ecological approach, the WFD interferes with various aspects of nature conservation. It has the general target of protecting and improving the status of aquatic ecosystems and, with regard to their water needs, terrestrial ecosystems and wetlands directly, depending on the aquatic ecosystems (Art. 1a WFD). The WFD considers water bodies as a whole and addresses their function as habitats for plants and animals.

The overall concept for achieving good water status is river basin management planning. The WFD provides two types of planning tools: the programme of measures (Art. 11 WFD) and the river basin management plan (Art. 13 WFD). Both types of plans form the basis for a coherent, all-embracing management concept for river basins. While the RBM Plans reflect the whole planning process in the river basin (cf. Annex VII WFD), the programmes of measures set out the actions to be taken to attain directive objectives during the plan period. For the first time, the plans and programmes had to be established in all EU member states by 2009. They are to be reviewed and updated by the end of 2015 and every 6 years thereafter.

The field of water management is particularly affected by climate change, because consequences for both water quality and water quantity are expected, accompanied by changes in ecological status, usability and the occurrence of extreme events such as flooding and low water levels (LAWA 2010). Beside these primary impacts, which are caused by climate change itself, there will be secondary impacts caused by adaptation measures (e.g. construction of dikes and dams) and mitigation measures (construction of water power stations to reduce CO_2 emissions) (Reese 2011, p. 63). Concerning water law, the question is whether the management system of the Water Framework Directive really is sufficient to meet climate change adaptation needs, or if it has itself to be adapted accordingly (Reese 2011, p. 62).

9.3.3 General Principles of Legal Climate Change Adaptation

As Craig has analysed, five principal characteristics of climate change adaptation law can be identified: (1) constant and comprehensive monitoring; (2) resilience improvement; (3) long-term cross-sector coordinated planning; (4) principled flexibility in regulatory goals and environmental resource management; (5) acceptance of inevitable loss (Craig 2010, p. 9 et seq.). The principles reflect the typical problems that climate change causes for the legal system. It is a highly dynamic process, it has a great variety of possible effects and affected objects, it is accompanied by considerable uncertainty, and its effects are of a long-term durability, requiring a de-centralised, location specific response (Reese et al. 2010, p. 13 et seq.). This means that there is no single, general adaptation option that suits all kinds of natural resource management regulations (Craig 2010, p. 16 et seq.). What is rather required are many different and specific adaptation measures that are flexible enough to meet every possible adaptation need that could arise in future, while at the same time not causing harm in cases where making use of their adaptive potential proves not to be necessary (no-regret measures).

It follows that nature conservation and water management require better surveillance of all impacts and effects, improved planning taking account of uncertainties on a long-term time scale in a preventive manner (monitoring and planning), and a more flexible system in order to react to unforeseen developments on the local level. The preventive provisions ought to be open to foreseeable changes from the beginning and should be designed in a highly resilient manner (resilience improvement). Reactive instruments have to be led by adaptation principles that ensure that the aims of mitigation and averting negative impacts are not set aside too quickly and that adaptation measures are targeted towards conservation aims, taking account of the new circumstances caused by climate change (principled flexibility). Basically, pro-active prevention is the rule, whilst reactive response should remain the exception. Typically, climate change specific monitoring and planning will lead to the implementation of management practices and interference prohibitions needed to avert negative impacts on good conservation status, e.g. early action in water management and water use regulations, when climatic developments are expected to lead to a problematic situation for a wetland habitat area. At the same time, regulations should be introduced that allow adequate reactions to more unlikely, not preventively tackled or even completely unforeseen events and impacts, e.g. the possibility to cancel permission granted for water cooling of a power plant when climate conditions worsen unexpectedly or extreme events have occurred. The last resort is the point where inevitable and final loss must be accepted, i.e. a definition of situations where the protection goals or even a whole protection area designation should be cancelled and possibly replaced. It must be made very clear in binding legal terms that this is not an option where reasonable efforts are still possible and bearable (Craig 2010, p. 69 et seq.).

The most challenging task is resilience improvement by reducing non-climatic impacts. Adaptation to climate change means – generally in the field of environmental law – above all the intensification of protective and preventive standards, as climate change mostly leads to an aggravation of existing environmental stresses, with nature becoming more and more intolerant (Craig 2010, p. 43 et seq.). The factual differences and consequently the legal difficulties are of a gradual, not categorical, nature (Reese et al. 2010, p. 12).

The legal steps required in order to adapt to climate change can either be taken on the level of the protection goals, or at the instrumental level of protection measures. The former could be made more open to changes, so that dynamic processes rather than fixed states become the goal of conservation: “Environmental Protection and Environment Asset Usage will have to retire from the leading principle of a relatively static environment that is to be conserved near the original state. Instead, a dynamic protection concept is needed [. . .].” (cf. Reese et al. 2010, p. 13). Rather than conserving ecosystem states and functions, the goal should be to increase resilience and hence strengthen adaptive capacity (Craig 2010, p. 39). However, it is important to bear in mind that such a goal, i.e. protecting dynamic processes and adaptive capacity by improving resilience, remains a static goal, not one that is subject to change through time.

In addition to these “new but fixed” goals, the goals could themselves be changed when natural developments justify this. The goals set for environmental and spatial development policies have to be revised regularly, whether or not the quality and protection goals or the resource management aims are still appropriate, and whether or not the respective operational directives and measures remain purposeful (Reese et al. 2010, p. 13 et seq.).

As far as conservation measures are concerned, the focus is on high flexibility in regulatory law and openness in planning and prevention. Also on the instrumental level, more dynamic environmental development has to be taken into account (Reese et al. 2010, p. 14). In spatial and sector planning as well as in the regulation and permission of land use and exploitation of natural resources, it cannot be assumed as it used to be that current environmental assessments retain their validity in the future. This aspect has to be taken into account in state planning procedures and administrative decisions. The new dynamic environmental conditions mean that environmental law has to be tested to ascertain whether it can cope with the necessary adaptations on the levels of goals and measures and the status quo of land use practice (Reese et al. 2010, p. 14).

9.3.4 Adaptability of European Nature Protection and Water Law

Against this theoretical background, the Natura 2000 and Water Law can be tested with regard to its adaptability. The Habitats Directive already reflects several of the adaptation law principles, without making any of them explicitly considerate of aspects of climate change adaptation. For example, surveillance is within the scope of Art. 9–11 HD, entailed by the duties to report and research in Art. 17 and 18 HD. The situation is similar regarding the WFD. Whilst the monitoring programmes stipulated in Art. 8 WFD are generally not designed to cater for the need to identify and monitor climatic aspects, they will inherently contribute to the detection and understanding of aspects of climate change (EC 2009, p. 50). The Birds Directive contains no monitoring duties, but it does stipulate research and reporting obligations (Art. 10 and 12 BD). Most significantly, on the level of an individual protected area, management planning according to Art. 6 (1) HD induces the scope of monitoring needed in order to identify the ecological requirements of the natural habitat types that are protected in the area and under the prevalent conditions (Schumacher and Schumacher 2012, p. 120).

The general deterioration prohibition, Art. 6 (2) HD, and the assessment of implications of plans and projects stipulated in Art. 6 (3), (4) HD serve the purpose of at least maintaining resilience, although improvement cannot be directly achieved with these instruments. With regard to climate change impacts, this implies that regardless of the human or natural origin of the deterioration, it has to be averted in both an anticipatory and restoring sense (Trouwborst 2011, p. 74; Schumacher et al. 2013, Sec. 5.4.2 et seq.). Plans and projects ought to be rejected when they are expected to interact negatively with present or future climate change induced impacts on the protected area (Schumacher and Schumacher 2012, pp. 120–122; Cliquet et al. 2009, p. 170). Whereas Art. 6 (2)–(4) HD provide for measures to avoid deterioration, area management according to Art. 6 (1) HD (Art. 3 BD) requires positive measures for restoring favourable conservation status (European Commission 2000, p. 16 et seq.). However, due to its vague formulation and the lack of both strict measurement planning obligations and target dates, it is not capable of enforcing satisfactory practical implementation, although the management duty is considered to be an obligation of result (Trouwborst 2011, p. 74, at Fn. 144; European Commission 2000, p. 17). The consequence of this inconsistency is that Art. 6 (1) HD cannot effectively guarantee active resilience improvement, although it gives ample room for positive measures that are aimed at raising the present protection standard through restoration (Verschuuren 2010, p. 437). Art. 4 WFD, in contrast, not only stipulates a deterioration prohibition, but also obliges the member states to achieve a good status of all surface and ground water bodies. These objectives and the required measures to achieve them can contribute to a great extent to the resilience of aquatic ecosystems.

Some principled flexibility is contained in the regulations of Art. 4 (1) (4) HD and Art. 4 (1), (2) BD, allowing adaptation of the list of proposed sites of community interest (Cliquet et al. 2009, p. 164 et seq.; Trouwborst 2011, p. 73 et seq.). Whilst the procedure according to the Habitats Directive requires the participation of the Commission, flexibility is inherent in the Birds Directive's ongoing duty to designate areas as required (Dodd et al. 2010, p. 147). Another hint of flexibility is contained in Art. 9 HD that allows the declassification of areas in rare cases where it is warranted by the results of the surveillance that has to take place according to Art. 11 HD (Thomas 2008, p. 4, 11). The Birds Directive does not contain similar provisions, but the criteria for declassification are just as strict (Schumacher and Schumacher 2012, p. 115 et seq.; Thomas 2008, pp. 9–11). The results of surveillance and research can also lead to the formation of a new technical and scientific standard and hence to an adaptation of the annexes according to Art. 19 HD (Art. 15 BD), including habitat type definitions, selection criteria and listed species (Schumacher et al. 2013, Sec. 5.4.8 et seq.). The objectives of Art. 4 WFD are flexible in two respects. Climate change may, on the one hand, justify the adaptation of the reference sites for good water status (cf. Annex II of the WFD), and, on the other hand, it may be the reason for making use of the exemptions from good water status (cf. Art. 4 (3) to (7) WFD) (Reese 2011, p. 72 et seq.). Exemptions without justification in line with the directive are not to be seen as a general strategy to cope with the consequences of climate change (EC 2009, p. 58).

Also management planning, Art. 6 (1) HD, and network coherence improvement, Art. 10 HD, are clear options for resilience improvement (Schumacher and Schumacher 2012, p. 107). However, they are not mandatory and their implementation is not enforceable (Trouwborst 2011, p. 74 et seq.; Cliquet et al. 2009,

p. 171). Additionally, these provisions lack appropriate alignment through guiding principles. This hinders overall network coherence and resilience improvement. If the administration does not take the step of translating the general aim of adapting to climate change into specific, area- and impact-based ecological requirements, targeted long-term adaptation will not occur. In contrast, the WFD stipulates river basin management planning combined with a cyclical review of progress, which is more consistent with the ideal of principled flexibility as it regularly ensures the sufficiency of chosen measures for the aims set.

Generally, the Habitats Directive already allows many climate change adaptation measures, but remains too unspecific with respect to climate change impacts. What is hardly possible at present is the targeted reduction of external, non-climatic stresses as a resilience-improving adaptation measure for a specific site, as the Habitats Directive provides no legal instruments for influencing already existing land use practices apart from the deterioration prohibition (cf. Trouwborst 2011, p. 74), which seems to be rarely applied for this purpose. Regarding the European regulations of water management, the reduction of external, non-climatic stresses is much easier due to the ambitious objectives of Art. 4 WFD, the target dates for achieving good water status and the obligation of the member states to undertake necessary measures (cf. Art. 11 WFD), although there is still a long way to go (Albrecht 2013, p. 389).

9.4 Results from a Legal Analysis of National Regulations in Seven Central European Countries

In order to render the different options of implementing the European law provisions visible and comparable, the legal situation of nature protection and water law regulations was compared in seven Central European states: Austria, Germany, Hungary, Italy, Poland, Romania and Slovenia.

9.4.1 Aim and Method of the Legal Comparison

The aim of the legal comparison is to find out how the requirements of the directives are legally implemented in the member states and whether, when compared with the stipulations of the European law, there are any legal peculiarities of national implementations that are relevant for climate change adaptation.

As the European directive law has to be implemented by the member states, binding with regard to the aims to be achieved, but free in the form and methods (Art. 288 Treaty on the Functioning of the European Union [TFEU][16]), differences

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[16] Consolidated version, OJ C 115, 9.5.2008, p. 47.

in the legal systems for the protection of Natura 2000 sites can be expected. This is mainly due to the fact that the required new regulations are typically integrated into a pre-existing environmental protection regime. This is the idea of European directive law, which is supposed to strive to respect different legal cultures in their individuality. On the other hand, it is possible that a member state creates a new, parallel system of nature conservation or water law. In this case, not so much the integration into the nature protection or water law system, but the integration into the whole national legal system is the issue. It is easier to fulfil the requirements of the directives with a specific legal instrument designed for this purpose, but, at the same time, it is harder to fit this instrument into the pre-existing structures of the legal system as a whole. The process of copying the directive's text does not usually lead to the coherent interaction of national and European legal concepts. This is also the case when a directive is not implemented or interpreted correctly or effectively with regard to its aims (cf. Trouwborst 2011, p. 71).

The legal comparison was performed in three steps. First, the Natura 2000 and water law was analysed with respect to its typical and most significant regulatory provisions and structures. In a second step, the functional core provisions of the regulations were identified. Third, these core regulations were sought within the various member states' nature protection and water laws. Finally, it can be assessed which system integrates the European requirements well, and can easily use its general legal provisions, also in order to perform climate change adaptation tasks.

The legal comparison was realised by identifying the most important rules of the Habitats, Birds and Water Framework Directive for climate change adaptation, following the above mentioned principles, and by compiling them in a questionnaire. This questionnaire was sent to project partners from seven different countries, who then filled it out by listing the regulations that implement the provisions selected from the directives.

9.4.2 Nature Protection Law Implementing Natura 2000 in Central Europe

The core provisions that have been selected for studying the adaptation challenges that the Natura 2000 law is facing are: area designation, conservation objective setting, taking conservation measures, the assessment of the impact of human activities, and network connectivity (cf. Cliquet et al. 2009, p. 163).

9.4.2.1 Procedure for Area Selection and Forms of Area Designation, Protection Goals, and Connectivity Improvement

The procedure for the designation of areas is rather different for the Birds and Habitats Directive, although the protected areas are all integrated in the same ecological network “Natura 2000” (Cliquet et al. 2009, p. 163). Whereas Art. 4 of the Birds Directive requires protection of “the areas most suitable for the conservation of those species [listed in Annex I, or migratory]”, the Habitats Directive has a three-step selection and designation procedure where responsibilities are well distributed between the member states and the Commission (Trouwborst 2011, p. 71). Although the Birds Directive approach seems to allow for highly flexible handling, the selection criteria are rather static: only the presence of a certain number of a specific bird species may be considered, there is no option for planning and steering the protection of birds’ habitats (Cliquet et al. 2009, p. 164). Similarly, the Habitats Directive sets selection criteria that are based on the idea of a single selection and designation process. Whereas the criteria for selection are less restricted than for bird protection, as, e.g., the ecological restoration potential is considered, the size, number, and conservation status of habitats at a certain moment are still the most important criteria (Cliquet et al. 2009, p. 165). This concept will be seriously challenged by a changing climate (Köck 2007, p. 400).

Within the Central European countries, three models of area designation can be identified. In the state of Burgenland that belongs to Austria, for instance, areas are designated as “European Protection Areas” by law or ordinance; if such an area coincides with a pre-existing national protected area, the latter has to be cancelled in favour of the former according to Sec. 22b (3) Burgenland Nature Conservation Act.[17] This means that there is always a precise protection regime for Natura 2000 areas that can be adapted specifically, regardless of the requirements for national protected areas. Similarly, in Romania and Slovenia there are specially designed protection area categories for Special Areas of Conservation (SAC) and Special Protection Areas (SPA). In Slovenia, all of these areas are designated by government decision (Art. 4, App. 2 of the Decree no. 49/2004 on Special Protection Areas (Natura 2000 areas)),[18] and in Romania area designation is a parliamentary decision according to Art. 8 (1) (b) of Law no. 49/2011 on protected areas for the conservation of wild flora and fauna.[19]

In Germany, area designation is in principle entirely integrated into the national system of protected areas, as Sec. 32 (2) of the Federal Nature Conservation Act[20] requires that SACs and SPAs are declared by a specific ordinance using the categories provided in Sec. 20 (2) of the Federal Nature Conservation Act. However, Sec. 32 (4) of the Federal Nature Conservation Act gives the federal states the

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[17] Gesetz vom November 1990 über den Schutz und die Pflege der Natur und Landschaft im Burgenland (Burgenländisches Naturschutz- und Landschaftspflegegesetz – NG 1990) LGBl. Nr. 27/1991 (XV. Gp. RV 468 AB 479).

[18] Uredbo o posebnih varstvenih območjih (območjih Natura 2000), Uradni list RS, št. 49/2004 z dne 30.4.2004.

[19] Legea 49 din 7 aprilie 2011 (L 49/2011) pentru aprobarea Ordonanţei de Urgenţă a Guvernului nr. 57/2007 privind regimul ariilor naturale protejate, conservarea habitatelor naturale, a florei şi faunei sălbatice, publicat in Monitorul Oficial 262 din 13 aprilie 2011 (M. Of. 262/2011).

[20] Bundesnaturschutzgesetz vom 29. Juli 2009 (BGBl. I S. 2542), zuletzt geändert durch Artikel 5 des Gesetzes vom 6. Februar 2012 (BGBl. I S. 148).

opportunity to deviate from this principle if the required protective status can be equally well achieved using other legal instruments.

In Hungary, a parallel system combining both national and European protected areas has been established. Although in principle all SPAs and SACs are to be declared as nationally protected areas, regulated in the Nature Conservation Act 1996/53[21] (Bársony and Dieckmann 2007, p. 55), there are areas for which this has not (yet) happened. They are protected according to the regulations of a separate Government Decree on Areas of Community Interest 275/2004[22] (Bársony and Dieckmann 2007, p. 54 et seq.). Interestingly, the latter regulations are considered to be more precise, specific, stricter and give the impression of representing less unsuitable implementation, although they are meant to be more or less provisional (Bársony and Dieckmann 2007, p. 62 et seq.). Also in Italy (Art. 3 (2) DPR 357/1997[23]) and Poland (Art. 6 (1) (5), 25 Law on Nature Conservation[24]), there are specifically designated SACs and SPAs alongside those that are overridden by, or integrated in, the protection regime of an existing national protection area (Italy: Art. 4 (3) DPR 357/1997, Poland: Art. 25 (2) Law on Nature Conservation).

Implementation of climate change adaptation measures related to the whole protection area seems to be more flexible within systems that fully integrate Natura 2000 sites into the existing legal regulations for nature protection areas, as the relation of nature protection to other land uses and the general rules of administration are already well established. These relations have to be specifically created for separate models, requiring, e.g., rules on how climate change adaptation needs for Natura 2000 sites are to be considered in spatial planning; similarly the administrative body responsible for setting up management plans and enforcing the deterioration prohibition has to be determined.

Improving network connectivity is a vital option for allowing nature to adapt to climate change as it offers the endangered species the possibility to migrate. The main problem of connectivity improvement as formulated in Art. 3, 10 HD, however, is its weak legal design: "Where they consider it necessary, Member States shall endeavour to improve the ecological coherence of Natura 2000"/ "Member States shall endeavour, where they consider it necessary, in their land-use planning and development policies [. . .] to improv[e] the ecological coherence of the Natura 2000 network". These provisions are not only too unspecific to demand properly binding implementation (cf. Cliquet et al. 2009, p. 171; Trouwborst 2011, p. 74), but cannot even be enforced against member states that do not make the required effort (Möckel and Köck 2009, p. 323). As connectivity is

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[21] 1996. évi LIII. törvény a természet védelméről.

[22] 275/2004. (X. 8.) Korm. rendeletaz európai közösségi jelentőségű természetvédelmi rendeltetésű területekről.

[23] Decreto del Presidente della Repubblica (D.P.R.) 357/1997, Regolamento recante attuazione della direttiva 92/43/CEE relativa alla conservazione degli habitat natuali e seminaturali, nonche' della flora e della fauna selvatiche. (Gaz. Uffic. n. 248 del 23.10.1997 – Suppl. Ordin. n. 219).

[24] Ustawa o Ochronie Przyrody z 16.04.2004 r. Dz. U. z 2009 r. Nr 151, poz. 1220.

also a transboundary issue, even more irritating is the fact that there is hardly any commitment on the EU level to improve the connectivity of areas and protection regimes between the member states. This is required to enhance the coherence of the Natura 2000 network (Trouwborst 2011, p. 75; Cliquet et al. 2009, p. 171).

9.4.2.2 Protection Regime (Legal, Administrative and Contractual Measures, Area Management Planning, Impact Assessment)

The protection regime has been implemented in most of the countries more strictly than required by the directive. In the state of Burgenland in Austria, Natura 2000 sites must be protected at least by means of a decree according to Sec. 22b (1) of the Burgenland Nature Conservation Act, and area management planning is compulsory for every site according to Sec. 22c (3) of the Burgenland Nature Conservation Act, whereas the Habitats Directive states in Art. 6 (1) that such plans shall be established "if need be". Germany has copied the directive's provision in Sec. 32 (5) of the Federal Nature Conservation Act, Italy in Sec. 4 (2) of the Decree of the President of the Republic 357/1997 on the Implementation of the Directive EC/92/43.

Most of the other Central European countries have installed a compulsory management planning procedure. In Hungary management plans are made specifically for every site, they stay in force for a maximum of 10 years, and they are legally binding to everyone exercising any activity within the protected area, according to Sec. 26 (3) of the Nature Conservation Act 1996/53. Very similar provisions on area management are contained in Romania's Art. 21 of the Law no. 49/2011 on protected areas for the conservation of wild flora and fauna. Slovenia has a system involving a centralised, regularly revised "operational programme on area management" that is specified for individual areas as needed (Art. 12, 13 of the Decree no. 49/2004 on special protection areas (Natura 2000 areas)), and in Poland there is a very similar "plan of protection tasks" set up for 10 years which becomes concretised on the local level (Art. 28 Law on Nature Conservation).

The procedure for assessing implications for the site in view of the site's conservation objectives according to Art. 6 (3), (4) HD, which is also applicable for SPAs, Art. 7 HD, is laid out in great detail in the directive and allows hardly any room for substantial deviations in its implementation. The procedure can either be integrated into existing permission procedures, or a specific Natura 2000 permission procedure can be created. Some countries include a definition of the term plan or project, whereas others do not specify these terms further than the Habitats Directive (Epiney and Gammenthaler 2009, p. 159 et seq.). In Germany, the impact assessment was not sufficiently implemented until the European Court of Justice intervened (Epiney and Gammenthaler 2009, p. 186 et seq.). Impact assessment can and should include climate change considerations related to future impacts of plans and projects (Cliquet et al. 2009, p. 170), however this is expressed by neither the Habitats Directive nor the implementing laws.

9.4.3 Water Law

The main tool with which the Water Framework Directive achieves its objective of good water status is river basin management planning. For a legal comparison of water law, therefore, the most important planning steps in terms of climate adaptation were selected. These are the initial analysis of the water status (Art. 5, Annex II WFD), the economic analysis of the costs of water services (Art. 5 WFD, Annex III), monitoring of the water status (Art. 8 WFD, Annex V), objective setting and making use of exemptions (Art. 4 WFD), and the establishment of the programmes of measures (Art. 11 WFD) (cf. EC 2008, p. 4; EC 2009, p. 39).

9.4.3.1 Risk Analysis and Economic Analysis, Monitoring

Within the compared Central European countries, the Water Framework Directive was implemented by national or federal water law and a series of governmental decrees containing more detailed information. In all of the countries river basin management planning and the cyclical updating of the plans are obligatory (Austria: Sec. 55c Act on Water Law,[25] Germany: Sec. 83 and 84 Federal Water Act,[26] Hungary: Sec. 3, 4, 21 Governmental Decree 221/2004,[27] Italy: Art. 117 Legislative Decree No. 152/2006,[28] Poland: Art. 113 and 114 Water Act 2001[29] and Gov. Decree of 18 June 2009 on water management planning,[30] Romania: Art. 43 Water Law,[31] Slovenia: Art. 55 and 59 (1) Water Act 2002[32]). The obligation to establish, review and update river basin management plans includes risk analysis for the water status and the economic analysis of water services. Both instruments are of great importance from the perspective of climate adaptation. Whereas the risk analysis requires a

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[25] Wasserrechtsgesetz (WRG) BGBl. Nr. 215/1959 zuletzt geändert durch BGBl. I Nr. 24/2012.

[26] Wasserhaushaltsgesetz (WHG) vom 31. Juli 2009 (BGBl. I S. 2585), zuletzt geändert durch Artikel 5 Absatz 9 des Gesetzes vom 24. Februar 2012 (BGBl. I S. 212).

[27] 221/2004. (VII. 21.) Korm. rendelet a vízgyűjtő-gazdálkodás egyes szabályairól.

[28] Decreto Legislativo 3 aprile 2006, n. 152 "Norme in materia ambientale" – Gaz. Uffic. n. 88 del 14.04.2006 – Suppl. Ordin. n. 96.

[29] Ustawa z dnia 18 lipca 2001 r. Prawo wodne, Dz.U. z 2001 r. Nr 115, poz. 1229, consolidated version of the text: Dz. U. z dnia 9 lutego 2012 r., poz. 145 (Obwieszczenie Marszałka Sejmu R.P. z dnia 10.01.2012 r.w sprawie ogłoszenia jednolitego tekstu Ustawy – Prawo Wodne).

[30] Rozporządzenie Rady Ministrów (Dz. U. Nr 106, poz. 882 z dnia 18 czerwca 2009), w sprawie szczegółowego zakresu opracowywania planów gospodarowania wodami na obszarach dorzeczy.

[31] Lege nr. 107 din 25/09/1996 (forma consolidată 19/02/2010) – Legea apelor, publicat în Monitorul Oficial nr. 244 din 08/10/1996; aceasta este forma actualizată cu modificările şi completările aduse de următoarele acte: Hotărâre nr. 83 din 15.03.1997, Hotărâre nr. 948 din 15.11.1999, Lege nr. 192 din 19.04.2001 republicare 1, Ordonanţa de urgenţă nr. 107 din 05.09.2002, Lege nr. 404 din 07.10.2003, Lege nr. 310 din 08.06.2004, Lege nr. 112 din 04.05.2006, Ordonanţa de urgenţă nr. 12 din 28.02.2007, Ordonanţa de urgenţă nr. 3 din 05.02.2010.

[32] Zakon O Vodah (ZV-1), Uradni list RS, št. 67/2002 z dne 26. 7. 2002, 3237.

review of the impact of human activity on the water status which is influenced by climate change, within the economic analysis long-term forecasts of supply and demand for water should incorporate scenarios for climate change (EC 2009, p. 44 et seq. and p. 59 et seq.). In all of the central European countries under consideration, the legal stipulations require both an initial and an economic analysis and thus enable the consideration of climate change in river basin management planning (Austria: Sec. 55d and Annex B Act on Water Law, Germany: Sec. 3, 4 and 12 Federal Ordinance on Surface Water,[33] Sec. 2, 3 and 14 Federal Ordinance on Ground Water[34]), Hungary: Sec. 12–14 (initial analysis), Sec. 17 (economic analysis) Governmental Decree 221/2004, Italy: Art. 118 Legislative Decree No. 152/2006, Poland: Sec. 4 and 6 Gov. Decree on water management planning, Romania: Art. 43(1^4), Annex 1^1 No.1.1 and 1.2, 4 Water Law, Slovenia: Art. 55 para. 2 1.7 Water Act). Surface and groundwater monitoring obligations are stipulated in all of the countries too (Austria: Sec. 59c – 59i Act on Water Law, Ordinance on Water Status Surveillance,[35] Germany: Sec. 8, 9 and 11 Federal Ordinance on Surface Water, Sec. 9 Federal Ordinance on Ground Water, Hungary: EnvWatMin. Decree 30/2004[36] – Surface Water and EnvWatMin. Decree 31/2004 – Groundwater,[37] Italy: Art. 78 et seq. Legislative Decree No. 152/2006, Poland: Decree of the Minister of the Environment on the forms and ways of conducting the monitoring of the uniform parts of the surface and underground waters,[38] Romania: Art. 35 1^5, Annex 1^1 No.1.3 WL, Slovenia: Art. 55 para. 2 1.6 Water Act). Monitoring is essential for understanding and appropriately responding to climate change. Therefore the monitoring networks should be carefully planned with a long-term perspective (EC 2009, p. 50 et seq.).

9.4.3.2 Environmental Quality Objectives and Measures

Climate change also has to be considered with the designation of environmental quality objectives for water bodies (cf. Art. 4 WFD) and the selection of appropriate measures to achieve these objectives (Art. 11 WFD). The planning process must include assessment of whether in the long run the good status can be maintained even under future climate conditions, e.g., extreme summer droughts. The WFD offers the possibility to change the status of the reference sites (cf. Annex II WFD)

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[33] Oberflächengewässerverordnung vom 20. Juli 2011 (BGBl. I S. 1429).

[34] Grundwasserverordnung vom 9. November 2010 (BGBl. I S. 1513).

[35] Gewässerzustandsüberwachungsverordnung (GZÜV) BGBl. II Nr. 479/2006, zuletzt geändert durch BGBl. II Nr. 465/2010.

[36] 30/2004. (XII. 30.) KvVM rendelet a felszín alatti vizek vizsgálatának egyes szabályairól;

[37] 31/2004. (XII. 30.) KVVM rendelet a felszíni vizek megfigyelésének és állapotértékelésének egyes szabályairól.

[38] Rozporządzenie Ministra Środowiska z dnia 15 listopada 2011 r. w sprawie form i sposobu prowadzenia monitoringu jednolitych części wód powierzchniowych i podziemnych (Dz. U. Nr 258, poz. 1550).

and thus to adapt the objectives for the affected water bodies in the process of the cyclical review and updating of river basin management plans. Where achieving the water quality objectives would require unproportional efforts, restrictive exemptions allow the objectives to be set aside (cf. Art. 4 para. 5, 6, 7 WFD) (Reese 2011, p. 67, 73 et seq.). The objectives and exemptions stipulated in Art. 4 and Annex II WFD are legally implemented in all of the central European countries compared (Austria: Sec. 30a to 30f Act on Water Law, Quality Regulations on Ecology and on Chemistry of Surface Waters and on Chemistry of Groundwater, Germany: Sec. 27–30, 44 and 47 Federal Water Act, Sec. 5, 6 Federal Ordinance on Surface Water, Sec. 4–11 Federal Ordinance on Ground Water, Hungary: Sec. 5, 6 (definition of ecological objectives), Sec. 7–10 (exemptions) Governmental Decree 221/2004, Italy: Art. 76 et seq. Legislative Decree No. 152/2006, Poland: Art. 38, 38a and 114a Water Act, Decree on the classification of the ecological status, ecological potential and the chemical status of the uniform parts of surface waters,[39] Romania: Art. 2 WL, Slovenia: Art. 2, Art. 7 No. 24–26, Art. 55 (2), Art. 56, Art. 62 et seq. Water Act). If there is strong evidence showing that the situation changes significantly at sites where there is little impact, reference conditions can be revised or exemptions can be applied. To avoid misuse, however, it is necessary to underpin such decisions with clear monitoring evidence: modelled assumptions of future climate alone are not sufficient (EC 2009, p. 58). Last but not least, particular emphasis should be placed on ensuring that the programmes of measures (PoMs) are adaptive to future climate conditions. Therefore, a “climate check” of the PoMs should be carried out with the aim to enhance the robustness of the measures against changing climate conditions, especially as far as cost intensive and long life-time measures are concerned. Measurement planning is stipulated in all the countries of Central Europe included in the comparison, leaving the administrations wide discretion for selecting the measures (Austria: Sec. 55f, 55g Act on Water Law, Germany: Sec. 82 Federal Water Act, Hungary: Sec. 18 Governmental Decree 221/2004, Italy: Art. 116 et seq. Legislative Decree No. 152/2006, Poland: Art. 113a and 119 Water Act, Romania: Art. 43($1^{8,\ 9}$) WL, Slovenia: Art. 57 Water Act). From the perspective of climate adaptation, measures should be favoured that are robust and flexible in the context of uncertainty and that cater for the range of potential variation related to future climate conditions (“no regret”). Furthermore, sustainable measures, especially those with cross-sectoral benefits (“win-win”) and which have the least environmental impact (incl. green house gas emissions), should be selected (EC 2009, p. 63 et seq.).

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[39] Rozporządzenie Ministra Środowiska z dnia 9 listopada 2011 r. w sprawie klasyfikacji stanu ekologicznego, potencjału ekologicznego i stanu chemicznego jednolitych części wód powierzchniowych; Dziennik Ustaw Nr 258, Poz. 1549.

9.5 Identification of the Legal Options, Their Limits, and the Need for Legal Changes

9.5.1 General Findings

Although climate change issues are not explicitly mentioned in the regulations of the HD, BD and WFD, most of the adaptation requirements for the areas can be realised within the existing legal framework in the Central European Countries. Area designation and area management and protection regulations are flexible enough to introduce the measures needed, be it the designation of new protected areas, the making or amending of (climate change adaption specific) management plans, or indeed changes to the protection regime. The latter are typically difficult to implement, as they usually require changing the protected areas statutory instrument or law. The differences in the implementation of nature protection law are sometimes considerable, especially concerning the procedure and effects of area management planning according to Art. 6 (1) HD and 4 (1) BD. For the water law, the differences are far less significant, as the WFD hardly allows any room for deviating implementations. The impact assessment procedure (Art. 6 (3), (4) HD) is a suitable instrument with scope for scientifically uncertain climate change adaptation considerations, but binding permission decisions could then face more legal uncertainty (Cliquet et al. 2009, p. 170). Generally, problems arise when climate change adaptation conflicts with other land use interests, for instance with the construction of highways or the extraction of water.

9.5.2 Nature Protection Law

9.5.2.1 Options for Climate Change Adaptation of Natura 2000 Areas

There are already many options within the Habitats and Birds Directive that allow for climate change adaptation (Trouwborst 2011, p. 77). New areas can be designated both for habitats and bird protection purposes, based upon the duties of Art. 4 (1) (4), Art. 11 HD and Art. 4 (1) (4) BD, using the legal provisions that implement these duties in the respective member state. In the case of SACs, this requires a report to and the participation of the Commission, whereas new SPAs have to be designated automatically as the distribution of wild bird species requires (see above 3.b.aa). However, at least in the case of the Habitats Directive, it is sometimes argued that the designation process is complete (Schumacher et al. 2013, 5.4.4.2, Footnote 454).

Area management can be adapted as climate change impacts require, more effectively in countries with compulsory and regularly revised management planning. In those countries where management planning is optional (cf. 3.b.bb), the need to make a new management plan can arise from climatic changes that severely affect the conservation goals. In this case, special Climate Change Adapted Management Plans (CAMPs) could be a suitable instrument (see Chap. 10).

The options granted by the – typically purely declaratory – implementations of Art. 3 (3) and 10 HD also constitute many and far-reaching opportunities to integrate climate change adaptation into spatial planning by addressing the specific needs of expected network connectivity improvements.

The impact assessment for new plans and projects according to Art. 6 (3), (4) HD can, together with knowledge gained through surveillance (Art. 11 HD), be used to estimate future impacts with respect to expected climate developments. In terms of the maintenance of sites, the deterioration prohibition is the key instrument for keeping up resilience as required by the current conservation status.

9.5.2.2 Limits of Practical and Legal Adaptation

The existing legal framework still has, however, some considerable shortcomings with respect to climate change adaptation. For example, the designation of new protection areas needs space, which is typically not available, as most of the territory of member states is in use. An option could be the creation of “expectation areas” that become reserved for future nature protection in long-term planning processes (Hendler et al. 2010, p. 689 et seq.). But as a first step, it would already be an improvement if climate change adaptation options were explicitly included in the area selection criteria according to Annex III of the Habitats Directive (Cliquet et al. 2009, p. 166).

Network coherence improvement according to Art. 3 and 10 HD is a promising adaptation option; however, it clearly lacks legally binding force (Trouwborst 2011, p. 74; Cliquet et al. 2009, p. 171).

Another typical shortcoming is the lack of an externally binding effect of management planning provisions. Hungary and Romania have made strict rules on this, so that management requirements also directly influence other land use activities, at least within the protected areas. Other countries have to first introduce specific statutory prohibitions to reach the same goal, for example in cases when intensive agriculture must be restricted in order to keep the protected habitats’ resilience to climate change impacts at an appropriate level.

Even more problematic are existing, permitted activities outside the protected areas that affect the areas’ ecologic quality, like industry emissions, infrastructure construction and traffic, urban planning and building activities, tourism and agriculture. In this respect, apart from the single permission granted according to the legal provisions implementing Art. 6 (3), (4) HD at the time of granting the permission, there is hardly any option that allows the restriction of such activities in reaction to climate change induced developments in order to strengthen resilience and thus maintain the favourable conservation status of habitats and species. Only the deterioration prohibition as implemented according to Art. 6 (2) can, in principle, be used for this purpose, if the initial impact assessment did not cover future effects, as can be deduced from ECJ rulings in the cases concerning cockle fishery in the Wadden Sea[40] and the Papenburg wharf.[41]

9.5.2.3 Proposed Changes to European and National Nature Protection Law

Legal rules should be introduced that can control land use activities that weaken the ecologic resilience of protected areas to climate change impacts. Laws are needed as citizens' fundamental rights, especially those of property and profession, but also in terms of general freedom of movement and behaviour, are affected by the restrictions necessary to maintain the effectiveness of nature protection activities under future changing climate conditions.

Furthermore, there should be climate change specific surveillance (Art. 11 HD) and comprehensive planning for network coherence improvement, including implementation stricter than required by Art. 3 and 10 HD, and with accompanying guidelines for criteria to help improve connectivity, also with respect to climate change impacts. Especially the aspect of cross-border connectivity requirements should be taken into account on the European and international level.

As a last resort, clear regulations are required about the conditions under which Natura 2000 sites can be cancelled as a whole or their protection goals changed because they have proved impossible to sustain. In the rare cases where no new Natura 2000 protection goal for such an area can be defined, protection can nevertheless be maintained according to national nature protection law.

9.5.3 Water Law

9.5.3.1 Options for Climate Change Adaptation in RBMP

Regarding river basin management planning, it is agreed that the step-wise and cyclical approach of the WFD (regular review and update) makes it well suited to handling climate change (European Commission 2008, p. 4). On the one hand, it is possible to influence the quantity and quality of water that will be available and be used in the future. On the other hand, the adaptation requirements of water-dependent habitats and species can be fulfilled. In addition, the objective of good ecological water status supports the resilience of aquatic ecosystems. The European Commission has published two documents with far-reaching recommendations for

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[40] ECJ 7.9.2004, Case C-127/02 "Waddenvereniging and Vogelbeschermingsvereniging", [2004] ECR I-7405, para. 34 et seq.

[41] ECJ 14.1.2010, Case C-226/08 "Stadt Papenburg", [2010] ECR I-131, para. 48 et seq.

climate change adaptation, which are to be implemented by member states: the Policy Paper "Climate Change and Water" (EC 2008) and the Guidance Document No. 24 "River Basin Management in a Changing Climate" (EC 2009). This approach can be qualified as a "soft" steering method that uses recommendations and guidance, specifying the legal provisions of the WFD.

9.5.3.2 Proposed Changes to European and National Water Law

Although river basin management planning under the WFD offers a range of possibilities to consider climate change, the recommended adaptation measures are not legally binding. In particular, there is a lack of requirements to carefully evaluate and consider actual adaptation needs. Especially, constructive rules on how to adapt the objectives are missing, ones that effectively prevent the premature or abusive setting aside of objectives (Reese 2011, p. 61 and 73). Another weakness in the conception of river basin management planning is that a long-term, structural adaptation need is not formally taken into account (Reese 2011, p. 80). Furthermore, quantitative water management goals are not sufficiently integrated (Reese 2011, p. 81 et seq.). To ensure that climate change adaptation measures are definitively implemented by the administrations in the member states, therefore, the respective obligations should be integrated into the legal framework of the WFD.

9.6 Proposed Changes to the Political and Legislative Process of Climate Change Adaptation

The political framework for adapting nature conservation to climate change is rooted in the European legal documents. The review of European legal commitments (Bern Convention and the EU Wild Birds and Habitats Directives) has been undertaken from the perspective of the need to assist nature with adaptation to climate change (Trouwborst 2011). It has illustrated that both the Bern Convention and the EU directives subject countries to legal obligations to take measures to facilitate the adaptation of biodiversity to climate change. These measures encompass a variety of activities such as the restoration and protection of species and habitats and the establishment of ecosystem connectivity to enable climate-induced range shifts (Trouwborst 2011).

Most of the countries concerned are well aware of the necessity of proactively instigating action supporting climate change adaptation of natural and managed ecosystems and integrating climate change adaptation measures with protected area planning, management strategies and the design of protected area systems (Naumann et al. 2011). It can thus be inferred that the political climate now favours the introduction of more demanding actions to adapt measures of ecosystem management so as to maintain their resilience to extreme climate events and to help mitigation of and adaptation to climate change.

On the level of the legal system, this entails the need to make new rules that plan and prepare future habitat protection requirements using no-regret management and protection measures based on surveillance of climate change impacts and research findings. It will also require the creation of a set of regulations that can be used to react to unforeseen or extreme events in the spirit of "principled flexibility". The climate change specific integration of network coherence of planning provisions on the regional, national, European and international levels as well as throughout the relevant sectors of public and private land use is the corresponding superordinate field of action that provides possibilities to control conflicting land use activities for resilience improvement.[42] In the case of water law, climate change impact-oriented regulations about adapting the objectives and undertaking long-term structural adaptation of river basin management planning should explicitly be taken into account within the legal framework.[43]

However, making nature protection and water law more resilient to climate change is politically challenging. A stricter protection regime will inevitably cause conflicts with established economic and infrastructural land uses that may themselves need to be reshaped and adapted to climate change. For example, increased efforts to mitigate greenhouse gas emissions can conflict with the interests of climate change adapted nature protection. Developments in the energy sector involve more and more power lines, wind turbines, biomass farming and water power use leading to increases in the amount and intensity of land use and thus affecting natural resources, habitats and species. To achieve the challenging and interrelated objectives discussed here, it could be beneficial to consolidate all required new regulations about climate change-specific surveillance, coordinated planning processes, the implementation of no-regret measures for resilience improvement and instruments for controlling land and water use activities. This consolidation should be flexible and guided by adaptation principles, and could take the form of a single, climate change adaptation-oriented regulation that encompasses European environmental law generally, rather than involving the successive and individual amendment of the respective legal acts. The political decision that needs to be taken either way concerns the status of biodiversity protection when conflicting legal rights and interests are weighed against each other – not neglecting the fact that biodiversity, too, is of economic significance, but even more importantly, has a great ethical value of its own and is the foundation of our life on earth.

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[42] See above, 4 (b) (cc).

[43] See above, 4 (c) (bb).

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Chapter 10
A Methodical Framework for Climate Change-Adapted Management in Protected Areas

Christian Wilke and Sven Rannow

10.1 Introduction

This chapter gives practical advice and recommendations to protected area managers on how to prepare and organise the process of adaptation to climate change. It highlights topics and working steps that are essential in the process of adaptation but also need special attention and good preparation in order to be successful.

In this chapter, we present an approach for adapting protected area management to climate change based on the specific duties, tasks, and competences of protected area managers. This approach aims at helping those practitioners who have to plan, implement and review conservation strategies and measures to protect biodiversity in protected areas. The framework builds on the results of a literature review and – even more substantially – on the experience gathered in the trans disciplinary project HABIT-CHANGE (see www.habit-change.eu), where the approach was developed, discussed, tested and improved as a result of the close cooperation between scientists and protected area managers. The project focused on the management of protected habitats in large protected areas like National Parks, Biosphere Reserves and Nature Parks in Central and Eastern Europe. Its main purpose was to integrate climate change issues into management planning for protected areas. This process of adaptation resulted in "Climate-Change Adapted Management Plans" (CAMPs).

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This framework helps to identify the response options available to managers of protected areas on a local or regional level but also emphasises the need for cooperation with stakeholders and scientists. It is applicable in all protected areas across Europe and other continents. However, this approach needs an adequate budget, as well as time and expertise. Without additional financial means that have to be provided to protected areas the adaptation of conservation management will be not feasible.

Recommendations for required adaptations at policy level targeted at planning and implementation by regional, national, and international institutions – in parallel to adaptation in protected areas – are described in Chap. 9.

The methodical approach presented in this chapter aims to answer the key questions for managers in protected areas when it comes to adaptation:

- How can management of protected areas be adapted to climate change?
- What problems and difficulties may be experienced in adapting protected area management and how can they be solved?
- How can protected area managers reduce uncertainties by managing natural resources and learning about them at the same time?

10.2 Adaptation Requirements for Nature Conservation: Results from Literature Reviews

Current scholarly publications provide numerous suggestions and recommendations for the adaptation of nature conservation management to climate change (e.g. Glick et al. 2011; Hansen and Hoffmann 2011; West et al. 2009). Most authors discuss general problems of conservation management (e.g. Game et al. 2011; Hannah 2003; Lovejoy and Hanna 2005; Araujo et al. 2011). Only a few address the needs and response options for protected area managers (e.g. Lawler 2009; Welch 2005; Baron et al. 2009) or offer guidelines for adaptation of protected area management (e.g. European Commission 2012; Idle and Bines 2005; Prutsch et al. 2010).

Many recommendations for adaptation in nature conservation address the policy level or regional and national scale but are not specific enough to be applied to the tasks and capabilities of protected area management at a local level. Other recommendations aim at the scientific community and do not take practical requirements of protected area management practice into consideration.

Of the few recommendations that are focused on protected area management even fewer have been tested in the field. In their review of recommendations for adaptation to climate change Heller and Zavaleta (2009) conclude that the majority of recommendations in the published journal literature lack sufficient specificity to direct immediate action to adapt conservation practice. The general recommendations given are not applicable at the level of protected area management; therefore a practice-oriented approach - as presented below – with detailed guidance for the adaptation process is needed.

10.3 Adaptation of Management Planning for Protected Areas

The adaptation of protected area management to climate change requires consistent definitions and objectives for the manifold activities, strategies and practices that are part of the active management of nature conservation. Management activities affect different stakeholders or require specific data, competencies, cooperation, and strategies. Management of protected areas is limited by financial, institutional, and legal restrictions. In addition, lack of competence within relevant administrations and a limited acceptance or willingness of local stakeholders to support the goals of nature conservation hampers its implementation. These aspects define the decision-making context and need to be considered when adapting conservation management to climate change.

The adaptation of protected area management requires an evaluation and revision of existing management practices, strategies and measures described in management plans. According to the IUCN-Definition these plans should document the "management approach and goals, together with a framework for decision making, to apply in the protected area over a given period of time. [. . .] Plans may be more or less prescriptive, depending upon the purpose for which they are to be used and the legal requirements to be met" (Lausche 2011, p. 29). Management plans provide guidance and standards for all management decisions and for the implementation of conservation goals, and form a basis for transparent and acceptable management decisions. Management plans are usually not so detailed that they define precise and measurable objectives for all protected species and habitats in the area, but they serve as guiding documents establishing a framework for everyday management decisions.

To address the specific tasks and challenges in adaptation, management tasks in protected areas can be divided into different groups of activities and strategies, each requiring a specific set of know-how, data, skills or expertise. Based on categories suggested by The Heinz Center (2008) we divided management tasks into activities and strategies related to:

- Land and water protection and management,
- Species conservation,
- Monitoring and planning,
- Law and policy,
- Stakeholder involvement, public relations and creation of awareness,
- Knowledge and research, science and technology.

Since most management personnel in protected areas do not have experts on their staff for all of these tasks, external expertise should be acquired to ensure effective adaptation.

Not all management activities are documented in detail in management plans. Activities related to stakeholder involvement or knowledge and research are rarely defined. Nevertheless, they have to be considered in the process of adaptation.

10.4 Preparing for the Process of Adaptation

Before starting the process of adapting management plans the scope and boundary conditions of the process have to be defined.

Adapting management of protected areas is a complex and time-consuming process in which different aspects and constraints have to be considered:

- Information and expertise: What kind of data is needed and where can it be obtained? What kind of know-how is necessary and who can provide it?
- Methods, models and tools: How can information and data from climate change scenarios be used and integrated into protected area management? How can one assess sensitivity and/or vulnerability? How does one deal with uncertainties? Who can one perform the modelling and impact assessment?
- Planning process and procedures: Which steps are essential? How does one structure the process? How and when should one include the public/local expertise, land users or stakeholders? How is the concept of an active adaptive management established?

Each aspect requires specific professional, technical, and methodical skills and expertise. Not all of them will be at hand within the managing authorities of protected areas. Additional funding and cooperation with external institutions and experts from national and international organisations is therefore essential.

Prutsch et al. (2010) present a set of ten generic guiding principles for good adaptation giving directions on how to successfully carry out the adaptation process:

1. Initiate adaptation, ensure commitment and management.
2. Build knowledge and awareness.
3. Identify and cooperate with relevant stakeholders.
4. Work with uncertainties.
5. Explore potential climate change impacts and vulnerabilities and identify priority concerns.
6. Explore a wide spectrum of adaptation options.
7. Prioritise adaptation options.
8. Modify existing policies, structures, and processes.
9. Avoid maladaptation.
10. Monitor and evaluate systematically.

The methodical approach presented below takes all these factors into account and applies them to the field of protected area management.

Following the recommendations of Idle and Bines (2005) the production of management plans for conservation should actively involve the managers of the area, all stakeholders using the area for various purposes (e.g. farmers, foresters, hunters) and their respective organisations and national bodies and institutions as well as scientists and local experts. The participation of different stakeholders, institutions and other administrations (agriculture, forestry, water, etc.) must be planned and organised at the beginning of the adaptation process.

Major challenges in adapting nature conservation management originate from a lack of sufficient understanding of the complex functional relations in natural systems and from uncertainties in predicted changes or impacts due to climate change. Additionally, knowledge about the effectiveness of different management practices is usually scarce or poorly documented. A methodical adaptation approach has to deal with these uncertainties and knowledge gaps in order to foster decision making with a limited workforce and limited time and funds available at local levels (Hansen and Hoffmann 2011). External scientific input and support is essential for all protected areas but must be tailored to meet the needs and decision contexts of each area's management (see Chap. 5).

10.5 Introducing Adaptive Management

Management of protected areas should be based on profound knowledge about the functional and structural components, and the conservation status of species, habitats and ecosystems. It should also be based on knowledge about the effectiveness and efficiency of different management options and their impacts on the conservation status. Unfortunately, knowledge about complex natural systems like habitats and ecosystems, about the impacts of climate change on these natural systems, and about the effectiveness of different management activities is still insufficient. However, lack of knowledge or understanding, and uncertainties in projected climatic changes or in responses to these changes can be no excuse for inaction! Instead of hesitation, the concept of simultaneously managing natural systems and learning about them should be introduced in protected area management.

Adaptive Management is organised as a learning process (Williams 2011). It is an active approach that can be used to reduce uncertainties and knowledge gaps regarding actual impacts of climate change, functional changes in ecosystems and the effectiveness of different response options. Adaptive Management is one of the most recommended strategies for dealing with climate change. It "allows managers to determine systematically whether management activities are succeeding or failing to achieve objectives" (Williams et al. 2009, p. 57). A climate change adapted management plan should prepare for the implementation of Adaptive Management and guide the necessary working steps. Williams et al. (2009) offer practical guidance for the introduction in nature conservation. The concept cannot be applied at all scales and for all management tasks (Gregory et al. 2006); however, if it is carefully prepared and tailored to a well-defined management situation, it is the key to an effective conservation under changing climatic conditions.

Its main feature is the implementation of different alternative response options at the same time in conjunction with systematic monitoring of effectiveness and efficiency of those options. Impacts of future changes along with potential measures have to be monitored and evaluated as part of the management process in order to learn about the managed resource and to improve management decisions. In that way, experts in the field can reduce the uncertainty regarding possible system responses and gain knowledge about processes and functional relations in habitats and ecosystems. Adaptive Management is based on intensive stakeholder involvement, precise definition of (measurable) objectives and the identification of different responses which can then be tested for effectiveness.

10.6 Working Steps to Adapt Protected Area Management to Climate Change

All working steps described below were selected for and tested within the HABIT-CHANGE project. The choice of working steps was based on analyses of recommendations for the process in literature.

The main outcome of the recommended adaptation process is a “Climate Change Adapted Management Plan” (CAMP) covering all aspects of climate change relevant to the respective protected area and its management. A CAMP should provide rules for decision making with regard to climate impacts. It should support all management activities in a protected area, also those implemented by land users and other stakeholders. It should contain target values and thresholds indicating if and when specific management action is required and allow for evaluation of management effectiveness. A CAMP must give specific advice on how to implement the concept of “Adapted Management” including a concept for monitoring of achievements to facilitate evaluation. The CAMP must build on existing management plans – if available – and take into account current activities and should consider continuity in management. Climate change related information, objectives and management requirements should be integrated into existing plans, structures and management concepts and aim to improve them incrementally.

The objectives of a Climate Change Adapted Management Plan (CAMP) are to:

- Analyse and present information about existing and expected pressures on natural resources and about existing and projected climatic conditions in the protected area;
- Assess the impacts of climate change on biodiversity and other protected area objectives and to identify and prioritise areas and items requiring immediate action;
- Review the current management plans in the light of the expected impact and to identify objectives, strategies and measures needing adaption in order to reduce the negative impacts of climate change;
- Develop a selection of strategies and measures to be implemented in active Adaptive Management in order to maintain a good conservation status of protected habitats and to increase knowledge about ecosystems.
- Provide recommendations to successfully involve relevant stakeholders, authorities, organisations and individuals wherever this is necessary for reaching conservation goals in a protected area;

- Establish systematic documentation of management activities, monitor results and evaluate management effectiveness in order to make the adaptation and learning process transparent and comprehensible.

The following working steps are not intended for execution in chronological order but should be planned and started simultaneously since some of the steps are longer running and others may have to be done repeatedly. The following working steps are described below:

– Definition of objectives and scope of the adaptation process
– Revision of existing management and management plan
– Data collection and inventory of available data
– Assessment of climate change and its impacts on biodiversity
– Stakeholder involvement, communication and participation
– Development of monitoring concept
– Definition of adapted management strategies and measures

10.6.1 Working Step: Definition of Objectives and Scope of the Adaptation Process

The guiding question of how to adapt management of a protected area to climate change must be answered specifically in order to get a clear understanding of the scope of the adaptation process. This can be accomplished by answering the following questions:

- What is the **object** of adaptation: management strategies and measures; objectives, monitoring concept; communication concept, management plan; zoning of protected area, etc.?
- What **context** has to be considered in the adaptation process: organisational structures; legal and institutional frameworks; land users and stakeholders, existing and new collaborations, incentives and subsidies etc.?
- Which **data**, modelling results, and methods are or can be made available for the adaptation process: climate-change scenarios; sensitivity and impact analyses; monitoring results; guidelines and checklists; results of stakeholder dialogue and consultations, etc.?
- What are the expected **results** of the adaptation process: for example: a new management plan; new conservation objectives; an adapted legal and institutional framework; new concepts (Adaptive Management) and strategies; new monitoring concept; institutionalised stakeholder dialogue; changed land use, etc.?

The objectives, methods, and the scope of adaptation have to be discussed and decided in cooperation with all relevant stakeholders and the results must be documented for later evaluation.

10.6.2 Working Step: Revision of Existing Management and Management Plan

The adaptation of protected area management should be based on a critical revision of the effectiveness of existing management. What must be evaluated is how well a protected area succeeds in managing the area under current climatic conditions, if management objectives and targets are reached and at what cost. Guidelines for assessing protected area management effectiveness (e.g. Hockings et al. 2006; Nolte et al. 2010) can be useful for this revision.

Key questions for the revision of management are:

- What are the main pressures on biodiversity, what problems exist and what activities and measures are available or implemented for improving conservation status?
- Are sufficient data and staff available to fulfil all management tasks?
- Is the area accepted and supported by local institutions, stakeholders and land users? Which groups have the strongest influence on the status of the protected area and cause non-climatic pressures on biodiversity?
- Does the plan contain sufficient information about planned and implemented management measures for reaching a favourable conservation status of protected species and habitats?
- Does it contain information about monitoring techniques and indicators used in monitoring the development of a protected area?

Revision of the topical management activities provides important insight into the process of adaption because an adapted management plan should not only target climate-induced pressures and impacts but also cover existing pressures and problems in order to establish successful and efficient procedures.

Available conservation plans and programmes have to be checked if they are up-to-date, complete and relevant to the upcoming day-to-day management decisions. They must be updated or amended in accordance with concepts of stakeholder dialogue, systematic monitoring or Adaptive Management activities.

Reviews within the HABIT-CHANGE project revealed that most management plans are not sufficiently specific or detailed for climate adapted management. Usually, management activities within the protected areas are not all described in the plans, which are furthermore often out of date and do not contain measurable, time-bound objectives or measures. This makes it difficult to evaluate the success and effectiveness of management. None of the reviewed plans contained any information on climate change and its impacts or a comprehensive monitoring concept as a basis for evaluating management effectiveness and establishing the concept of Adaptive Management.

It was also ascertained in the project that financial resources and manpower were often insufficient for fulfilling legal obligations. This is especially true for requirements derived from EU regulation, e.g. the EU-Habitats-Directive. Specific management plans for areas established under the EU-Habitats-Directive were not available in any of the areas HABIT-CHANGE investigated, although the directive came into effect over twenty years ago.

10.6.3 Working Step: Data Collection and Inventory of Available Data

An inventory of available data and maps for the adaptation process should be compiled very early in the adaptation process to enable the identification of gaps in the data and missing information. Up-to-date data about species, habitat distribution and conservation status, soil, water and land uses, as well as data about observed impacts of climate change are considered essential for the process of adaptation. The questions "How much data do we need to support decisions?" and "How can we provide relevant information?" must be discussed in detail before starting extensive data collection. Otherwise the process may be overloaded with data irrelevant to the planning effort.

Existing data must be evaluated with regard to how complete and up-to-date it is. For the introduction of Adaptive Management, monitoring data and information about applicable indicators are of particular relevance. Special attention should be paid to information on observed changes in biodiversity, species composition and habitat quality in comparison with historical data.

Information about past and current conflicts with stakeholders, existing pressures on protected habitats and species, as well as evaluation data regarding management effectiveness are also other important sources for the adaptation process.

10.6.4 Working Step: Assessment of Climate Change and Its Impacts on Biodiversity

Hardly any protected area is sufficiently equipped for carrying out assessments of climate change and its impact. Cooperation with research institutions or other scientific support is essential for obtaining relevant information. Before models are used, protected area managers have to decide what kind of results they need for management decisions (see Chap. 5). For example, data on annual, seasonal or monthly temperature changes may be less relevant than data about precipitation changes, late frosts or heavy rain. It has to be ensured that the results really fit the needs and situation of the protected area and that they help to identify possible response options such as management and mitigation measures. The time frame and reference period for models should be selected with regard to regional or national scenarios and with regard to adaptation planning results of use to important stakeholders like water-boards, agriculture or forestry. When using climate models it should also be taken into account that for example, projections about future temperature changes are more certain than projections about precipitation changes or extreme events. For more intensive discussion of climate projections and an overview on the currently available climate data for Central Europe see Chap. 2.

To identify impacts of climate change on a protected area and its natural assets a sensitivity analysis and an impact assessment need to accompany the modelling. Many different models are available and to date no standardised method for modelling of ecological or even social responses to climate change can be recommended without reservation. In most cases, selection of models used for sensitivity and impact analysis is strongly guided by the know-how of available scientific institutions and data. Hence, there needs to be a wholehearted discussion regarding whether or not proposed modelling results specifically address the management decisions at hand (see also Chap. 5). A special challenge is the definition of elements of the ecological or socio-ecological system that may be affected by climate change and therefore should be analysed. In some cases protected area management might be able to limit modelling of sensitivity and impact analysis to a few habitats or species because the results can easily be transferred to other parts of the area. In other cases, however, more complex and integrated modelling of all relevant features is needed (e.g. due to heterogeneous spatial conditions in the protected area).

10.6.5 Working Step: Stakeholder Involvement, Communication and Participation

Many conflicts in protected areas are caused by land-users and other stakeholders not accepting the objectives and measures of nature conservation because they stand contrary to their interests. It is essential to include and integrate those stakeholders and land users in the process of adaptation. This is vital for the increase of acceptance and to find win-win-solutions that help all parties involved to adapt to climate change. To foster stakeholder involvement existing conflicts and problems with land-users and stakeholders have to be analysed and documented, and suitable strategies for participation and communication must be identified.

Furthermore, land-users and other stakeholders will also have to adapt to climate change (for example, artificial irrigation to avoid drought, or snow cannons to extend tourist seasons). Such autonomous adaptation activities might not even be directly attributed to climate change. However, they can be in conflict with protection efforts, increase existing problems or even create new threats to conservation goals. Hence, the autonomous adaptation of stakeholders should be monitored and guided by conservation management.

Successful adaptation to climate change requires the close cooperation of diverse stakeholders, land-users, administrators, and scientists. Each of the stakeholders needs different services and should be involved at different stages of the adaption process. Hence, it is essential to tailor recommendations to the needs of the different stakeholders and make their roles in the process explicit.

In organising professional and effective stakeholder involvement special qualifications and competences are required. External expertise and support from mediators may help to organise the participation process and to overcome deadlocked conflicts. The process of stakeholder involvement is time-consuming and should be started early in the adaptation process.

10.6.6 Working Step: Development of Monitoring Concept

Effective management requires permanent control and evaluation of implemented measures and their impacts. Sustainable resource allocation is only possible if management effectiveness is frequently monitored. Monitoring concepts have to cover indicators for the evaluation of management effectiveness but also indicators to track status changes in important natural resources like species, habitats, biotic and abiotic conditions. Status indicators should be standardised on regional and national levels to allow tracking of changes across a wider region. Developing a monitoring concept should include a concept for data management and for data exchange and storage, in order that monitoring data can be used and evaluated by different scientific or conservation institutions and at local, regional or national levels. Systematic monitoring is the basis for the identification of local effects of climate change, but it is also essential for the obligatory review and revision of management practices in the concept of Adaptive Management.

All monitoring activities should be coordinated with regional and national institutions and monitoring tasks should be shared according to the resources and competences of the institutions involved. Protected areas cannot carry out complete climate change monitoring on their own. External support and delegation of monitoring tasks is essential. Monitoring directed and implemented by protected area staff should focus on measuring effectiveness and impact of management activities.

10.6.7 Working Step: Definition of Adapted Management Strategies and Measures

Management activities that are adapted to climate change are based on management strategies and measures aiming to obtain a favourable conservation status under current climatic conditions. Experience from HABIT-CHANGE shows that most current management measures are expected to be effective even under changing climate, but they have to be supported by additional measures or slightly modified (for example by changing the intensity, frequency or timing of measures). The most promising or effective measures should be selected and tested based on the concepts of Adaptive Management. Different management options should be implemented, monitored and evaluated under controlled conditions.

One of the most promising strategies for climate change adaptation is to strengthen the resilience of natural systems by reducing non-climatic pressures from land-use, land-use changes, fertilisation, traffic, recreational activities, etc. A wide set of management activities focusing on the alleviation of existing pressures is well known and has already been implemented. In many cases such activities need to be intensified due to the additional pressure of climate change.

The advantage of such a strategy is that it can be started immediately and that it will already be effective under current climatic conditions. However, this strategy requires profound knowledge about management effectiveness and a sufficiently equipped area management team.

10.7 Lessons Learned from Adaptation of Management Plans in HABIT-CHANGE

In HABIT-CHANGE the adaptation process was tested in six investigation areas and discussed with several conservation managers in Central and Eastern Europe. Experience showed that the process of adaptation needs to be tailored in a site-specific manner to meet the needs of each protected area. There is no simple solution or general approach beyond the recommended working steps. Many decisions relevant for an effective adaptation are not solely in the hands of conservation administrators. The process of adaptation depends on local expertise and intensive communication with relevant stakeholders who may shape and design tasks and processes in a way very specific to the site. Important stakeholders need to be included, convinced and motivated to act. Local adaptation processes should be supported and partly coordinated by regional and national policies, programmes and guidance. Also the provision of funds and resources for the climate adaptation of management in protected areas has to be ensured. Many strategies have to be prepared at the national or regional level, before they can be applied at a local level. This is especially true for monitoring tasks, for modelling and assessment and for the legal framework as well as for institutional competencies and structures that cannot be implemented at or initiated from the protected area level.

From the HABIT-CHANGE project it was apparent that providing checklists and guideline documents can be helpful in supporting protected area managers, but it takes more than guidelines to initiate and maintain the adaptation process. It must be accompanied by intensive consultations with experts and it has to be tailored to the specific and individual situation of each protected area. In most cases, protected area management is not sufficiently equipped for gathering and analysing relevant data or information on its own, due to limited resources.

In consequence, a useful approach for climate change adapted management in protected areas is one in which there is a flexible framework that defines essential working steps but leaves enough freedom for tailoring specific adaptation processes to the site-specific needs.

At the start of HABIT-CHANGE major obstacles for implementation of climate change adapted management were identified, which included:

- Missing or outdated data;
- Lack of support for climate adaptation (even within the administration of the protected area);
- Uncertainties related to modelling results on climate change and its impacts;
- Missing resources, manpower or expertise within the protected areas;
- Missing methodical approaches for incorporating modelling output, scenarios and assessment results into management plans;
- Established management "habits" that conflict with the systematic learning process required by Adaptive Management.

However, within the project's lifetime the consortium was able to overcome these obstacles and gain missing data by biotope mapping and analyses of remote sensing data; to gain support by sustained communication and awareness raising; to reduce uncertainties by using an ensemble approach for climate scenarios (see Chap. 2); to make up missing resources by obtaining external support from project partners and by providing detailed step-by-step guidance for all working steps within the methodical approach. Future steps for the implementation of climate change adapted management plans will show if established management habits will change towards a systematic learning process.

Adaptation to climate change has to be considered a continuous process as knowledge about climate change, its impacts and the effectiveness of management grows. Adaptive Management is a promising concept for gaining new knowledge and adjusting conservation efforts to changing conditions. This requires that management plans are revised and updated on a regular basis (e.g. every 5–7 years) to ensure the application of suitable adaptation strategies and measures. However, it is uncertain if all conservation goals can be maintained and harmonised with the ever-increasing need for evaluation and realignment of conservation work. Only if all potential management options fail should a discussion on changing or giving up objectives be started.

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Part IV
Approaches to Adapt Management to Impacts of Climate Change in Selected Areas

Chapter 11
Monitoring Concept of Climate-Induced Impacts on Peat Bog Vegetation in Pokljuka Plateau in Triglav National Park, Slovenia

Tina Petras

11.1 Introduction to the Case Study

The understanding of ecosystems as dynamic systems and considering future environmental changes and periodical oscillations are essential aspects for conservation planning. In particular, for an appropriate management of ecosystems and species populations, the knowledge of broad-scale environmental impacts, like climate change, as well as problems, related to specific habitats or species following human impacts and natural disturbances, are essential (McComb et al. 2010). On the other hand, to consider species response to those changes is also important for taking particular management action. Therefore, the monitoring and analysis of data on habitats and species populations are crucial for conservation and should constitute an essential part of management in Triglav National Park (TNP).

TNP is situated in the mountain region in the NW Slovenia (Fig. 11.1) and is part of Julian Alps. Diverse relief and high variation in altitudes between valley's bottoms (with minimum 400 m a.s.l.) and the higher peaks (with maximum 2,864 m a.s.l.) are characteristic for the park. This has a significant influence on local climate.

In the high mountain regions of the national park where extreme environmental conditions prevail, habitat changes may be detected earlier. Considering that climate is one of the most significant abiotic factors which determine the structure, composition and function of alpine ecosystems, considerable impacts of climate change on alpine and nivale habitats are expected. Indicator species for monitoring the effects of global warming in TNP were chosen according to predictions of the effects of climate changes on main habitat types and expected changes of human and economic pressures (changes in management) on different ecosystems. In the following paper, the case study of monitoring of peatland vegetation is presented.

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Fig. 11.1 The position of Triglav National Park in Slovenia (Cartography: Miha Marolt) (Modified from the Environmental Agency of the Republic from Slovenia 2010)

Long-term surveys of vegetation communities will provide a better understanding of the mechanisms of vegetation change as well as mechanisms of species coexistence (Bakker et al. 1996).

The plateau Pokljuka is located in the eastern Julian Alps, between ca. 1,200 and 1,500 m a.s.l. It is a carst plateau that has become its typical alpine appearance due to glacial processes (Kunaver 1985). The prevailing vegetation is human influenced secondary spruce forest, which was replaced due to forestry – on the place of former beech forest (*Anemone trifoliae–Fagetum*) (Wraber 1985). The peatbogs in Pokljuka plateau are one of the most visible remains from the glacial period. They have developed from former glacial lakes, carved by glacier and, additionally, filled with thick layer of organic substrate (Piskernik and Martinčič 1970). The bogs are lying mostly on carbonate ground, frequently mixed with Chert (Kuntnar and Martinčič 2001). The most important factors influencing peatland formation and its survival, besides topography (plateau surface with a diverse microrelief) (Dierssen and Dierssen 2001), include climate characteristics such as the precipitation-evaporation relationship (Moore and Bellamy 1974 cited in Gignac and Vitt 1994) and low temperatures (Gignac and Vitt 1994).

Šijec with its surrounding (ca. 30 ha) (Fig. 11.2) is one out of 12 peat bogs on Pokljuka high plateau. The area is characterised by different vegetation types, like active raised bogs, alkaline fens, fen meadows, transition mires and quaking bogs,

Fig. 11.2 Šijec peat bog in Pokljuka plateau (Photo: Tina Petras)

and bog woodlands with *Pinus mugo* and *Picea abies*. Anyway, this vegetation is only the transitional phase and among others also the result of natural processes in the past. The information about vegetation in the history and its gradual changing could be determined by pollens, which are stored in sediments, like peat layers (Šercelj 1996). Furthermore, on the base of stable isotopes of carbon, oxygen and hydrogen the changes in hydrology and temperature could be determined (Joosten and Couwenberg 2008). Considering the peatbogs as a place to accumulate the organic substrate (peat), of which at least 50 % is carbon, they are valuable to understand environmental changes in the past (Arnold and Libby 1949; Šercelj 1996; Joosten and Couwenberg 2008).

Peatland ecosystems are characterised by extreme environmental conditions, like low nutrient supply, seasonally and annually changing humidity, great day-night variations in air temperature and low pH-values to which only specialists are adapted (Anderson 2010). Therefore, many endangered species, such as *Drosera rotundifolia, Pinguicula alpina, Menyanthes trifoliata, Carex pauciflora* and *Sphagnum* sp. are characteristic for these ecosystems. They provide also important breeding and/or feeding habitats for some animal species, including *Somatochlora arctica*, *Leucorrhinia dubia* (Kotarac 1997), as well as *Sorex minutus*, *S. alpinus*, *Scolopax rusticola* and *Tetrao urogallus*, respectively.

Considering the comparatively small area of peat bogs in TNP as well as the location of Šijec peat bog at the southern-border of peat bog distribution in Europe, impacts of climate change will be detected very early. The main management goal for peatlands in TNP is to conserve the natural dynamics of peatland ecosystems (Javni zavod Triglavski narodni park 2013). TNP's peatland monitoring is designed as a combination of vegetation monitoring by permanent sampling plots and remote sensing.

The Šijec peatland is a relatively undisturbed ecosystem and is therefore valuable for long-term studies to understand natural processes and provide a baseline for comparisons when disturbances or perturbations occur (Spellberg 1991). That knowledge would be of considerable importance in decision-making process in management applications in a changing environment.

11.2 Climate-Change Related Problems

Since climate is the most important determinant of the distribution and character of peatlands, a strong influence of any future changes of climate on these ecosystems is expected (Charman et al. 2008; Gignac and Vitt 1994; Heijmans et al. 2008). A warmer and drier climate with higher rates of evapotranspiration will accelerate the decomposition of organic matter and the amount of nutrients in the ecosystem will increase. Consequently, higher levels of CO_2 and other greenhouse gases will be released into the atmosphere. The changes in hydrology, followed by climate changes could affect distribution and ecology of plant and animal species in peatland ecosystem (Parish et al. 2008). In addition, the tree cover of bogs will increase as the result of lower water tables (Gignac and Vitt 1994). On the other hand, peatlands affect the climate via a series of feedback effects which include the sequestration of carbon dioxide, as well as exchanges of heat and moisture balance (Charman et al. 2008; Thompson et al. 2004).

11.3 Monitoring Objectives and Methods for Peat Bog Ecosystems

The most important monitoring goals for peat bog ecosystems are: (1) to understand the ecosystem processes and its dynamic; (2) to determine the influence of changing climatic conditions (changes in temperature, precipitation regimes etc.) and human impacts on peat-bog vegetation (species composition and abundances); (3) to define plant species which are the best indicators for climate change; (4) to compare response of different plant communities to climate changes; and (5) to perform long-term surveys of the dynamics of peatland ecosystems.

An approach by stratified random sampling was chosen for monitoring peatland vegetation in TNP. Based on the knowledge of the extension and distribution of different habitat types in the park, sampling areas were divided in advance into homogeneous units, i.e. vegetation types (Fig. 11.3), while for each unit sampling plots were chosen randomly. In each homogeneous sampling unit maximum ten samples (1 m^2) were taken with minimum distances ≥ 5 m between randomly selected sampling plots (Fig. 11.3). Parameters which are measured in each sampling plot include the floristic species composition of vascular plants and

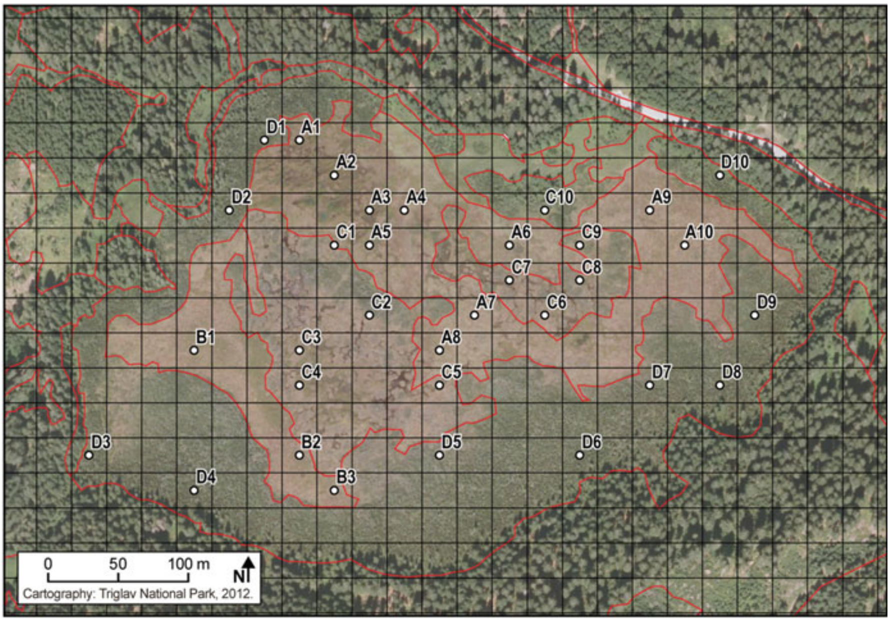

Fig. 11.3 Stratified habitat types in peat bog Šijec with randomly selected sampling plots (A1-D10). As a basis a net from Slovenian Forest Service is used, and modulated by size 25 × 25 m. Different letters indicate different habitat types with maximum ten samples per spatially separate habitat type (Cartography: Miha Marolt) (Modified from Public Information of Slovenia 2011)

bryophytes and species abundances. Additionally, selected environmental factors like ground and air temperatures, humidity, precipitation amount, water level, and pH-values are measured. The number of tree species is counted in all sample units along $\geq$100 m long transects. Sampling should take place between June and August. To avoid human impacts by monitoring, vegetation and environmental monitoring will proceed in 3–5 year intervals. To detect changes of environmental conditions we applied also indirect phyto-indication methods, i.e. Ellenberg indicator values, which in many situations reflect habitat quality rather well (Diekmann 2003; Ellenberg et al. 2001).

With the help of remote sensing applications, using aerial photography, it will be possible to monitor the distribution and extension of peat bog habitats on the landscape scale and to monitor broad-scale changes (succession) in habitats. Additionally, field survey is required for habitats that are difficult to identify from the photographs (Birnie et al. 2010; Ploompuu 2005).

To detect human impacts, (1) the presence of grazing in the direct vicinity of bogs will be noted, and (2) air pollution will be monitored by mapping epiphytic lichen vegetation in the forests around peatland ecosystems (Batič and Kralj 1995). (3) With regard to the impact of winter salting of roads in the direct vicinity of bogs, analyses of snow and soil samples, and analysis of the spruce needles will be provided (Čotar 2010; Le Roux et al. 2005; Levanič and Oven 2002).

Table 11.1 Selected indicator species of peat bog Šijec according to Ellenberg's values and habitats characteristics

Indicator species	Low T	High H	Low pH	Low N
Carex hostiana	–	x	–	x
Carex nigra	–	–	x	x
Carex pauciflora	x	x	x	x
Carex rostrata	–	x	x	–
Drosera rotundifolia	x	x	x	x
Eriophorum latifolium	–	x	–	x
Eriophorum vaginatum	–	x	x	x
Menyanthes trifoliata	–	x	–	–
Molinia caerulea	–	–	–	x
Oxycoccus microcarpus	x	x	x	x
Pinguicula vulgaris	–	–	–	x
Potentilla palustris	–	x	x	x
Trichophorum alipinum	–	x	x	x
Vaccinium uliginosum	–	–	x	–
Vaccinium vitis-idaea	–	–	x	x
Valeriana dioica	–	–	–	x

The selected species are related to different vegetation types for the whole peat bog Šijec ecosystem. (*T* temperature, *H* humidity, *pH* chemical reaction, *N* nitrogen content)

11.4 Expected Results of Climate Change Impacts on Peat Bog Ecosystems

According to the results of other studies on peatbog and fen vegetation (Dakskobler et al. 2011; Graf et al. 2010) the occurrence of different plant species seems to be a good indicator for detecting early environmental changes. Earliest changes will be most probably detected according to the composition of different *Sphagnum* species, species abundances, the decrease of indicator species for low temperature, high humidity, low pH and low nutrient value (Table 11.1), the increase of generalists and of species which are characteristic for more dry habitats at the cost of peatbog specialists. Changes in replaced community types are expected to be seen later. The successional changes in plant communities, from alkaline fens to subalpine siliceous grasslands due to changing moisture conditions (warmer climate and less snow cover) have been already observed in Slovenian mountain fens (Dakskobler et al. 2011). This is one of the successional stages towards climax montane spruce or beech forests, with intermediate communities with *Pinus mugo* and *Larix decidua*.

11.5 Conclusions for Nature Conservation and Management of Peat Bogs

Considering the great dependence of small groundwater-fed systems to hydrological and climate changes (Grootjans et al. 2006) both aspects should be included in conservation activities. With water contents around 90 % (Parish et al. 2008), hydrological regimes are the fundamental component of peatlands. For the appropriate functioning of mires and fens, an increase of mean summer water levels to maximum depths of about 10 cm are necessary (Graf et al. 2010). At this level, fens start to produce peat during the summer months, whereas they loose peat if the water table is lower (Blankenburg et al. 2001 cited in Graf et al. 2010). According to great biodiversity value of peat bogs, and the fact that natural peatlands play a key role for global climate regulation by minimising CO_2 emissions (Parish et al. 2008) as well as for water regulation, it is important to ensure their strict protection and conserve their functions.

In TNP the uncontrolled recreation activities, occasional grazing with cattle, motor traffic, forest operations close to sensible peatbog areas (Dobravec et al. 2003), water discharge from public roads and the privatisation of larger part of the land, including bog forests with some peatlands are the main pressures. Therefore, to reduce negative impacts, the long-term goal should be to put peatbog ecosystems from the buffer zone into the core zone of the Park-management, with most strict protection regime laid down by Triglav National Park Act (Zakon o Triglavskem narodnem parku 2010). Anyway, the conservation of peat bogs in TNP is partly ensured by their protection under Natura 2000 and protection in the frame of Management Plan of TNP (which will be adopted in 2013) as a closed area (Javni zavod Triglavski narodni park 2013). According to regulation in peat bogs-closed areas, all activities, interventions and access are prohibited. Moreover, in the frame of forest planning, all peat bog ecosystems are excluded from forest management (Gozdnogospodarski načrt 2011–2020).

By monitoring the biological and environmental parameters, along with human impacts, early warnings for changes in bog ecosystems will be possible. Consequently, actions to prevent species loss and habitat destruction can be taken in time. In the event that climatic changes will be indicated by the alteration of vegetation cover (e.g. an increase in woody species) and decreased indicators for humidity and low temperatures, action to improve hydrological conditions in peat bogs and their surroundings can be taken. An increase in nitrogen-indicator species (*Trifolium pratense*, *Poa alpina* etc.) is connected with grazing and traffic. Therefore, livestock crossings and grazing on peat bogs or in their direct vicinity will be reduced or prevented. Meanwhile, forest management in the surroundings of peatlands should apply sustainable techniques for maintaining biodiversity and carbon storage (Parish et al. 2008).

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Chapter 12
Concept for the Monitoring of Climate Induced Impacts on Rock Ptarmigan (*Lagopus muta*) in Triglav National Park, Slovenia

Tina Petras

12.1 Introduction to the Case Study

Part of the main management goals for the alpine ecosystem in Triglav National Park (TNP) are the (1) preservation of a representative portion of high mountain grasslands and pastures, (2) prevention the disturbances in the living environment of the species, (3) establish a network of habitats connection which will enable the preservation of grassland ecosystems and (4) maintaining viable population of mountain species. To monitor effects of climate change key indicators that correspond to these aims and relate to climate change have been chosen.

In the following paper, the case study on the population monitoring of rock ptarmigan (*Lagopus muta*) in TNP is presented. Rock ptarmigan is considered an indicator species for the extreme alpine environment with good response to human impacts.

To understand the population dynamics of a species with regard to environmental and/or human impacts, long-term surveys are essential. With monitoring indicators it is possible to evaluate management strategies. For the appropriate conservation of viable species populations, aspects of the environment, distribution, biotic interactions, morphology, physiology, demography, behaviour, genetics and human impacts should be addressed in the monitoring programme (Primack 2006). However, monitoring alone produces no information on the causes and consequences of particular conditions in ecosystems and for population's dynamics. Therefore, it should be complemented by scientific research (Alexander 2008) on key environmental factors and the population biology of key species.

The rock ptarmigan is an arctic-alpine grouse species (Fig. 12.1) widespread throughout the northern Eurasia and North America (Storch 2007). It inhabits opened habitats, in Alps above the tree-line, mainly between 1,700 and 2,400 m a.s.l.

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Fig. 12.1 Male of rock ptarmigan (*Lagopus muta*) in summer plumage (Photo: Luka Markež)

(Cramp and Simmons 1980). It occurs in flocks during autumn and winter, and is monogamous in breeding period. The rock ptarmigan is a species with short-distance movements during the year, in late summer it often moves only to higher altitudes (nival belt) (Cramp and Simmons 1980). In TNP, the species was observed within an elevation of 1,600–2,600 m a.s.l. during the summer period (Jančar 1997) and between 1,350 and 2,350 m a.s.l. during the winter period (Kmecl 1997). Optimal habitats for the species are grasslands, interspersed with smaller shrubs, high and small-scale variation of inclination and exposition. In winter both factors provide mosaics of variable snow cover and different snow heights, while during summer a variety of microclimates favour high plant and food diversity (Bossert 1980; Nopp-Mayr and Zohmann 2008). Size of territories in Alps varies between 10 and 35 ha, while the distribution, extent and numbers of territories appear to be rather stable for decades (Bossert 1980, 1995; Favaron et al. 2006). Breeding density varies among years and areas, and it is mostly estimated from 2 to 7 breeding pair per km^2 (Bossert 1995; Peer 2005; Nopp-Mayr and Zohmann 2008).

Rock ptarmigan is evaluated as least concern species in IUCN Red List due to extremely large range and population size (BirdLife International 2012) and it is listed in Annex I of the EU Birds Directive (Direktiva 2009). In the Red Data book of Slovenia it has a status of vulnerable species (Ur. l. RS 2002).

In contrast to the central distributional area of rock ptarmigan where the species still occupies most of the original range, some local declines in relatively small populations in Alps and Pyrenees, on the southern border of its distribution area, have been noted (Novoa et al. 2008; Revermann et al. 2012; Storch 2007). In some studies, based on the effect of climate on the rock ptarmigan and its related white-tailed ptarmigan (*Lagopus leucurus*), climate change has been recognised as one of the major factors influencing the population dynamics of these species (e.g. Revermann et al. 2012; Wang et al. 2002).

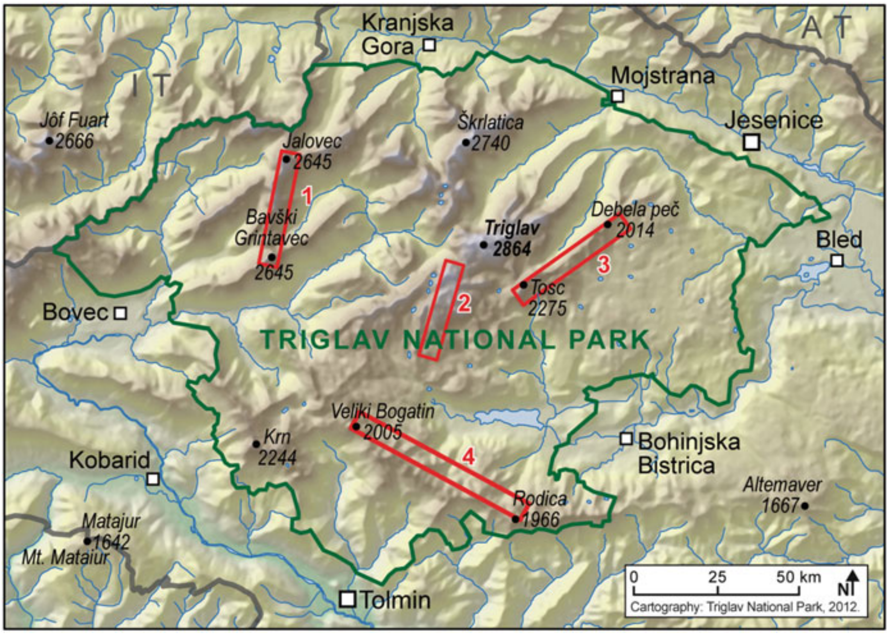

Fig. 12.2 Survey area of the mountain ranges: (*1*) Jalovec – Bavški Grintavec, (*2*) Kanjavec – Mala Tičarica, (*3*) Debela peč – Tošc, (*4*) Veliki Bogatin – Črna prst (Cartography: Miha Marolt) (Public Information of Slovenia 2008)

Nevertheless, human influences, specially uncontrolled tourism (ski-resorts, recreation activities) still remains the most important impacts on the rock ptarmigan population in the Alps and Pyrenees (Storch 2007). As a consequence of mass tourism the population of *Corvus* species, which attack chicks and reduce breeding success, increase (Storch and Leidenberger 2003; Watson and Moss 2004). Although responses of the species to human disturbances differ between areas, mitigating human disturbances in core breeding areas is essential (Ellmauer et al. 2005).

The species distribution area in Slovenian Alps encompasses the Julian Alps, the Karavanke and the Kamniško-Savinjske Alps (Geister 1995). Its population in Triglav National Park is estimated at 100–300 breeding pairs (Jančar 1997). Due to the lack of surveys on rock ptarmigan in Slovenian Alps, no adequate published data on species population dynamics and distribution is available. Hence, there is a need for knowledge on its distribution, population density and trends, as well as a need to understand the disturbances that are influencing the species' population dynamics. The first samplings of rock ptarmigan in the TNP are restricted to the pilot areas of the mountain ranges: (1) Jalovec (2,645 m) – Bavški Grintavec (2,347 m); (2) Kanjavec (2,568 m) – Mala Tičarica (2,071 m); (3) Debela peč (2,014 m) – Tošc (2,275 m); (4) Veliki Bogatin (2,005 m) – Rodica (1,966) (Fig. 12.2). Selected areas are under different level of human impacts, especially mountaineering, skiing and paragliding. Eventually, the pilot areas will also be implemented in other parts of TNP. Anyway, for better understanding the status of the alpine population of rock ptarmigan and its sufficient protection, the analysis of the monitoring results from the whole Alps would be necessary.

12.2 Climate-Change Related Problems

In order to predict the effects of climate change on the species population, knowledge of the effect of climate on its life history is essential (Novoa et al. 2008). Climate and weather characteristics are considered to be one of the most important factors influencing the population dynamics of rock ptarmigan. Breeding success, juvenile and adult survival heavily depends on weather conditions. Nesting success is negatively correlated with the amount of rainfall in particular during the hatching period (Novoa et al. 2008). The proportion of chicks in August depends on the onset of snow melt, mean minimal and maximal air temperatures during spring and early summer (Novoa et al. 2008). In all the species distribution models, the mean July temperature, annual precipitation, July water budget and July cloud cover were found to be the most powerful bioclimate variables for determining the distribution patterns of rock ptarmigan (Revermann et al. 2012). Furthermore, the powerful influence of the mean July temperature on rock ptarmigan distribution was stressed by Revermann et al. (2012) in connection with the heat dissipation limit theory (Speakman and Król 2010). Following this theory, we can explain the appearance of endothermic animals, including rock ptarmigan, in areas with lower temperatures in an attempt to avoid hyperthermia.

The increasing temperatures and smaller amounts of precipitation in winter months will result in a thinner snow layer. This means a lack of snow for deep burrows for roosting and sheltering in harsh winter conditions (Bossert 1980; Cramp and Simmons 1980; Hoffman and Braun 1977). Additionally, a decreased snow layer results in a deficiency of certain available food (Bossert 1980).

Events related to global warming, such as a higher frequency of extreme weather conditions, may affect hatching success, chick survival (Webb 1987 cited in Wilson and Martin 2008) and energy expenditure for food provisioning and thermoregulation of nesting females (Wiebe and Martin 1997 cited in Wilson and Martin 2008).

12.3 Monitoring Objectives and Methods for Rock Ptarmigan Population

Counting of calling males is based on the fact, that displaying proceeds inside territories or on borders and that territory borders may remain unchanged for decades. Territorial males can be heard for distances $\geq$ 1 km (Bossert 1977). The most important monitoring goals in TNP are:

1. To determine the distribution and dynamics of rock ptarmigan populations by direct observations, callings, and tracks, like feathers, droppings, footprints etc. (monitoring and dispersed observations): all year.

Table 12.1 Sampling form for rock ptarmigan (*Lagopus muta*)

Sampling form for rock ptarmigan	Name of observer	Datum of observation	Sampling unit
Time of sampling (from-to)	Cloudiness	Wind	Precipitation
Patchiness of snow cover	Habitat description	Corvid-species and their number	Presence of *Aquila chrysaetos, Accipiter gentilis* and *Falco peregrinus,* and the number of individuals
Mammal species and their number	Human impacts	–	–
ID of individual + (♂, ♀)	Behaviour (calling, displaying, flying, feeding. . .)	Time of observation of each individual	Time of successive calls of each male

2. To investigate the population densities in TNP with standardised counting of displaying and calling: May-June.
3. To estimate breeding success by field observations of females with chicks and nest records and with help of radio-transmitters (Wilson and Martin 2008): July.
4. To describe habitat requirements of the species by vegetation sampling, remote sensing techniques and environmental parameters: June-August.
5. To identify the link between climatic factors, influencing on species population dynamics (Meteorological station).
6. To determine major impacts on the species population with help of monitoring human impacts and environmental conditions: all year.
7. To identify ecological relationships between rock ptarmigan and other species: all year.
8. To develop a model of potential species distribution with considering changing in climate: combining results from long-term surveys and mathematical modelling. With population viability analysis (PVA) the different management scenarios and assessment of the potential impacts of habitat loss will be evaluated. In the models and analysis the whole alpine rock ptarmigan population will be included.

The method is recapped from Bossert (1977, 1995). The study area is divided into sections that are separated by topographic structures (ridges, mountain passes). In study plots numbers of simultaneously calling males are determined by a team of stationary observers that will cover the whole sampling area. Observation points within potential ptarmigan habitats were selected in the field according to good visibility and audibility. Sampling proceeds between the end of May and the beginning of July during early morning hours from 3:00 to 7:00 (8:00) CTE. Individual observations of the species seeing or callings, together with observation sites (points), are recorded on map 1:3,500 and documented in the sampling form (Table 12.1). Monitoring surveys will be performed in 5 year intervals.

The topographic parameters (elevation, exposition and slope aspect) (Wilson and Martin 2008) and habitat types will be sampled in order to described environmental characteristics of rock ptarmigan's territory. Additionally, more detailed vegetation sampling will be done in feeding and nesting habitats. With the use of aerial photography, the vegetation changes – succession in the rock ptarmigan's habitat will be detected.

The human impacts will be evaluated indirectly, due to the presence of Corvid-species, the number of accommodations in mountain huts, and by direct observations of human disturbances in the field.

12.4 Expected Results of Climate Change Impacts on Rock Ptarmigan Population

Like in other Alpine countries (e.g. Beniston 1997; Keiler et al. 2010), changes of some climate factors were already observed in Slovenian Alps. The increase of mean annual, minimal and maximal temperatures in the period from 1961 to 2011 is statistically significant in all analysed meteorological stations in TNP (547–2,514 m a.s.l.). Furthermore, the negative trends in the number of days with snow cover during snow season were also noted (Črepinšek et al. 2012). Considering those environmental changes, we expect alterations in population and distribution of rock ptarmigan, as well as changes of its habitat. In particular, due to its strong dependence on weather conditions during the breeding season, the breeding phenology and breeding success are expected to be largely effected.

Following the effects of climate changes which have already been detected in some alpine grassland vegetation (Cannone et al. 2007; Körner 1999; Keller et al. 2000), we predict accelerating plant succession by which the proportion of woody species will increase. Additionally, the tree-line will shift upwards to higher altitudes. This process is expected to proceed faster in dry habitats on carbonate ground, which is widespread in the Slovenian Alps. Similar results are presumed in species distribution modelling where due to increasing temperatures during the breeding season, potential habitats are expected to decrease by up to two-thirds of area by the year 2070 (Revermann et al. 2012). Such vegetation changes could reduce suitable habitats for rock ptarmigan resulting in the greater isolation of already fragmented populations (Storch 2007) and consequently lower gene flow exchange between them.

Additionally, the increase overlap between rock ptarmigan and other grassland bird and/or small mammal species, causing greater competition between them, is expected. So far, only few published data on interactions between rock ptarmigan and other grassland species exist. The evidence about alpine marmot predation on rock ptarmigan nests were reported from the Alps (Jordana et al. 2006 cited in Figueroa et al. 2009), whereas the results from Pyrenees suggest that such interaction is only a sporadic event (Figueroa et al. 2009).

Finally, the loss of appropriate habitats with increasing human disturbances, lower breeding success, as well as greater interspecific competition could affect the viability of rock ptarmigan population in a level that cause the decline or extinction of local populations.

12.5 Conclusions for Nature Conservation and Management of Rock Ptarmigan Population in Triglav National Park

Due to the lack of basic data on the species' distribution and influences of environmental and human impacts on population numbers, active conservation management of rock ptarmigan in TNP does not exist, yet. With the help of long-term surveys and related research the park should be able to implement appropriate management measures for conserving viable populations of this species. Anyway, with the monitoring results the management authority of TNP will be able (1) to determine what environmental factors and human activities influencing rock ptarmigan population distribution and dynamics, (2) to determine the areas with specific restrictions and areas with strict protection, and (3) to define the areas where the corridors should be implemented.

For conservation purposes the monitoring programme should answer the following questions:

1. How will climate change effect the species' distribution and population numbers in TNP?
2. How will human impacts effect the species' distribution and population numbers in TNP?
3. How will vegetation changes effect seasonal movements, distribution, reproduction, and diet for the species?
4. Which species will compete for habitat, food and other resources in a changing environment with ptarmigans?
5. Where are potential future nesting and wintering habitats for ptarmigan population in TNP?

The present research will provide the introduction to gathering answers to the above questions.

The conservation of appropriate habitats (Fig. 12.3) is probably the most important management strategy for maintaining a viable population of rock ptarmigan when declines in local populations of this species will be observed due to climate change. Especially the areas with large variation in topographic and geomorphologic structures (Fig. 12.4) are particularly important, because they provide better potential for the birds to adapt to weather fluctuations by taking advantage of differences in micro-site-specific climates (Favaron et al. 2006; Revermann et al. 2012). Therefore, the strict protection – the closure of some of such areas together with the highest peaks of the mountains within TNP should be provided. Those areas should serve as the last breeding refugia as the breeding place is expected to shift to the higher elevations. Additionally, the establishment and maintenance of the corridors connections will contribute to gene exchange with other local populations.

The anthropogenic pressures, like: (1) ski touring, (2) paragliding, (3) mountaineering, (4) intensive pasture, should be limited or prohibited where they are recognised as a treat to the species. In such habitats with reduced additional stresses, the species is

Fig. 12.3 Potential future nesting and wintering habitats in terms of habitat and altitudinal aspect for the rock ptarmigan (*Lagopus muta*) population in TNP (Cartography: Miha Marolt) (Jarvis et al. 2008)

Fig. 12.4 Typical habitat for rock ptarmigan with diverse relief structures (Photo: Luka Markež)

more likely to adapt to environmental changes. According to human pressures on rock ptarmigan population, the closed areas should be defined, or time and space limitations in areas with rock ptarmigan presence should be ensured.

The use of population viability analysis and applying species distribution models to identify the treats and suitable habitats for rock ptarmigan are, in addition to monitoring and scientific research, the most important task in adaptive conservation strategies. Species-habitat relationship modelling helps to organise and document factors associated with habitat evaluation and planning as well as provide help to monitor species and environments (Guisan and Thuiller 2005; Morrison et al. 1978).

Considering the small population size and naturally fragmented populations of rock ptarmigan in the Alps (Favaron et al. 2006; Storch 2007) genetic approaches in species conservation are particularly important. Furthermore, the knowledge on genetic basis of selectively favoured phenotypes allows the prediction and mitigation of the effects of climate change on population viability (Reusch and Wood 2007 cited in Oyler-McCance et al. 2011).

Finally, the understanding of species ecology, interactions with other species and potential overlapping ecological niches will be possible with long-term monitoring and scientific research. So far, the interactions of rock ptarmigan, corvids (*Corvus* sp.), alpine marmots (*Marmota marmota*) and golden eagle (*Aquila chrysaetos*) were observed and analysed under different conditions or situations (Figueroa et al. 2009; Storch and Leidenberger 2003; Watson and Moss 2004). In order to include predictions of such complex species interactions in changing environmental conditions or under human impact in our park's management issues will require more specific studies.

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Chapter 13
Suggested Management Measures for Natura 2000 Habitats in Körös-Maros National Park, Hungary

Ákos Malatinszky, Szilvia Ádám, Eszter Falusi, Dénes Saláta, and Károly Penksza

13.1 Introduction

Various effects of climate change are among the greatest challenges that Hungarian agriculture and nature conservation has to face, both currently and in the near future (Pullin et al. 2009). Considering annual precipitation in Hungary, there has been a 100 % difference between the two consecutive years of 2010 and 2011 (data of the National Meteorological Service). In Central Europe, wetlands are already seriously affected by weather extremes (Erwin 2009; George 2010; United Nations Economic Commission for Europe 2009) and, the challenge for agriculture and nature conservation is – besides assessing vulnerabilities and risks – to develop policies to adapt so as to achieve sustainability (Perdomo and Hussain 2011). Forty-six percent of the total grassland areas of Hungary are protected Natura 2000 sites. Over 90 % of these areas need specific forms of management, i.e. grazing, mowing, shrub removal, or combating weeds. This is why harmonising the aims of agriculture and nature conservation is highly important. This may be ensured either by national park directorates (management organised by them or renting state areas with restrictions) or private owners. Therefore, they are the stakeholders who play a crucial role in wetland maintenance by proper management. In favour of developing wetland resilience to climate change, there is an urgent need to develop adaptive management through stakeholder dialogue at an early stage (Sendzimir et al. 2007; Werners et al. 2010) to discover user known problems.

It is possible for conservation managers to proactively respond to probable influences of climate change which threaten habitat integrity and diversity. We have analysed the changes of habitats caused – with any possibility – by the climate

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change and simultaneously focused on the necessary changes in conservation management and land use in the designated protected areas. The main aim of our adaptation policies is to increase the resilience of agricultural systems. Our initiative aims at combining ecological aspects, nature conservation, and climatic adaptation with social and economic factors concentrating on the sustainability of this type of protected land management.

During the preparation of climate change adapted management plans, our main aim was to obtain a favourable conservation status and to improve resilience of habitats listed in the Habitats Directive of the EU (92/43/EEC) that is Natura 2000 habitat types comprising the ecological network of the European Union. To achieve these, goals and objectives, strategies and measures were defined, simultaneously identifying uncertainties while also integrating climate scenarios.

Included in the discussion are probable effects of climate change and suggested management measures for each conservation aim (beginning with the maintenance of the habitat type itself, focusing on each Natura 2000 species and protected species that was living in the habitat type or was reported within the sample areas), which are followed by an inclusion of other aspects to consider for each habitat type, except for the forested areas that usually require alternative management from non-forested habitat types.

13.2 Study Areas and Applied Methods

Habitat observations were done in the Körös–Maros National Park, which is located in South-Eastern Hungary among the rivers Tisza, Körös and Maros (Fig. 13.1). The landscape of the area is dominated by freshwater habitats, marshes, and grasslands of agricultural use. Considering the vegetation of the Hungarian Great Plain geographical macro-region, this territory belongs to the most diverse of landscapes; thanks to the complex effect of several natural factors. Among them, climatic and edaphic characteristics are the dominant ones. Investigation areas belong to the lowest located areas of the Hungarian Great Plain, having formerly been an extensive swamp area for several millennia. Areas which are constantly covered by water consist mainly of clay, while slightly higher, elevated patches, that only have temporary water coverage, entail appropriate conditions for different types of sodic (alkaline) habitats.

The sample areas designated for investigations are the Kisgyanté swamp, the Kisvátyon swamp and the Sző-rét meadow, all of which carry natural values of high environmental importance, and are located in the geographical micro-region called Kis-Sárrét, in close vicinity to the Romanian border. These areas are located within the Kis-Sárrét operational part of the Körös-Maros National Park, belonging to the so-called “A zone” of the park (strictly protected areas). Complex studies on the effects of management on vegetation and forage value of wetlands in these sample areas has already been carried out by Nagy et al. (2007) and Kiss et al. (2008).

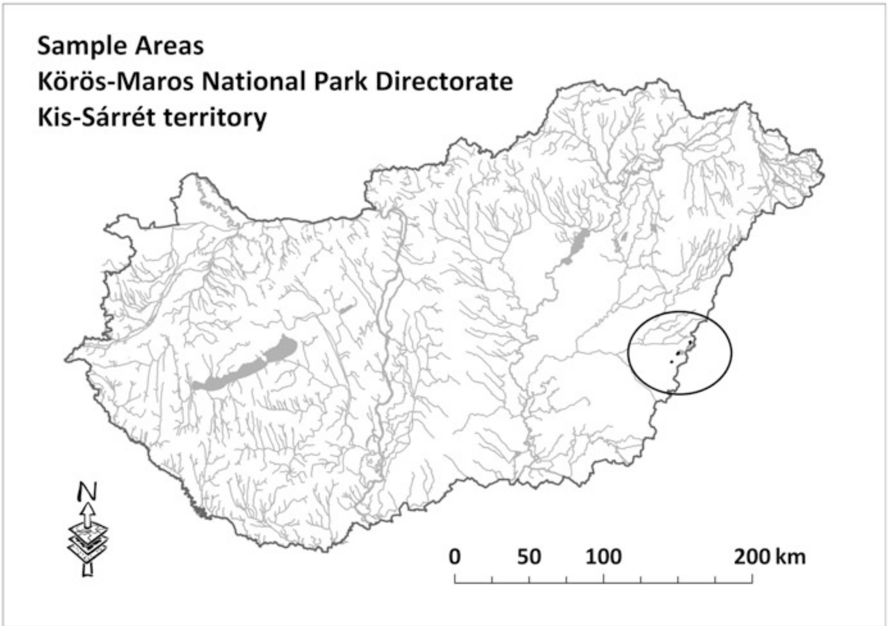

Fig. 13.1 Geographical situation of the sample areas

The sample areas host five types of habitats that are under protection within the Natura 2000 programme of the European Union: Pannonic salt steppes and salt marshes (Habitat Directive code 1530), Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation (3150), Pannonic loess steppic grasslands (6250), Alluvial meadows of river valleys of the *Cnidion dubii* (6440) and Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (91E0). This is why, on top of being a national park area, those habitats have been also designated as Natura 2000 sites (both Special Protection Areas (SPA) and Special Areas of Conservation (SAC)). They are especially important as preservers of salt steppes and salt marshes. Due to the high ecological values, these habitats are in focus of adaptive management planning.

Arable lands cover a larger portion of the Kis-Sárrét SAC and SPA areas. However, the national park's directorate supports their conversion of grasslands. The rate of inhabitants living in the investigation area and working in agriculture is higher than the national average. However, most of them own less than 5 ha. Some former agricultural cooperatives have been converted to economic enterprises. The national park's directorate primarily uses those areas which benefit from habitat reconstruction or restoration. Other state-owned protected areas are worked by farmers, with certain restrictions from to the national park's directorate. The main crops grown in these areas are autumn wheat, autumn barley, oat, corn, sunflower, alfalfa. Alternative crops are oil pumpkin, oil rape, and oil radish. Rice had been produced between the 1930s and 1960s around Mezőgyán, Geszt and Biharugra villages, resulting in artificially created wet areas that were later inhabited by native species.

The number of grazing livestock has increased during the past couple of years after a massive fall in the 1990s. Next to the area of research, the second largest artificial fishpond system of Hungary (about 1,600 ha water surface) is operating. Most of the forested areas are state owned and managed by a state forestry service. Only 12 % of the forested areas are covered by indigenous species, of which 33 % remains oak. Touristic activities are dominated by the bird-watching (mainly on the fishponds). To promote environmental conservation, a 7 km long educational trail was developed along the edge of the Kisvátyon swamp area.

Considering historical development of the landscape, the Kis-Sárrét territory, once called Sárrét of the Körös river, has undergone severe landscape changes during the past 200 years. Extended marshes and fens used to dominate the area before the landscape was converted resulting in very diverse landscape attributes and therefore different management types that were adapted to the ecological conditions. The original state of the land had started to change in the mid-nineteenth century due to severe water regulation activities between 1856 and 1879. As many areas under constant or temporal water cover disappeared, the traditional management changed and a significant portion of local inhabitants were forced to give up traditional way of living. Dried-out areas were converted to arable lands, while wet parts have started to serve as pastures or hayfields, preserving the high importance of raising livestock in the region.

There were significant landscape changes in the twentieth century. The creation of the fishponds near Biharugra village started in 1910, which currently provide sanctuary for rare bird species. There was extended forestation in 1930s, resulting in several new wood patches. Despite landscape conversions, some wetlands remained in a favourable conservation state, remaining today as the last remnants of the once extended marshes and marshy patches. As a consequence of inland water regulatory works, the area of marshes has decreased, but their state can be still considered as almost natural.

The research conducted as a part of this study was based on vegetation mapping, climate data collection, analysis of former and present management, botanical and zoological review, and the analysis of soil and water characteristics. In order to obtain feedback from stakeholders, semi-structured interviews based on open ended questions according to Leech (2002) were prepared, focusing on management and the problems that had been experienced that either directly or indirectly connected to the effects of climate change. The interviews were usually done on the spot with individual responses given in person.

13.3 Determining Priority of Conservation Aims

Problems reported by stakeholders, as well as drivers and pressures delivered from sensitivity maps prepared during the HABIT-CHANGE project, focus on those phenomena that are directly or indirectly connected to climate change and draw attention to future changes on habitat status and their consequences for land management. As different plant and animal species living within the same habitat type have different requirements, the management of habitats should vary according to the specific conservation aim. This is why at the beginning of the process of adaptive management preparation, a priority order of conservation aims should be determined (e.g. which species, species groups, habitats, or habitat patches should be preserved first and foremost). These could be nesting or feeding birds, butterflies and their feeding plants, orchids, other plant species, or landscape view (see also http1 and http2). In the case of other taxa (mammals, reptiles, amphibians, fishes, and invertebrates not mentioned), management that creates optimal conditions for the appropriate habitat type itself is usually sufficient. Besides basing on scientific research, the process of setting conservation aims requires more insight from stakeholders. Therefore, they should be involved to integrate their interests and needs into the management plans and it has already been recognised in biodiversity conservation that most of them really wish to take part (Idle and Bines 2005).

The landscape scale for planning a unit of management (habitat patches or their mosaics or whole habitat types or protected area level, administrative unit etc.) should also be determined in prior to management planning.

The setup of conservation aims should be based both on scientific research on the area in question and the insight from stakeholders about the possibility of practical implementation. Literature sources draw attention to the fact that, despite of the general assumption that farmer decisions are mostly driven by economic rationality costs are not the most important factor (Sattler and Nagel 2010).

13.4 Suggested Management Measures for Natura 2000 Habitat Types Occurring in the Sample Areas

13.4.1 Pannonic Salt Steppes and Salt Marshes (HD Code 1530)

A special problem emerges when planning adaptive management of this Natura 2000 habitat, as it unites every sodic habitat from the driest steppes to the wettest marshes. Thus, we discuss this habitat referring to the Hungarian habitat classification system (ÁNÉR), which divides this HD code towards six habitat types (*Artemisia* salt steppes and *Achillea* steppes on meadow solonetz, Salt meadows, Tall herb salt meadow steppes, Dense and tall *Puccinellia* swards, Annual salt pioneer swards of steppes and lakes, and Salt marshes). A special feature of these habitats is that they change, even just within a few centimetres of elevation, due to different water conditions (Fig. 13.2).

Maintenance of the *Artemisia* salt steppes and *Achillea* steppes on meadow solonetz only allow open sheep grazing with medium intensity, and taking care to regulate the distance from each other and intensive mobility of animal. In addition,

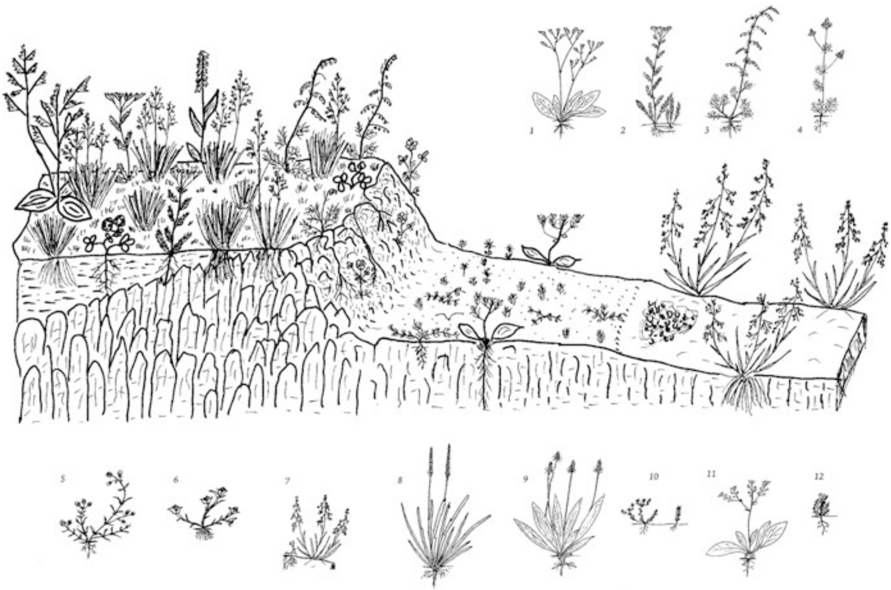

Fig. 13.2 Geographical situation and species composition of three habitat types (*Artemisia* salt steppes and shoulders, Annual salt pioneer swards and *Puccinellia* swards) belonging the Pannonic salt steppes and salt marshes (HD code 1530) habitat category. 1 *Limonium gmelini* subsp. *hungaricum*, 2 *Achillea* spp., 3 *Artemisia santonicum*, 4 *Matricaria recutita*, 5 *Spergularia maritima*, 6 *Crypsis* spp., 7 *Puccinellia* spp., 8 *Plantago maritima*, 9 *Plantago schwarzenbergiana*, 10 *Sedum caespitosum*, 11 *Lepidium cartilagineum*, 12 *Camphorosma annua*

selective weed control (or winter burning) may be necessary (Nagy et al. 2008). Spring inundation may last only for a short period (national park rangers I. Bíró and I. Tóth ex verb.). Erosion by overgrazing may lead to the generation of shoulders (a special landscape form), being another habitat type. Probable effects of climate change, such as excess rainfall or some months of longer spring inundation may reduce salt characteristics, and thus, degrade the habitat. This can be avoided by temporal overgrazing and trampling, which increase open soil surfaces and transpiration. Hotter and less rainy summers strengthen habitat condition. Other aspects to consider are the need to protect against farmers ploughing into these protected habitats from adjacent arable lands by creating hedges of shrubs. *Eleagnus angustifolia* may thrive on upper areas, providing shade for livestock and nesting places for raptor birds; however, it may invade the pasture. Normally there are neither invasive species nor scrub encroachment. Another conservation aim is to protect *Aster tripolium* that thrives on the saltiest parts and needs grazing and tolerates trampling. *Aster sedifolius* occurs on less sodic parts and benefits from mowing or grazing by horse or cattle. *Plantago schwarzenbergiana* and *Orchis morio* thriving on this habitat type also tolerate sheep grazing. *Spermophilus citellus* needs constantly low grass, which can be attained through grazing or mowing. It is important to control grazing during nesting period of birds.

Maintenance of the Salt meadows habitat requires an adequate water supply with temporary inundation, usually between autumn and early summer (at least May). The optimal time for mowing would be the second half of May in order to gain quality hay and pasture for the summer. However, this may destroy bird's nests. Therefore, mowing is advised to be done in late June. Intensive grazing and trampling are harmful. Livestock hooves may harm the soil surface among the sedges as they graze on top of soils filled with water during early spring, thus creating optimal surface for other species to appear (Mann and Tischew 2010). However, usually weed species (from the edges and adjacent arable lands) settle onto these harmed surfaces. Hence, mowing in late June may be advised. This also helps the grassland to close which allows the grass species to thrive, and the grazing livestock can be lead onto the area after drying up. Pykälä (2005) draws attention to the fact that species benefitting from mowing may appear on pastures as well. Slight grazing creates more mosaics (open water patches) and limits the invasive species, reed and *Typha* spp., and prevents scrub encroachment. Decreasing rainfall, as a probable effect of climate change, leads to early drying out, while excess summer rainfall may result in soil leaching and a reduction of salt content which causes soil degradation. Another aspect to consider is to abolish the effects of historical water management initiatives (construction of canals and ditches). No invasive species have had an effect on the habitat, except for *Eleagnus angustifolia*. Occasional burning (in sections) may help to control the weed expansion. To cut back *Typha* stands, the habitat needs to dry up for the late summer. If the conservation aims at protecting the nesting birds, the area should be mowed annually after the 15th of June, leaving un-mown strips (changing their exact place every year), and use wildlife alarming chain. Grazing should be avoided during nesting periods. Milder winters and warmer springs caused by changing climate may lead to earlier blooming of vegetation. This requires earlier mowing, which is harmful for nesting birds. High water levels can also be harmful for birds. However, draining may threaten privately owned arable lands and lowers the groundwater table below adjacent loess steppes. In favour of conserving amphibians and reptiles, alternating scythe should be used instead of bung scythe during mowing.

Tall herb salt meadow steppes require regular spring inundation and drying up in summer. In order to preserve environmental conditions of the habitat, mowing should be done after the 15th of June. Decreasing rainfall leads to early dry-up (a regular trend of drying was already observed in historical times (Saláta 2011)). No invasive species were recorded within our study habitat area. Temporal scrub encroachment does not underpin the degradation of this habitat; however, this process needs to be monitored. Sheep grazing degrades the habitat if they graze too much, or they do not manage to graze tall herb vegetation because of its height. If the conservation aim is to preserve *Peucedanum officinale* – the foodplant of the Natura 2000 butterfly species *Gortyna borelii lunata* – mowing is necessary, but only needs to be done every second year. In favour of preserving this invertebrate, it is imperative to conserve the landscape mosaic. This can be done by leaving un-mown strips of land and switching around the areas that are mowed from year to year. Early mowing (before the mid-July) kills the larvae of *Gortyna borelii lunata*, which remain in the stem of the food plant at this time. Also the hatching of the *imago* out from the *pupae* form is blocked by the use of heavy mowing machines. Therefore, hand mowing should be preferred. Natura 2000 tall herb species *Cirsium brachycephalum* needs spring rains and late summer drying; mowing harms the tall herb physiognomy. Nesting birds benefit from late mowing (after 15 June), leaving un-mown strips to be mowed in the late summer, and use wildlife alarming chain. If the habitat is grazed, it should be limited for the nesting period.

Dense and tall *Puccinellia* swards thrive if they get regular precipitation, (not necessarily constantly between autumn and spring, but for several shorter periods) and then dry up for summer. This habitat presents strong sodic characteristics. Mowing is required after nesting period. Pasture grazing should not be allowed during wet periods. Hotter and less rainy summers will probably strengthen the condition of this habitat; however, short-term inundation also remains important. Excess rainfall or longer spring inundation reduces salt characteristics. This process can be avoided by temporal overgrazing and trampling which increases open soil surfaces and transpiration. Unbalanced circumstances caused by climate change are beneficial for this habitat. Moderate sheep grazing is not harmful. Erosion by overgrazing may lead to the generation of shoulders; this being a new habitat type. If the priority is to preserve *Aster tripolium*, constant inundation by rain should not be allowed and the area could be covered with water just for several shorter periods of year.

Annual salt pioneer swards of steppes and lakes are sensitive to trampling, especially in wetter periods, but they tolerate moderate grazing. Long lasting water inundation and intensive transpiration is beneficial for the habitat, and hotter, less rainy summers may also strengthen their condition. Climate extremes are favourable for this habitat. Intensive trampling assists its generation, but may also destroy the shoulders.

Salt marshes should experience excessive rain between late autumn and summer. Its vegetation mainly consists of tall and rigid species unpalatable for most livestock species and breeds. Therefore, only the robust Hungarian Grey Cattle breed (or water buffalo) is optimal for their grazing. This breed is also more resistant to the effect of heat waves increasing especially on the Central European plain areas (Twardosz and Batko 2012). Long water inundation and intensive transpiration is beneficial. This habitat regenerates easily in rainy periods after drying up in dry years, thus making the area sensitive to the climate extremities. Abolishing the effects of past water management works (canals, ditches) may be necessary. Occasional mowing or grazing (Hungarian Grey Cattle or water buffalo) may prevent the expansion of this habitat type onto other ones. No invasive species were recorded in this habitat within our study area. If the main aim is to preserve *Eleocharis uniglumis*, no special management measures need to be implemented besides the monitoring and sustaining of ample precipitation between late autumn and summer.

13.4.2 Natural Eutrophic Lakes with Magnopotamion or Hydrocharition-Type Vegetation (HD Code 3150)

This habitat requires constant water supply. Decreasing rainfall may harm hydrophyte vegetation as its levels will simplify. *Ceratophylloide*-type submersed floating life forms may fall and *Lemnoid*-type emersed floating life forms (with smaller space claim) may gain space. Species number may fall as species with limited ecological tolerance disappear. Species requiring a high naturalness state of habitat (*Myriophyllum verticillatum, Ceratophyllum demersum, C. submersum, Utricularia australis, Salvinia natans*) may disappear. Increase of less sensitive *Lemna minor* and *Trapa natans* is expected. Protected species such as *Salvinia natans, Misgurnus fossilis, Emys orbicularis, Triturus cristatus* etc. need constant water supply in this habitat type, and it appears that no special measure is required to be applied.

13.4.3 Pannonic Loess Steppic Grasslands (HD Code 6250)

Maintenance of this habitat is possible with slight section grazing, which should be limited within the wetter spots. Mowing once a year (June) and/or autumn grazing by sheep, cattle, or horse are also a possible management measures. Keeping mown buffer zone on the edges helps to prevent expansion of weeds. Mosaic landscape should also be retained. Species composition alters depending on annual rainfall; this may be augmented with stronger changes in climate. Continuous attention is needed to prevent overgrazing. Deflating water from wet areas during summer threatens the habitat by the groundwater table decline. If nature conservation aims at protecting the *Spermophilus citellus,* low cut grass should be maintained which can be obtained as a result of grazing and/or mowing. Converting arable lands into alfalfa production in parallel with cutback of shrubs (e.g. *Prunus spinosa*) is beneficial for *Otis tarda. Cirsium furiens* does not require intervention, only cutback of shrubs.

13.4.4 Alluvial Meadows of River Valleys of the Cnidion Dubii (HD Code 6440)

Mowing in June and autumn grazing by sheep, cattle, or horses on the young grassland is beneficial. As a consequence of lowering groundwater table these habitats may evolve towards drying out and in parallel, become weedier. *Cirsium brachycephalum* requires spring inundation of the area with a dry climate in late summer. Late mowing harms its tall herb physiognomy. In favour of conserving amphibians and reptiles, alternating scythe should be used instead of bung scythe during mowing. *Orchis laxiflora* ssp. *elegans* needs late June mowing, after the ripening of its seeds. A rare remnant of ancient marshlands, *Carex divisa,* requires water cover between autumn and June as drying threatens its proliferation.

13.5 Further Insights

We experienced various management methods even within the same habitat type on our relatively small sample areas. A favourable conservation status of protected habitats is not only threatened by pressures and impacts driven by climate change, but also by those emerging from land use and its changes. Therefore, planning climate adapted management requires the intense involvement of stakeholders and amongst them, land users. Preparing a compilation of problems with the stakeholders, focusing on problems that are connected with climate change helps to identify the most important questions that should be answered during the planning of adaptive management. Conflicts between stakeholders concerning the management of the protected area should also be explored. It should be decided in each case which factors are of the highest importance (e.g. species-oriented or habitat requirements) and which climatic effects might affect the natural values (both species and habitats) at the highest level. Thus, management cannot be uniformed or standardised.

Several ecologists and other officers working at Hungarian national park directorates underlined that a high flexibility of the authorities is needed when ordering certain management restrictions for farmers on protected areas; the regulations should be revised every year or even within a year (e.g. time of mowing should be tied to vegetation phenophase instead of exact date). They also reported that currently there is a lack of such flexibility due to strict legal regulations. A general guideline is that management planning should be based on current, exact, relevant ecological and social circumstances, and historical land uses. Therefore, this process cannot be simplified into following a planning scheme. This especially applies on the Natura 2000 habitat type Pannonic salt steppes and salt marshes (HD code 1530) as it unites every sodic habitat from the driest steppes to the wettest marshes. The scale of planning its management should be based on the Hungarian habitat classification system (ÁNÉR), which divides it towards six habitat types. This scale should be refined onto administrative management units according to national park officers.

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Chapter 14
Climate-Induced Challenges for Wetlands: Revealing the Background for the Adaptive Ecosystem Management in the Biebrza Valley, Poland

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14.1 Introduction

Although climate change has already been recognised as a challenge for European wetlands, with regard to their hydrology (Acreman 2012; Okruszko et al. 2011; Winter 2000), ecology (Keddy 2010), agriculture (Hardig et al. 1997) and even tourism (Wall 1998), the management of protected wetlands still faces a fusion of problems regarding the definition and implementation of effective, climate-change-orientated conservation and adaptation strategies. In cases of broad wetlands, such as the Biebrza Valley (NE Poland; Fig. 14.1), environmental and socio-economic management problems are often related to hydrological processes and a chain reaction of ecosystems and stakeholders to (climate-change induced) the temporal alteration of groundwater levels, flood frequency and duration of regular floods and their volume (Schneider et al. 2011). Those hydrological factors strongly depend on

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Fig. 14.1 Geomorphologic outline of the Biebrza catchment and Biebrza Valley: *1* – water gauge Osowiec on Biebrza, *2* – rain gauges, *3* – River Biebrza, *4* – rivers and canals – Biebrza tributaries, *5* – boundaries of the Biebrza Valley, *6* – lakes, *7* – Biebrza catchment, *8* – boundaries of the Biebrza National Park

both long- and short-term climatic fluctuations, of which the most important is the temporal distribution of precipitation responsible for runoff dynamics and air temperature variability, which determines snow accumulation, snowmelt and evapotranspiration.

The complexity of hydrological processes and their spatial relations within the Biebrza Valley induced the development of various types of wetland: minerotrophic calcareous fens, regularly flooded riparian marshes and ombrotrophic bogs (Okruszko 1991; Oświt 1991; Wassen et al. 2006). In many parts of the analysed area the status of wetlands can be considered as near-natural, because they evolve within the feedback of natural, physical and ecological processes, not being directly influenced by any type of water management nor agricultural pressures (Grygoruk et al. 2011a; Wassen et al. 1990). Therefore, one of the most important, trans-national, European value of the Biebrza Wetlands is the fact that they are considered a representative reference for wetland restoration (Wassen et al. 2002). To protect this valuable geoecosystem, the Biebrza National Park (BNP) was founded in 1993. Since then, almost 60,000 ha of unique wetland habitats have been covered by protection of the highest national priority. Despite that, more than 40 % of the area of BNP remains privately-owned. Therefore, along with environmental conservation priorities, stakeholder pressures aimed at the intensification of agriculture polarises the goals of wetland management in the Biebrza Valley. The dominant demands of stakeholders are aimed at increasing agricultural production (haymaking) and draining the wetlands. This would entail a dramatic loss of biodiversity and deterioration in wetland habitats. The drainage pressure has increased in the last few years of the first decade of the twenty-first century, when extreme weather conditions (heavy rainfall in the summer, extensive droughts in the autumn and frosty winters) entailed summer flooding, which – while formerly rare – became a frequent obstacle to agriculture. Thus, not only has the primary impact of climate change (hydrological processes alteration due to climate change) recently appeared as a challenge for wetland ecosystems in the Biebrza Valley, but also this secondary impact (considered as a climate-change-induced stakeholder pressure) became an aspect to be widely-discussed in the preparation and application of appropriate management strategies for the BNP. Hence, wishing to establish an appropriate diagnosis of the Biebrza Wetlands' functioning in regard to contemporary and prospective habitat dynamics and facing increasing stakeholder pressures, special emphasis should be given to a long-term temporal analysis of the hydrology and climate of the Biebrza Valley.

The implementation of the HABIT-CHANGE project ("Adaptive management of climate-induced changes of habitat diversity in protected areas"), started in 2010, allowed the establishment of an international, interdisciplinary analytical approach to potential challenges for the environment and their socio-economic aspects induced by climate change. This study, by considering the climate-induced impacts on wetlands and stakeholders, presents the most important results of the project's implementation in the BNP. Although some general analysis on temporal variability of hydro-meteorological phenomena were considered by Grygoruk et al. (2011b), Ignar et al. (2011), Kossowska-Cezak (1984), Kossowska-Cezak et al. (1991), Maksymiuk (2009) and Maksymiuk et al. (2008), the context of climate change in ecosystem management and habitat development in the Biebrza Valley has so far not been considered in the literature. Therefore, this chapter becomes the first step towards a measurable estimation of the challenges, which come along with both the so far observed and projected climate change impacts, to wetland ecosystem management in the Biebrza Valley.

The main aim of this chapter is to provide elementary information on climate-induced challenges for ecosystems and stakeholders of wetlands in the Biebrza Valley. In the first part of this chapter, we analyse hydro-meteorological phenomena recorded in the Biebrza Valley within the years 1970–2011 (with respect to the precipitation analysis) and 1951–2011 (in order to define flooding frequency and temporal dynamics). In the next step, we analyse the projected climate change for the Biebrza Valley in the time horizon 2070–2100 on the basis of ten different ensembles of Global Circulation Models-Regional Climate Models (GCM-RCM) combined with the SRES A1B emission scenario. On the basis of the GCM-RCM projections on temperature and precipitation changes, we set up two hypothetical scenarios to be analysed in the context of climate-change related challenges for habitats, and also for the socio-economic development of the Biebrza Valley. In the last section of the chapter we discuss the interface between the potential environmental conservation of valuable wetland habitats and the management pressures of various groups of stakeholders. Concise conclusions from our research are highlighted in the last part of this chapter.

14.2 Environment and Management of the Biebrza Valley

Biebrza Valley and its wetlands have become a sink of the catchment of the River Biebrza, which covers 7,120 km^2, (almost 2.5 % of the total area of Poland). Surrounded by glacial plateaus of the Wartian (Riss) Glaciation (Goniądzka and Kolneńska Plateau, Sokólskie Hills) and morphologic units of the Vistulian (Wurm) Glaciation (Ełckie Lakeland and Augustowska Outwash Plain), the ice marginal valley of Biebrza (Fig. 15.1) is one of the largest coherent wetland areas in Central Europe. The majority of the valley is covered with peat (locally decently decomposed due to former drainage), which rests on the sandy plain of the Biebrza Ice Marginal Valley. The maximum thickness of the peat layer reaches from approximately 3 m in the southern-most part of the valley, up to approximately 8 m in the northern part, in the so-called Upper Basin (Żurek 1984). Locally, the continuous peat cover is perforated by sandy dunes, which play an important role in sustaining the biodiversity of the wetlands. The temperate climate of the Biebrza Valley with continental influences can be characterised by the average annual air temperature of 6.6 °C (Banaszuk 2004), with annual magnitudes of more than 55 °C (maximum and minimum values of air temperature measured in the Biebrza Valley in 2011 reached 30.5 °C and −25.6 °C, respectively). The average annual sum of precipitation calculated by Kossowska-Cezak (1984) for the Biebrza Valley equals 583 mm. On the basis of precipitation measurements in the Laskowiec rain gauge (see Fig. 15.1) for the years 1996–2011, we estimate an average annual sum of precipitation of 574 mm. The average sum of precipitation in the summer (May–August) – a critical season for wetlands due to the high rate of evapotranspiration – equals 260 mm (data from the Laskowiec rain gauge). The constant saturation of the valley, preconditioned by the hydrogeology and low slopes, occasions the appropriate conditions for valuable wetland habitats and species. Among the most important wetland habitats in the Biebrza Valley, there are alkaline fens, mire meadows, transition mires and bogs with pine bog forest and alder forests. All are listed in Annex I of the 92/43/EEC "Habitat Directive". Due to presence of unique plant species (e.g. *Saxifraga hirculus, Liparis loeselii, Polemonium coeruleum, Swertia perennis, Betula humilis*), those habitats have become those of the highest ecological value and consequently of the highest conservation status. The exceptionally rich fauna of the Biebrza Valley is represented by numerous, rare wetland birds (e.g. *Acrocephalus paludicola, Aquila clanga, Grus grus and Philomachus pugnax*), mammals (e.g. *Alces alces, Canis lupus, Lynx lynx*), fish (e.g. *Rhodeus sericeus, Aspius aspius, Cobitis taenia*) and invertebrates (e.g. *Parnassius mnemosyne*). The majority of habitats and species of the Biebrza Wetlands are determined by hydrological processes (groundwater level, soil saturation, flooding and inundation). Therefore, Wagner and Förster (2011), using the algorithm of habitat sensitivity assessment for climate change provided by Petermann et al. (2007), reported on the high general sensitivity of wetland habitats in the Biebrza Valley to possible climate change. For more details on the environmental features of the Biebrza Valley the reader is referred to Banaszuk (2004), Wassen et al. (2006) or the numerous other scientific publications regarding the ecology of the Biebrza Wetlands.

Due to the complex structure of land possession and the fact that approximately 40 % of the area of the BNP remains privately owned, a vast share of the wetlands is agriculturally managed. Agricultural use of the area is dominated by extensive meadow mowing and – seldom – pasture grazing. Due to exceptional environmental value of the Biebrza Valley, most of the agricultural activities, such as haymaking, are supported by agro-environmental schemes and direct agricultural subsidies, co-financed by the European Union.

With regard to the agricultural management of the Biebrza Valley, especially within the BNP, numerous conflicts arose on the interface of environmental conservation and agricultural management. Conflicts are related to the necessity of meadow drainage claimed by farmers and local authorities. The pressure of local stakeholders has escalated in years, when the amount of precipitation in the summer exceed average values (such as in the years 2010 and 2011, when the sum of precipitation recorded in the period May–August reached 377 mm and 398 mm, respectively). Moreover, the fact, that the River Biebrza receives the outflow from the whole catchment, underpins even more water-related problems, as the water levels in Biebrza and its tributaries in the river valley are controlled by water management in the upper parts of the catchment. Large-scale modelling studies conducted in NE Poland revealed that the climate change-induced outflow variability should be considered at catchment scale (Piniewski et al. 2012). Hence, in order to derive climate-adapted management strategies for the Biebrza Wetlands, the analysis should concern the spatial scale of the whole catchment and include all the stakeholders that are involved in water management.

14.3 Climate Change in the Biebrza Valley

14.3.1 Observations

Among the hydrological processes that induce the function and state of the wetlands in the Biebrza Valley, precipitation (sums and temporal distribution) and flooding (frequency and temporal distribution) appear the most important. In this regard, temporal variability of precipitation and flood dynamics were analysed in order to search for possible trends that can be brought about by climate change.

Analysis of precipitation in the Biebrza Valley was done on the basis of data recorded in rain gauges located in Laskowiec (1996–2011 dataset) and Burzyn (1970–2010) (see location on the Fig. 14.1). Flood analysis was done on the basis of discharge data for the River Biebrza in Osowiec in the years 1951–2011. The flood threshold of river discharge (bankful flow) was set up on the basis of multi-year observations as 25 m^3/s (Grygoruk et al. 2011b). Also the largest floods (over the threshold of the median of the highest annual discharges of Biebrza in Osowiec: $Q > 84.1\ m^3/s$, which is a flood of 50 % exceedence frequency) were analysed in order to reveal the temporal dynamics of flooding in particular seasons. Those sizeable floods are important from an ecological point of view, as they cover a large extent of the valley and induce the development and function of riparian zones as well as a network of ox-bow lakes, entailing water exchange between the river and a large share of the floodplain.

Temporal variability in amounts of precipitation recorded in the Burzyn rain gauge during hydrological "summer" (May–October) and "winter" (November–April) was analysed for each particular year (Fig. 14.2a), as well as the ratio of winter to summer precipitation (Fig. 14.2b). A slightly decreasing trend in summer volumes of precipitation within the years 1970–2010 can be observed, along with the considerable trend in increasing winter precipitation. One can conclude that the share of precipitation in the cold part of the year increases in the total amount of annual precipitation. However, a vast increase in rainfall intensity in the summer can be observed (Fig. 14.2c) – although in general summers seem to be drier, the increasing temporal concentration of precipitation entails possible flooding and remains a challenge for management and ecosystems. This observation confirms the results of Liszewska and Osuch (2000), who stated that more extreme weather conditions can occur as a major consequence of climate change in Central Europe. Similar results for the analysis of precipitation data recorded in the climate monitoring station of the IMGW (Institute of Meteorology and Water Management) in Białystok (50 km from the Biebrza Valley), in the years 1971–2010, were observed by Grygoruk et al. (2011a). Hence, the precipitation dynamics and their temporal distribution analysed herein on the basis of data from the Laskowiec and Burzyn rain gauges most likely reflect the long-term regional trend.

The increasing temporal concentration and intensity of summer sums of rainfall correspond with the results of temporal analysis of the largest floods (Fig. 14.2e). It indicates a significant increase in summer flooding in the first decade of the twenty-first century, compared to the second half of the twentieth century. Also, the total volume of individual summer floods (calculated as the amount of water momentary stored in the Lower Biebrza Basin during the flood events; Fig. 14.2f) increased in the last 15 years. Temporal analysis of snowmelt floods in the Biebrza Valley (Fig. 14.2d) indicates the continuing trend of the earlier occurrences of floods in 1950–2012. The analysis of the start of the spring flood was emphasised since this process induces the ecosystem services of marshes, such as their role in strictly temporal fish spawning and nutrient removal (Okruszko et al. 2011). It was

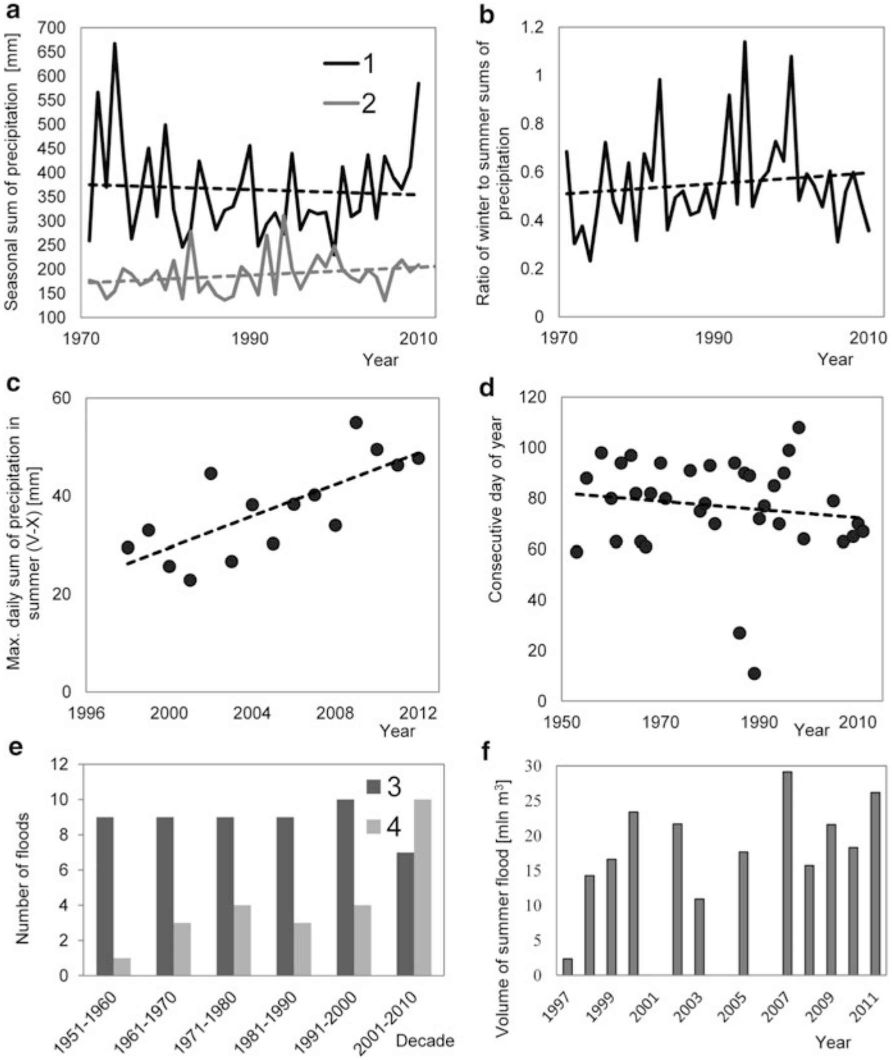


Fig. 14.2 Climate variability indicators recorded in the Biebrza Valley: (**a**) seasonal sums of precipitation recorded in Burzyn rain gauge: *1* – summer (May–October); *2* – winter (November-April); (**b**) annual ratios of winter and summer sums of precipitation; (**c**) maximum daily sums of precipitation in summer (May–October), (**d**) day of the start of the snowmelt flood calculated for floods; (**e**) number of floods ($Q > Q_{50\%}$) recorded in Osowiec water gauge, *3* – winter (November–April), *4* – summer (May–October); (**f**) total volumes of summer floods in the Lower Biebrza Basin (based on the Burzyn gauge). *Dashed lines* present general trends (Source of data: Institute of Meteorology and Water Management (IMGW))

recognised that over the time scale 1951–2011, the average day of the start of the spring flood moved earlier by about 10 days (Fig. 14.2d). Such an observation, combined with the results presented by Ignar et al. (2011) who revealed the decreasing trend in flood volume in the Biebrza Valley within the period 1961–2000, permits the assumption that the climate-induced changes in spring flood dynamics has become an issue in ecosystem continuity and function (especially for water-dependent terrestrial habitats of marshes and for fish species). This fact, which can partly remain controlled by water management in the upper parts of the Biebrza catchment, is suspected to be the main challenge for migratory birds such as geese, which are strongly dependent on the flood occurrence and extent (Polakowski et al. 2011). The earlier appearance of floods along with the decreasing volume of the flood wave limit the extent of fish spawning and induce an increasing in-situ fertilisation of meadows with the remains of vegetation and nutrients from previous seasons. Variability in the spring flood dynamics is of minor importance to agriculture, as field activities such as haymaking start later, once the spring flood has finished (May–June). Contradictorily, the changing dynamics of summer floods remain a challenge for both the agricultural maintenance of wetlands and ecosystems, remaining the most significant climate-related pressure on ecosystems and management for wetlands in the Biebrza Valley.

The analysis of precipitation and flood dynamics in the Biebrza Valley leads to the general conclusion that (1) during the analysed period of 1970–2010 the share of summer precipitation in the annual sum of precipitation has decreased, (2) maximum daily volumes of precipitation have increased, which expresses the increasing frequency of extreme precipitation events, (3) significant increase in sizeable summer floods occurrence ($Q > 84.1\ m^3/s$) was reported in the period 2001–2011 compared to the years 1951–2000, and (4) the regular spring floods in the Biebrza Valley start under average contemporary conditions approximately 10 days earlier than in the 1950s.

14.3.2 Projections

As some visible trends in precipitation dynamics and flooding in the Biebrza Valley were observed (Fig. 14.2), the next step of our research was to establish and assess prospective climate change projections for the Biebrza Wetlands. Climate change data for the Biebrza Valley was derived from the ENSEMBLES project results (van den Linden and Mitchell 2009; after Stagl and Hattermann 2011). There were ten different GCM-RCM combinations for the SRES A1B emission scenario considered with regard to climate change impact analysis in the Biebrza Valley: HadCM3-C4I/RCA3, CNRM/Arpege-DMI/HIRHAM5, ECHAM5-DMI/HIRHAM5, HadCM3-ETHZ/CLM3.21, HadCm3Q0-HC/HadRM3Q0, HadCM3Q16-HC/HadRM3Q16, HadCm3Q3-HC/HadRM3Q3, ECHAM5-ICTP/REGCM3, BCM-SMHI/RCA3 and HadCM3Q3-SMHI/RCA3. Prospective relative changes in monthly sums of precipitation [P; mm] and average monthly air temperatures [T; °C] in the time horizon 2070–2100 were referred to the values of average monthly temperature and precipitation recorded at the Laskowiec monitoring station of the BNP (see Fig. 14.1) in the years 2000–2011. As ten different GCM-RCM-emission scenario combinations were

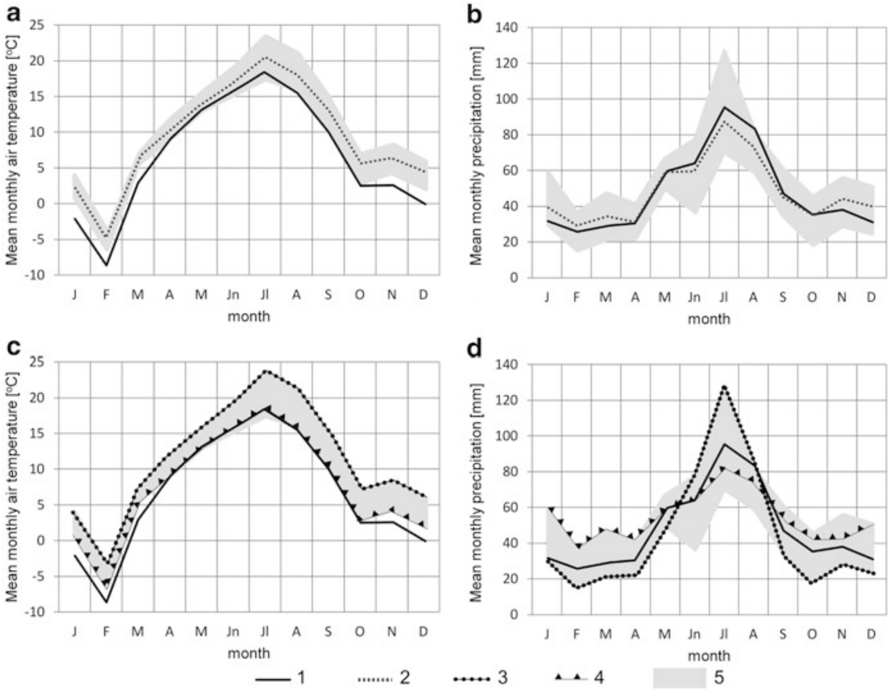


Fig. 14.3 Climate change projections for the Biebrza Valley and hypothetical "mild" and "extreme" climate change scenarios (time horizon 2070–2100); (**a**) comparison of prospective changes in mean monthly air temperature referred to the present conditions, (**b**) comparison of prospective changes in mean monthly precipitation referred to the present conditions, (**c**) "mild" and "extreme" scenarios of mean monthly temperature changes referred to the present conditions, (**d**) "mild" and "extreme" scenarios of the mean monthly precipitation changes referred to the present conditions. *1* – present conditions (2000–2012), *2* – average values of all analysed climate change projections for SRES A1B greenhouse emission scenario, *3* – hypothetical "extreme" scenario for the Biebrza Valley; *4* – hypothetical "mild" scenario for the Biebrza Valley, *5* – uncertainty range

considered in prospective climate change analysis, potential future changes of P and T in particular months in time horizon 2070–2100 varied in the range 17–57 mm in the case of the average monthly sum of precipitation, and from 1.2 up to 5.8 °C in the case of the average monthly air temperature. Lower and upper extreme projections derived from the GCM-RCM's analysed for each particular month were considered for the purpose of this study as the boundaries of the projection's uncertainty range (Fig. 14.3a–d). In other words, the uncertainty range of prospective changes in P and T in the Biebrza Valley can be considered as a most probable range of climate change dimensions predicted with the analysed GCM-RCM and emission scenarios combinations.

Among the GCM-RCM-emission scenarios ensembles analysed for the Biebrza Valley, a general increase in average monthly air temperature is projected (Fig. 15.3a). Throughout the whole prospective average year in 2070–2100, the projected mean monthly air temperature is higher in the case of every month than that observed in 2000–2011. The biggest absolute differences between projected and contemporary observed monthly average air temperatures were defined for the Biebrza Valley for autumn and winter (October–January), whereas the smallest differences are projected for late spring (April–June).

Prospective alterations in monthly sums of precipitation derived from the analysed GCM-RCM's do not present such a clear direction of changes as the values of average monthly air temperature. However, a similar trend in precipitation increase in the winter months (November–January) can be seen (Fig. 14.3b), whereas the mean values of projected monthly sums of precipitation in the summer, projected for the time horizon 2070–2100, are slightly lower than the values observed in 2000–2011. However, the relatively wide range of uncertainty (herein referred to as the difference between the highest and the lowest prospective monthly sum of precipitation) does not allow the assumption as to whether the temporal rainfall distribution presents any unquestionable pattern.

Comprehensive analysis of observed and prospective trends in P and T quantitative variability revealed that in the time horizon 2070–2100: (1) the ongoing decrease in summer sums of precipitation will continue, (2) extreme rainfall events in the summer with increased frequency will occur, and (3) the average monthly air temperature is likely to increase, especially in winter months. Hence, it is suspected that the valuable ecosystems and wetland management in the Biebrza Valley will face a decreasing frequency of spring flooding (prospective increase of air temperature in the winter will induce a reduction in snow accumulation and consequently snowmelt flooding will be reduced). Moreover, an increasing frequency in summer flooding, with any possibility, will underpin an escalation of conflicts at the interface of environmental conservation and agricultural management, as with any likelihood the pressure on meadow drainage will increase. Moreover, it is likely that due to the general increase in air temperature, the potential evapotranspiration intensity will also increase. Thus, the water balance of wetlands in the Biebrza Valley may be affected and hydrological stress on the vegetation due to a lack of water in the soil can occur (Stagl and Hattermann 2011).

14.4 Climate-Induced Challenges for Adaptive Management – The Burning Interface of Habitats and Stakeholders

14.4.1 Mild vs. Extreme

As identified, adaptation strategies in the environmental conservation of wetlands in the Biebrza Valley in its agricultural context have to consider the observed and prospective trends in climate variability. The range of uncertainty of projected P and T changes (Fig. 14.3) permits two hypothetical scenarios to be derived – "mild" and "extreme", which can roughly be interpreted as the most positive and the most negative projections of P and T changes among the herein analysed GCM-RCM-ESs. Both "mild" and "extreme" scenarios were further analysed in order to define possible positive and negative climate change impacts on components of the environment in the Biebrza Valley, as well as for the socio-economic aspects of wetland management. Due to the reported and widely-discussed uncertainty of GCMs and RCMs (e.g. Anagnostopoulos et al. 2010; Kundzewicz and Stakhiv 2010; Wilby 2005, 2010), the authors of this paper state that the results presented herein on prospective climate change (including hypothetical "mild" and "extreme" scenarios) should not be considered as forecasts, but as a scientifically and statistically-based background for the analysis of possible, climate-induced impacts on environmental and socio-economic aspects of the Biebrza Valley.

The "mild" scenario (Fig. 14.3c, d) was derived in order to represent the most positive prospective climate change for the contemporary environment of the Biebrza Valley. The temporal variability in air temperature and precipitation provided in this scenario entails the sustainability of riparian ecosystems. The lowest possible increase in the air temperature during winter months (November–March) will sustain snow accumulation, which – along with an increased winter sum of precipitation – would underpin respectable spring flooding. Hence, nutrient removal from the floodplain, as one of the main ecosystem services of riparian wetlands (Maltby 2009), will also be sustained. Satisfactory and regular spring flooding would also entail appropriate fish spawning (e.g. in the case of the European pike *Esox lucius* whose spawning season occurs in March–April) and provide suitable conditions for migratory wetland birds such as geese (*Anserinae*), ducks (*Anatinae*), ruffs (*Philomachus pugnax*) and various waders (*Scolopacidae* and *Tringinae*). For the remaining part of the average year in the "mild" scenario of climate change, the air temperature will remain slightly higher than the average for contemporary conditions. Precipitation volumes and rainfall temporal distributions defined in this scenario assume a significant increase in the cold part of the year and a slight decrease in the summer. Though, in this way, the possibility of sizeable summer floods is likely to be reduced. Thus, the stakeholders' pressure on ecosystems by demanding intensive drainage will also be lowered. However, as none of the information on the temporal distribution of precipitation could have been derived from the analysed GCM-RCM ensembles, it is fairly possible that summer flooding in the Biebrza Valley in the "mild" scenario can still be an important management challenge in 2070–2100, if the observed increasing trend in maximum daily precipitation (Fig. 14.2c) persisted.

The "Extreme" scenario (see Fig. 14.3 c, d) was established to represent the most challenging conditions for the environment and management of the Biebrza Valley. It assumes the highest increase in the average monthly temperature among the entire set of GCM-RCM projections analysed, which is 4.1 °C in the scale of the average year in the period 2070–2100. The most significant increase in air temperature (up to 5.2 °C) was projected for the winter (December–March) and for the peak of summer (July) (Fig. 14.3c). A more polarised temporal distribution of the average monthly sums of precipitation was assumed in the "extreme" scenario.

Although the annual sum of precipitation was projected to remain almost equal to contemporary conditions, a vast reduction in precipitation in the winter (and consequently snow cover) (November-March), extensive droughts in spring (April–May), extremely wet summers (June-August) and extremely dry autumns (September) were hypothetically assumed in the "extreme" scenario on the basis of the uncertainty range of analysed GCMs-RCMs. Under these hypothetical conditions one can expect (1) sizeable summer flooding, (2) no snow accumulation and consequently a significantly reduced volume and extent of spring floods, and (3) serious droughts in the spring and autumn. As discussed in the case of the hypothetical "mild" scenario, fish, birds and plant associations of the Biebrza Valley will critically face hypothetical impacts of the "extreme" climate scenario even more, as most of the key environmental factors (flooding and (over)availability of water) are likely to be significantly altered. Hence, without a doubt, the long-term environmental conservation strategies of the BNP, in order to reach their environmental goals, will have to consider the climatic impacts on ecosystems and adapt to climate change.

14.4.2 Legislative Context of Environmental Management in the Biebrza Valley

Despite the fact that the environmental management of Polish national parks ought to be established in long-term "Protection Plans" (PPs) (Pol.: Plany Ochrony), contemporary environmental management measures implemented by the BNP (and numerous other national parks in Poland) are based on so-called "Management Objectives" (Minister of the Environment 2011). MOs become a short-term management strategy, proposed each 2 years by the national park's management, approved by scientists and authorised by the Minister of the Environment. MOs are substitutes for PPs, as the legislative context of PPs requires long-term procedures. In the case of many national parks in Poland the PPs' enhancement process is ongoing. PPs – in contrast to MOs – have to be approved by a broad audience of stakeholders (e.g. local authorities, NGOs) before they are signed by the Minister of the Environment, and therefore become much more complex and long-term management strategies. As MOs are renewed every 2 years, the management goals and measures are being (or can be) continuously verified and adjusted to current conditions and circumstances. In this regard, the environmental management implemented by the BNP can be considered "adaptive", as it (potentially) anticipates dynamic changes in particular elements of the wetland's ecosystems (Grumbine 1994; Lee 1991). On the other hand, due to the short-term set up, MOs of the BNP do not consider climate change as a driving force, which potentially induces a dynamic state of ecosystems. Moreover, contemporary stakeholder pressures that occur within the Biebrza Valley (intensification of agriculture, drainage of wetlands), although partly anticipated by the MOs, also have so far not been considered climate change-related. Therefore, although the environmental management, which is currently implemented by the BNP can be considered as adaptive, it does not emphasise the transient influence of climate. Hence, it cannot be considered climate-adapted.

14.4.3 Qualitative Impact Assessment and Stakeholder Context of Adaptive Management

Once the prospective climate-induced challenges for the Biebrza Valley were defined, then in order proceed with the first step towards the establishment of a climate-adapted management plan for the BNP, the qualitative assessment of selected, direct and indirect climate-related impacts on selected plant associations was carried out (Table 14.1). It should be stated that only selected plant associations have been analysed; in order to perform a comprehensive assessment of the ecosystem's response the whole set of species (including invertebrates, fish, birds and mammals) needs to be included. However, such an approach would have to be based on detailed and extensive ecological research, which was not the main purpose of this study. Therefore, only the most valuable plant associations were assessed. Only the best-defined, direct and indirect impacts of climate change on the plant associations of the Biebrza Valley were considered. The preliminary assessment was based on the estimation of projected positive/ambiguous/negative (quantified as 1, 0 and -1 respectively) influences of climate and climate-induced-management measures to habitats.

An expert knowledge- and literature-based review of plant associations' resilience to defined impacts revealed that valuable Natura 2000 associations such as *Caricion davallianae, Caricion nigrae, Alopecurion pratensis* and *Molinion caeruleae* (in general mire meadows) are among the most sensitive to the negative impacts of climate change in the Biebrza Valley. This is mostly due to the limitation of water as well as altered flooding in the summer, and due to the prospective spatial expansion of drainage. As some significant research on plant ecology in the Biebrza Valley with hydrological reference was already done (see e.g. Olde Venterink et al. 2009; Wassen et al. 1990), the presented expert-knowledge- and literature-based preliminary impact assessment approach can be critically reviewed in a more detailed way for particular environmental elements of the Biebrza Valley, with a strong, site-specific context. Nevertheless, it appears that the adaptation of management strategies in the BNP should – as a priority – consider buffering potentially negative direct and indirect climate-change impacts to the contiguity and function of mires.

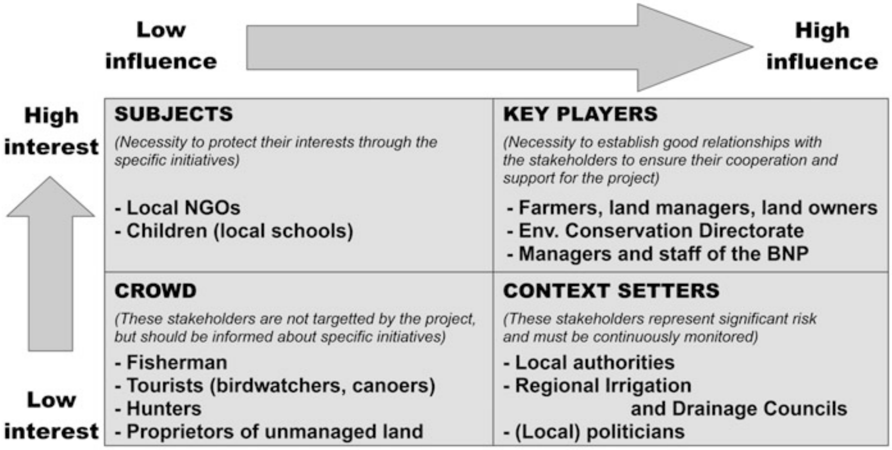
Indirect, negative, climate-related pressures on the ecosystems of the Biebrza Valley, such as drainage expansion, mowing cessation and meadow encroachment (see Table. 14.1), are clearly related to stakeholders' attitudes as to the climate-induced impacts. Therefore, it is likely that without appropriate stakeholder

Table 14.1 Qualitative assessment of direct and indirect prospective climate-related impacts to selected plant associations in the Biebrza Valley

Selected plant associations of the Biebrza Valley	Climate-related impacts to habitats		Climate change-related stakeholder pressures and habitat responses			**Σ of negative impacts**	**Σ of positive impacts**
	Increased frequency and volume of summer floods	Decreasing frequency and volume of spring floods and temporal switch in spring flooding	Drainage	Cessation of mowing	Spontaneous secondary succession of shrubs on open meadows		
Bidention tripartite	0	0	–1	0	0	**0**	**0**
Alnion glutinosae	1	1	–1	0	0	**1**	**2**
Alnion glutinoso-incanae	1	1	–1	0	0	**1**	**2**
Alopecurion pratensis	–1	–1	–1	–1	0	**4**	**0**
Arrhenatherion elatioris	0	0	0	–1	–1	**2**	**0**
Betulo-Salicetum repentis	0	0	–1	–1	–1	**3**	**0**
Calthion	0	–1	–1	–1	0	**3**	**0**
Caricion davallianae	–1	–1	–1	–1	–1	**5**	**0**
Caricion lasiocarpae	0	0	–1	–1	–1	**3**	**0**
Caricion nigrae	–1	–1	–1	–1	–1	**5**	**0**
Carpinion betuli	0	0	0	0	0	**0**	**0**
Corynephorion canescentis	0	0	0	0	–1	**1**	**1**
Dicrano-Pinion	0	0	0	0	0	**0**	**0**
Filipendulion ulmariae	0	–1	–1	0	1	**2**	**1**
Koelerion glaucae	0	0	0	–1	–1	**2**	**0**
Magnocaricion	0	–1	–1	–1	0	**3**	**0**
Molinion caeruleae	0	–1	–1	–1	–1	**4**	**0**
Phragmition	1	0	–1	0	0	**1**	**1**
Polio-Callunion	0	0	0	0	–1	**1**	**1**
Potentillo albae-Quercion	0	0	0	0	0	**0**	**0**
Salicetum pentandro-cinereae	0	0	–1	0	0	**1**	**1**
Spraganio-Glycerion	0	0	–1	0	0	**1**	**1**
Vacc.uliginosi-Betul. pubesc.	0	0	–1	0	0	**1**	**1**
Violion caninae	0	0	0	0	–1	**1**	**1**

1 – positive impact, 0 – ambiguous impact, –1 – negative impact. Only the "extreme" climate scenario for the Biebrza Valley was considered possible, the most challenging for ecosystem management. Associations of the most significant negative response are marked grey

communication, climate-adapted management of any kind will fail to effectively achieve its environmental goals (Lee 1991). Environmental conservation – especially in situations where a vast share of the protected area remains private (such as in the BNP) – requires the identification of stakeholders and the adjustment



	Low influence	High influence
High interest	**SUBJECTS** *(Necessity to protect their interests through the specific initiatives)* - Local NGOs - Children (local schools)	**KEY PLAYERS** *(Necessity to establish good relationships with the stakeholders to ensure their cooperation and support for the project)* - Farmers, land managers, land owners - Env. Conservation Directorate - Managers and staff of the BNP
Low interest	**CROWD** *(These stakeholders are not targetted by the project, but should be informed about specific initiatives)* - Fisherman - Tourists (birdwatchers, canoers) - Hunters - Proprietors of unmanaged land	**CONTEXT SETTERS** *(These stakeholders represent significant risk and must be continuously monitored)* - Local authorities - Regional Irrigation and Drainage Councils - (Local) politicians

Fig. 14.4 Stakeholder classification matrix – case study of stakeholder dialogue on valuable and protected wetlands management in the Biebrza Valley (Boumrane 2007, after Zarzo Fuertes et al. 2011, modified)

of communication strategies to achieve the goals of ecological sustainability conservation. In this regard, stakeholders in environmental management in the BNP were identified and grouped in order to define their importance and establish appropriate dialogue (Fig. 14.4).

It is likely that appropriate stakeholders' information about the measures that they plan to apply (e.g. long-term strategies for mowing, participation in environmental schemes, change in the type of land use) can be included in impact-assessment and ecosystem response analysis with the use of modelling tools (e.g. Wassen et al. 2011). Such an approach would become an integrated feedback assessment tool for the climate change – stakeholder reaction and environmental response.

Four groups with different levels of interest and influence were identified: key players, context setters, subjects and the crowd (Fig. 14.4). Among the stakeholders, which were defined as the "key players" in the adaptive management process in BNP, there are farmers, land owners, land managers and the Regional Environmental Conservation Directorate (RECD) *(Pol.: Regionalna Dyrekcja Ochrony Środowiska)*. In case of the most challenging discussed "extreme" scenario of climate change in 2070–2100, the most critical reaction of those groups is expected due to their legislative context. Farmers, land owners and land managers, all substantially benefitting from the presence of the unique habitats on their land (by obtaining EU environmental subsidies for rare species such as *Acrocephalus paludicola* and *Crex crex*), are expected to increase their pressure to drain the Biebrza mires as those measures are subsidised. In this regard, the RECD, as the key player responsible for management measures approval on Natura 2000 sites, will face the appropriate environmental evaluation of prospective initiatives, such as drainage. However, the utmost challenge in this process will be to deal with valuable habitats threatened by the same, direct climate change impacts as for the agriculture. The discussed, possible increase in the frequency of summer flooding can be given as an exemplary challenge for both agriculture and habitats, being equally negative for ecological function of particular habitats (*Caricion davallianae* and *Molinion caeruleae*) as well as for the agricultural use of wetlands (mowing will be impossible due to the high water level). This problem, already faced by the environmental management authorities in NE Poland, has to be widely-discussed and analysed in a broader context. Hence, the feedback from the other stakeholders should be obtained (e.g. local authorities, local NGO's and tourists), in order to set up the clear criteria for adaptive decision making and to minimise the negative influences of climate change on the ecosystems. It should be stated herein that some positive results from stakeholder dialogue conducted for numerous years in the form of environmental education in schools in the Biebrza Valley, supervised by the BNP, have already been obtained. The perception of environmental goals in the hierarchy of aspects remains positive in the group of children among the inhabitants of the Biebrza Valley. Despite that, still further emphasis has to be placed on climate change-related challenges for wetlands and management in the Biebrza Valley in environmental education.

Experience, which we obtained in the BNP in regard to stakeholder communication, allows the conclusion that climate change itself is often opposed, if not referred to a phenomena experienced by people. Moreover, climate change is often considered as a global problem and thus not relevant as a local challenge. Therefore, if in the stakeholder's perception climate change is denied, any further steps aimed at management adaptation and measure proposal fails to become successful from the very beginning of the process. It is worth noting that the effects of (changing) climate on the environment and agriculture continue to be denied, even among the environmental managers in the study area. Such a status is also assumed to occur worldwide, within the other protected areas. Therefore, despite the variability of levels in stakeholder classification and stakeholder's environmental consciousness, climate-related pressures to management and ecosystems has to be emphasised and communicated more and more efficiently.

14.4.4 Criteria of Climate-Adapted Wetland Management in the Biebrza Valley

Once the background and contexts of adaptive management in the Biebrza Valley are preliminarily revealed (Sects. 14.3.1, 14.3.2 and 14.4.1, 14.4.2, 14.4.3), contemporary management measures (generalised, after Minister of Environment 2011) are evaluated in order to indicate potential opportunities for management adaptation (Table 14.2).

As revealed by Grumbine (1994), Kadoya and Washitani (2007) and Lee (1991), management adaptation should continuously refer to the current status of ecosystems and species. Therefore, on top of impact assessment and stakeholder feedback, the well-established monitoring of the efficiency of the applied measures should become an inherent element of adaptive decision making. Due to the various

Table 14.2 Selected management measures applied by the Biebrza National Park, to be considered and adjusted in adaptive ecosystem management

No.	Management measure	Climate-induced challenges	Monitoring-based adaptation criteria
1.	Strict protection of valuable ecosystems	Change in abiotic factors (alteration of water level and temperature) can induce generic deterioration of protected habitats; shift in species	Monitoring of ecosystem status and species composition (change the boundaries of strict protection/ switch to active protection); monitoring of plots with no management measures applied;
2.	Active protection of selected habitats	Change in abiotic factors (alteration of water level and temperature) can induce generic deterioration of protected habitats; shift in species	Monitoring of ecosystem status and species composition (change the boundaries of active protection/switch to landscape protection); monitoring of plots with no management applied (e.g. similar habitats mown and unmanaged)
3.	Invasive species management	New invasive species can occur, which can be even more competitive to native species than those already defined	Reduction in invasive species populations, ecological monitoring, habitat monitoring
4.	Purchase of private grounds within the boundaries of the Biebrza National Park	More frequent summer flooding can encourage land proprietors that it is more feasible to sell certain portions of their land; possible reduction of price per hectare	Continuous and well established stakeholder dialogue, ground purchase strategies flexible to dynamic habitat distribution
5.	Increase in bird population density by meadow mowing and biomass removal	Summer flooding can limit the abilities of mowing and biomass removal; possible fluctuations in bird species populations regardless of applied management measures	Monitoring of bird population in a trans-national context, site-specific flexible adjustment of areas to be mowed
6.	Reduction in shooting of wild boar, racoon dog and fox	Possible shift in animal habitats and population density	Feedback with local hunting associations as to contemporary reduction in shooting and game species population dynamics
7.	Hydrographic network restoration (Rivers Jegrznia and Ełk)	Possible change in discharge regime of rivers can influence water management and negatively affect flood control; possible conflicts and increase in drainage pressure	Continuous hydrological monitoring and stakeholder dialogue; continuous feedback from farmers, land owners and land proprietors
8.	Open meadow maintenance by pasture grazing (Polish konik horses)	High groundwater levels can limit grazing and meadow productivity; dry summers can periodically increase meadow productivity (enhancement in biogeochemical changes of the peat)	Control of Polish konik population; control of grazing intensity, flexibility in pastures delineation

Based on Minister of Environment (2011)

potential responses of habitats and species to both management measures and climate-related impacts (e.g. Table 14.1.), each of the defined challenges for the environment of the Biebrza Valley and the stakeholders should be taken into consideration in the broad context of internal and external threats.

Despite the fact that the MOs are renewed every 2 years, the review of those documents revealed that not much attention is paid to any form of climate-proof management adaptation in the BNP. Neither the dynamic status of ecosystems nor climate changes were so far defined as threats to the ecosystems of the Biebrza Valley. In the long-term, more flexibility is needed in establishing management measures such as invasive species management, mowing, biomass removal and pasture grazing. It is likely that the contemporary setup of strictly/actively protected areas, which is not critically reviewed on the basis of habitat monitoring and species composition, will fail to fulfil sustainable environmental conservation requirements. The transient character of physical processes induced by climate as well as ecosystem dynamics can result in the deterioration of environmental values. In habitats of the most climate-change sensitive plant associations (*Caricion davallianae, Caricion nigrae, Alopecurion pratensis* and *Molinion caeruleae*), the lack of flexibility in management implementation is likely to induce habitat deterioration by the overexploitation of certain vegetation patches by mowing, or by the cessation of mowing in wetter conditions. Hence, the establishment of an effective “monitoring-decision making” feedback tool is needed in order to prevent negative management influences on the environment. As such, some decision support tools were already proposed for the Biebrza Valley (Chormański et al. 2009; Kardel et al. 2011). However, further interactive and practice-orientated approaches should be developed in order to manage climate-induced impacts on stakeholders and ecosystems. Even though the climate change influence on the Biebrza Wetlands was not so far revealed in detail, a knowledge base and scientific support regarding the hydrology and ecology of the Biebrza Valley is rich and can be successfully applied in wetland adaptive management.

Despite the intensified monitoring of ecosystems and their species composition, further functional assessment is required in order to analyse the continuous feedbacks between the ecosystem status, response to management and resilience to climate change. It is certain that when facing the climate-related pressures, certain ecosystems will require newly developed measures. Contradictorily, it is likely that some other ecosystems will not require any active management measures as they will either evolve into the new ecosystems, adapted to the changing conditions, or the new (climate) conditions will be sufficient in order to maintain the ecosystem in an appropriate ecological status. Therefore, the adaptive management should require extensive ecosystem monitoring in which both the “managed” and “unmanaged” ecosystems will be critically reviewed as to the (1) efficiency of the applied measures in order to conserve the nature, (2) influence of climate and ecosystem evolution processes on the habitat with no measures applied, and (3) possibility of new measures development and application, which will be adjusted to possible climate influences and accepted by the managers and stakeholders. The iterative, management-response feedback loops (Fig. 14.5) should therefore

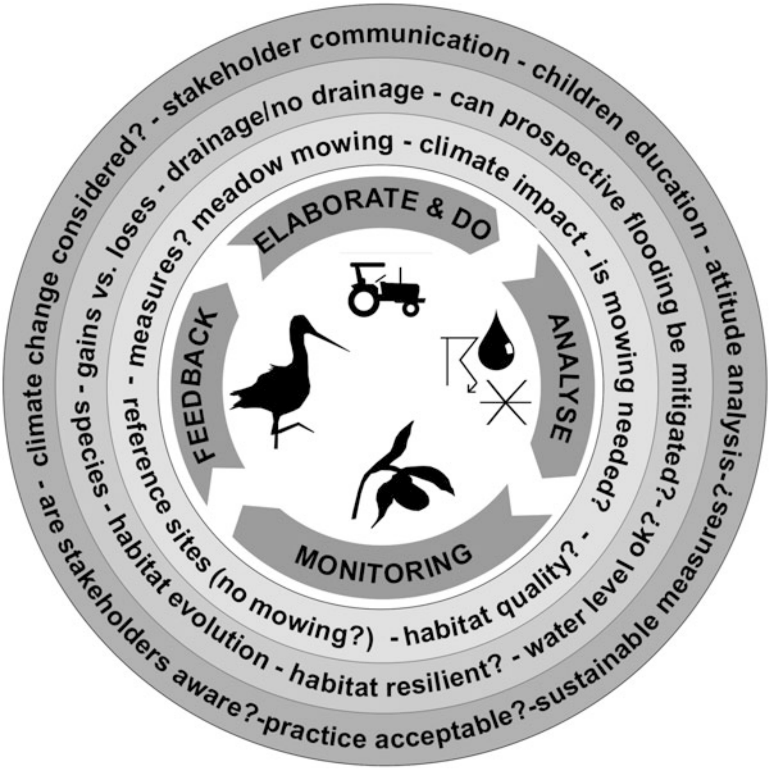


Fig. 14.5 Three levels of adaptive climate-proof wetland management: feedback on direct climate change impacts to habitats (e.g. is meadow mowing needed?), feedback on climate-driven-human enforced impact to habitats (e.g. drainage of wetlands – gain or loss?) and the stakeholder communication process (what, how and who to communicate?)

contain the analysis of three possible levels of complexity: climate-ecosystems, climate-management-ecosystems and climate-communication-management-ecosystems.

In the case of Biebrza Valley it is likely that some plant alliances facing the climate change influences (e.g. *Caricion nigrae* and *Molinion caeruleae*), such as increasing water levels, will no longer require mowing (ref. to Tables 14.1 and 14.2) as the secondary succession of encroachments will be naturally limited. Management flexibility based on direct, site-orientated monitoring should allow the decision to be made in such examples. Also the technical and relatively invasive measures of ecosystem restoration (such as blocking ditches, topsoil removal) should in this regard be monitored and referred to observed and projected climate change responses. It can appear that the natural evolution of ecosystems influenced by climate (e.g. higher hydration of soil due to higher precipitation and reduced draining influence of rivers and canals to adjacent wetlands due to higher water levels in the summer induced by short but heavy rainfalls projected for the future within the Biebrza Valley) is likely to evoke similar "restoration" processes that the undertaken technical measures. Furthermore, the continuous monitoring of stakeholder's consciousness and attitudes (indicated in the outermost ring in Fig. 14.5) will allow the selection and application of the best strategies for communication in order to sustain appropriate, climate-proof adaptive environmental management in the Biebrza Valley.

14.5 Conclusions

With no regard to the uncertainty of the GCM-RCM-emission scenarios-based climate change projections, the management of the BNP should implement climate-adapted management strategies which consider the range of various prospective climate impact projections. Strategies should anticipate the potential increase in summer flooding frequency, temporal and quantitative changes in spring flooding as well as indirect, climate-induced pressures on ecosystems, herein defined as the potential escalation of drainage in the valley and also as the secondary succession of trees and shrubs in mire meadows.

Since following the reports of Kossowska-Cezak (1984) and Kossowska-Cezak et al. (1991), the climate of the Biebrza Valley was not analysed in detail, it is essential to revisit their results on the basis of observations over the last 20 years. Such research would critically reveal the long-term changes in multiple elements of the climate and could become a comprehensive baseline for the establishment of climate change scenarios and their impacts on the ecosystems of the Biebrza Valley.

All the contemporary environmental management measures implemented so far by the BNP and local stakeholders are likely to be affected by the observed/ prospective climate change.

The most negative prospective climate scenario for the Biebrza Valley in the time horizon 2070–2100 assumes a significant increase in precipitation in summer (which will result in an increased frequency of summer flooding), a decrease in precipitation in autumn, winter and spring (which will induce a reduction in spring flooding and underpin the hydrological stress on wetland vegetation at the start of the growing season) and a general increase in the average air temperature (which will induce an increase in potential evapotranspiration in the summer and reduction of snow accumulation in the winter).

Climate change impacts to wetlands can be defined as direct (climate change influences the environment: less rain – less flooding – habitats induced) and indirect (climate change entails the reaction of managers and stakeholders, which consequently induce habitats: more rain – flooding mitigated by the drainage – declining groundwater levels challenge the wetlands). Both levels of impacts should be anticipated in climate-adapted environmental management.

Plant associations such as *Caricion davallianae, Caricion nigrae*, *Alopecurion pratensis* and *Molinion caeruleae*, are suspected to be among the most sensitive to negative impacts of climate change in the Biebrza Valley. While for certain habitats projected impacts of climate change are positive, for others they seem to remain negative (e.g. increased frequency of summer flooding: positive for *Phragmition*, negative for *Caricion davalianae*).

If the hydrological impacts of climate change remained continuing the trends observed in 1951–2009, reactions of stakeholders (mostly farmers and land owners) will induce indirect, but still climate-related pressures to ecosystems, among which the most important and the most negative to wetlands seems to be the drainage.

In the case of numerous management measures, which have so far been successfully implemented in the BNP (hydrographic network restoration, purchase of private grounds), the enhanced establishment of stakeholder dialogue is necessary in order (1) to underline the awareness of climate change impacts to the management and (2) to obtain appropriate feedback – a key to successful management adaptation. Observing the attitudes of stakeholders we state, that still more emphasis should be put in order to present the climate change as a local problem than – as so far considered – a global undefined phenomenon.

More spatial flexibility is needed when setting up both short- and long-term management measures on wetlands in the Biebrza Valley, especially due to meadow mowing and the establishment of strict and active protection. It is likely that the contemporary management measures will lose their conservation efficiency if the continuous feedback of direct climate influences, indirect climate influences (by changing management) and natural evolution of ecosystems was not considered in environmental management on wetlands in general, and in the Biebrza Valley in particular. Adaptive approaches in environmental management of wetlands (and the Biebrza Valley in particular) should be aimed at (1) continuous and extensive monitoring of management measures efficiency along with (2) analysis of reference, unmanaged sites dynamics. Once the climate impacts were defined in positive feedbacks to ecosystem status, management measures such as meadow mowing should be critically reviewed as to their ecological efficiency.

Facing the presented results we conclude that any prospective, long-term conservation and maintenance strategies, which are planned to be implemented in valuable wetlands with no particular regard to possible direct and indirect climate-induced alterations on hydrological processes, will fail to fulfil the requirements of sustainable ecosystem management.

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Chapter 15
Habitat Changes Caused by Sea Level Rise, Driven by Climate Change in the Northern Adriatic Coastal Wetlands, Slovenia

Mitja Kaligarič and Danijel Ivajnšič

15.1 Seacoast and Climate Change

Coastal zone, as a boundary between sea and land is the most dynamical and sensitive area, which comprises a great variety of natural ecosystems and resources (Palazov and Stanchev 2006). Coastal habitats are already one of the most severely endangered habitats due to intensive land-use changes occurring during the last decades. Most changes are driven by tourism, which has caused substantial destruction of most endangered habitats such as coastal dunes. The second threat is increasing area of ports, which require more and more space for containers or car terminals. Urbanisation in general has caused an important pressure to coastal areas, which offer higher living standards, better economic conditions, job and education possibilities and favourable climate. Therefore, immigration pressure to coastal areas is substantial. Besides that, there is also agriculture, developed in adjacent areas to the coast, driven by favourable climate and increased requirement of fresh products. The constantly increasing anthropogenic pressure is additionally intensified by climate change effects, among which the sea level rise is a serious threat. Sea level rise is a parameter which – in contrast to many other climatic parameters, being also congruent among – is showing quite clear trends. However, factors which cause changes in morphology of coasts are numerous and include sediment supply, tidal currents, wave action, extreme weather events (Cooper and Pilkey 2004), and also the subsidence of the surface (Lambeck et al. 2004). Baustian et al. (2012) reports that in certain situation, such as high sedimentation of both organic and inorganic materials coastal wetlands may be able to keep pace with rising sea level. There are different projections of the sea level rise in different coastal areas across the globe; thus the only relevant basis for reliable predictions are local measurements on the concrete studied sites. For instance, one study in

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DOI 10.1007/978-94-007-7960-0_15,

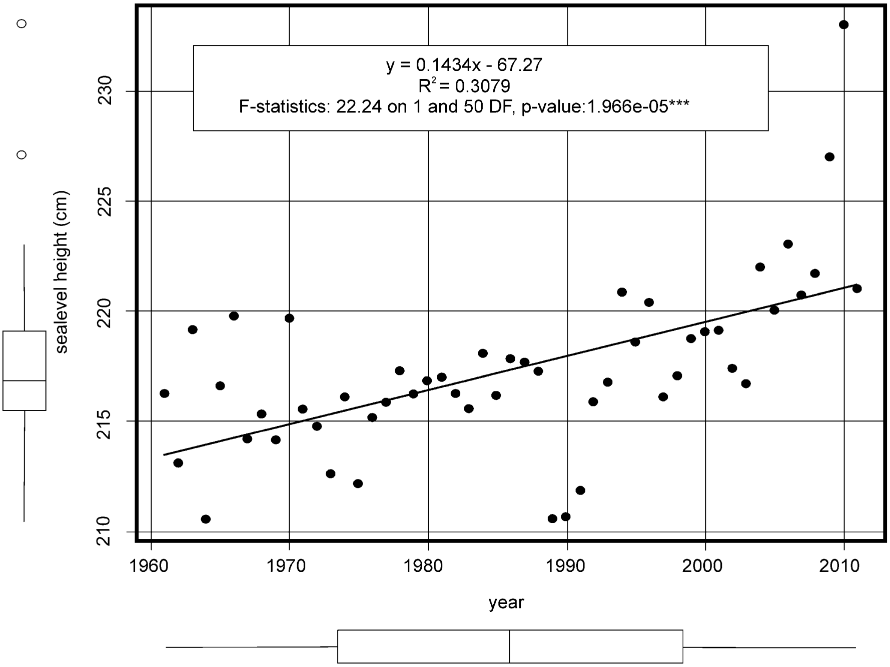

Fig. 15.1 Average sea level trend (0.14 cm year^{-1}) and some statistical parameters for the sea level height measuring station Koper (1961 to 2011; ARSO 2012)

Australia (Elumpe Akumu et al. 2011) demonstrated that a metre rise in sea level could decrease inland fresh marshes from 225.67 to 168.04 km^2 by the end of the century.

In that light we wanted to address the following research questions in the present study: (1) Is sea level rise a serious threat for coastal wetlands on the sedimentary coast of the Northern Adriatic – what are the trends of sea level rise in the nearest measuring point to the two coastal protected areas with Natura 2000 (N2000) habitat types? (2) Do the present spatial distribution of coastal habitat types (*a habitat map*) match with micro-elevations (*digital elevation model*)? To which extend? (3) Is it possible to develop a relevant habitat transition model using different scenarios of sea level rise? (4) Which mitigation measures are feasible?

The data about sea level rise are available from the sea level height measuring station Koper from year 1961 to year 2011 (ARSO 2012; Fig. 15.1). But the trend of sea level rise is more realistic when divided in two intervals. The first one from 1961 to 1985 is not statistically significant ($p = 0.247$, slope = 0.02 cm year^{-1}); however, the second one from 1986 to 2011 shows strong statistical significance ($p = 0.0003$, slope = 0.43 cm year^{-1}; Fig. 15.2).

During the twenty-first century, global average sea level is expected to rise considerably faster than in the 20th, even if a common conclusion from all the coupled atmospheric-ocean general circulation models is that the sea level change

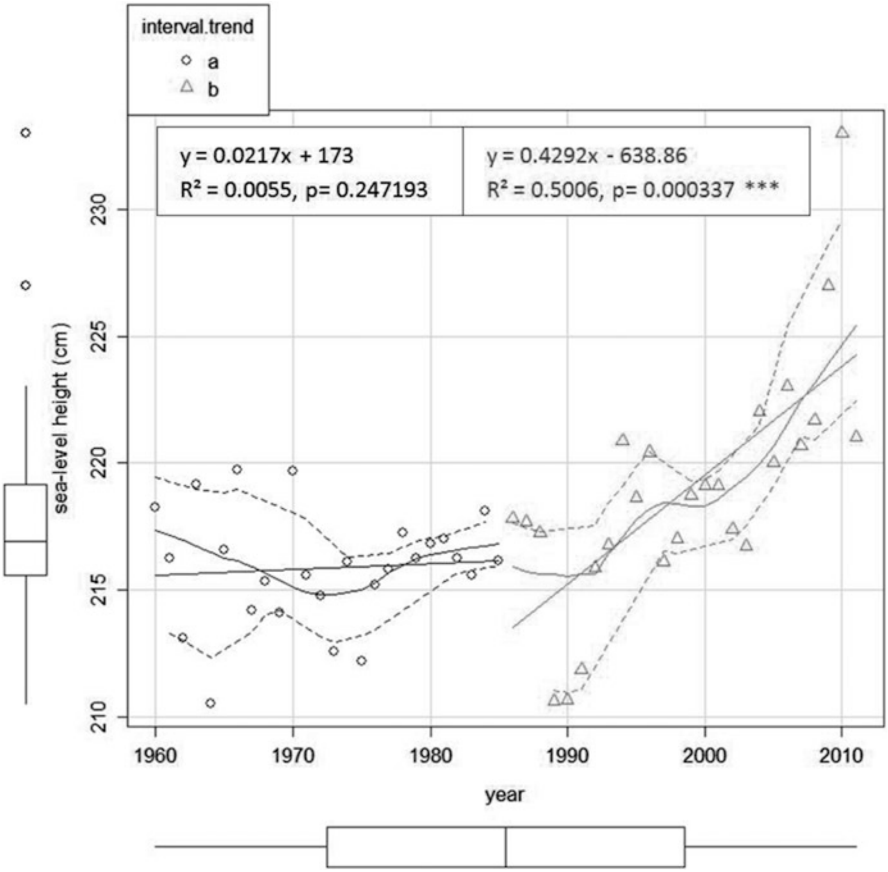

Fig. 15.2 Trend of sea level rise, divided into two intervals, where the latter shows statistical significance (p = 0.0003, slope = 0.43 cm year^{-1})

will be far from uniform (Gregory et al. 2001; IPCC 2007). Thus, we believe that it is more proper to use the second trend – although very pronounced – to predict the time when the habitat transition scenarios in both study areas will occur.

It is also possible to make predictions of time frames (year ± standard error) according to the sea level rise scenarios with two different sea level trends in Koper (Table 15.1).

We can assess from the above shown data that the scenarios will be realised in quite short time if the trends (1960–2011 and 1986–2011) will continue. Comparable results have been shown also for global sea level rise (e.g. Church et al. 2008). That means that the countermeasures to mitigate the habitat changes should be planned for a period of 10–20 years from now if we aim to prevent drastic changes.

Table 15.1 Prediction of time frames (year ± standard error) according to the sea level rise scenarios with two different sea level height trends in Koper

				Rising sea level scenarios			
ST	a	M	Trend	L 5 cm	L 10 cm	L 15 cm	L 20 cm
Koper	1960–2011	1	$Y = 0.1434X - 67.27$	2045 ± 3.31	2080 ± 3.48	2115 ± 3.78	2150 ± 4.10
Koper	1985–2011	2	$Y = 0.4292X - 638.86$	2015 ± 1.34	2027 ± 1.62	2038 ± 1.89	2050 ± 2.16

L 5, L 10, L 15 and L 20 cm: sea level rise scenarios for 5, 10, 15 and 20 cm
ST sta-tion, *a* year, *M* model, *L* sea level rise scenarios

15.2 The Investigated Areas

The two most important coastal wetlands in Slovenian seacoast are Sečovlje Salina (Sečoveljske soline) and Škocjan Inlet (Škocjanski zatok). Sečovlje salina area is a Nature Park established in 2002, which covers about 650 ha along the Slovene-Croatian boundary in the extreme south-western part of Slovenia. Its northern part, where active salt-making is still taking place, is called Lera. From the Park's southern part, called Fontanigge, it is separated by the bed of the Drnica stream. The Fontanigge is full of large basins which, are being gradually overgrown by different types of halophile vegetation; many of them are classified as Natura 2000 habitats. The main freshwater vein is the Dragonja River, which after few tens of kilometres joins the sea at the Sečovlje salt-pans and creates a small estuary. Despite the salina having been made by man in early Middle Ages, it is a mosaic of natural habitats today, which contains not less than 6 Natura 2000 habitat types!

Škocjan Inlet Nature Reserve is a Mediterranean wetland established in 1998 and covering an area of 122 ha. Located at the outskirts of the town of Koper, the reserve is commonly known as 'the green heart of Koper'. After the restoration in 2007, Škocjan Inlet has regained its past biodiversity or it has even been improved in terms of surface of coastal Natura 2000 habitats. After the vegetation succession period of five years a lagoon with artificial islets at different altitudes enabled – the development of mainly two valuable habitats dominated with halophytes.

15.3 Targeted Natura 2000 Habitats

There are two non-vegetated habitat types which are important predominately for marine fauna and birds. Estuaries (N2000 code 1130, PAL.CLASS.: 13.2, 11.2) are considered as a marine habitat and actually were not a subject of our study. There are three estuarine habitats in the Sečovlje Salina and none in Škocjan Inlet. "Mudflats and sandflats not covered by seawater at low tide" (N2000 code 1140, PAL.CLASS.: 14) constitute a habitat type, widespread in both investigated areas, important mainly for bird nesting and feeding. In both areas we can find very small patches of the "tall rush salt marshes (communities of *Juncetaliamaritimi*)" or "rush salt marshes dominated by *Juncusmaritimus* and/or *J. acutus*" (N2000 code

1410, PAL.CLASS: 15.6 or 15.51). The tall rush salt marshes occur in a water regime similar to freshwater marshes dominated by freshwater *Juncus* species. The inflow of fresh saltwater is essential to maintain a certain level of nutrients in these marshes. Small patches of "*Spartina* swards (*Spartinionmaritimae*)" (N2000 code 1320, PAL.CLASS.: 15.2) occur at the edge of the Sečovlje Salina area, where this type colonise the stable muddy islets at the mouth of the Dragonja river, disturbed at high tide and by sea turbulence. It was found also in similar conditions along the lower part of the S. Giorgio channel close to its mouth. It supports also brackish water, which should be rich in nutrients.

The most widespread and also the most ecologically extreme coastal wetland habitat type vegetated with vascular plants, is "*Salicornia* and other annuals colonizing mud and sand" (N2000 code 1310, PAL.CLASS: 15.1). It is formed mostly of halophyte annuals, where annual glassworts (*Salicornia* spp.) are dominant. This habitat occurs on periodically inundated mudflats or sand. It is characterised by poor – soil nutrient status, low oxygen conditions and exposure to the regular tidal regime. Although this glasswort-dominated vegetation is considered as one habitat type, it consists of two types, each dominated by one glasswort species: *Salicornia patula*, a diploid, and *Salicornia emerici*, a tetraploid. The second habitat type, developed on higher micro-elevation, is "Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornetea fruticosi*)" (N2000 code 1420, PAL.CLASS.: 15.6). It is composed of perennial halophytes. The dominant plants are *Halimione portulacoides*, *Inula critmoides*, *Limonium angustifolium, Atriplex hastata, Artemisia coerulescens* and shrubby *Sarcocornia* (*Arthrocnemum*) species (*S. fruticosa* and *A. glaucum*). It occurs mainly at the edges of the abandoned salt pans of the Sečovlje salina, on elevated sites, banks and enclosed muddy surfaces with only temporary inundation.

15.4 Methods

Different methods were used address the scientific questions set within this study – from field vegetation mapping, field geodetic measurements, LIDAR scanning to spatial statistics.

- Habitat mapping (PHYSIS typology, 1 m resolution)
  The PHYSIS typology, based on Palaearctic classification (Devilliers and Devilliers-Terschuren 1996), was chosen as one of the most accurate for habitat mapping. The hierarchically based PHYSIS enables us to refine the habitat type with additional information about the vegetation level. This classification was adopted and modified for Slovenian conditions (Jogan et al. 2004). The 'hybrids' (transitional forms, mixtures or mosaics) between two habitat types were also used in field mapping. The PHYSIS typology is also the ground for FFH codes (Natura 2000 codes).
- Determination of micro-elevations (two methods: geodetic; LIDAR)

Geodetic measurements were carried out by a professional geodesist, using a high resolution GNSS (Global Navigation Satellite System) instrument with geodetic of 1 cm. Afterwards we scanned the study area with LIDAR technology. The data were taken from 650 m height with a recording frequency of 142 kHh and a flight speed of 85 kts. Thus we obtained an average point density of 4 points per square metre and a horizontal accuracy of 10 cm.

- Attribution of micro-elevation intervals to mapped habitat types
  We used the ArcGIS Spatial analyst tool to combine the elevation data with the habitat type map and thus define the micro-elevation intervals for each habitat type aggregate. The modelled scenarios are therefore very dependent on the morphology of the study area relief.
- Habitat transitions model (ArcGIS, Idrisi Selva software)
  We built a GIS-based habitat transition model to predict the spatial distribution of protected habitats according to the sea level trend and prior to defined scenarios of sea level rise (5, 10, 15 and 20 cm).

15.5 Habitat Shifts and Habitat Loss According to Different Scenarios of Sea Level Rise

We built a prediction model which demonstrated to which degree, how and where coastal habitats will shift to each other and decrease their surfaces in total. In Sečovlje Salina the GNSS geodetic method was applied to obtain micro-elevations in different habitat types. Only then the four scenarios of sea level rising have been applied (Fig. 15.3).

In Tables 15.2 and 15.3 the percentage shares of the habitat type areas (based on 2010 mapping) and the modelled scenarios of sea level rise in Sečovlje Salina and Škocjan Inlet study areas are shown.

As outlined in the methods section, the results are dependent on the micro-relief structure of the study area and therefore they differ from each other. In Sečovlje Salina Natural Park, the area of N2000 habitat type – “mudflats and sandflats not covered by seawater at low tide (code 1140)” – is decreasing in all modelled scenarios (L 0–L 20 cm). This habitat type will lose almost 54 % of the predicted area. Compared to Škocjan Inlet Nature Reserve, the same habitat will gain a few percentage points in area in the case of sea level rise of 5, 10 and 15 cm, and will then decreases when the water rises by 20 cm, representing just 6 % of the total area.

In both areas the Mediterranean glasswort swards (N2000 code 1310) are decreasing in land cover, except for the scenario involving a sea level rise of 10 cm in Sečovlje Salina Nature Park, where the percentage area increases to almost 21 %. The habitat type where we detected the largest difference in predicted spatial distribution is the Mediterranean saltmarsh scrubs (N2000 code 1420). In Škocjan Inlet Nature Reserve, this habitat covers 7 % of the total area. If the sea level rises by 5 cm, the habitat type will represent almost 25 % of the reserve area. The predicted area then decreases at the next stage of sea level rise, but it still represents a greater percentage of the area than at present time. In Sečovlje Salina Nature Park

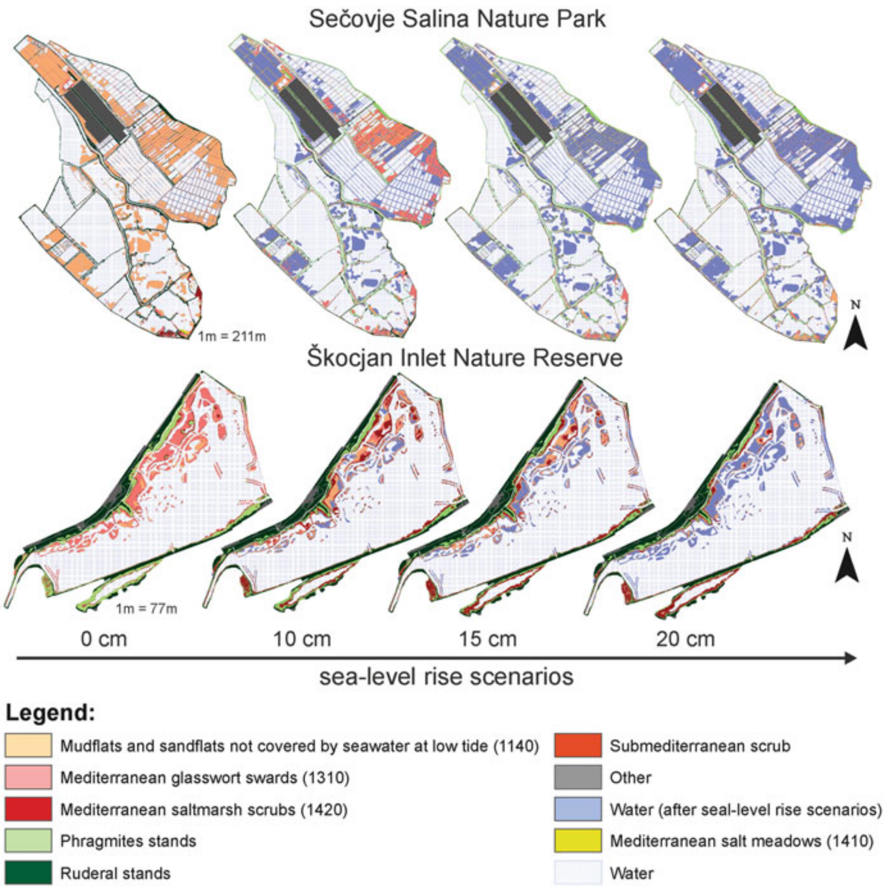

Fig. 15.3 Predicted spatial distributions of habitat types (aggregates) in the case of sea level rise for 0, 10, 15 and 20 cm in Sečovlje Salina Nature Park and Škocjan Inlet Nature Reserve study areas

Table 15.2 Percentages of habitat type area according to 2010 mapping and the modelled scenarios of sea level rise in Sečovlje Salina Nature Park study area

Sečovlje Salina Nature Park study area	Sea level rise scenarios				
Habitat type	L 0 cm	L 5 cm	L 10 cm	L 15 cm	L 20 cm
Mudflats and sandflats not covered by seawater at low tide (1140)	56.56	22.25	7.13	5.94	3.28
Mediterranean glasswort swards (1310)	7.70	8.01	20.76	3.54	5.46
Mediterranean saltmarsh scrubs (1420)	2.13	0.61	0.57	0.75	2.36
Phragmites stands	2.49	4.21	0.57	15.51	13.15
Ruderal stands	16.23	13.79	14.54	1.19	1.10
Submediterranean scrub	0.47	0.46	0.45	0.45	0.46
Other	14.09	13.94	13.79	13.64	13.48
Water	0.01	0.35	37.53	57.32	59.54
Mediterranean salt meadows (1410)	0.32	36.38	2.30	1.66	1.17

L 0 cm: habitat types defined with relative micro-elevation
L 5, L 10, L 15 and L 20 cm: sea level rise scenarios for 5, 10, 15 and 20 cm
L sea level

Table 15.3 Percentages of habitat type area according to 2010 mapping and the modelled scenarios of sea level rise in Škocjan Inlet Nature Reserve study area

Sečovlje Salina Nature Park study area	Sea level rise scenarios				
Habitat type	L 0 cm	L 5 cm	L 10 cm	L 15 cm	L 20 cm
Mudflats and sandflats not covered by seawater at low tide (1140)	7.23	11.17	14.02	13.16	5.89
Mediterranean glasswort swards (1310)	33.53	8.26	7.48	4.84	3.75
Mediterranean saltmarsh scrubs (1420)	3.75	24.56	18.87	14.87	12.43
Phragmites stands	22.47	17.70	15.35	16.36	11.99
Ruderal stands	25.22	26.73	26.39	25.94	25.41
Other	7.80	7.21	6.63	6.14	5.66
Water	0.00	4.36	11.85	21.71	34.87

L 0 cm: habitat types defined with relative micro-elevation

L 5, L 10, L 15 and L 20 cm: sea level rise scenarios for 5, 10, 15 and 20 cm

the same habitat covers just around 7 % of the total area and will (L 5, L 10 and L 15 cm) lose more than a half of its recent land cover in the predicted scenarios. In the worst case scenario, the habitat will gain some space and will represent 0.23 % more area than today. The overall reduction of coastal habitats was already described as "coastal squeeze" in Australia (Bayliss et al. 1997) – obstacles, roads or settlement prevent the landward migration of some ecosystems such as salt marshes.

Prediction of the spatial distribution of the *Phragmites* stands is problematic. The correlation coefficient between the relative elevation and the *Phragmites* stands habitat area cover is one of the lowest, or – in other words – the frequency distribution of the relative heights is far from normal, which means that the habitat occurs in almost all relative elevation zones. Thus, it is difficult to predict its spatial distribution according to sea level rise scenarios. However, we did manage to model the *Phragmites* stands in both study areas, the results, however, are surprising. In Škocjan Inlet Nature Reserve the habitat constantly decreases in area (from 22 to 12 % of the total area) within the sea level rise gradient. In Sečovlje Salina Park the results indicate the opposite situation. According to the model the habitat gains space from its current 2.5 to 15.5 % in the L 15 cm and finally 13 % in the worst case scenario. In all the scenarios modelled the habitat's ruderal stands, sub-Mediterranean scrub and "other" maintain a constant percentage of spatial cover.

We have to point out the N2000 habitat type Mediterranean salt meadow (1410), which occupies less than 1 % of the total area in Sečovlje Salina Nature Park. The model results do not realistically represent its spatial distribution because we could not measure the real relative elevation on which it occurs. The habitat aggregate is constructed almost exclusively of *Juncus maritimus* plants, which grows in water.

All the model results are much more reliable for Škocjan Inlet Nature Reserve, due to its far more natural topography and because we scanned the whole area using the LIDAR technology and a high resolution geodetic GNSS to calibrate the dense LIDAR point cloud data.

15.6 How to Preserve Coastal Habitats in the Future?

It could be concluded from this study that sea level rise is a serious threat to coastal wetlands in the Northern Adriatic. It revealed that the spatial distribution of habitat types follows the micro-elevations and therefore a habitat transition model could be developed. The prediction model demonstrated to which degree, how and where coastal habitats will shift to each other and decrease their surfaces in total. It was summarised already by Nicholls et al. (1999) that there is need to start strategic planning of appropriate responses immediately in order to prevent the wetland loss. The countermeasures should take three directions, depending on the natural features of each area.

Where there is a shallow sedimentary coast, the creation of artificial islets at desired micro-elevations, suited to specific habitat types is possible. In such areas, artificial islets, fitted within natural bays of lagoons, would function in a completely natural manner. The islets should be carefully levelled to a certain micro-elevation and consolidated at the edges with wooden kerbs. This method has already proven to be efficient in the renaturation of Škocjan Inlet. In some cases the coastal habitats are shaped geometrically, developed in artificial man-made structures (abandoned ports, coastlines, Salinas etc.). In such cases the artificial islets can also consist of rectangular or any other regularly-shaped structure.

The second possibility is only appropriate where there is enough space in the buffer zone of coastal wetlands: if the shore is not too steep, we simply wait for the effects of sea level rise (waves, elevated salinity and moisture) to reach the higher zones, where new halophyte habitats will be established. This process could also be facilitated by removing the ruderal vegetation and preparing the suitable elevation.

The third possibility is only applicable in rare cases, where it is possible to regulate the sea level in areas with targeted habitats, using artificial sea barriers. This is already partially possible in the Sečovlje salina area: to some internal sections not directly connected with the open seawater, the influx of water comes through channels that are artificially regulated. However, because the surface in the Sečovlje salina covered with Natura 2000 habitats is already minimal, we suggest also creating artificial rectangular islets inside the largest salt-pans (water reservoirs).

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Chapter 16
Potential Impacts of Climate Change on Forest Habitats in the Biosphere Reserve Vessertal-Thuringian Forest in Germany

Nico Frischbier, Ingolf Profft, and Ulrike Hagemann

16.1 Forest Ecosystems Under a Changing Climate – The Status Quo

Forests are particularly sensitive to climate change as the long life-span of trees does not allow for rapid adaptation to environmental changes (Profft and Frischbier 2009; Lindner et al. 2010). Climate change considerably influences forest ecosystems through the potential alteration of temperature and precipitation regimes as well as the intensity and frequency of disturbances. Two decades of research have identified drought, heat waves, storm events and forest fires as some of the most relevant impacts for forestry. Climate change can also alter the distribution and life cycle of forest pests, thus modifying the species composition of forest ecosystems (Jönsson et al. 2009; Lindner et al. 2010). In contrast, longer vegetation periods, increased atmospheric CO_2 concentration and, regionally, precipitation may positively affect forests and some native species (Zebisch et al. 2005; Bolte et al. 2009; Araujo et al. 2011; Kind et al. 2011; Milad et al. 2011). The sensitivity and vulnerability of forestry, forests and forest habitat types to climate change impacts generally depends on tree species and tree species composition, soil conditions, current climatic conditions and the rate of change.

However, the adaptation potential of forest ecosystems may be restricted by historic and current land use. Since the large-scale forest clearance in medieval times, forests in Central Europe are often restricted to locations where shallow soil, nutrient deficiency, topography, climatic extremes and water deficiency or surplus

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prohibited agriculture and settlement. Compared to other biogeographical regions, the adaptation potential of European forests is also limited in terms of genetic and structural diversity, because the cultural landscape is characterised by low biodiversity, lack of spatial connectivity of biotopes and populations, and loss, genetic depletion or specialisation of species, partly due to refuges during and remigration following glaciation. The special situation of forests embedded in the European cultural landscape therefore necessitates profound vulnerability analyses with respect to the expected climatic changes and the subsequent development of substantiated adaptation strategies.

Various approaches have been used to assess the manifold responses of ecosystems and habitats to environmental changes. A basic approach to vulnerability assessment focuses on the climate envelope of a particular species (Box 1981). In combination with relevant climatic and species distribution data, species distribution models (SDM) can be used to derive species absence and presence maps for present and potential future climatic conditions, identifying potential distribution shifts. For silver fir (*Abies alba* Mill.), currently a rare species in Central Europe, Falk and Mellert (2011) present a risk evaluation based on different SDM's. This approach has also been used for vulnerability assessment of habitat-specific species in Natura 2000 habitats (Harley 2011).

Following a different approach (for details see Chap. 8), Petermann et al. (2007) classified the sensitivity of several habitat types in Germany with respect to pressures (land use, eutrophication), regenerability, spatial distribution, invasion of alien species, dependency on ground water and overflow as well as conservation status. Different levels of sensitivity were expected for habitats with differing biogeographical distribution, dependency on ground water or periodical flooding as well as for habitats under climate change pressure. Azonal forest types such as alluvial forests, bog woodlands and ravine forests were classified as particularly sensitive. The most vulnerable forest type, however, is the montane to alpine acidophilus *Picea* forest type (*Vaccinio-Piceetea*-FFH-type 9410, see Lindner et al. 2008; Gartner et al. 2011), which is a major element of the Biosphere Reserve (BR) Vessertal-Thuringian Forest and other mountain ranges in Europe.

16.2 Our Case Study – The Biosphere Reserve Vessertal-Thuringian Forest (Germany)

The BR is dominated by the Thuringian Forest, a mountain range characterised by deeply carved valleys. The main ridge features a maximum elevation of 978 m a.s.l., dropping off to approx. 450 m a.s.l. As a result of this morphology, the mainly atlantic, moderately cool and moist central mountain climate is modified, resulting in a large variety of local climatic conditions.

The landscape of the BR presents itself as a largely contiguous forest system, with ~90 % forest cover and some small upland meadows in stream valleys and at

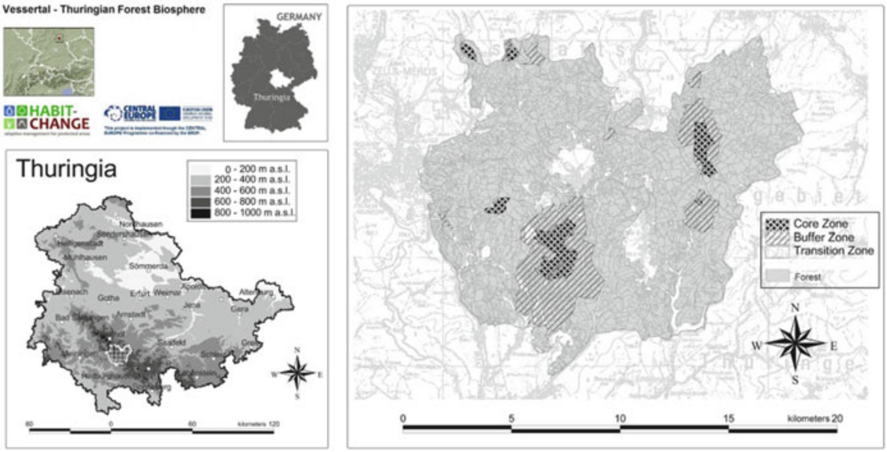

Fig. 16.1 Zoning scheme of the BR Vessertal-Thuringian Forest, located within the montane region of the Federal State of Thuringia in Central Germany

higher elevations. Runoff from the ridge has led to the formation of small raised bogs and feeds a dense network of streams. Although *Luzulo-Fagetum* and *Asperulo-Fagetum* beech forests are the predominant potential natural vegetation types, the BR is dominated by single-layer Norway spruce (*Picea abies* (L.) Karst.) monocultures established following historic overexploitation, calamities and subsequent intensive reforestation. Spruce forest types of higher conservational value are mainly located around treeless ombrotrophic bogs and along the ridge. Except for a handful of small populations, Silver fir – formerly a major component of mixed mountain forests – has disappeared from the area in only a few decades due to air pollution, acid deposition and unsuitable forest management. As most bogs have been drained and subjected to forest management, the restoration and protection of these bogs was the main objective of the BR after its creation in 1979. Today, the BR covers an area of 17.081 ha, with 3.3 % of the area classified as fully-protected core zones surrounded by ~2.000 ha of buffer zone (Fig. 16.1). Current debates focus on the enlargement of the BR and the modification of the zones in order to meet the UNESCO requirements.

A total of eight Natura 2000 sites are at least partially located within the BR (Fig. 16.2) and have been mapped and evaluated with respect to forest habitat types and their conservation status (Table 16.1). Presence of the Great Crested Newt (*Triturus cristatus* Laurenti) and several bat species of Annex II and IV of the Flora-Fauna-Habitat Directive has been confirmed for the BR. The BR is also part of the Special Protection Area (SPA) EU-No. DE 5430-401 under the Birds Directive 79/409/EWG and home to numerous bird species relying on forest habitats, e.g., the Black, Grey-headed and Middle Spotted Woodpecker (*Dryocopus martius* Linnaeus, *Picus conus* Gmelin, *Dendrocopos medius* Linnaeus), the Capercaillie (*Tetrao urogallus* Linnaeus) and the Black Stork (*Ciconia nigra* Linnaeus).

Table 16.1 Evaluation of forest habitat types in the BR Vessertal-Thuringian Forest according to the Habitat Directive

Habitat type	Description	Total area [ha]	Number of habitats	Conservation status A	B	C
9110	*Luzulo-Fagetum* beech forest	949.2	165	(–)	50	115
9130	*Asperulo-Fagetum* beech forest	644.7	37	(–)	14	23
9180[a]	*Tilio-Acerion* forests of slopes, screes and ravines	13.4	9	2	7	(–)
91D0[a]	Bog woodlands	75.2	5	(–)	5	(–)
91E0[a]	Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*)	13.8	19	2	16	1
9410	Acidophilous *Picea* forests of the montane to alpine levels (*Vaccinio-Piceetea*)	69.3	16	(–)	6	10

[a] Priority natural habitat types of Directive 92/43

Mean annual temperatures (1901–2000) range from 4.0 to 7.5 °C depending on elevation. However, average temperatures are assumed to have already increased by 0.4–1.0 °C between 1951 and 2000. Further temperature increases of 1–3 °C and 3–4 °C until 2050 and 2071–2100, respectively, are considered as very likely (cf. Frischbier and Profft 2011). The number of hot days and tropical nights will thus increase, while frost and ice days become less frequent. From 1971 to 2000, the forest vegetation period varied between 100 and 150 days per year depending on elevation. It may increase by 12–17 days until 2041–2070, and by 35–40 days by 2071–2100.

The region currently receives 750–1.200 mm of precipitation per year. Climate monitoring data and climate projections clearly show a shift of the inter-annual precipitation patterns with increasing amounts in autumn and winter and decreasing amounts in spring and summer. This would result in a decreased water supply during the growing season. At the same time, in combination with increased solar radiation, frequent heavy rain events associated with surface runoff and incomplete soil water saturation can result in an 8–14 % increase of the potential evaporation, which further aggravates the situation. The current climatic water balance normalised to the vegetation period ranges from 5 to 35 $\mathrm{l\ m^{-2}\ month^{-1}}$ (1971–2000). It may decrease by as much as 20 l (2041–2070), indicating potential water deficits (Frischbier and Profft 2011).

Although expert opinions about the future frequency and intensity of severe storm events in Central Europe differ widely, there is general agreement on their often disastrous consequences for forests. In 2007, the winter storm *'Kyrill'* completely destroyed more than 560 ha of spruce-dominated forests and considerably damaged another 400 ha within the BR. A major spruce bark beetle outbreak occurred as a result of windthrow and breakage and further deteriorated habitat and conservation status.

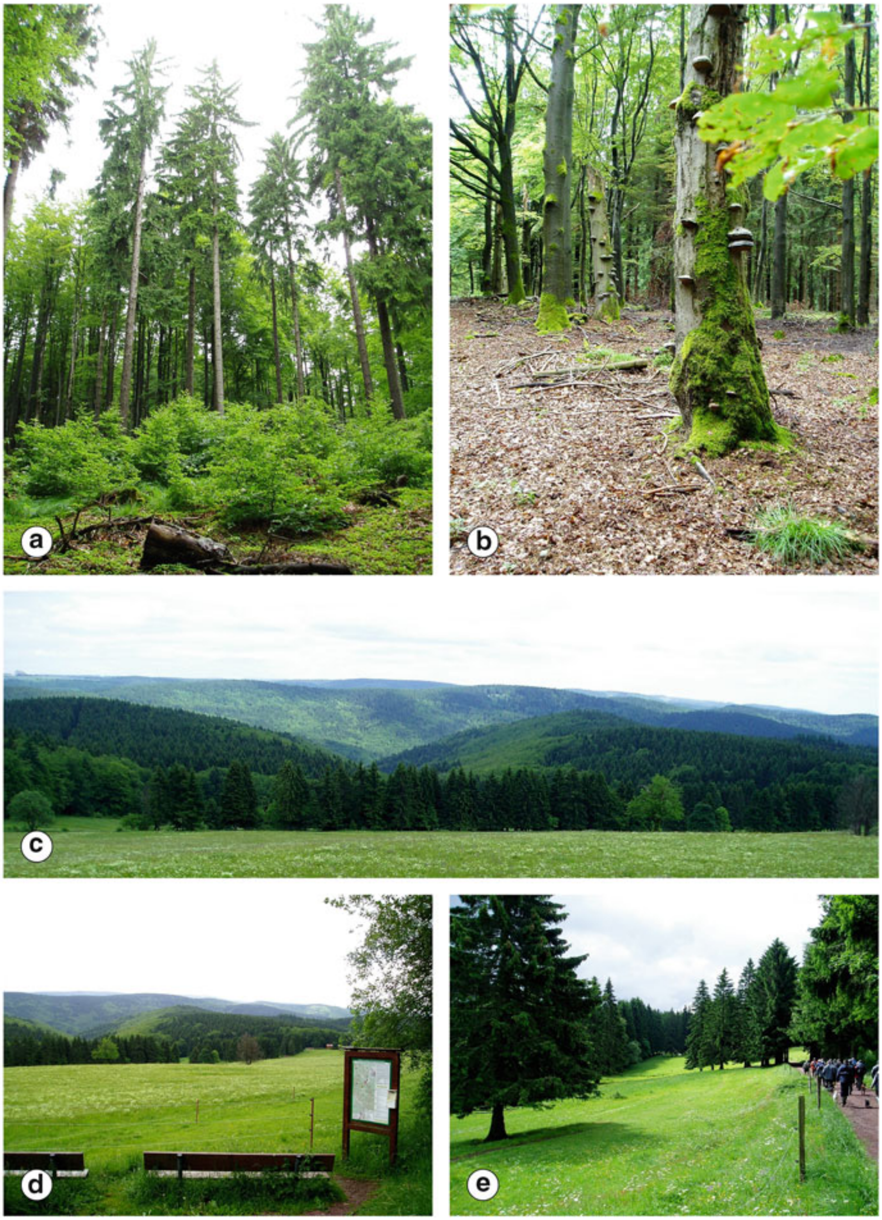

Fig. 16.2 (**a–e**) Impressions from the BR: (**a**) Near-natural forests with a mixture of beech and spruce and (**b**) old-growth forests in the degradation phase offer valuable habitats and microstructures, particularly in gaps and at the highly structured edges. The BR offers a (**c**) diverse landscape mosaic and (**d, e**) adequate infrastructures for tourism and nature recreation

16.3 Methods for Identifying Hotspots of Climate Change Impacts – And How to Inform and Engage Stakeholders

Study objectives were (i) to spatially identify hotspots of climate change impacts in the study area, and (ii) to inform the BR administration and land owners about these impacts and potential adaptation strategies. The study therefore focused on the analysis of the climatic requirements of forest habitat types following the definitions of the EU Habitat Directive and the potential alteration of these habitat types. Moreover, general recommendations for the establishment of near-natural forests in the BR were developed to promote pro-active forest adaptation, which may also positively influence certain habitat types by creating biotope networks.

16.3.1 Climate Change Impacts on Forest Habitats and their Conservation Status According to the EU Habitat Directive

Using the terminology of the international nomenclature for the evaluation of forest habitat types (see Ssymank et al. 1998; European Commission 2003; Burkhardt et al. 2004), climate change will modify habitat structure and species composition, increase habitat impairments, and change the presence, frequency and abundance of different forest development phases, of biotopes and over-mature trees and of deadwood. These changes will introduce various levels of diversity depending on the specific type of climatically induced changes:

- Climatically induced, large-scale disturbance (e.g., storm or forest fire).
- Climatically induced, selective small-scale failure of individual tree species, forest structures or forest development phases (e.g., due to drought, frost or species-specific pests).
- Climatically induced, gradual modification of site and environmental conditions (e.g., modified climatic water balance or vegetation period length).

In the case of large-scale wind-induced disturbances, the degree of storm exposure was estimated for the entire BR area by means of GIS analyses (ArcGIS 9.3. spatial analyst). Based on the digital elevation model of Thuringia (resolution of 5 m), elevation, slope angle, slope direction and relative exposition compared to the surrounding area were determined for 50 m grid cells. Grid cells that are not protected from storms by higher topographical elements at distances of 500, 1.000, 1.500 or 2.000 m were assigned a particularly high degree of exposure in accordance with the Thuringian damage analysis conducted following the 2007 storm *'Kyrill'* (Clasen et al. 2008). Regardless of protection from distant topographical elements, forests located on the wind-facing south-westerly slopes featured at minimum a high degree of exposure.

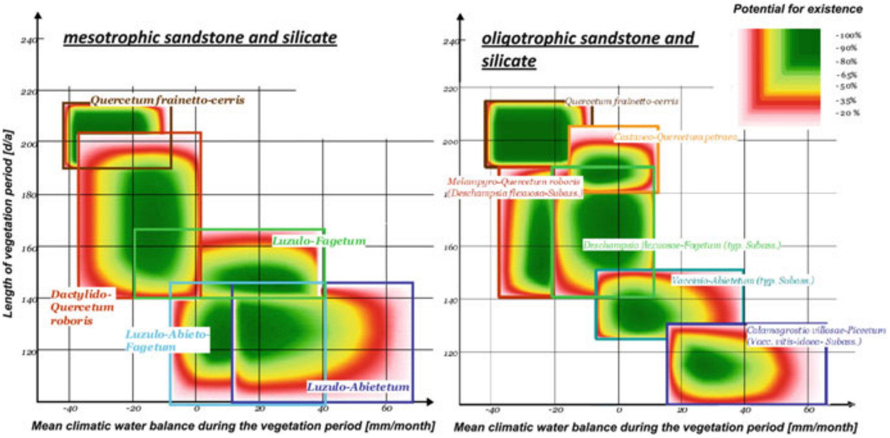

Fig. 16.3 Ecogram for the mesotrophic (*left*) and oligotrophic (*right*) nutritional classes of sandstone and silicate soils

In order to estimate and evaluate potential impacts of climate change-induced gradual modifications of site and environmental conditions on the typical species composition of forest habitat types, climate-induced shifts of tree species and related plant associations were simulated. Following the approach by Schlutow and Huebener (2004), ecogram analyses based on more than 17.000 vegetation surveys in Central and Southern Europe (Profft and Frischbier 2009) were used to evaluate the ecological potential of particular forest associations and the associated tree species for the specific site conditions, the current (1971–2000) and the projected (2041–2070, SRES-A1B; IPCC 2000) climate of the study area (Fig. 16.3). Schlutow and Huebener (2004) modelled the existence potential based on the presence and absence data of particular forest associations and the associated tree species as well as the climatic and soil data of the respective vegetation survey. In their species distribution models, the multidimensional niche is derived from numerous environmental factors (e.g., vegetation period, climatic water balance, soil nutrient status, soil substrate, and soil water regime). Schlutow and Huebener (2004) differentiate between the realised and the fundamental niche (cf. Hutchinson 1957) and assign forest ecosystems to the Natura 2000 habitat types according to the German classification scheme (Ssymank et al. 1998). Habitat types covering a wide ecological range were subdivided into sub-associations based on soil type, climate or elevation. In addition, the regionally recommended potential natural vegetation types were used to estimate the potential climatic drift of tree species and related plant associations.

16.3.2 Involving Stakeholders in the Definition of Forest Conversion Strategies

In order to avoid ecological and economic damage, the conversion of homogenous to diverse near-natural forests is particularly urgent for vulnerable non-autochthonous

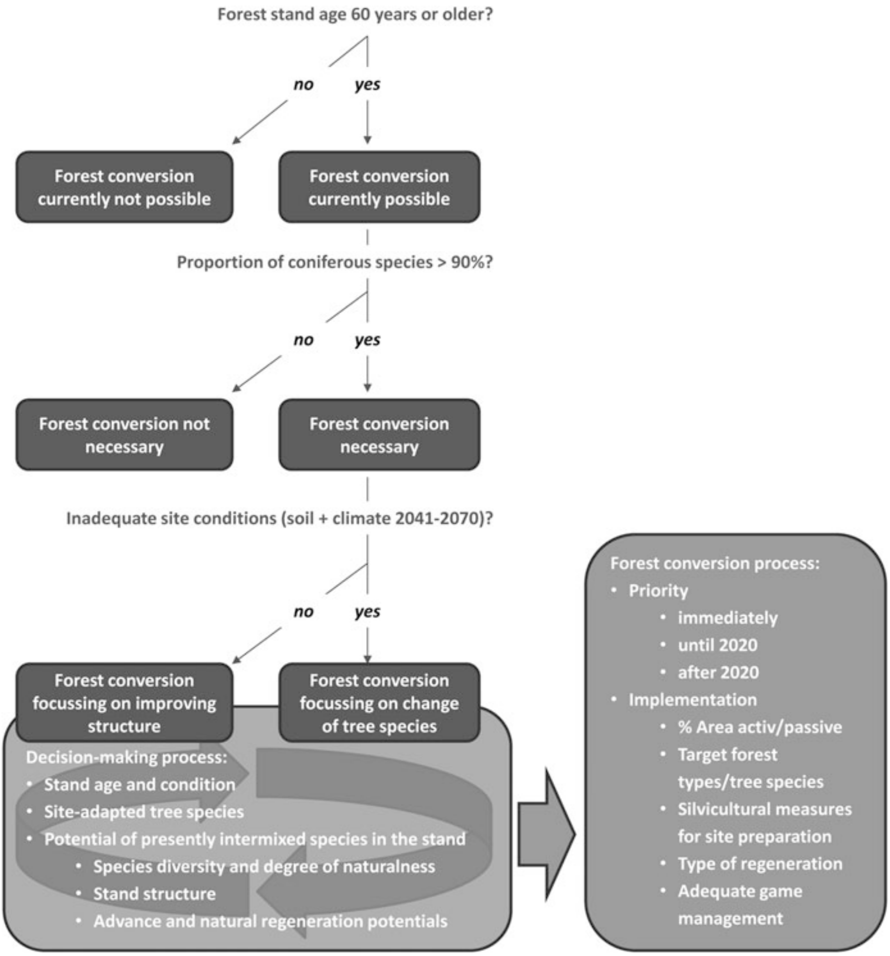

Fig. 16.4 Decision-making scheme for selecting options during the forest conversion process

and poorly structured spruce forests. To evaluate site-specific stand vulnerability based on current and projected climate, middle-aged and mature poorly structured coniferous stands were selected using digital site maps and current forest inventory data (Fig. 16.4). As the central element of an adaptation strategy, site-adapted species composition was then defined for these stands according to the Thuringian recommendations.

The subsequent decision-making process involved joint evaluations and agreements with forest owners, regional stakeholders, the public forest administration and the Thuringian forest authority regarding the short, intermediate and long-term necessity of forest conversion, the self-regulation potential of the selected stands and the silvicultural and financial implementation of forest conversion measures.

16.4 Which Climate Change Impacts Are Relevant for Forest Habitats and their Conservation Status According to the EU Habitat Directive?

16.4.1 Habitat Change Following Disturbance Events

Although the frequency of large-scale disturbances within the BR is similar to other regions, spruce-dominated forest associations are nevertheless characterised by a particular vulnerability (Wermelinger 2004; Schütz et al. 2006). Due to the predominant occurrence on windy ridges and adjacent to treeless bog areas as well as the frequent formation of pure stands on peats, gleys, other hydric soils and on blocky or silicate scree material, shallow rooting spruce trees and stands are especially vulnerable for stand-replacing disturbances.

Although these disturbances may create deadwood and valuable micro-habitats (e.g., upturned root plates), the loss of intact stand structures will result in an area loss subject to reporting under the Habitat Directive for the registered forest habitat type 9410. The re-registration of a damaged stand and the subsequent evaluation of its conservation status can only be initiated following forest management measures or the onset of succession. The failure of spruce as dominant species will have a long-lasting negative effect on the criteria related to habitat-typical species composition. Impairments, particularly of the forest floor and the hydrology, are likely. Valuable spatial structures such as the fine-grained mosaic of different forest development phases are often homogenised by large-scale disturbances and thus depreciated. Moreover, the total loss of medium and large-diameter trees due to disturbance events results in the worst rating with respect to spatial structures. If, additionally, snags, biotope and over-mature trees are blown down and more or less entirely lost, forest habitat types may be at risk of general downgrading in terms of habitat structure. Large amounts of disturbance-induced downed deadwood, however, may at most result in a ‘good’ rating for the deadwood criterion.

In the BR, the *Vaccinio-Piceetea* habitats located along the bog edges within the FFH areas DE 5330-301 *‘Schneekopf-Schmücker Graben – Großer Beerberg’* and DE 5331-301 *‘Erbskopf-Marktal und Morast-Gabeltäler’* have a particularly high risk of storm damage due to elevation, slope angle, slope direction and relative exposition compared to the surrounding areas. Located in the Northwestern and Eastern parts of the BR, these habitats are mostly left to develop naturally as part of the core zone (Fig. 16.5).

Small-scale, species- or structure-specific failure of individual elements of forest ecosystems may have no or even a positive effect on the evaluation of the conservation status of forest habitat types. This applies particularly to spatially intimate mixtures of different forest development phases and to snags, biotope and over-mature trees. The immediate post-disturbance establishment of early successional phases of tree species typical for the respective habitat may also result in improved ratings. Potential impairments due to small-scale disturbances will not be serious.

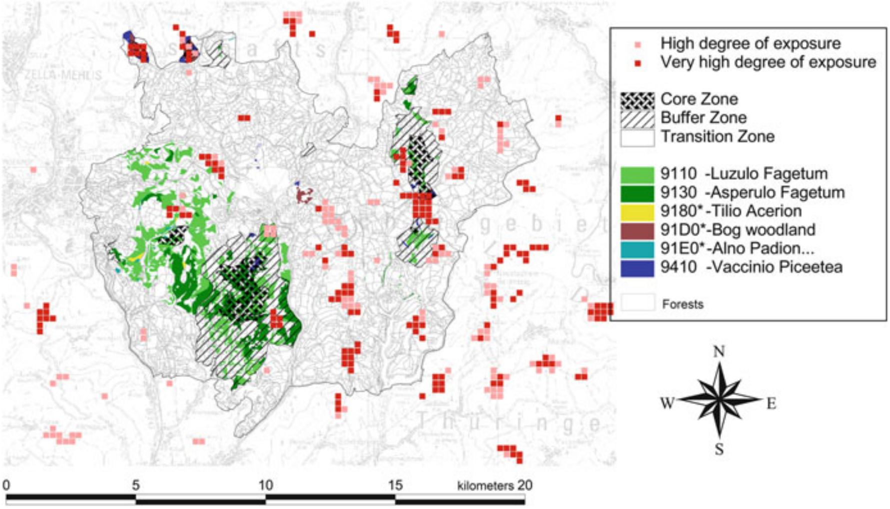

Fig. 16.5 Classification of the area of the BR according to the degree of exposure to storms from indeterminate directions in relation to the BR zones and the distribution of forest habitat types

16.4.2 Habitat Shifts Due to Gradual Climatic Changes

Gradual climatic changes may require the reassessment of any given forest habitat type regarding its characteristic site suitability. This applies particularly to bog woodlands (91D0), which are by definition associated with wet organic sites, deep peat layers and high ground-water levels, as well as to alluvial softwood forests (91E0) that lost their functional connection to a flowing water body and are no longer regularly flooded. In both cases, small-scale loss or drift of the respective habitat types is theoretically possible. However, serious changes of the water regime are currently not expected for montane zones characterised by windward weather situations with high amounts of precipitation.

The climate-based evaluation of gradual zonal habitat drifts within the BR relies on the assumption that the current classification is ecologically plausible and correct. However, the first reporting and surveying of the forest habitat types was relatively coarse. For example, *Luzulo-Fagetum* habitat types are reported for spring-influenced or alluvial azonal stand patches, where habitat types 91E0 and 9180 (*Stellario-Alnetum, Carici remotae-Fraxinetum* and *Ulmo glabrae-Aceretum pseudoplatani*) ought to be present.

Highly likely changes of the species composition typical for correctly classified habitat types were evaluated regarding the potential occurrence of plant associations (realised niche) and typical species (fundamental niche) of the respective habitat types (see Fig. 16.6). Depending on the habitat type, ‘optimal’ and ‘good’ ratings for species composition are lost if the share of typical species falls below 90 % and 60 %, respectively. This is expected for 6 ha of *Vaccinio-Piceetea* habitats (9410) on wet or moderately moist mesotrophic, slightly to highly skeletal

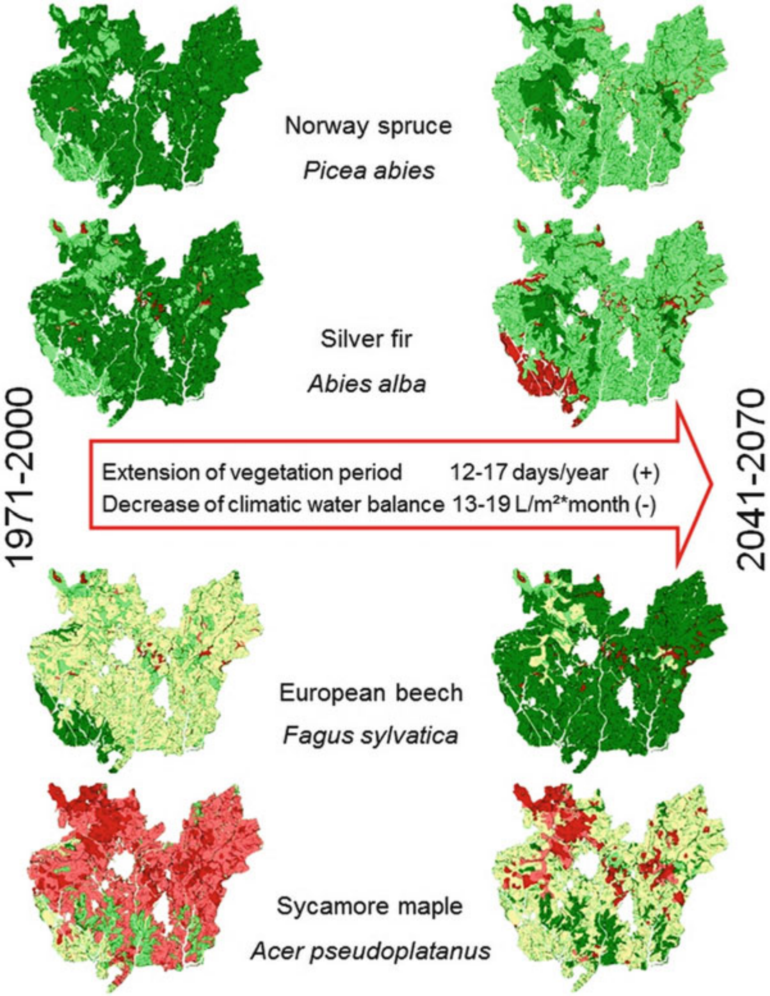

Fig. 16.6 Predicted survival probability (*red* = low, *green* = very high) for key species of the habitat types *Luzulo-Fagetum*, *Asperulo-Fagetum* and *Vaccinio-Piceetea* for the BR using specific soil conditions and SRES-A1B, ECHAM5 and WETTREG-regionalisation following the approach of Schlutow and Huebener (2004) employed by Profft and Frischbier (2009)

silicate soils if the climatic changes until the middle of the century favour European beech (*Fagus sylvatica* L.) in terms of temperature and vegetation period length and promote the transition to various sub-associations of the *Luzulo*-(*Abieto*-)*Fagetum* habitat type (9110). On the other hand, transitions from the *Luzulo*- to the *Asperulo-Fagetum* (9130) are highly likely for the eutrophic, highly skeletal silicate soils if the milder climate increases the probability of occurrence for sycamore maple (*Acer pseudoplatanus* L.) and European ash (*Fraxinus excelsior* L.) and allows for the establishment of the *Galio rotundifolii-Abietetum*, *Mercuriali-Fagetum* and

Asperulo-Fagetum. Although sessile oak (*Quercus petraea* Liebl.) is slowly replacing European beech on water-deficient and poorer sites with milder climatic conditions, not even high proportions of oak will cause a perceivable drift in the typical species composition as long as the proportion of beech does not fall below 30 %.

16.4.3 Habitat Impairment Due to Invasive Species

All aspects of habitat impairment are of special relevance for the evaluation of forest habitat types, because individual ratings are not averaged and the worst rating has a direct impact on the overall rating. The gradually increasing occurrence of non-typical plant species always results in a considerable downgrading of the habitat status. Apart from known species like the Giant hogweed (*Heracleum mantegazzianum* Somm. u. Lev.), European black pine (*Pinus nigra* Arnold), Hybrid poplar (*Populus* x *canadensis* Moench), Black locust (*Robinia pseudoacacia* L.) and Canada Goldenrod (*Solidago canadensis* L.), other invasive species that may potentially become relevant for the BR due to climatic and pedological conditions include the Japanese and the Giant knotweed (*Fallopia japonica* Houtt. and *F. sachalinensis* (F. Schmidt) Ronse Decr.), Himalayan balsam (*Impatiens glandulifera* Royle) and the Bigleaf lupine (*Lupinus polyphyllus* Lindl.). Although the occurrence of these species is often restricted to forest edges and open areas, these locations may function as initials for future large-scale dispersal. This is of particular importance for alluvial forest habitats (91E0) where the spread of invasive plants, e.g., along the riverbank, needs to be closely monitored and inhibited.

16.5 Habitat Development by Pro-active Forest Conversion

Regardless of the BR zoning concept and the designated Natura 2000 sites, structure and site-adapted forest conversion is also required from the perspective of forest owners generating their income mainly from forestry (Fig. 16.7). This approach follows the recommendations of the German Commission for UNESCO (2011) to *"intensify efforts to develop innovative approaches for climate change [...] adaptation (including financing models), implement these approaches, [and] adapt management plans."* Activities outside of the designated core and buffer area focus on areas which were hitherto managed traditionally under a clearcut management system and are therefore characterised by single-layer stands with few species and low conservational value. The decision-making scheme (cf. Fig. 16.4) allowed for the identification of these forest areas at the level of individual stands in cooperation with the stakeholders. Potential forest conversion areas located near protected areas now need to be assessed with respect to options for habitat development and connectivity (see McComb 2008). To this purpose, the monitoring and management of forest habitat types is an integral component of general forest

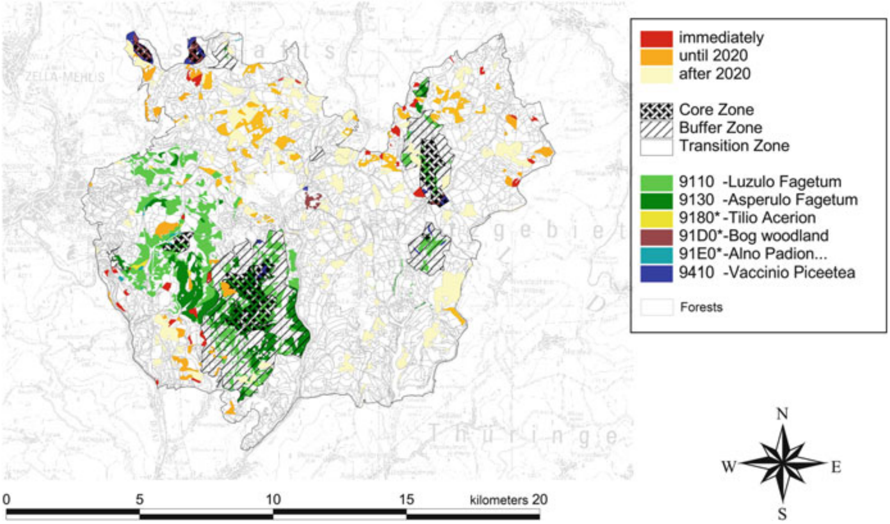

Fig. 16.7 Current agreement on structure and site-adapted forest conversion of single-layer pure coniferous forest stands within the BR. Classes of forest conversion priority (immediately, until 2020, after 2020) were assigned according to the initial situation and general consensus

inventory and management planning. Nevertheless, the concept of near-natural climate-plastic forest management in the region needs to be firmly supported by site-adapted game management, a modern concept for managing deadwood as well as nesting, cavity and biotope trees, the thoughtful use of forest machinery and minimal impairments by other pressures and impacts such as pollution, land consumption and biotope fragmentation.

16.6 Conclusion

The general evaluation of the sensitivity and vulnerability of forest habitat types of Petermann et al. (2007) and Harley (2011) has been confirmed for the specific area of the BR. Azonal and spruce-dominated forest habitat types are likely subject to particularly drastic changes associated with climate change. We emphasise that disturbances may not only have disastrous consequences for the habitat status but also for the contribution of forest ecosystems to climate change mitigation. Options for adaptation by management outside of the strictly protected BR core zone mainly involve the restoration and water deregulation of bog areas and along streams in favour of the forest habitat types 91D0 and 91E0 of the EU Habitat Directive.

The ecological gradient of the mixed mountain forest of the montane zone can be ensured by the anticipatory establishment or promotion of site-adapted tree species and structures. Vast areas of poorly structured spruce monocultures still need to be converted into diverse, highly structured mixed stands. Structured forest edges, spatial diversity and small patches of different forest development phases also have to be promoted. Although the climate-induced spreading of European beech into the ridge areas of the BR may threaten the typical species composition of the acidophilous *Picea* forests of the montane zone (9410), the positive effects of an active management in favour of spruce and supplementary intermixed montane species could quickly be offset by disturbances.

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Chapter 17
Potential Impact of Climate Change on Alpine Habitats from Bucegi Natural Park, Romania

Anca Sârbu, Paulina Anastasiu, and Daniela Smarandache

17.1 Climate Change and Protected Areas

The predicted increase in global temperature (annual average 1.1–6.4 °C) and the changes in the amount and distribution of precipitation (IPCC 2007), represent a significant challenge for the plants and habitats within and outside of protected areas (Andrade et al. 2010). Some studies anticipate a reduction of 58 % of plant and animal diversity in the protected areas of Europe by the end of 2080 (Araújo et al. 2011). Alpine plants within and outside protected areas, are expected to experience significant impacts as a results of climate change, during this century (Erschbamer et al. 2009). According to Theurillat et al. (1998), high mountains such as the Alps can be particularly vulnerable to climate change and the impact of the combined effects of human activity and climate change are more and more visible (Fischlin et al. 2007). In this context, the concept of adaptative management of nature reserves can become a potential way to proactively respond to climate change influences (Fazey et al. 2009).

17.2 Area of Study

The focus of this chapter is the identification of the threats that concern alpine habitats, of the way in which these habitats might react to such threats and of those aspects that could be scientifically significant in supporting the selection of the adequate management practices. For the purpose of this study, Bucegi Natural Park in Romania was taken as a case study and the *Festuca supina* Schur grassland (Natura 2000 code 6150–Siliceous alpine and boreal grasslands), which represent

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Fig. 17.1 Natural Park Bucegi, alpine grasslands on the plateau of the Bucegi mountains (Photo: Anca Sârbu)

26 % of its alpine grasslands (Puşcaru et al. 1956) and are the most widespread type of habitat in the alpine area (Administraţia Parcului Natural Bucegi 2011) was used as an example.

Bucegi Natural Park (32,497.6 ha) is located on the South-Eastern extremity of the Romanian Carpathians, lying between 800 and 2,507 m in altitude (Administraţia Parcului Natural Bucegi 2011), its normal climate is cold and humid, with temperatures well below zero during winter, long periods of snow and frost, violent winds especially on peaks, frequent fog especially in the alpine area, and heavy rainfall (Administraţia Parcului Natural Bucegi 2011) (Fig. 17.1).

The Park belongs to the Natura 2000 Bucegi Site which hosts 24 types of Natura 2000 habitats of the following categories: shrubs, natural meadows, hydrophilic vegetation, deciduous forests, coniferous and mixed forests. About 30 % of all taxa known in the Romanian higher plant flora are present in the Park including 59 endemic plants (Administraţia Parcului Natural Bucegi 2011) and four plants recorded in Annex II of the Habitats Directive (Council Directive 92/43/EEC 1992), as well as a rich bryoflora and many species of fungi and lichens. The land use includes: national forestry fund (62 %), pastures and grasslands (32 %), rocky habitats and *Pinus mugo* formations (4.9 %), water surfaces (0.4 %), quarries and touristic infrastructure (0.7 %) (Administraţia Parcului Natural Bucegi 2011).

17.3 Data Collection in Bucegi Natural Park

The identification of the effects of climate change and of the different potential threats affecting the protected area was based on the results of a survey conducted in 2010, addressed to 97 subjects (landowners, land users and significant stakeholders) involved in the management of Bucegi Natural Park.

Estimation of the potential vulnerability of *Festuca supina* (Ciocârlan 2009) grasslands to the potential impacts of climate change was based on analysis of 16 plots of 25 m^2, identified on the plateau of the mountain between 2010 and 2012. All 16 plots of habitat type 6150 were located at an altitude between 1,900 and 2,300 m, with low temperatures (annual average temperature between −2.5 and 3 °C), sufficient humidity (1,100–1,400 mm/year) and a minimum snow coverage of 200 days per year (Puşcaru et al. 1956; Doniţă et al. 2005).

The following parameters were used: species richness, species abundance-dominance and species potential sensitivity. The species conservation value was defined according to the Red List of Higher Plants of Romania (Oltean et al. 1994) and to the Annex II of the Habitats Directive. Species nomenclature is in accordance with The Plant List (2010).

The assessment of the potential sensitivity of species to climate changes used the following criteria: the life span, biological form, the requirements in terms of humidity, heat and nutrients, evaluated according to the groups of biological forms and to scales for moisture, heat and nutrient requirement, used in determining the ecology of species in Romania (Popescu and Sanda 1998; Ciocârlan 2009).

17.4 Potential Pressures and Consequences of Climate Change in Bucegi Natural Park

The results of the survey addressed to owners, users and stakeholders involved in the management of Bucegi Natural Park revealed four categories of climate change pressures, associated with either the phenomenon of global warming or with rainfall imbalances or severe weather and seasonal disturbances: increase in temperature, decrease in rainfall, seasonal changes in precipitation and temperature and increase of extreme weather phenomena. Their effects can threat directly and indirectly plants diversity and habitats quality (Fig. 17.2).

The habitat type 6150, which was considered in this study comprises of alpine grasslands of *Festuca supina*, which form dense vegetation, composed of many plant taxa (122–130), widely dominated by *Festuca supina* (65–85 %), with 10–22 % *Agrostis rupestris* All. and *Potentila ternata* Freyn (Fig. 17.3). It is an oligotherm habitat, a glacial relict, which shelters 26 taxa with conservation value listed in the Red List of Higher Plants of Romania (Oltean et al. 1994).

The dominant species are perennial, and dependent on moderate humidity (mesophilic), the presence of snow (hemicryptophyte and chamaephyte) and low

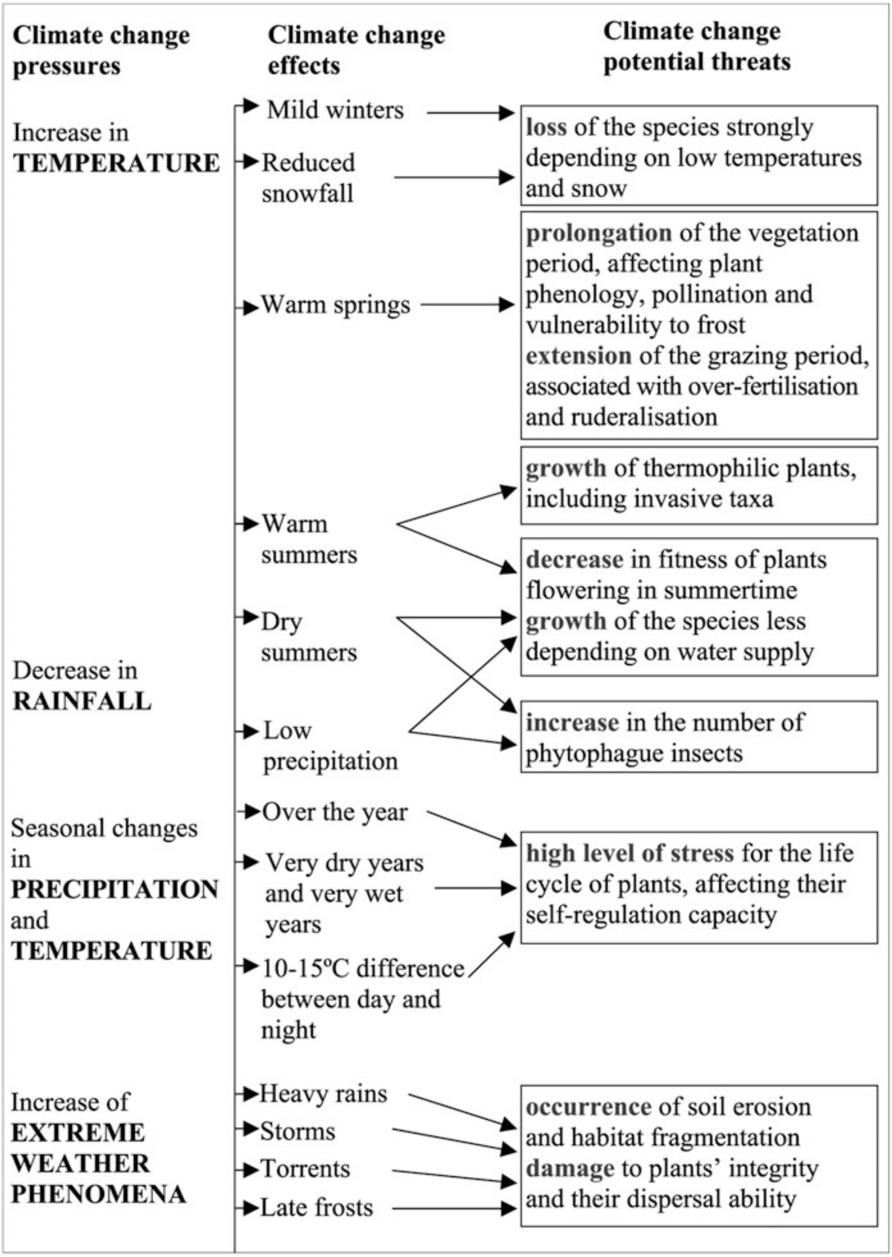

Fig. 17.2 Potential climate change effects and induced threats on the alpine plants and habitats from Bucegi Natural Park

Fig. 17.3 Natural Park Bucegi, *Festuca supina* grassland (Natura 2000 code 6150) (Photo: Anca Sârbu)

temperatures (hekistothermophytes and psychrothermophytes). They are oligotrophic plants. The accompanying species are 89 % hemicryptophyte and chamaephyte. Seventy percentage of the identified species are dependent either on humidity (mesophytes and mesohydrophyte) or on low temperatures (hekistothermophytes, psychrothermophytes and microthermophytes), and 40 % are oligotrophic. About 52 % of the plant species of *Festuca supina* grasslands, include the dominant species, twelve rare plants and three endemics *Achillea oxyloba* subsp. *schurii* (Sch.Bip.) Heimerl, *Androsace villosa* var. *arachnoidea* (Schott, Nyman & Kotschy) R. Knuth, *Dianthus glacialis* subsp. *gelidus* (Schott, Nyman & Kotschy) Tutin, require both low temperatures and moisture for an adequate growth.

The analysis of the species identified in habitat type 6150 revealed the presence of some eurithermophyte and mesothermophyte, and some eutrophic species, which are not normally found in this type of habitat (Doniţă et al. 2005; Gafta and Mountford 2008). Some of these might have migrated from neighbouring habitats, at a lower altitude. We mention here *Deschampsia caespitosa* (L.) P. Beauv., *Gnaphalium sylvaticum* L., *Cardamine pratensis* L., as well as *Nardus stricta* L., which is a dominant and characteristic species for the habitat 6230* (Species – rich *Nardus* grasslands). This habitat develops at lower altitudes (800–2,070 m) and in climate conditions characterised by average annual temperatures of between 1.5 and 6.0 °C (Mountford et al. 2008).

The existence of some eutrophic and mesothrophic species (*Biscutella laevigata* L., *Alyssum repens* Baumg., *Ranunculus repens* L. s.o.) can be explained by the tendency towards eutrophication of these grasslands, which is in general, a process associated with grazing activities (Doniţă et al. 2005).

17.5 Climate Change Threats and Worrying Aspects

One of the consequences of climate change that alpine plants and habitats will have to face is the potential occurrence of milder winters with less snow. The length and depth of snow cover, correlated with low temperature is considered as a key climatic element in alpine areas (Ozenda and Borel 1991) and the plants from the alpine level, such as the hekistothermophytes and the psychrothermophytes from Bucegi mountains, are sensitive to these factors.

At the same time, a reduction in the duration of snow coverage and amount of snowfall will affect the regeneration of plants from the high elevation of Bucegi mountains, which depend on vernalisation. According to Ozenda and Borel (1991), the species living in snow beds will be the most vulnerable to warming.

Plant species can respond to changes of the climatic conditions in different ways: genetic adaptation, species extinction, biological invasion (Huntley 1991). Up to now we have minimal empirical evidence of how the alpine plants from Bucegi mountains will react to environmental changes.

However, it is worrying that the dominant species of *Festuca supina* grasslands and also the majority of the other present species including rare and endemic plants are mostly hemicryptophyte and chamaephyte, and microthermic dependent.

Another worrying aspect is related to the upward migration process of plants which can produce changes in the vegetation from the existing habitats and can affect the cryophilous plants. An upward migration of some species from lower altitudes seeking climatic conditions suitable for their life functions was also observed for the habitat type 6150 from Bucegi Natural Park. This type of response to the effects of climate change has also been reported in the Alps (Theurillat et al. 1998; Pauli et al. 2003).

The alpine habitats from Bucegi National Park are subject to various influences of human activity. As far as grasslands are concerned, grazing has a particularly significant impact and should be taken into account because both the dominant plants in the studied habitat type, and the associated species are oligotrophic and sensitive to eutrophication. According the evaluation from the Management Plan of the Bucegi Natural Park, chapter IV (Administraţia Parcului Natural Bucegi 2011), pastures and meadows in Bucegi Natural Park have different amounts of livestock that often exceed the optimum number of units for grazing land, set at 0.30 LUs/ha. Intense grazing by various livestock (sheep, horses, goats, cows) is a source of intense eutrophication and of soil quality degradation, associated with ruderalisation (Doniţă et al. 2005), a process that can affects the integrity of *Festuca supina* grasslands. The emergence of early and warm springs, allows the prolonging of the grazing period and for the grazing to start at an earlier time, affecting the regeneration and breeding capacity of spring plants and increasing soil nutrients.

In these circumstances, the question is: “How will alpine habitats from Bucegi mountains respond to climate change?” Certainly each habitat react rather individually, but the current structure of the plant communities and the ecological spectrum of the component species may offer some indication. In an environment showing evidence of a change in climate and by limited options for intervention, alpine plants are very likely to become a disadvantaged category.

However, the reduction of the non-climatic stress such as grazing (extension in time, diversity of livestock, livestock overload), motorised tourism and the development of the tourism infrastructure, can be an alternative measure to buffer as much as possible the impact that climate change has or might have on the alpine plants and habitats from Bucegi Natural Park.

According to Theurillat and Guisan (2001), the perpetuation of traditional land-use, without intensification can be considered a key factor to offset climate change over the following decades, especially for extensively used ecosystems such as subalpine and alpine grasslands.

17.6 Conclusions

Significant climate change pressures such as increasing temperatures, decreasing precipitation, seasonal changes and extreme phenomena, affect the habitats of the Bucegi Natural Park and we can expect the loss of those plants which will no longer have adequate conditions for survival and a gradual change of their habitats. The analyses of the structure of the plant communities and of their ecological spectrum offer some indication of the potential future tendencies in the habitats' changes. In this regard, the selected Natura 2000 habitat type 6150, well represented in the Carpathian Mountains, populated by plant species strongly depending on low temperatures and the presence of snow can be considered as potentially vulnerable.

A way to buffer as much as possible the effects of climate change on alpine habitats, could be linked to efforts to decrease or limit the impact of human activities, thus avoiding, or at least diminishing, the cumulative effects of climatic and non-climatic stress.

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Chapter 18
Potential Impacts of Climate Change on Habitats and Their Effects on Invasive Plant Species in Danube Delta Biosphere Reserve, Romania

Mihai Doroftei and Paulina Anastasiu

18.1 Introduction

It is widely accepted that climate change effects have repercussions everywhere around us; the Danube Delta Biosphere Reserve (DDBR) is no exception. The spreading of invasive plant species is mainly influenced by climatic factors. Most invasive species, regardless the place of occurrence, follow the same climatic pattern as in their place of origin (Richardson and Pysěk 2006). Changes of climatic features showed habitat alteration by decreasing, increasing or shifting of species' range in size and abundance (Leech et al. 2011). In climate change context, one of the effects is the spread and persistence of invasive plant species in natural habitats and the interference on plant community's structure. These opportunist species take advantage of every climatic change in order to expand their survival rate leading to the loss of the native species (Hellmann et al. 2008). The aim of the study was to identify the spreading potential of invasive species within DDBR habitats by their present features of adaptation and their occurrence in plant communities considering climate change impacts. Annual climatic values (temperature, precipitation) collected between 1961 and 2007 from the eastern (Sf. Gheorghe – Black Sea shore) and western (Tulcea) meteorological stations located in DDBR were used and processed. DDBR is situated in South-East Europe, respectively in South-Eastern Romania. As a biosphere reserve, this wetland is also the largest (5,800 km^2) Romanian Natura 2000 site (ROSCI 0065 and ROSPA 0031). It is a fluvial-maritime floodplain on two bioregions, a steppic and a pontic one

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(Ciocârlan 2011). By means of management measures, adaptation is undertaken in order to reduce potential impacts of climate change on DDBR habitats.

18.2 Methods

The spreading potential of invasive species was analysed by their present features of adaptation, plant community qualitative indices (Braun-Blanquet scale) and annual climatic values (temperature, precipitations). The time-frame 1961–2007 data was used from the eastern (Sf. Gheorghe – Black Sea shore) and western (Tulcea) meteorological stations located in DDBR. The obtained data was compared to the reference (Sanda and Arcuş 1999; Hanganu et al. 2002; Ciocârlan 2011). Subsequently, the data was interpreted by means of mapping software ArcMap 9.1 and presented on a digital map.

18.3 Results: DDBR Habitats and Invasive Plant Species

Presently, 180 plant communities have been reported within DDBR (Sanda and Arcuş 1999; Hanganu et al. 2002), integrated within 29 habitats according to the European Habitats Directive (92/43/EEC). A list of 168 alien plant species, based on references and field research done during 2009–2011, has recently been compiled (Anastasiu 2011). Twenty-one plant communities mainly consisting of alien plants identified in the field are listed in Table 18.1.

Regarding the impact of alien plant species on Natura 2000 habitats and its spreading potential, five habitats from DDBR revealed the following: the annual vegetation on drift lines of habitat 1210 is strongly modified by the presence of *Xanthium italicum*; habitat 1310 *Salicornia* and other annuals colonising mud and sand are invaded by *Symphyotrichium ciliatum* and *Xanthium italicum* (up to 40 % coverage) at Sacalin island and the Sulina area; habitat 1410 Mediterranean salt meadows, characterised by the presence of *Juncus maritimus* and *Juncus littoralis*, is in a very good state in Sf. Gheorghe area, but strongly overrun by *Elaeagnus angustifolia* in Sulina and invaded by *Ambrosia artemisiifolia* at Sacalin island; 1530* Ponto-Pannonic salt-steppes and salt-marshes is only rarely invaded by *Amaranthus blitoides* or *Amaranthus blitum* subsp. *emarginatus*; habitat 2110, Embryonic shifting dunes, is strongly modified by *Xanthium italicum* often with A-D 1 and 100 % frequency, *Conyza canadensis*, *Cuscuta campestris* and *Amorpha fruticosa* (Anastasiu 2011).

The most important element in DDBR is the hydrological system (branches, channels, and lakes). In other words, water circulation and distribution are at the core of this wetland. While aquatic habitats are invaded by *Azolla filiculoides* and *Elodea nuttallii*, which competes against aquatic communities (Anastasiu et al. 2007), riparian and alluvial habitats are invaded especially by *Amorpha fruticosa*, which often forms the monodominant communities *Fraxinus*

Table 18.1 Plant communities within the Danube Delta Biosphere Reserve mainly consisting of alien plants based on field research (Anastasiu 2011)

Plant communities mainly consisting of alien plants
Acoretum calami Eggler 1933
Amarantho-Chenopodietum albi Morariu 1943
Amorpha fruticosa comm.
Artemisietum annuae Morariu 1943 em. Dihoru 1970
Artemisio annuae-Heliotropietum curassavicae Dihoru & Negrean 1975
Cladietum marisci (Allorge 1922) Zobrist 1935
Elaeagnus angustifolia comm.
Elodeetum canadensis Eggler 1933
Elodeetum nuttallii Ciocârlan et al. 1997
Heliotropio currasavicae-Petunietum parviflorae Sanda & al. 2001
Hippophae-Salicetum eleagni Br.-Bl. et Volk 1940
Ivaetum xanthifoliae Fijalk. 1967
Lemno-Azolletum carolinianae Nedelcu 1967
Lemno-Azolletum filiculoides Br.-Bl. 1952
Potentillo supinae-Petunietum parviflorae Dihoru et Negrean 1975
Riccio-Azolletum carolinianae
Salsolo ruthenicae-Xanthietum strumarii Oberd. et Tx. 1950
Xanthio strumarii-Chenopodietum Pop 1968
Xanthietum italici Timar 1950
Xanthietum spinosi Felf. 1942
Xanthietum strumarii A. Paucă 1941

pennsylvanica, *Xanthium* spp., *Eclipta prostrata*, *Lindernia dubia*, and *Dysphania ambrosioides* (Anastasiu et al. 2007). However, most of the alien species within DDBR are present in ruderal vegetal communities strongly influenced by anthropogenic activities, while fewer of them are found in natural and semi-natural communities (Anastasiu 2011) (see Table 18.2).

Figure 18.1 presents a map with the spreading potential of invasive species. The dark red colour (e.g. 5) shows the core areas, where species are considered to have a high rate of spreading. In order to enhance the vulnerability of DDBR strictly protected areas are presented as well.

18.4 Discussion

18.4.1 *Climate Change-Related Features of Invasive Species*

Dragotă et al. (2011) explain that DDBR's climatic frame originates from the interaction between the main positive weather parameters and extremes. The most climatic extremes from Romania are: the uppermost air temperature values;

Table 18.2 Alien plant species recorded in different types of natural and semi-natural plant communities/Natura 2000 habitats

Invasive species	Plant community (Natura 2000 habitat type)	Qualitative Index
Amaranthus blitoides	Artemisietum maritimae (1530*)	AD + −1, F ≤ 50 %
Amaranthus blitum subsp. *emarginatus*	Eleocharidetum acicularis (3130)	AD +, F 100 %
Ambrosia artemisiifolia	1: Hordeo murini-Cynodontetum (1530*); 2: Juncetum maritimi (1410)	1:AD + −1; 2:AD +
Amorpha fruticosa	1: Atripliceto hastatae – Cakiletum euxinae (1210); 2: Salicetum albae (91E0*); 3: Rubo caesii – Salicetum cinereae; 4: Salicetum triandrae; 5: Calamagrostio epigeji-Hippophaëtum rhamnoidis (2160); 6: Argusio-Petasitetum spuriae (2130*); 7: Elymetum gigantei (2110)	1: AD +; 2: AD + -4; 3: AD + -3; 4: AD +; 5: AD +; 6: AD +; 7: AD +, F ≤ 10 %;
Azolla filiculoides	Lemno-Hydrocharitetum morsus-ranae (3150), Lemno-Salvinietum natantis (3150) and Lemno-Azolletum carolinianae (3150)	coverage of water surface up to 85 %
Conyza canadensis	1: Elymetum gigantei (2110); 2: Convolvuletum persici (1210); 3: Plantaginetum coronopi (2110); 4: Argusio-Petasitetum spuriae (2130*)	1:AD + −1, F ≤ 60 %; 2:AD +; 3: AD + .
Elaeagnus angustifolia	1: Elymetum gigantei (2110); 2: Plataginetum coronopi (2110); 3: Juncetum maritimi (1410); 4: Calamagrostio epigei-Hippophaëtum rhamnoides (2160)	1: AD +; 2: AD +; 3: AD + −4; 4: AD +;
Elodea nuttallii	Ceratophylletum demersii (3150)	AD + −2
Euphorbia maculata	1: Plantaginetum coronopi (2110); 2: Trifolio fragifero-Cynodontetum (1530*)	1: AD + −2; 2: AD +;
Lindernia dubia	Dichostylido michellianae-Gnaphalietum uliginosi (3130);	AD +
Symphyotrichium ciliatum	1: Argusietum sibiricae (1210); 2: Acorelletum pannonici (1310);	1: AD +; 2: AD +;

(continued)

Table 18.2 (continued)

Invasive species	Plant community (Natura 2000 habitat type)	Qualitative Index
Xanthium italicum	1: Argusietum sibiricae (1210); 2: Atripliceto hastatae-Cakiletum euxinae (1210); 3: Convolvuletum persici (1210); 4: Acorelletum pannonici (1310); 5: Elymetum gigantei (2110); 6: Suaedo-Kochietum hirsutae (1310); 7: Calamagrostio epigei-Hippophaëtum rhamnoides (2160); 8: Suaedeto maritimae (1310)	1: AD +; 2: AD +; 3: AD +; 4: AD +; 5: AD + −3, F 10–100 %; 6: AD +; 7: AD +; 8: AD + −3, F $\leq$ 100 %;
Xanthium spinosum	Trifolio fragifero-Cynodontetum (1530*)	AD +, F $<$ 10 %

the lowest mean multi-annual precipitation amounts; the highest precipitation amounts fallen in short intervals (24 and 48 h) due to extreme weather events; extended periods of dryness and drought phenomena, thus ranking the area among the first three in the country in terms of frequency, duration and intensity; high wind speeds and frequencies, this yields the highest wind power energy in the country; high degree of vulnerability to strong winds ($\geq$16 m/s); increased frequency and intensity of dangerous climatic events (e.g. heavy rains, fog, blizzards).

Changing climatic conditions influence three essential elements of invasion: the source location, the pathway, and the destination (Dangles et al. 2008; Hellmann et al. 2008). Species that tolerate a wide range of climatic conditions could become the most successful invaders (Taush 2008). For example, precipitation variations could cause water-demanding/resistant species to outcompete one another (Fig. 18.2). The average annual precipitation of DDBR decreases from west (Tulcea – 438.4 mm) to east (Sf. Gheorghe – 403.6 mm).

From the perspective of alien's bio-geographical origin, rising temperatures would allow some species of Mediterranean origin to spread northwards and enhance the winter survival chances of some other organisms (Dragotă et al. 2011). Phenological stages are sensitive to temperature. It is more likely for annual plants to flower earlier than it is for perennials, and more likely for insect-pollinated plants than for wind-pollinated ones (Fitter and Fitter 2002).

Various flowering phases have been registered for the same species in the same period of time but at different locations (Tulcea and Sf.Gheorghe) within DDBR (Fig. 18.3). At the sea side flowering phases are now occurring earlier. The average annual temperature in Tulcea is 11 °C and in Sf. Gheorghe 12 °C (Dragotă et al. 2011). Monthly average of daily extreme temperatures have a significant role in the distribution of different phenological phases, as they are calculated from instantaneous values at different moments of the day, measured with maximum-minimum thermometers representing the true contrast between day and night.

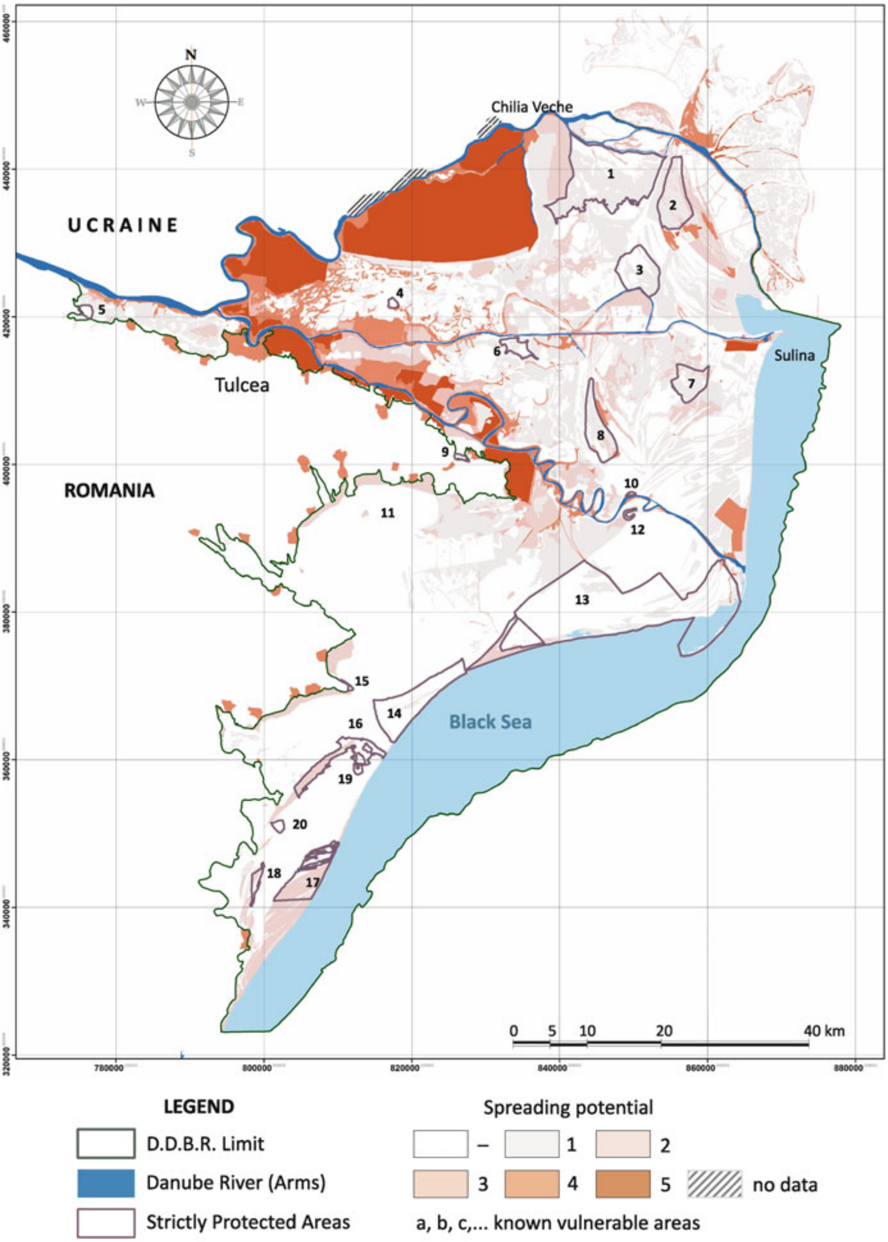

Fig. 18.1 Spreading potential of invasive plant species in DDBR

In January monthly averages of daily maximum temperatures are positive, ranging from 3 to 4 °C in the entire area, increasing in July to over 25 °C in the fluvial-maritime part and Razim-Sinoe lake complex, to over 26 °C in the central regions of the DDBR, and to over 27 °C in the western parts. Climate change effects, such

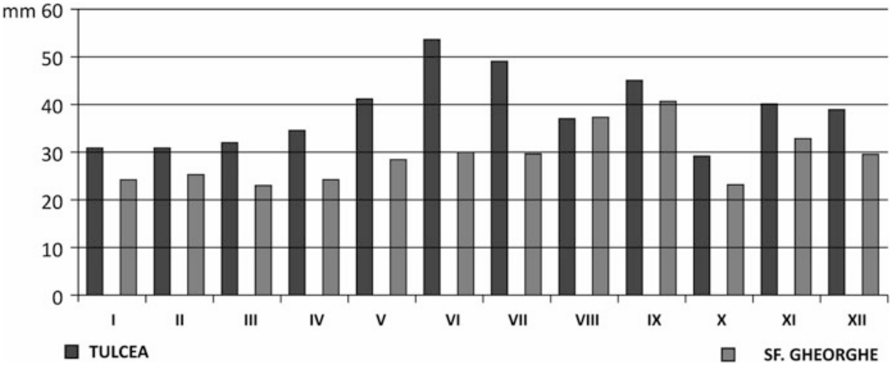

Fig. 18.2 Mean annual precipitation amounts in the Danube Delta Biosphere Reserve (1961–2007) (Dragotă et al. 2011)

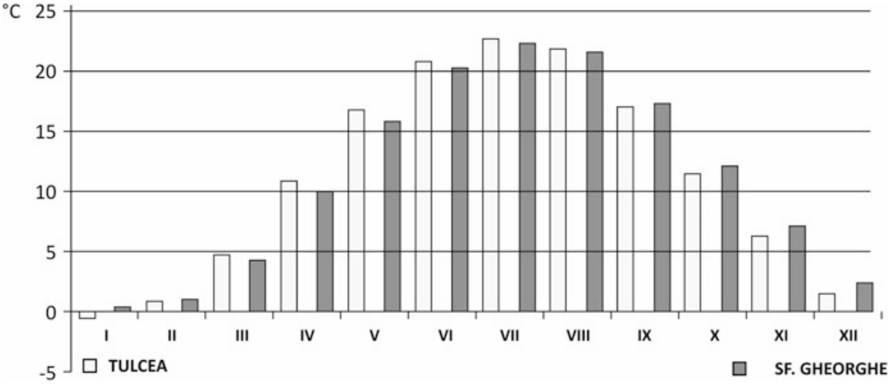

Fig. 18.3 Mean annual air temperatures in the Danube Delta Biosphere Reserve (1961–2007) (Dragotă et al. 2011)

as extreme duration of droughts, low temperatures, or floods in wetlands can haste the spreading of alien species. By comparing alien plants to natives ones, it has been observed that *Fraxinus pennsylvanica, Ailanthus altissima, Amorpha fruticosa,* and *Morus alba* are very resistant to these phenomena (Anastasiu and Negrean 2007). The actual spreading of alien ligneous species was not entirely based on their adaptive capacity given that most of them were massively planted in the past (Anastasiu and Negrean 2009). The species' resistance to frost is high, even though its spindles freeze every year. The first small plants begin to appear after the last frost period of the year when the soil is saturated with water and the evaporation process of water from soil is intense (Gregory and James 2003; Harold et al. 2005). The findings of previous studies revealed that the germination of seeds from *Amorpha fruticosa, Fraxinus pennsylvanica,* and *Robinia pseudoacacia* is influenced by both low temperatures below 16 °C and duration (Doroftei et al. 2005). With regard to distribution within DDBR, it may be mentioned that alien species' have been identified in almost all types of areas, environmental conditions, and habitat types.

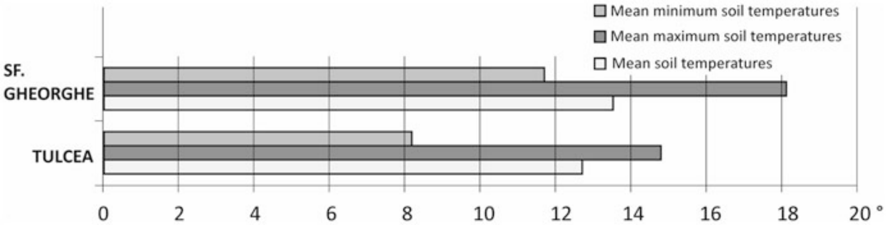

Fig. 18.4 Mean annual soil temperature parameters in the Danube Delta Biosphere Reserve (1961–2007) (Dragotă et al. 2011)

But the species' abundance and dimensions vary from area to area. Generally, the alien species have a preference for gleisoil 68 %, alluvial soils 11 %, and shifting sand hills 8 %; they also require a poor and moderate-drained soil (Munteanu and Curelariu 1996), but they are able to grow on poor soils and withstand the floods in DDBR. Although their development needs well-drained soils, they can resist in drought conditions (Gregory and James 2003). *Gleditsia triacanthos* can also tolerate strong winds but is unable to adapt to the coast area even under optimum conditions (*Ailanthus altissima, Amorpha fruticosa, Fraxinus pennsylvanica*) because of the winds from the sea. The exceptions are *Elaeagnus angustifolia* and *Lycium barbarum* as they do not require a soil with a specific pH to develop (Doroftei et al. 2005). They have a higher abundance and resistance in fluvial (western part) than in fluvial-maritime (eastern part) delta areas; the difference between these sectors consists in the amount of precipitation (Fig. 18.2), air (Fig. 18.3), and soil temperature (Fig. 18.4), and secondary, in drainage, salinity, soil texture (Munteanu and Curelariu 1996), and vegetation architecture type.

Furthermore, natural disturbances, such as fire regime, flood, bank-slides, and tree falls caused by dryness also provide good conditions for the development of alien species. The most abundant invasive species in DDBR are: around lakes and river banks – *Acer negundo, Ailanthus altissima, Amaranthus blitum* subsp. *Emarginatus, Ambrosia artemisiifolia, Amorpha fruticosa, Azolla filiculoides*, *Conyza canadensis, Elaeagnus angustifolia, Elodea nuttallii, Lindernia dubia* and *Robinia pseudoacacia*; in seaside areas – *Amorpha fruticosa, Elaeagnus angustifolia, Euphorbia maculate, Lycium barbarum, Symphyotrichium ciliatum* and *Xanthium italicum*; in localities – *Acer negundo, Robinia pseudoacacia, Ailanthus altissima, Lycium barbarum* and *Xanthium spinosum.*

18.4.2 Management Priorities and Strategies Related to Climate Changes

The research of Anastasiu (2011), Ciocârlan (2011) and Sîrbu and Oprea (2011) indicates that the number of alien plant species is increasing within DDBR. One of the reasons is that of all places in Romania DDBR is the most exposed to alien species through the many possible gates of their introduction: Constanţa, Sulina, Tulcea, Brăila, and Galaţi harbours (Anastasiu and Negrean 2009). Another reason is that certain plants communities are not well established. Therefore, in a climate change-induced changing landscape invasive species find opportunities for settling themselves by different dispersal factors (e.g. hydrological, wind). Presently, DDBR's management plan (2007–2013) provides only the action of inventorying invasive species and recommends some precautionary measures for their management that are not related to climate change. Also, in accordance with the 5th Convention on Biological Diversity and key directions of Seville's Strategy (UNESCO 1996), it recommends control or attenuation of climate changes in order to maintain a good habitat state. Among the potential measures that may be taken within DDBR in order to prevent negative effects of the invasive species in relation with extreme climate events are keeping the present population of some invasive species in control; maintaining a good habitat status in strictly protected areas by monitoring the newly arrived species; identifying new potential areas in order to replant species with decreasing populations because of environment frequent variations; changing the management of some habitat types by means of reducing climate change effects with minimum long-term consequences. The biggest challenge is the uncertainty of long-term effects that actions taken in present climate change conditions might have. Even if the present actions seem to be the most appropriate for the actual conditions there is no certainty that they will have the same effect in future climatic conditions. Scenarios combined with expert knowledge are needed at the local level in order to reduce this uncertainty. In this regard one example are mechanical control methods that are useful to some species in particular portions of their range. If warmer winter temperatures allow these plants to overwinter, management will have to be more aggressive and sustained and, thus, will be more expensive (Hellmann et al. 2008). Furthermore, it is necessary to ensure high-quality information about climate changes is available for park rangers training in order to enhance the capability of adapting and applying the required measures.

Climate change adaptation is being undertaken through management measures in order to reduce potential impacts of invasive species spreading in DDBR habitats. Priority challenges, responsive measures and their actions with possible risks are listed below for the Natura 2000 habitat types 1210, 1310, 1410, 1530*, 2110, 2130*, 2160, 3130, 3150 and 91E0*.

I. Challenge: habitat conservation; **(a) Measure:** identify areas that are likely to be resilient to climate change and support a broad range of plant species under changed conditions; **Actions:** identify and map high priority areas for conservation using information on species distributions, habitat classification, and land cover; spot the most problematic invasive plant species, their coverage, and spreading potential areas. **Risks/Uncertainty:** lack of implementation capacity because of the knowledge gap on habitats conservation; in the long term unpredictable changes of climate can sustain the propagule availability and, thus, the spreading of invasive plant species.

(b) Measure: restore habitat features; **Action:** restore degraded habitats to reduce species vulnerability by creating refuge areas in a changing climate;

prioritise projects whose conservation targets are invasive plant species and resilience in a changing climate; **Risks/Uncertainty:** the lack of political will; the features of restored habitats cannot be maintained due to climate change pressures.

II. Challenge: species and habitat management in the context of climate change; **Measure:** bring the management plan up-to-date by taking climate change risks in account and support adaptation; **Actions:** use management practices that are already being successfully applied in other protected areas; take climate change effects, potential risks, and invasive plant species distribution for entire Danube River Basin into account; improve risk assessments and vulnerability scenarios to be able to develop and choose suitable measures; use species distribution models to identify new potential habitats for translocation of endangered plants; **Risks/Uncertainty:** insufficient data for assessments and scenarios; lack of interpretation ability in the field of predicted results; the long-term effects of actions taken in present climate change conditions can prove inefficient;

III. Challenge: improve capacity for effective management in a changing climate; **(a) Measure:** increase awareness of invasive species threats in climate change context and increase the capacity of stakeholders to implement adaptation programmes for habitats and plant species; **Actions:** conduct training on different levels of organisation (e.g. park rangers, head managers) initiating hypothetical management activities on extreme climate events and trends of invasion; develop a network of training opportunities and materials addressing climate change impacts on protected areas management through agreements with universities and research institutes; **Risks/Uncertainty:** lack of communication interest;

(b) Measure: assist a coordinated response to climate change between protected areas administration, stakeholders, nature protection agencies, and specific NGO's; **Actions:** identify and address conflicting management objectives of involved decision-makers and find effective policies and methods for climate change pressures; develop trans-boundary common management to adapt to and mitigate climate change impacts in shared areas (Danube Delta Biosphere Reserve – Romania and Ukraine); **Risks/Uncertainty:** possible future changes in management objectives of protected areas;

IV Challenge: reduce non-climate pressures; (a) **Measure:** slow and reverse habitat loss and fragmentation; **Actions:** collaborate with environmental agencies to evaluate historical water fluctuations and improve water management options to protect or restore aquatic habitats; identify the range of most disturbing activities in habitats on a map and compare it with habitats and invasive plant species distribution maps in order to identify vulnerable areas. This reduces/changes pressure activity on habitats and enables restoration, where loss and fragmentation due to invasive plant species occurred; increase restoration, enhancement, and conservation of riparian zones; create buffer zones to agricultural areas minimising the spreading potential of invasive plant species to natural areas; **Risks/Uncertainty:** invasive plant species can easily spread in the present climate conditions. Insufficient correlation between control/eradication measures of invasive species and non-climate pressure activities.

(b) Measure: involve, assess, and improve existing programmes to prevent, control, and eradicate invasive species; **Actions:** develop different approaches to detect established invasive species, including entries monitoring; raise public awareness by non-formal activities and media to foster understanding for regulations and potential risks for native species and habitats; overall risk assessment to identify actions and prioritise responses to invasive species that pose the greatest threats to habitats and species; **Risks/Uncertainty:** inefficient knowledge transfer to stakeholders and the public; no cooperation between decision-makers. no sufficient funds for control/eradication measures.

18.5 Conclusions

Regardless that DDBR is a wetland, dryness and drought have the greatest intensity and frequency in Romania. DDBR's annual average quantities of precipitation decrease towards the sea shore area, while the average temperature increases. In these conditions, Natura 2000 habitats types 1210, 1310, 1410, 1530*, 2110, 2130*, 2160, 3130, 3150 and 91E0* are exposed to the spreading potential of invasive species. The biggest challenge is the uncertainty of long-term effects of actions taken for the control and eradication of invasive species in current climate changing conditions. More research into dynamic modelling and scenarios tools that should be developed is needed. This should be done both at a regional and local level involving experts in order to understand extreme events and how to diminish their effects by applying appropriate measures.

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Chapter 19

Reproduction Biology of an Alien Invasive Plant: A Case of Drought-Tolerant *Aster squamatus* on the Northern Adriatic Seacoast, Slovenia

Nina Šajna, Mitja Kaligarič, and Danijel Ivajnšič

19.1 Alien Plant Species Might Benefit from Global Warming

Since 2007, it has been widely accepted that the global climate is warming and that human-induced increases in greenhouse gas emissions are mostly the cause (Kerr 2007). Global warming has been recognised to have profound impact on physical and biological systems. Of particular concern is the effect of global warming on biological diversity. Predictions of extinction have estimated that 20–30 % of species might face increasingly high risk of extinction. However, mechanisms of species persistence could lower the estimated extinction rate, while taking into consideration other human impacts (e.g., habitat destruction, landscape fragmentation or alien species introduction) could account for additional biodiversity loss (Botkin et al. 2007). Invasive species have been recognised as one of the most salient threats to biodiversity. Non-native species occurring in habitats where they were not present before the introduction are termed invaders or alien species. Rapidly increasing problems caused by invasive alien species worldwide demand the effective implementation of various policies aimed at reducing the impact of potentially or currently problematic non-native species (Richardson and Pyšek 2004).

To understand changes in biodiversity, we must take into consideration at least the effects of global warming and the possibility that alien species might benefit from them. The future impact of global climate warming will vary from region to region. The most striking variation will involve changes in precipitation, and drought is expected in some areas like the Mediterranean (Kerr 2007). To these changes local species might respond with forced migrations. On the other hand, the alien invasive species already found in the Mediterranean might respond

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differently. In some cases, low soil water availability reduces their invasiveness (Alpert et al. 2000; Stohlgren et al. 2001), while some other alien species can tolerate drought better than local species (Williams and Black 1994; Milchunas and Lauenroth 1995; Nernberg and Dale 1997). In the latter case, such aliens might extend their range boundaries. Drought might have a particular effect on increased invasibility of fast-growing alien species if habitats are un-shaded (Schumacher et al. 2008).

Another recognised impact of global warming is the shift in plant phenology caused by an earlier biological spring and a delayed winter; while again, these effects will vary according to water availability and regional characteristics (Peñuelas et al. 2009). The lengthened vegetation period might represent additional benefits for invasive species in the Mediterranean, since these are mostly species which flower late and their flowering period is terminated by oncoming winter. The end of flowering in late season is one of the significant differences between native and non-native species in general (Knapp and Kühn 2012). Similarly, growth and biomass accumulation in non-natives are terminated by the first occurring low temperatures and are not ended gradually by plant senescence, as in most native species. This should be especially important for annual species.

Thorough studies are needed to better predict whether any alien species that are currently regarded as non-invasive non-native species and are already present could benefit from global change and turn into invasive alien species. This is why every alien species must be taken into consideration. In this chapter we discuss whether global warming might favour the non-invasive alien *Aster squamatus*, which is already present and whether it could potentially become invasive.

19.2 *Aster squamatus*, a Non-invasive Alien in Slovenia

Aster squamatus (Sprengel) Hieron. is a hemicryptophyte originating from central South America, occupying habitats like salt marsh landscapes from Central Argentina (Cantero et al. 1998). Even though *A. squamatus* does not usually form large dense stands in introduced habitats, the species is distributed widely in many European countries, among them Italy (Pace and Tammaro 2001), Spain (Molina et al. 2004), France (Bassett 1980), Malta (Deidun 2010), Cyprus (Hand 2000), and Greece (Theocharopoulos et al. 2006).

The first record of *A. squamatus* in Slovenia was noted in 1973 (Wraber 1982), and the species has been constantly present since then, although not highly invasive (Kaligarič 1998; Glasnović 2006). This species has also been observed in urban areas (urbanophile species) like the old town centre of Izola. Even though it is not highly invasive, where present, its occurrence is disturbing, especially near the two most important coastal wetlands along the Slovenian coast: Sečovlje salina and Škocjan inlet, representing various Natura 2000 habitats. Sečovlje salina is a traditionally built salt-pan system where active salt-making is still partly practised. The salt-pan system includes natural salt pools (flooded and dried out), which are maintained exclusively by high tide, and salts flats which both offer habitats for halophile species, and the lower course of the Dragonja river with its river mouth and freshwater as well as brackish riparian habitats along the banks. Škocjan inlet was renatured some years ago and here, too, different Natura 2000 habitats developed. In some years *A. squamatus* was found to be very abundant, even exceeding the abundance of the native halophile vegetation (Glasnović and Fišer Pečnikar 2010). The occurrence of *A. squamatus* is especially dense within and around the port of Koper, possibly the source of the arrival of the species on the Slovenian coast.

Species-specific empirical data are important for individual-based modelling of future changes of biodiversity; in particular, data about dispersal and life history trade-offs might improve model realism (Botkin et al. 2007). Additionally, knowledge about preferred environmental conditions helps to improve niche-based models because it allows forecasting of the persistence and distribution of species (Botkin et al. 2007). Thus, knowledge of a species' reproductive success is needed for better understanding of its invasive potential, while on the other hand, micro-scale habitat properties along with biotic interactions also influence trends in the richness and abundance observed in alien species (Aguiar et al. 2006). This is why we estimated the reproductive potential of *A. squamatus* by measuring seed production of individual plants in relation to plant height and soil properties, especially soil salinity and humidity. Additionally, we tested the seeds for their germination characteristics.

19.3 Determining the Reproductive Potential and Habitat Characteristics

In evaluating the reproductive potential of *A. squamatus* plants, we recognised five categories of plant height: 1 – below 50 cm; 2 – from 50 to 70 cm; 3 – from 70 to 110 cm; 4 – from 110 to 140 cm; and 5 – from 140 to 170 cm. The potential reproductive success of *A. squamatus* plants was estimated by counting the number of flower heads for plants belonging to each category, as well as seed number per single flower head. The data obtained were used in making a calculated estimation of the total seed number for an individual plant. Subsequently, we tested the seeds for their germination rate in laboratory conditions. We collected ripe seeds in the field in October 2011; these were dry-stored until the beginning of the experiment. Twenty seeds were allowed to germinate untreated on filter paper, watered with distilled water for 31 days. Observations were performed every 2 days, at which point germinated seeds were counted and removed.

Soil samples collected from plots where *A. squamatus* was absent (0) or present (1), were analysed for P, K, organic matter, C, total N, C:N content, Zn and pH. Additionally, we measured the salinity and humidity of the soil samples. Where present, the *A. squamatus* plants were categorised into different height classes (a – 50 cm or less, b – between 50 and 100 cm, and c – above 100 cm).

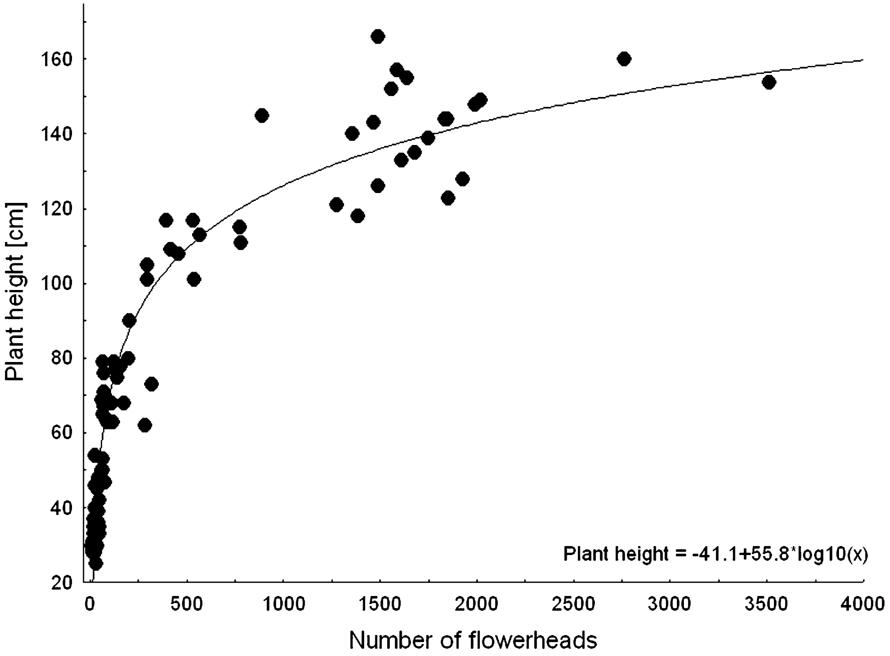

Fig. 19.1 Relation between plant height and number of flower heads of *Aster squamatus* (equation of logarithmic fit is given)

Mapping of *A. squamatus* occurrence was predominantly used to estimate its distribution, not its habitat preference. However, it was obvious that this species favours disturbed ruderalised habitats, including ruderalised grasslands with slight to moderate elevations in salinity level.

Results show high reproductive potential and low soil C:N ratio.

Aster squamatus plants show high reproductive potential, which increases with the plant's height (Fig. 19.1). The relation between a plant's height and its reproductive potential, measured through the number of flower heads, shows no significant differences between plants up to 110 cm tall; however, taller plants from the height categories 4 and 5 differ significantly from the first 3 categories and between each other (ANOVA, $F_{(4,69)} = 69.07$, $P < 0.001$, post-hoc Unequal N HSD; Fig. 19.2). The average number of seeds (achenes) in a single flower head seems to be fixed (31 and 35 seeds in categories 1 and 2, respectively), since the number increases only slightly with plant height (38 seeds in categories 3–4).

Different height categories (a–c) did not differ among each other in any of the soil chemical properties tested (ANOVA, at $P < 0.05$). However, there is statistically significant difference (t-test, $P < 0.05$) in phosphorus content (t-value $= 2.1$; d.f. $= 28$; $P = 0.045$) and C:N ratio (t-value $= -3.77$; d.f. $= 28$; $P = 0.0008$) between the soil samples taken from sites where *A. squamatus* is present and these where it is absent, irrespective of plant height (Table 19.1). Additionally,

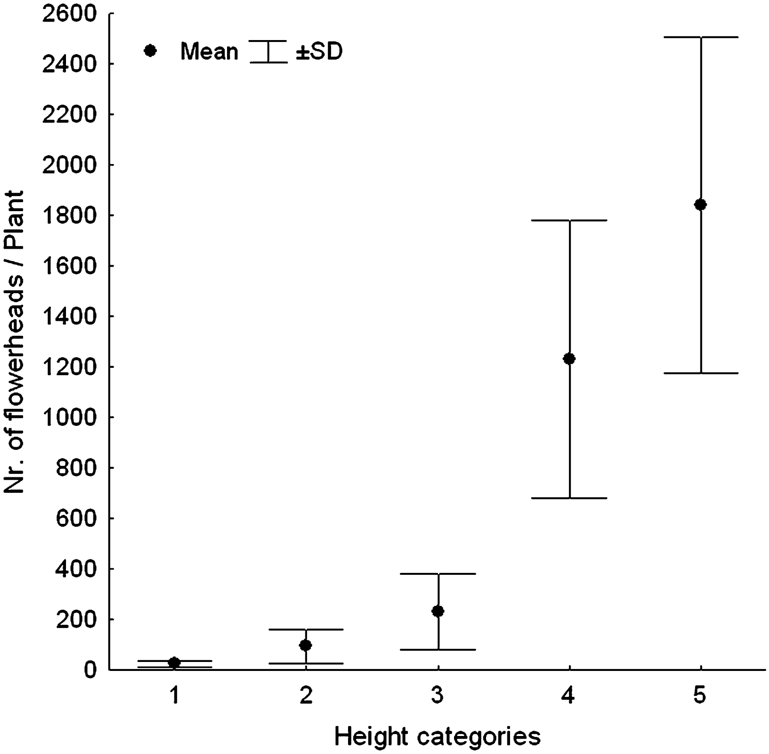

Fig. 19.2 Reproductive potential of *A. squamatus* plants from different height categories (*1*: <50 cm; *2*: 50–70 cm; *3*: 70–110 cm; *4*: 110–140 cm; *5*: 140–170 cm) measured through the number of flower heads per single plant (significant differences are marked with different letters; ANOVA, post-hoc Unequal N HSD)

Table 19.1 Comparison of soil samples with (N = 22) or without *A. squamatus* (N = 8) with student t-test (significance at $p < 0.05$)

	A. squamatus present	*A. squamatus* absent		
Soil parameter	Mean ± s.d.	Mean ± s.d.	t-value (at 28 df)	P
Salinity	104.4 ± 59.8	97.6 ± 36.3	0.30	0.767
Humidity [%]	11.8 ± 5.4	12.8 ± 7.8	−0.40	0.694
pH in n/10 KCl	7.3 ± 0.3	7.3 ± 0.3	−0.38	0.706
pH in Ca-acetate	93.4 ± 28.0	102.0 ± 0.0	−0.86	0.395
P [mg/100 g]	16.2 ± 13.7	5.9 ± 1.7	2.10	0.045
K [mg/100 g]	40.1 ± 26.7	24.0 ± 17.2	1.58	0.125
Humus [%]	5.6 ± 4.6	3.5 ± 2.0	1.24	0.224
C-organic [%]	3.2 ± 2.7	2.0 ± 1.2	1.24	0.224
Total N [%]	0.26 ± 0.2	0.14 ± 0.1	1.78	0.086
C:N ratio	11.9 ± 2.1	15.3 ± 2.3	−3.78	0.001
Zn [mg/kg]	134.9 ± 125.7	55.5 ± 51.7	1.72	0.098

differences in total N (t-value = 1.78; d.f. = 28; $P = 0.086$) and zinc content (t-value = 1.72; d.f. = 28; $P = 0.098$) were close to significance.

Until now, the occurrence of *A. squamatus* has been restricted by the low number of available habitats. In Slovenian coastal habitats *A. squamatus* was found restricted to semi-saline habitats, which are represented only by a narrow strip near the coast between the typical halophile vegetation and coastal grasslands or arable land farther from the sea. The habitat types where *A. squamatus* thrives belong to halophytic scrubs (1420), halophilous reeds and rush salt marshes dominated by *Juncus maritimus* (1410; Fig. 19.3).

19.4 As an Engineering Species *Aster squamatus* Could Potentially Become Invasive

Since the first record of *A. squamatus* in Slovenia, the species has had a constant presence. Its abundance and distribution is limited by habitat availability, which is scarce along the Slovenian coast, since coastal grasslands are poorly represented on the Slovenian coast because of considerable human impact and because they belong to low-productive grasslands. Such specific habitat properties do not enable *A. squamatus* to become abundant or highly invasive, even though the species has an enormous seed production and fairly high germination rates. However, these low-productive habitats could be altered by species' decomposing biomass, as discussed later. On the other hand, in several European countries, coastal grasslands are common habitats and could potentially be invaded by *A. squamatus*. It has been observed before that *A. squamatus*, sometimes together with *Conyza canadensis* – another alien species, invades vegetation with coarse perennial grasses and sedges or rushes (Bassett 1980). Along with such invasions, it was mainly the abundance of small annuals that declined: for example, *Catapodium rigidum* and *Parapholis incurva*. We made similar observations in Slovenian habitats for *Spergularia marina* and *Parapholis strigosa*, rare plants from semi-saline habitats. If in any way the preferred semi-saline habitats become more common, *A. squamatus* could rapidly invade favourable habitats. Our results show that *A. squamatus* has some of the characteristics that have been recognised by statistical models from Knapp and Kühn (2012) to be significant for non-native species. One of them is a high level of seed production, which may be explained by non-native species being more frequently able to self-pollinate (Knapp and Kühn 2012).

The study site is located in the Sub-Mediterranean part of Slovenia, and between 1951 and 2010 the temperature has risen and precipitation shifted to autumn. There are more sunny days between May and August; all these consequences could be attributed to global warming (Anonymous 2006). There is already a slight increase in autumn temperatures, and predictions for the years 2036–2065 by various models (C4I, ETHZ, KNMI, MPI, SMHI_BCM, SMHI_HadCM3Q3, DMI_ECHAM5, DMI) based on climate data from 1971 to 2000 do show an increase in mean temperature especially in the middle of the vegetation season (the ENSEMBLES

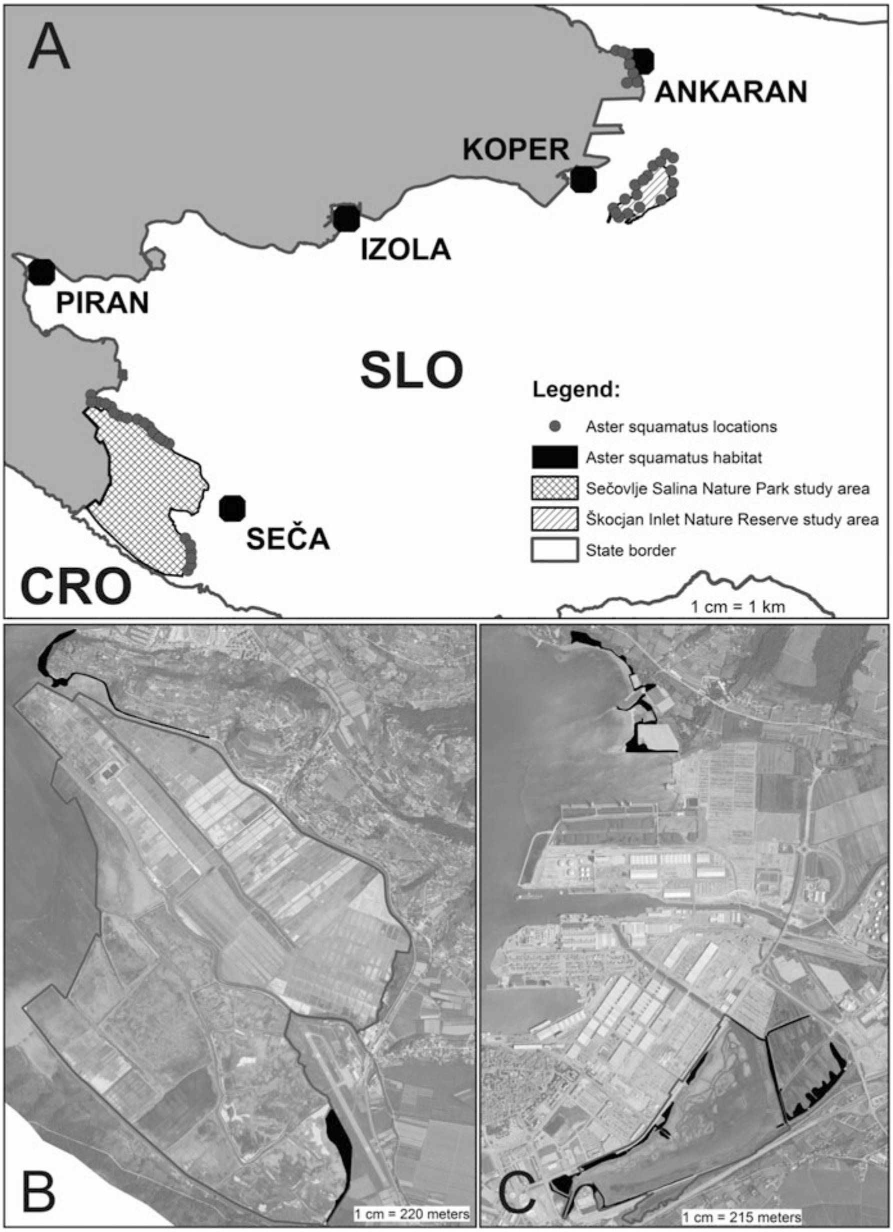

Fig. 19.3 Locations where *A. squamatus* is present on the Slovenian sea coast (**a**). Two protected areas are shown in detail: Sečovlje Salina (**b**) and Škocjan Inlet (**c**)

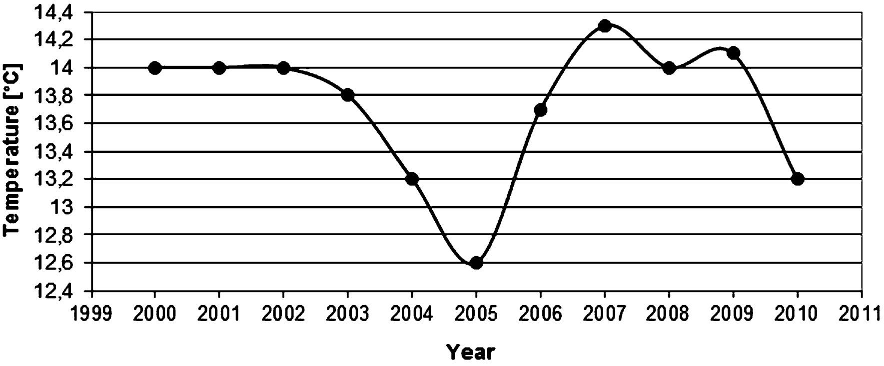

Fig. 19.4 Mean annual temperature from 1998 until 2012 at the meteorological station in Portorož (Graph constructed from data provided by Slovenian Environmental Agency freely available at http://meteo.arso.gov.si/met/sl/app/webmet/)

dataset and the HABIT-CHANGE-database 2012). Even though models predict a slight increase in precipitation (about 20 mm/day), the number of dry days (<1 mm/day) per vegetation season is expected to increase by 4–5 days. When combining these models the predicted beginning of the vegetation period will shift from 22nd February (1971–2000) to 27th January (2036–2065). Additionally, the predicted water balance, calculated as the mean precipitation minus the potential evapotranspiration, is expected to decrease slightly in autumn.

Global-warming-related effects on biodiversity can be mitigated in the short term by designing an appropriate nature reserve (Botkin et al. 2007). However, the challenges of biodiversity loss are daunting, since biodiversity is decreasing even in protected areas. For this reason, alien invasive species found in the Mediterranean, even if not highly invasive, like *A. squamatus*, might nevertheless potentially become so. In Fig. 19.3 we can recognise the distribution of *A. squamatus* in areas adjacent to both protected areas of Sečovlje Salina and Škocjanski Inlet. As previously noted, in some years like in 2008 the abundance of *A. squamatus* increased (Glasnović and Fišer Pečnikar 2010). Our analysis of temperature showed a highly increased mean annual temperature the previous year 2007 (Fig. 19.4), which resulted in a prolonged vegetation period and must have resulted in high seed production as well.

To prevent a potential invasion by *A. squamatus* plants should be removed before reaching the height of 110 cm to prevent or at least minimise seed production, since smaller plants have more than five times fewer flower heads (Fig. 19.2), even though the number of seeds in a single flower head is more or less the same. Calculation show that plants smaller than 110 cm could bear from about 700 to 8,700 seeds, while plants taller than 110 cm produce at least five times more seeds from about 47,000 to 70,000 seeds. Obviously, it is necessary to constrain eventual accumulation of seeds in the soil seed bank and to prevent plants from forming a reservoir for future invasions if appropriate conditions might recur.

On the other hand, where *A. squamatus* plants are present, the soil C:N ratio is significantly lower (Table 19.1), indicating high biomass production and high quality litter, which enables faster decomposition and nutrient cycle rates. This is consistent with other invasive species, especially if they are capable of N-fixing (Williams and Baruch 2000). It is generally accepted that many invasive species benefit from high levels of nutrients (Schumacher et al. 2008 and references therein). We can regard *A. squamatus* as an engineering species, fertilising its own habitat. We can expect that the longer the species would be present in the habitat, the more the nitrogen content in the soil would increase and further promote *A. squamatus* growth. Climate change, prolonging the vegetation period, would enable more biomass accumulation followed by rapid decomposition. These nutrients from decomposed biomass can be better used by fast-growing species that start their development slightly later in the season than early spring species, which often begin to grow by utilising nutrients accumulated in their storage organs. In such cases of engineering alien species, adapted management is needed. Plants should be removed from occupied habitats irrespective of height, so that biomass accumulation cannot promote their own growth. This also includes dead plants from the previous season. However, this is not always feasible, so again plants should not be allowed to attain 1 m in height. Additionally, fertilising urban and ruderal sites could also promote invasions by alien species.

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Part V
Conclusion and Recommendations

Chapter 20
Conclusions and Recommendations for Adapting Conservation Management in the Face of Climate Change

Sven Rannow, Christian Wilke, Moritz Gies, and Marco Neubert

20.1 Introduction

Climate is changing and nature is responding at increasing speed. Many protected areas are already noticing the first consequences for biodiversity. The timing of seasonal events like the first flowering date for plants and the breeding dates of birds have advanced as spring is taking place earlier in the year. Species are changing their geographic distribution northwards or to higher altitudes. Consequentially, typical ecological interactions like hatching of offspring and availability of food sources are disrupted in time or in space. In addition, extreme events like floods and heavy rain but also heat waves and dry seasons are changing their pattern and intensity. This has severe impacts on individual species and habitats. Altered water regimes or other abiotic conditions are likely to change the character of habitats and ecosystems. Projected future climate trends will further accelerate changes in distribution and abundance of endangered species and ecosystems, and intensify overall biodiversity loss.

Even though mitigation of climate change is of utmost importance, conservation management must also be adapted to climate change. Otherwise climate change impacts will result in the degradation of habitats, the extinction of species and the loss of ecosystem services that are essential for human well-being.

Adaptation to climate change is defined as the adjustment in ecological, social or economic systems to prevent or reduce harm or benefit from potential opportunities

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(Smit and Pilifosova 2001). Adaptation of conservation management means adjustments in management practices, decision-making processes and organisational structures (Welch 2005). Although the adaptation process should be started now, it must be planned as a long term process. It will be successful only if as many institutions and stakeholders as possible are actively involved and are willing to support it.

Scientists have an important role to play in the development of adaptation strategies, but to facilitate effective implementation of adaptation actions local communities and decision-makers are essential. Expertise and data provided by research are a basis for a transparent and understandable decision-making process, but scientific results need to be translated and presented in a form that is accessible to professionals and decision-makers and local stakeholders (Welch 2005). The scientific information for local climate adaptation must be relevant for the decision at hand and tailored for the decision context. It should be authorised and trusted by the people affected, and transparent in the process of production. Meeting and addressing the needs, knowledge and language of local communities who have to implement adapted management practices is a major challenge for many scientists in climate impact research.

Acknowledging this challenge, the project HABIT-CHANGE initiated a science-management approach to plan jointly for adaptation in protected areas. This kind of collaborative research has already produced beneficial results in other areas (Littell et al. 2012; Lonsdale and Goldthorpe 2012). The science-practice partnership for collaborative research proved to be invaluable for testing useful methods, the identification of applicable solutions and the enhancement of practical conservation management within HABIT-CHANGE. It was built on an intensive dialogue between an interdisciplinary panel of scientists and local management and facilitates the co-production of knowledge. In this process several barriers to the practical implementation of theoretical concepts were identified. Much data and many methods provided by science did not fit with planning reality and the decision context of protected area management. On the other hand, many management practices were lacking a foundation in solid facts and evaluation of their success was often neglected. Furthermore, it seems that much of the available knowledge and guidance on adaptation of conservation management does not reach local management.

From the experience gained in the project we could see that climate change is rarely perceived and accepted as a high priority challenge on site level. There is often too little awareness that climate change is already a main driver of biodiversity loss and that its significance will increase even more in the future. Usually, neither management authorities nor land users and stakeholders have enough information, knowledge or incentives to plan and negotiate necessary adaptations to climate change. The adaptive capacity of local institutions like the administrations of National Parks or Biosphere Reserves is a crucial component too. The lack of expertise, methods and tools for climate adaptation as well as limited resources prevents proper management and adaptation (Fig. 20.1). The institutional setting of protected areas influences capacity and willingness to respond to new challenges

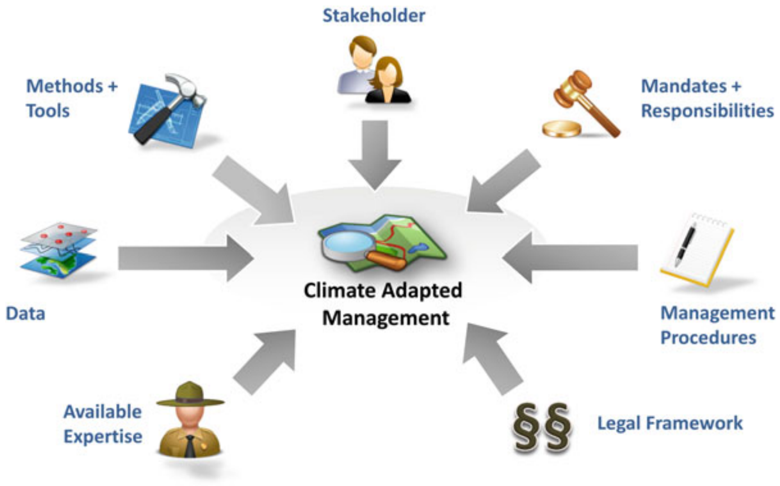

Fig. 20.1 Aspects affecting the adaptation process of protected area management

and opportunities. This institutional adaptive capacity is at least as important for the conservation of biodiversity at the local level as the biological capacity of species to adapt at the level of individuals (e.g. by changes in phenology), populations (e.g. by migration) or species (e.g. by evolution).

From the work documented in this book and the project implementation further insights have been gained for more specific topics. What we consider to be the most important lessons learned are summarised in the following subchapters.

20.2 Lessons Learned from Modelling, Impact Assessment and Monitoring

Climate change is often associated with melting glaciers, melting pole caps and rising sea levels; however, most impacts are more subtle and hidden and thus not as easy to identify. Several methods can help to generate knowledge about potential climate change impacts as well as the effectiveness of adaptation measures. In HABIT-CHANGE modelling of exposure, impact assessment and monitoring methods have been applied.

Regional climate modelling (see Chap. 2) estimates changes for a possible future climate. The project results reinforce the expectation that Central and Eastern Europe is a sensitive region in terms of climate change (Auer et al. 2007). A distinct trend for temperature rise is projected while a shift of precipitation from summer to winter becomes visible. Due to considerable regional climate variability a high spatial resolution of future climate scenarios seems advisable to support local decision-making. This may increase uncertainty of the extent of expected future changes, but this information is also important as it provides a bandwidth of the potential changes.

Based on climate scenarios it is possible to calculate the impacts on further parameters of the natural balance, like water balance (see Chap. 3), flooding, soil-moisture, or species distribution. Modelling water balance is a key issue concerning future habitat development since most habitats are affected by changing hydrological conditions (see Chap. 4). Yet incomplete knowledge on ecological responses means that conservation management will inevitably experience surprising impacts in the future and needs to prepare for unexpected effects.

The issue of uncertainty also arises in the case of parameter-related modelling, since models are only simplifications of reality (see Chap. 5). Errors cannot be avoided since a model output strongly relies on the understanding and reproduction of real natural processes (Maslin and Austin 2012) and on the quality of its input data. Thus, modelling results should be used with care in the decision-making process (Millner 2012). On the other hand, models allow for an illustration of potential future developments, especially when using different scenarios, and thus support action and adaptation to impacts.

Impact assessment in HABIT-CHANGE followed the framework of IPCC (2001), consisting of the sensitivity and the exposure which defined the potential impacts (see Chap. 8). The aim was to apply a simple and transferable approach that is understandable for conservation managers. The framework requires only a minimum of local data and results in sensitivity maps and potential impact maps per season. The approach does not incorporate adaptive capacity; however, it can be a valuable assessment tool for climate-induced impacts on habitats. Identifying sensitivity of species and habitats is a good way of producing relevant information on the local level, especially when downscaled climate projections are not available. First of all, it supports the identification of habitats that are very susceptible to climatic changes. Furthermore, it helps to focus measures and activities as well as setting priorities. The sensitivity assessment allows for ‘what if’ scenarios. It can be used to exemplify the potential direction of habitat dynamics for different temperature changes (e.g. 2 °C).

Monitoring with all its facets is a crucial aspect of documenting and understanding the effects of changes in the landscape, biodiversity or specific parameters caused by human or natural impacts. A wide variety of appropriate methods for monitoring already exist, but they often lack the capacity for continuous long-term application.

In HABIT-CHANGE different monitoring methods have been applied. The objective was to provide indicators of potential climate change impacts (see Chap. 6) by the application of in-situ or Earth observation (see Chap. 7) methods. In-situ methods (like meteorological observations, soil moisture or water level sensor measurements, monitoring animal and plant populations) were applied to monitor specific aspects in the diverse investigation areas. Remote sensing approaches require a highly site and context specific design to fit data, methods and indicators and derive useful results. Short-term indicators can be used, e.g. to monitor the percentage of natural tree types at Natura 2000 sites, and long-term indicators can be utilised, for instance, to monitor the immigration of beech in a spruce dominated region. Also retrospective analysis can be an interesting source to analyse historical developments e.g. using remote sensing data from the last decades or historical maps from the last centuries. For continuous remote sensing monitoring comparable data sources with a high revisit rate and an appropriate spatial and spectral resolution are required.

In addition, coordination and standardisation for monitoring changes in biodiversity and impacts of climate change are necessary on a larger scale. Monitoring programmes should cover regional and national levels and provide for centralised data management, so that biodiversity status and its responses to climate change can be identified. Monitoring programmes for protected areas should focus on impacts and effectiveness of management activities within the areas. Only harmonised monitoring methods allow for an exchange of results between areas and provide a network of data to identify regional or continental trends. Furthermore, monitoring is an integrative part of the Adaptive Management cycle. Results can be used to review the performance of measures and for awareness raising activities.

In summary, it can be said that a lot of effort is needed to generate this kind of scientific-based knowledge. On the other hand much specific local expertise exists that should be captured (e.g. within a stakeholder involvement process) and used.

The most important finding was that science-based results need to be broken down to locally applicable knowledge for conservation management. There are several techniques available, like visualisations and maps, story-telling or experimental games that can illustrate the regional effects of climate change and its impacts on everyday activities.

20.3 Lessons Learned from the Process of Adapting Conservation Management

During recent years guidelines and concepts for the adaptation of conservation management have mushroomed (e.g. Baron et al. 2009; Cross et al. 2012; European Commission 2012; Glick et al. 2011a; Hansen and Hoffmann 2011; Lawler 2009; Welch 2005). Building on this wealth of literature and intensive discussions a framework for the adaptation of conservation management in protected areas of Central and Eastern Europe was drafted. The framework aimed at the development of Climate Change-Adapted Management Plans (CAMPs).

The application of this framework in six protected areas showed that the framework needed to be adapted to the site-specific conditions and management tasks. Sometimes additional steps were necessary and some required extra efforts. Particularly the definition of objectives and scope of the adaptation process needs special attention, and a clear definition of the area to be analysed, the problems and sectors to be included (e.g. agriculture, tourism) and target groups to be addressed is required. These decisions are essential to identify adequate methods for the assessment and to streamline stakeholder involvement.

In HABIT-CHANGE the development of a conceptual impact model that helps to identify drivers and pressures as well as their interaction was an integrated part of the assessment. However, there are also good reasons to include it as an individual step (e.g. Cross et al. 2012; Rannow 2011).

Based on the experience gained in the project, we consider the framework as a basic structure. Protected area managers may select and add elements from the plethora of frameworks that they consider useful for their specific situation. The willingness to adapt is more important than the strict application of any framework, guideline or handbook. At present, experimenting as well as learning by doing still plays a fundamental role in the adaptation of conservation management. Climate adaptation is as much a social learning process as it is a science-based procedure. It has to be considered a continuous process as knowledge about climate change, its impacts and the effectiveness of management will grow. In this context, Adaptive Management is a promising concept for gaining new knowledge and adjusting conservation efforts to changing conditions on the local level.

However, the time to initiate the adaptation process is now. Several areas have learned that climate impacts are already evident on the local level and management strategies and measures need to be adapted. Some management activities might even become superfluous with changing climate conditions. Especially when it comes to large restoration projects, the consideration of climate impacts is crucial for their long term success and changes might be necessary to ensure their effectiveness.

Early adaptation can help to reduce financial loss and preparedness can help to save money otherwise necessary for expensive emergency actions. In addition, there is a great wealth of local knowledge and a plethora of readily available research results, so that adaptation processes can be initiated without extensive investments or modelling efforts. Nevertheless, adaptation to climate change does not come free of charge. Adaptation of protected area management to climate change requires financial and methodological assistance. Many elements of the adaptation process cannot be implemented by protected area management alone. Support needs to be provided by scientific, regional or national partners. Management of protected areas faces the challenge of establishing new coalitions and strong cooperations in order to make adaptation work.

20.4 Lessons Learned from Stakeholder Involvement and Awareness Raising

The conservation status of many habitats is influenced by current land use practices like agriculture, forestry or tourism and their intensity. Most protected habitats can only be maintained through cooperation between protected area management and land users. Especially in the context of the cultural landscapes of Europe, only a few core zones in strictly protected areas like National Parks are solely dedicated to the conservation of natural habitats and exclusively managed by protected area administrations. In addition, it is already obvious that uncoordinated adaptation strategies by different land users will lead to new and severe conflicts, especially concerning water resources. Therefore in times of climate change the active involvement of stakeholders in the setup and implementation of management and conservation policies is essential for their success (Forshay et al. 2005; Harris et al. 2006; Maltby 1991; Walker et al. 2002). Sustainable land use requires an integrated approach involving conservation goals, economic growth, social welfare and climate change adaptation. Both nature and society will benefit from highly resilient biodiversity protection structures. Planned adaptation measures will affect land use practices, and their implementation will only be possible with the support of local stakeholders. However, adaptation to climate change is not only a challenge; it offers a chance to reshape the future of land use and conservation strategies for the benefit of all.

The main objectives of stakeholder involvement for climate-adapted conservation management are:

- to identify the range of stakeholders and land users (and those who are assessed as being especially affected by climate change),
- to enhance knowledge on climate change and land use-related problems,
- to include local knowledge on climate-related changes and their impacts,
- to identify and anticipate conflicts between planned and autonomous adaptation.

Effective stakeholder involvement should be based on a stakeholder analysis. This includes three steps:

- Identification and classification of target groups including characteristics of target groups and their interrelationships,
- Analyses of expectations of target groups and scope of involvement,
- Development of a participation concept for stakeholder involvement.

The stakeholder involvement must be context specific, because target groups have different levels of knowledge, different social dynamics and different forms of communication. Consequently, there will be no general recipe for organising stakeholder dialogue that can be beneficially applied to all places or participants.

The target groups for the stakeholder involvement should be identified to enable specific communication concepts to be tailored. Following Reed et al. (2009) stakeholders can be classified into four groups based on their importance for and influence on the decision at hand. Key players are essential to make decisions and guarantee their implementation. Context setters (e.g. local authorities, ministries, business/trade unions) are stakeholders with much power but little interest in the problem. Subjects are those who are very interested in participating, but have little effect on the implementation (e.g. scientists, recreational users). Finally, the "Crowd" is defined as those stakeholders that have neither influence nor interest.

There are different forms of stakeholder involvement. This can range from passive forms of involvement like information or consultation, to active participation like collaboration, cooperation or delegation in the decision-making process (Muro et al. 2006). In the adaptation process, all stakeholders should be included in information and consultation activities. However, collaboration and cooperation might be restricted to key players and context setters.

The development of local adaptation strategies should be supported by scientific information and expertise. This structured communication of scientific results and processes can be termed science-based stakeholder dialogue (Welp et al. 2006). It is a social learning process based on communication and interaction in small groups. The science-based dialogue is not only targeted at stakeholders outside management. Sometimes communication of scientific background information on climate change and its impacts is also needed within administrations and between different conservation experts.

The science-based stakeholder dialogue should use several principles to ensure effective communication of climate knowledge on the local level. They can be summarised as follows (see CRED 2009; Futerra 2009; ICLEI 2009):

- Build your message on local solutions and action instead of threats and warnings.
- Reflect on the aims of your target audience and then show how your vision/project will make them happen.
- Translate scientific data into concrete experience and make it visual and vivid.
- Provide information focused on local problems and people’s everyday lives.
- Present information in manageable chunks and use a reasonable timeframe (e.g. a strong and simple five-year plan).
- Use spokespeople and allow stakeholders to take part in the conversation so that people have agency to act.

Stakeholder involvement should facilitate information exchange among participants and might help in finding win-win-solutions to climate change-related problems. It might also improve the public support of local adaptation actions and anticipate as well as manage related conflicts.

20.5 Summary of Support Needed and Actions to Be Taken

Conservation managers do not yet consider climate change adaptation in their day-to-day management. They will need further support to identify the relevant impacts of climate change, develop adaptation strategies and implement relevant measures. Scientific projects and programmes targeted at knowledge transfer can help to provide information and data. However, there is also a need to strengthen the adaptive capacity of protected areas. This capacity building should focus on:

- **The capacity to monitor, assess, manage and report the effects of climate change and their interaction with other pressures:** Adequate investments for implementation have to be warranted, especially for long-term monitoring. Training for site managers and administration is essential to be prepared for changes resulting from climate change. Capacity building should also include technical and advisory services for financing and realising projects related to climate adaptation and biodiversity conservation.

- **Transnational cooperation and exchanges of experience with adaptation processes:** Knowledge transfer across national borders and between managers of individual sites must be improved.
- **Awareness raising:** Dedicated action should be taken to raise awareness of the local effects of climate change and the need for adaptation. The benefits of ecosystem-based adaptation through climate-adapted management in protected areas should be explored and illustrated in this regard. The potential of adaptation activities in protected areas to provide win-win situations for strengthening environmental, economic and societal resilience on the local level must be capitalised.
- **Guidance for land use-related adaptation activities:** Cooperative processes based on stakeholder involvement should be strengthened to guide autonomous or unplanned adaptation of other sectors (e.g. farming, forestry or water management). Existing provisions for the protection of natural resources need to be enforced and economic instruments (e.g. subsidies and rural development programmes) must be harmonised to prevent maladaptation. Climate change policies of other sectors must not become an additional threat to biodiversity.

20.6 Priorities for Future Work and Open Questions

20.6.1 Adaptation as a Cross-Sectoral Issue

Biodiversity protection is an important component of sustainable economic growth and the protection of societal systems. Climate change adaptation cannot be planned and implemented separately for biodiversity protection. Climate change adaptation will involve changes in land and natural asset use. All sectors and policies have to plan adaptation strategies and often these sectors will need additional areas to mitigate the impacts of climate change, for adaptation measures and for nature disaster protection. As long as the adaptation of different sectors is not coordinated, conflicts will arise and the objectives of biodiversity and nature conservation will be harder to achieve, causing ecological and ultimately economic damage. Therefore, climate change adaptation needs to be understood as a coherent cross-sector task with common aims but specific measures.

20.6.2 Adaptation as a Long-Term Process

Adaptation processes are focused on the regional and local level. Climate change is starting to affect protected areas on the local level. This trend will continue and many regions will have to handle the intensifying impacts for a long time. Hence, adaptation is a long-term concern. Project-based activities like research or INTERREG projects are not able to provide long-term support. Projects like HABIT-CHANGE can only start processes and initiate actions that need local institutions as drivers of change. Adaptation planning is a first step in initiating a long-term adaptation process. It should help to improve understanding of the current and potential future impacts of climate change, raise awareness and acceptance for adaptation actions, start development of inclusive planning approaches that guarantee adequate stakeholder involvement and initiate Adaptive Management. However, without local-based and long-term-oriented support the implementation of climate adaptation will fail. Short-term oriented projects might even cause harm if they raise expectations in regard to results and participation in decision-making at the local level that cannot be fulfilled. This can result in participants becoming demotivated and valuable resources being used in an ineffective way.

20.6.3 Definition of Acceptable Change

In the long run, climate change will change distributions of species as well as the composition of habitats (Lindenmayer et al. 2008). It is unlikely that all specific conservation goals can be achieved with such grave environmental changes. In the future, we might be confronted with the need to balance near-term goals for the protection of species and habitats with more long-term goals for sustaining ecological systems and functions that are more likely to persist under changed climate conditions (Glick et al. 2011b). However, we might also find that not every change in species distribution or habitat composition is a reason for concern. In HABIT-CHANGE we have seen many changes that just accelerate natural succession. More research and open discussions will be necessary to answer the question as to which changes in habitats can be tolerated and which habitats should be preserved in their current state. It would be useful to define the limits for acceptable changes for each habitat type.

Nevertheless, some species and systems may only be conserved through intensive interventions (Heller and Zavaletta 2009). If no actions are capable of achieving the stated objective, it may even be necessary to adapt and revise objectives (Cross et al. 2012). Letting go of existing objectives and negotiating new aims will be a painful process for many conservationists. Furthermore, there is the risk that arguments involving climatic changes and reformulation of goals might be used to compromise years of protection efforts and achievements. Climate change must not be used as an excuse to limit conservation efforts or inefficient protection. To be prepared for this discussion a proactive conservation management should have answers ready on when, how much, and in what ways conservation management must be adapted (Glick et al. 2011b). Limits on acceptable change might help to identify thresholds related to when and where strategies could change from conserving the current state, to accommodating changes, to initiating transformation of habitats (Morecroft et al. 2012).

20.6.4 Further Need for (Transdisciplinary) Research

Climate change issues have become a high priority for research activities over the years. Nonetheless, many knowledge gaps still exist. Future research on the impacts of climate change on biodiversity should focus more on cooperation between science and practice. Our experience is that transdisciplinary projects provide a suitable setting for the identification of knowledge and data gaps, the formulation of relevant research questions, the understanding of climate-related problems, and the transfer of results into adaptation action. Many research activities are primarily focused on the production of information (e.g. about impacts and vulnerabilities) without much guidance on how this data should be used within the decision-making process. Consequently, there has not been a great deal of uptake into management and actions. Transdisciplinary research can help a shift towards a more action-oriented production of knowledge. In addition, the exchange of experience and good practice examples can be a strong motivation for action, whilst sharing unsuccessful experiences is important for understanding problems and identifying barriers to adaptation.

Scientific support can strengthen conservation, but more research into assessment tools and methods is necessary. It should be focused on:

- The potential climate-induced reactions of specific habitats and species. Individual species will respond differently according to their tolerances to climatic changes, their ability to migrate to new locations, their potential to alter phenology (e.g. breeding date) or their dependence on shifting food sources.
- A framework for the identification of adequate responses to climate-induced changes and succession of habitats. It should include evaluation criteria and thresholds for adequate reactions by conservation management.
- Methods to handle results from multiple scenarios for future development and to harmonise climate projections for adaptation on the local level without prescribing data.
- Useful and applicable indicators for evaluating possible local impacts of climate change on biodiversity at site level.
- The potential effects of climate change on the competitiveness of alien invasive species.

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