

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.

T. Petras (✉)

Triglavski narodni park, Ljubljanska cesta 27, 4260 Bled, Slovenia
e-mail: tina.petras@gmail.com



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 karst 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 CO₂ 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 m²) 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

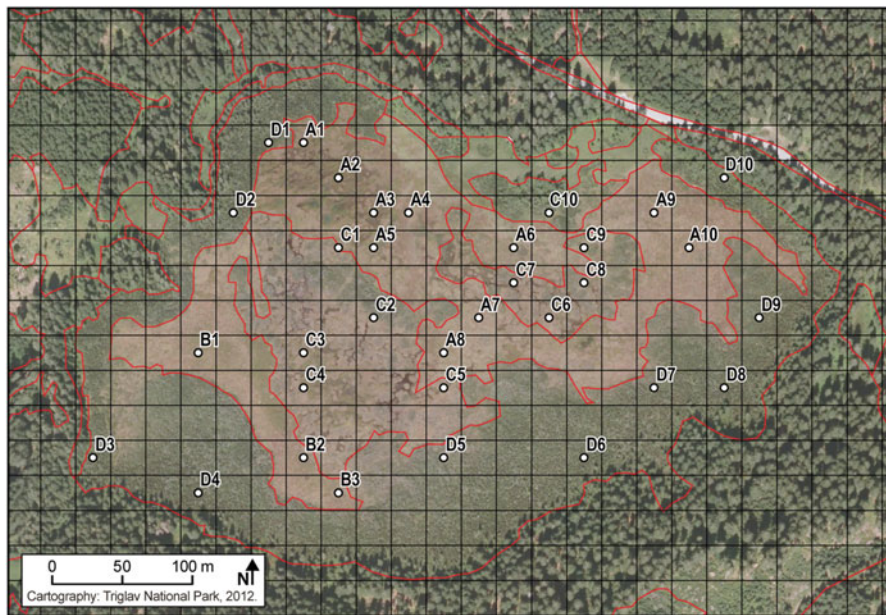


Fig. 11.3 Stratified habitat types in peat bog Šijec with randomly selected sampling plots (A1-D10). As a basis a net from Slovenian Forest Service is used, and modulated by size 25×25 m. Different letters indicate different habitat types with maximum ten samples per spatially separate habitat type (Cartography: 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 ≥ 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
<i>Carex hostiana</i>	–	x	–	x
<i>Carex nigra</i>	–	–	x	x
<i>Carex pauciflora</i>	x	x	x	x
<i>Carex rostrata</i>	–	x	x	–
<i>Drosera rotundifolia</i>	x	x	x	x
<i>Eriophorum latifolium</i>	–	x	–	x
<i>Eriophorum vaginatum</i>	–	x	x	x
<i>Menyanthes trifoliata</i>	–	x	–	–
<i>Molinia caerulea</i>	–	–	–	x
<i>Oxycoccus microcarpus</i>	x	x	x	x
<i>Pinguicula vulgaris</i>	–	–	–	x
<i>Potentilla palustris</i>	–	x	x	x
<i>Trichophorum alipinum</i>	–	x	x	x
<i>Vaccinium uliginosum</i>	–	–	x	–
<i>Vaccinium vitis-idaea</i>	–	–	x	x
<i>Valeriana dioica</i>	–	–	–	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 CO₂ 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 (Dobracev 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, live-stock 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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