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Climate change vulnerability in Biodiversity sector

Melovski Ljupčo, Matevski Vlado, Hristovski Slavčo

Institute of Biology, Faculty of Natural Sciences and Mathematics, Ss. Cyril and Methodius University, Skopje, Republic of Macedonia

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1.1 Introduction – climate change and Biodiversity Sector

Global climate change will have and has a significant impact on different environmental components. Biological diversity, as the most dynamic environmental segment, is constantly exposed to the climate change impact and it reacts according to its own adaptation capacity. The direction of adaptations, migrations and successions of different biodiversity components at a certain area or region depends on many factors. Above all, these are heterogeneity, differentiation, zonation, richness and complexity and similar parameters of particular biodiversity components.

The Republic of Macedonia has specific geographic position on Balkan Peninsula where different climatic influences (continental and Mediterranean) on a small area in separate parts of the country intertwine. In combination with other ecological and historic factors they have led to development of a specific and very rich biological diversity. Beside its intrinsic value, biodiversity in Macedonia has other values, especially economic, and it provides a lot of goods and services.

In that sense, we try to assess and find explanation for the impact of the current global climate changes on the most sensitive components of flora, vegetation and fauna in this report. These assessments are mostly based on habitat and species modelling, but expert judgment was also an important approach due to the lack of data and continual monitoring of biodiversity components. All available data on climate parameters were taken into consideration in the assessment.

1.1.1 Climate change vulnerability in Biodiversity Sector

Biodiversity is recognised to be one of the most vulnerable sectors to climate change globally. It is an important and urgent issue in Europe as well (e.g. Usher 2005 – Council of Europe). This is an indisputable fact, widely accepted among the scientific and policy making community.

This was stressed for Macedonian conditions in the First National Communication (FNC) and Second national Communication (SNC) to United Nations Framework Convention on Climate Change (CC). This studies were based on the analysis of vegetation belts, species and their (plant) communities as well as refugial zones. From these reports it is obvious that anthropogenic impact is always combined with climate change impact and thus, has significant role in vulnerability assessment of the biodiversity. The most important climate parameters in the estimation were temperature and precipitation. The most prominent anthropogenic factors are construction of hydrosystems (especially those in the

* Institute of Biology, Faculty of Natural Sciences and Mathematics, Ss. Cyril and Methodius University, Skopje, Republic of Macedonia

mountainous areas), water extraction systems, roads and railways, power lines, pylons, industrial buildings, expansion and abandonment of the agricultural lands, uncontrolled forest exploitation.

The alpine belt is the most vulnerable to climate change due to the most intensive air temperature rise in alpine and subalpine regions, according to the local climate scenarios. Loss of the alpine belt can be expected. Alpine grasslands, rocky habitats, screes, and rock vegetation are distributed only on the highest parts of mountain summits and occupy very small areas (only 0.5% of the country territory). Vertical movement of these communities will be hindered by many relief-related obstacles, ecological preferences, and especially available space. Only north-facing slopes would offer suitable ecological conditions since the alpine zone in Macedonian mountains will disappear. On the other hand, the termophyllous communities in the Kermes and Pubescent oak belt are going to benefit from the temperature rise i.e. they will expand their distribution in Macedonia.

Overall, 79 fungi and lichen species, 74 species of algae, 392 higher plants, and 113 vertebrates were considered to be under threat.

Species in the mountain belt are vulnerable to climate change impact. A number of plant (e.g. *Crocus cvijici*, *Trollius europaeus, Salix alpina, Rhododendron myrtifolium, Rhododendron ferrugineum, Empetrum nigrum, Loiseleuria procumbens*) and animal species (e.g. *Rana temporaria, Triturus alpestris, Lacerta vivipara, Pyrrocorax pyrrocorax*) are identified as the most susceptible to changes in climate. However, some of the lowland species might be considered as vulnerable due to their restricted distribution or specificity of their habitats. The human impact can be estimated as even higher threat for these species (e.g. *Thymus oehmianus, Ramonda serbica, Adianthum capillus-veneris*, *Drosera rotundifolia, Blackstonia perfoliata, Cladium mariscus, Carex elata, Marsilea quadrifolia, Salvinia natans, Rana balcanica*, *Triturus vulgaris*, *Pelobates syriacus balcanicus.*

Wetland ecosystems in Macedonia were severely altered in the 1950s and 1960s - however, the process of their destructions goes on even nowadays. Climate change impact combined with the human impact will have irreversible consequences on the functioning of these ecosystems as well as particular species and plant communities. Some of the relict communities (*Caricetum elatae*, *Mariscetum*, *Cypero-Caricetumacutiformis*, *Osmundo-Thelipteretum*, *Scirpo-Alopecuretum cretici*) should be considered as top priority for conservation. In terms of species there is a long list of plants and animals that require attention (*Nuphar lutea, Nymphaea alba, Salvinia natans, Aldrovanda vesiculosa, Trapa natans,Carex elata, Senecio paludosus, Ranunculus lingua, Eunapius carteri dojranesis, Chirocephalus pelagonicus,Salmo peristericus*, *Barbus prespensis*etc.).

One of the most striking features of the Macedonia biodiversity is the existence of the refugial sites within larger refugial zones. All of them can be considered as highly vulnerable, particularly to climate change, and less to human impacts. However, climate change will influence some of the communities within these refugial zones in a positive way (pseudomaquis, plant and animal species of warm and open habitats). Most of the plant communities will face extinction (flooded communities in the lowlands, refugial beech forests, relict mountain and alpine species, etc.).

Penetration of animal and plant species from the south is possible; some of them might be invasive species.

However, due to the lack of basic information on biodiversity in the Second National Communication, modelling of species and habitats was not performed. Thus, the vulnerability assessment will be improved in the Third National Communication by more detailed analyzes, especially by ecological modelling of certain species and habitats. Historical overview of the glaciation in Europe and movement of species on the Balkans will serve as an analogue for the modern climate change and will be also included in the Third National Communication.

1.1.2 Climate change adaptation in Biodiversity Sector

There are numerous measures that can be undertaken in order to cope with climate change impact on biodiversity. These measures vary in the countries depending on the territory, relief, specifics of the biodiversity etc. The most important measures include change in land-use policy, adaptation of spatial planning, etc. More concrete measures include a) enlarging of the protected areas system, b) incorporating climate change measure in the management plans of the protected areas, c) connecting these areas by biological corridors and) to allow free movement of species and habitats across the linear infrastructure objects (roads, railways, hydro-systems). All of these measures aim to allow shifting of the range of species and habitats across altitudinal and longitudinal gradient in accordance to the change of climate change parameters. It is very important to improve the knowledge, scientific base, awareness among decision-makers and general public to allow for better implementation of the adaptation measures.

The separate report on Biodiversity as part of SNC (Matevski et al., in: Azievska ed., 2008) contains action plan with prioritized activities. All of the activities were designed to address the 10 main identified problems (all of them in relation to biodiversity and climate change): 1) lack of information, 2) lack of monitoring, 3) non-existent ex-situ protection, 4) climate change is not incorporated into Spatial Plan, 5) insufficient number of meteorological stations for bioclimatic data, 6) low public awareness, 7) inappropriate water-capture in mountainous areas, 8) water-level fluctuations, 9) case studies for mountainous and alpine ecosystems and 10) low institutional capacity. In total, 36 (project) activities were elaborated. Analysis of the action plan reveals that none of the 36 proposed activities was undertaken or implemented. Even more, some of the identified problems worsened (e.g. activity in regard to biological minimum of the water-flow of Adzhina Reka; water level of some glacial lakes - Podgorechko Ezero; the number and quality of meteorological stations, etc.).

1.2 Overview of Biodiversity Sector

1.2.1 Characteristics

Both FNC and SNC present in general terms the rich floristic, vegetation and faunistic diversity in Macedonia resulting from the specific geographic position of the country, geological past, heterogenic relief and climate characteristics. As an example, according Matvejev (Lopatin and Mavejev 1995) and Filipovski et al. (1996) in the territory of Macedonia eight biomes (out of nine in Balkan Peninsula) and climate-vegetation-soil zones can be recognized. These zones contain large number of ecosystems and habitats characterized by extraordinary species richness.

In order to get an impression about the significance of the biodiversity in Macedonia, a short review of its richness and its status will be presented below. It was compiled on the basis of the data from the Study on the Status of Biological Diversity in the Republic of Macedonia (2003).

The biodiversity of the Republic of Macedonia has been relatively well studied, and is noted for its species richness and level of endemism, underlining the country's importance of a "hotspot" for biodiversity in Europe. To date over 16,000 species have been recorded in Macedonia, including 854 endemics (Petkovski, 2010).

At present, anthropogenic impacts have affected a range of species and habitats within the Republic of Macedonia. In particular, aquatic and wetland ecosystems are considered the most endangered and relict lowland marsh communities are now only found in fragments (including six sites, which are at critical risk). Similarly, within grassland communities, wet meadow communities are considered threatened. Other specific threats affect certain halophytic (saline) communities, and specific forest types.

Despite the high levels of research, data is still lacking on the status and direct threats to many of the country's endemic species.

The direct causes of biodiversity loss are many and varied, and include:

- Loss and modification of habitats
- Fragmentation of habitats
- Pollution
- Unsustainable exploitation

The factors underlining biodiversity decline in Macedonia include a general history of anthropogenic land use, the recent economic collapse, an unstable political situation, inadequate spatial planning and inappropriate land use. Several basic reasons underlying the loss of biological diversity in the Republic of Macedonia can be identified:

- A low level of education and a lack of information, resulting in low public awareness;
- A reduced and unstable economy, coupled with military actions that have been affecting the region for a number of years;
- Growing poverty;
- Uncontrolled urbanisation, abandonment of agricultural land;
- Ongoing migration from villages to towns;
- The move to the market economy, with the need to engage in a competitive market, growing globalisation and the move towards high production systems (including agricultural systems)

In addition, conservation is hindered by:

- Inadequate and incomplete legislation which fails to clarify responsibilities and results in overlapping roles between the agencies responsible for enforcement;
- Non-compliance with existing regulations and policy documents (for example not a single action foreseen in FNC and SNC was implemented up to now);
- Lack of spatial planning regulations for areas with special natural values;
- Lack of up-to-date technologies, including appropriate renewable power generation equipment and lack of treatment facilities for wastewater and waste gases; and
- Outdated spatial planning processes, resulting in improper land use changes, construction of infrastructure systems and agricultural conversion (in previous years).

Key sectors affecting biodiversity listed in order of decreasing impact are:

- Agriculture, which has had a particular impact on biodiversity in the decades following the Second World War, including drainage of marshes and wide-scale agricultural expansion, and subsequent declines in pastoralism;
- Fisheries, since over-fishing has resulted in serious threats to fish diversity in the Republic of Macedonia (especially in Lake Ohrid);
- The transport sector, especially due to the fragmentation of habitats;
- The energy sector, as a result of the consequences of pollution, construction of hydropower reservoirs and power line networks;
- Industry and mining, mainly as a result of soil, water and air pollution which has had major impacts on large areas of Macedonia;
- Tourism, where key impacts are associated with the illegal construction of holiday homes, incomplete infrastructure serving the main tourist resorts and inappropriate behaviour by tourists;
- Construction and civil engineering, as a result of land conversion, habitat destruction, disturbance of animal populations, as well as pollution due to poor waste disposal practices.

All these threats to biodiversity, their underlying causes and economic sectors have coupled impact with climate changes. More precisely, they hamper the ability of natural ecosystems, communities and species to adapt to the changing climate, or to move in space in order to avoid negative climate change impact.

At very recent period there is a new threat to biodiversity, emerging from the conflict created in the CCC itself. Namely, the CCC requirements for reducing of CO_2 input into the atmosphere are interpreted differently in different sectors. Energy sector strives to shift energy production by fossil fuels to production from renewable sources. This is "translated" in Macedonia (through the Strategy for Energy) as the need to use all available water resources in Macedonia. This causes and will cause significant and unrecoverable damage to biodiversity in Macedonia. On the other hand, biodiversity sector promotes the idea that improving the status of nature (conservation and enlargement of forests and wetlands) will significantly contribute to carbon sequestration, i.e. reduction of CO_2 in the atmosphere.

1.2.1.1 Biodiversity of species

The richness and heterogeneity of species and ecosystems is the most striking feature of the biodiversity of the Republic of Macedonia. This situation is a result of Macedonia's specific geographic position, climate, geology, geomorphology, hydrography, pedology and other characteristics, such as the changes which occurred during past geologic periods (e.g., from the end of Tertiary through the Ice Age, with its glacial and interglacial phases). A huge number of relict species and ecosystems are the result of these changes, which continue to have an effect on the recent flora, fauna and fungi (MEPP 2004).

Based upon an analysis of biodiversity richness within the countries of the European continent, the Republic of Macedonia holds the top position on the "European Hotspot" list. Despite the fact that the biodiversity of the flora and fauna has not been fully studied, the findings to date indicate its great abundance. As an example, the diversity of invertebrate species on a relatively limited surface at some sites (Ohrid Lake, marsh ecosystems and

others) can be directly compared to the diversity of coral reefs; in some cases, the biodiversity in Macedonia is higher (MEPP 2004).

Fauna

The overview of fauna is presented in the Country Study for Biodiversity (MEPP, 2003), National Biodiversity Strategy (MEPP, 2004) and later in Petkovski (2010). However, a number of scientific articles and databases (e.g. Fauna Europaea) have been produced which are not included in these estimates. According to Petkovski (2010) there are 10354 species of animals in Macedonia; Fauna Europaea - lists 10586 species (although similar, these numbers are based on elaboration of different groups). Nevertheless, the data show that the most diverse group of organisms in Macedonia is the arthropods, followed by Roundworms, Nematods and Chordates (Tab. 1).

In the recent period, several species of invertebrates were described from Macedonia farther stressing the richness of Macedonian fauna (**Orthoptera:** *Poecilimon* (*Poecilimon*) *jablanicensis* Chobanov & Heller, 2010, **Coleoptera**: *Trechus* (*Trechus*) *galicicaensis* Gueorguiev & Hristovski, 2010, *Duvalius* (*Euduvalius*) *karaormanicus* Hristovski, 2011, *Calathus* (*Calathus*) *jakupicensis* Gueorguiev, 2008, *Hydroporus macedonicus* Fery & Pesic, 2006, **Gastropoda**: *Montenegrina dedovi* Nordsieck, 2009, *Euxinella radikae hristovskii* Dedov & Neubert, 2009*, Euxinella subai* Dedov, 2012*, Euxinella alpinella* Dedov, 2012*).* Also, several checklists were published showing corrected numbers of species in Macedonia (e.g. Komnenov 2005; Chobanov & Mihajlova 2010).

Table 1. Number of animal species in different phylla.

Taxonomic Category	Taxonomic Group	Number of Species	Endemic species
Phylum	Protozoa (Protozoans)	113	32
Phylum	Porifera (sponges)	10	6
Phylum	Plathelminthes (flatworms)	85	35
Phylum	Cnidaria (Cnidarians)	2	0
Phylum	Nemertea (Nemertine worms)	1	0
Phylum	Rotifera (Rotifers)	269	0
Phylum	Nematoda (Nematods)	553	3
Phylum	Mollusca (Molluscs)	366	131
Phylum	Annelida (segmented worms)	186	48
Phylum	Arthropoda (Arthropods)	8234	383
Phylum	Chordata (Chordates)	535	30

With a total of almost 700 endemic species, the Republic of Macedonia represents one of the most important centres of faunistic endemism in Europe, in spite of its small land area (MEPP, 2004; Petkovski, 2010). The endemic taxa are distributed in different faunal groups. Petkovski (2010) lists groups with greatest percentage of endemic species as follows: Porifera - 60%, Plathelminthes - 41.2%, Mollusca- 35.8%, Protozoa– 28.3%, Annelida - 25.8%, Arthropoda - 4.65% and Chordata- 5.6%. The centres of endemism in Macedonia are the natural lakes (Ohrid and Prespa in particular) and high-mountain areas, and possibly the Macedonian caves. In terms of climate change analysis, special attention should be paid to high-mountain endemics since some of them are restricted only to the subalpine and alpine zones of the mountains.

The European Red Data List includes 113 of the vertebrate species present within the Republic of Macedonia (30 fishes, 66 birds, 16 Mammals and one species of Reptile). Seventeen of the 20 endemic fishes are included within the category of globally threatened species. The remaining endemic vertebrate species should also be included, as well as some other specific vertebrate species whose ranges end in or pass through Macedonia (*Algyroides nigropunctatus, Coluber gemonensis, Cyrtopodion kotschyi, Lacerta agilis, Pelobates syriacus, Rana balcanica, R. graeca, R. temporaria, Testudo graeca, Triturus alpestris, Vipera berus* etc.) (MEPP, 2004).

Flora

The flora of the higher plant groups is quite rich, possessing diverse floral elements (arctic-alpine, Caucasian, Eurasian, Greek-Anatolian, Illyric, Mediterranean. Middle-Europaean, Tertiary relict and Cosmopolitan) and a large number of endemic species (Balkan, Macedonian, south Balkan etc.). It is represented by 210 families (with 67 families of mosses), 920 genera and approximately 3700 species. The most numerous group is flowering (Angiosperm) plants, with about 3200 species, followed by mosses (about 350) and ferns (42).

In the scope of the published seven books of the edition Flora of the Republic of Macedonia, peat mosses, horsetails, ferns, gymnosperms and most of angiosperms were processed. In the previous period total of 108 families, 450 genera, 1750 species, i.e. 2814 taxa were elaborated.

Moss. They are represented by 67 families, 167 genera and 349 species. 25 families, 36 genera and 52 species belong to the cl. *Hepaticae*, 1 fam., 1 genus and 1 species to the cl. *Anthocerotae*, while to the cl. *Musci* – 41 family, 130 genus and 296 species. From the cl. *Hepaticae* most numerous is the family *Lophoziaceae* with 8 species, while from the cl. *Musci*, most numerous are the families *Bryaceae* (23 species), fam. *Amblystegiaceae* (23) and *Brachytheciaceae* (23). The most polymorphous genera are *Brachythecium* (23) *Bryum* (14 species) and *Orthotrichum* (11). Two species are Macedonian endemics (*Orthotrichum insidiosum* and *Melichoferia paradoxa*).

Peat-mosses. They are represented by 6 species mainly inhabiting the moist areas and peats in the mountain and high mountain areas, and are rarely found in lowlands, mostly on silicate ground. The species *Lycopodium clavatum, Huperzia sellago, Diphasium alpinum* and *Isoetes phrygia* have very restricted distribution.

Horse-tails. They are represented by 7 species and develop on very moist areas from lowlands to high mountain areas (by rivers, mountain streams, valleys, gorges, marshes,

moist meadows. The most frequent species are *Equisetum arvense* and *E. palustre*, and the species *E. fluviatile* and *E. sylvaticum* are rare.

Ferns**.** On the territory of the Republic of Macedonia 42 species of ferns are found, classified in 15 families. The most polymorphous genera are *Asplenium* (11 species) and *Dryopteris* (6). The following species are characterized by restricted distribution: *Osmunda regalis, Thelipteris palustris, Phyllitis scolopendrium, Ophioglossum vulgatum, Adiantum capillus-veneris, Blechnum spicant, Crytogramma crispa*, as well as the endemic species *Asplenium macedonicum* (in the proximity of Prilep). This group includes the two species of aquatic ferns (*Marsilea quadrifolia* and *Salvinia natans*).

Gymnosperms. They are represented by 4 families, 6 genera and 15 autochtonous species (the most polimorphous are the genera *Pinus* and *Juniperus* each with 5 species). Some species are introduced (alochtonous), mainly from the genus *Pinus, Abies, Picea, Sequoia, Taxodium, Juniperus* etc.

Angiosperms. These are represented by 120 families, 720 genera and about 3200 species (5000 taxa). The most polymorphous families of the cl. Dicotyledonae are Compositae (c. 470 species), Leguminosae (457), Caryophyllaceae (345), Cruciferae (264), and Labiatae (c. 260), while from the cl. Monocotyledonae – Gramineae (c. 280) and Liliaceae (c. 130).

Algae and fungi

According to the National Biodiversity Strategy (MEPP, 2004) there were about 1600 species of algae and 1250 species of fungi. The most diverse/investigated groups of algae were diatoms (40%) and green algae (35%). Since then, a number of scientific papers and monographs were published on diatoms (Levkov et al., 2005, 2007, Pavlov & Levkov, 2012; Levkov & Williams, 2012) with a description of many new species, mostly from the ancient lakes of Ohrid and Prespa. Thus, the total number of diatoms for Macedonia is about 1400 species (Levkov, *pers. comm*.). Unfortunately, other groups of algae were neglected and only few data were published in the recent period.

Most of the fungi species belong to the orders Ascomycota (130), Basidiomycota (1050), Myxomycota (10), Oomycota (20) and Zygomycota (35). Lichens (lichenoid Fungi) (Lichenes) number approximately 340 species. Karadelev (2000) proposed a Preliminary Red Data List of Fungi of the Republic of Macedonia that includes 67 species. There is substantial progress in the mycological research in Macedonia in the last decade due to the

Invasive species

In terms of invasion biology, vascular plants are the most intensively researched taxonomic group in Macedonia. After North America, Europe is the continent enjoying the most intensive study with a least 80 invasive plant species having been addressed. However, although there is a considerable amount of information on major plant invaders in Europe (Weber, 2003), the situation is much less satisfactory as far as complete national inventories of alien plants are concerned. Only few countries have sound information on the composition of their alien floras, available in specialized checklists (Austria, Czech Republic, Germany, Ireland and United Kingdom). This situation directly translated into poor knowledge across the European continent. The only available continental analysis of plant invasion patterns in Europe (Webber, 1997) was based on data from Flora Europaea (Tutin et al., 1964-1980).

However, some insights into a variety of impacts caused by alien plant species in Europe can be obtained from the inspection of species included in the 100 worst alien species; these taxa were selected so as to provide a representative sample of diverse impacts known to occur in Europe. Of the 18 plant taxa included, 17 are known to reduce the habitat of native species, and 8 are reported to cause disruption of the community assemblages. Iceplant *Carpobrotus edulis* (Vila et al.2006) and giant hogweed *Heracleum mantegazzianum* (Pysek et al. 2007) are examples of alien species causing serious decrease in species richness of invaded communities. This is, however, not always the case as documented for Hymalayan balsam (*Impatiens glandulifera*); under some circumstances the invasion of the species does not necessarily result in loss of the diversity of invaded communities, only in shifts in species composition towards ruderal, nitrogen demanding species.

Alien plant species exert ecological and economic impacts, both direct and indirect, at multiple levels. Regarding economic impacts, some of them (knotgrass *Paspalum paspaloides* and others) are known to negatively affect commercial production and yield of agricultural and forest products. *Robinia pseudoacacia* and *Ailanthus altissima* are typical examples of aliens to Europe causing serious damage to infrastructures and utilities.

The unique genetic nature of native or even endemic species of special conservation value can be lost through introgression of widespread aliens. Alien plants are reported to reduce availability of pollinators to native species as documented for Himalayan balsam Impa*tiens grandulifera* (Chittka and Schurkens 2001). Plant invaders can also modify community structure at higher trophic levels; the grass *Elymus athericus* was shown to affect spider population dynamics in salt marshes in France (Petillon et al. 2005).

There are 24 registered neophytes in the Flora of The Republic of Macedonia:

1. Elodea canadensis
2. *Ailanthus altissima*
3. *Paspalum paspalodes* (Micevski, 1956)
4. *Sisyrinchium bermudiana* (Micevski, 1956, 1963)
5. *Chenopodium ambrosioides* (Micevski, 1963)
6. *Lobularia maritime* (Micevski, 1969)
7. *Galinsoga parviflora* (Drenkovski, 1969; Matvejeva, 1973)
8. *Tagetes minuta* (Micevski, 1970)
9. *Heteranthera limosa* (Bukliev, 1980)
10. *Conyza bonariensis* (Micevski & Matevski, 1983; Matevski et al., 2001)
11. *Erigeron annuus* (Micevski, 1983)
12. *Eleusine indica* (Micevski, 1983; Matevski et al., 2001)
13. *Euphorbia maculata* (Micevski, 1987)
14. *Amaranthus spinosus* (Micevski, 1987)
15. *Sporobolus indicus* (Micevski, 1991)
16. *Ammannia baccifera* (Micevski, 1992)
17. *Lindernia dubia* (Micevski, 1992)
18. *Commelina communis* (Micevski, 1992)
19. *Galinsoga ciliata* (Matevski & Kostadinovski, 1990)
20. *Solanum elaeagnifolium* (Matevski,2000)
21. *Solanum cornutum* (Matevski, 2000)
22. *Chamomilla suaveolens* (Matevski et al., 2001)
23. *Rudbeckia laciniata* (Matevski, 2007)

24. *Ambrosia artemisifolia* (Teofilovski, Milkovska, Matevski, 2012)

In Macedonia, most of the invasive plant species are found on ruderal sites and in some aquatic ecosystems. An example is the species *Elodea canadensis* (Elodea), which was first introduced into Ohrid Lake through the channel Studenchishte in 1957. It is an invasive weedy species which rapidly reproduces and expands, out-competing the indigenous submersed macrophytic species and occupying their habitat. Some invasive species which have the direction of the area of distribution south-north, can be expected to go more aggressive to the northern parts of the territory of the Republic of Macedonia. Such is the case with the species *Solanum elaeagnifolium* and *Conyza bonariensis*.

Alien and invasive animal species are not well documented in Macedonia. Most of the introduced and invasive species of fauna belong to fish, mammals and insects. For instance, Lake Prespa has fish fauna of 23 species, which from 12 (more than half) are alien species. Some of them can be regarded as truly invasive species (e.g. Pumpkinseed – *Lepomis gibbosus*).

1.2.1.2 Habitats and vegetation (VM)

The vegetation diversity in Macedonia is represented by approximately 30 vegetation classes, 60 orders, 90 alliances and over 260 associations. The aquatic macrophyte vegetation (cl. *Potametea* and cl. *Lemnetea*), which develops in our natural lakes, all three of them, are very well studied. This also refers to the lowland swamp vegetation (cl. *Phragmitetea* and cl. *Isoeto-Nanojuncetea*), whereas about swamp vegetation developed in the mountainous marshes there is little data. Lowland meadows (cl. *Molinio-Arrhenatheretea*), are relatively well studied, and meadows from the montane to the subalpine belt are insufficiently studied. Halophyte vegetation (cl. *Thero-Salicornietea*), can be found on small areas and is completely studied, while the vegetation on the hilly pastures (cl. *Festuco-Brometea*), is in a phase of intensive research. The communities developing on silicate ground are better studied in relation to those developing on carbonate ground. The forest vegetation and the vegetation of the bushes are quite rich and diverse, and are represented by 100 associations. Part of them should be revised and harmonized with the International Code on Phytocenological Nomenclature. The mountainous and high mountain vegetation is not sufficiently studied, and because the studies of this vegetation type are out of date, it is necessary to make some revision and new research. In the meantime, a study about steppic vegetation on territory of the Republic of Macedonia was published (Matevski et al. 2008) as well as the Monograph on forest vegetation on Galicica Mt (Matevski et al., 2011)

1.2.1.3 Ecosystems

The diversity of ecosystems in Macedonia was documented in the National Biodiversity Strategy MEPP (2004):

- **Forest ecosystems.** Forest ecosystems cover a large portion of the land area of the Republic of Macedonia at elevations of 150-2,200 m. Broadleaf forests dominate (Hornbeam [*Carpinus betulus*], Chestnut [*Castanea sativa*], Beech [*Fagus sylvatica*], Hop-hornbeam [*Ostrya carpinifolia*] and Oak [*Quercus* sp.]), while evergreen forests (Fir [*Abies* sp.], Spruce [*Picea* sp.] and Pine [*Pinus* sp.]) as well as mixed forests (Beech-Fir) are distributed in small areas. Due to over-harvesting, they have been

degraded in the lowland areas and completely destroyed in some places. Nevertheless, they are represented by over 80 pure forest stands and include species from seven classes.

- **Dryland/grassland ecosystems.** These occur in the lowland and highland belts from 60-1,200 m msl. Dryland/grassland ecosystems encompass a higher number of differing plant communities such as: meadow, halophytic and steppe-like, as well as the plant communities of highland pastures.
- **Mountain ecosystems.** Mountain ecosystems are present within a large portion of the Republic of Macedonia; however, optimal conditions for their development are only present on mountains with elevations above 2,000 m. The communities of the mountain pastures, located on silicate (vegetative class Caricetea curvulae) and carbonate (vegetative class Elyno-Seslerietea) soils, are represented by approximately 15 associations. Communities that develop on limestone and silicate rocks, limestone screes, under snow banks etc. are also included within mountain ecosystems. The most striking feature of this fauna is the presence of indigenous relict-endemic, palaeo-Mediterranean and oreal (high-mountain) faunal elements such as.
- **Aquatic/wetland ecosystems.** The group of key aquatic/wetland ecosystems includes the three natural lakes, the well-developed river network and remnants of formerly widespread marshes and swamps.

Ecosystem studies in Macedonia were carried out on forest ecosystems and water ecosystems. There are several studies on the ecology of water ecosystems, especially the natural lakes and major rivers in Macedonia (especially Vardar river). Probably the best studied "ecosystem" in Macedonia is the Ohrid lake, together with Prespa and Dojran lakes. There are a lot of data on the composition of the flora and fauna of the natural lakes, their biomass and production, water chemistry, cycling of particular elements analyzes of the human impacts (pollution, water exploitation). Good examples are the complex projects on functioning of two oak and one beech forest ecosystems undertaken by the Institute of Biology (Faculty of Natural Sciences and Mathematics) in the period from late 1970s to 2005 (Mulev et al., 1999; Grupce & Melovski, 1999). These projects were aiming at estimation of the biomass and primary production (belowground and aboveground) including litter-fall processes, forest floor biomass and litter decomposition, characteristics of animal community, water percolation in the soil and these combined with the estimation of inputs (atmospheric deposition) and outputs enabled definition of overall nutrient cycling in the ecosystems. From the applicative point of view these data are very important in assessing the impacts and adaptation of ecosystems to climate change. Particularly, carbon sequestration was estimated, soil respiration, chemical quality of the litter (palatability).

1.2.2 Major stakeholders

Integration of the conservation and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans, programs and policies is the requirement of the Convention on Biological Diversity (Article 6(b)). In this regard, cooperation with a lot of stakeholders is crucial.

In general, two main groups of stakeholders regarding biodiversity management can be distinguished – the ones that regulate biodiversity issues (I) and the ones that and operate (II)and use (III) biodiversity resources.

I. Regulation function

a) National level

- The Parliament through its Commission on Transport, Communications and Environment and through its assembly concerning adoption of legislation.

- The Government has major role through the ministries and through its Commission for Economic System and Current Economic Policy.

- Ministry of Environment and Physical Planning (MoEPP) is the body of the state administration responsible for the affairs of nature protectionthrough the Administration for Environment. The body responsible for the execution of the expert works in the field of nature protection is Sector for Nature Protection with three departments: Department for Biodiversity, Department for natural Heritage Protection and Department for Protected Areas Management and Geodiversity. Other related sectors/departments in the Administration for Environment are the Sector for Environment (EIA Department) and Waters Sector. Some other sectors in the MoEPP have significant role in biodiversity regulation: Sector for Spatial Planning, Macedonian Environmental Information Center, Spatial Information System Department and the State Environmental Inspectorate.National Council for Nature Protection was established as an advisory body to the Minister of Environment in 2009(according to article 145, Law on Nature Protection), but not active in practice.

Other ministries that have important impact on biodiversity management are:

- Ministry of Agriculture, Forestry and Water Economy – especially through its Sector for Forestry and hunting (and the State Inspectorate for Forestry and Hunting), Veterinary Administration (and the State Veterinary Inspectorate), Agriculture Sector (Department for Organic Production), State Inspectorates of Agriculture, Rural Development Sector, Sector for registration and management of agricultural land (LPIS Department), Administration for Plant Protection, Administration for Seed and seedling,etc.;
- Ministry of Economy – responsible for issuing concessions for use of mineral resources and through its Tourism Sector and Energy Sector;
- Ministry of Finance – through its Custom Administration;
- Ministry of Transport and Communications – responsible for issuing various licences for construction, spatial and urban planning, and through its State Inspectorate for Building and Urbanism;
- Ministry of Culture – through itsAdministration for protection of cultural heritage in RM and through the Natural History Museum (which does not have regulation role but is important for keeping records and studying biodiversity), National Commission for UNESCO;
- Ministry of Local Self-Government – indirect role;
- Ministry of Education and Science – indirect role, financing scientific projects for biodiversity;
- Ministry of Health – indirect role.

b) Local level. On local level the responsibility for biodiversity management lie upon the mayor and the council of the local self-government unit. Other local units of the above mentioned ministries have also an important role.

II. Operational function

a) National level

- Among the most important players in the field of biodiversity management on the ground is probably the Public Enterprise "Macedonian Forests" with its local units. Various concessionaries for hunting and Fishing (regulated through the Ministry of Agriculture, Forestry and Water Economy) as well as concessionaries of pastures (regulated through Public Enterprise for Pasture Management) are also very important stakeholders.

- Management authorities of protected areas are responsible for biodiversity management of individual PAs; public institutions for management of national parks being the most important. Public enterprise was established for management and protection of 'Jasen' Multipurpose Area.Other institutions could be designated as responsible bodies for management of protected areas – in most cases these are local self-government units. In other cases, some institutes (Institute for Old Slavic Culture – Prilep) or NGOs (Peoni, Izvor – Kratovo) might be appointed as management body.

- Scientific institutions are responsible for research, studying and monitoring of biodiversity components to a various extent. The most important scientific institutions at the moment are: Institute of Biology from the Faculty of Natural Sciences and Mathematics, Faculty of Forestry, Faculty of Veterinary Medicine (with Veterinary Institute), Faculty of Agricultural Sciences and Food (with Institute of Agriculture, Institute of Livestock -Fishery Department), Faculty of Pharmacy from the University "Ss. Cyril and Methodius", Macedonian Academy of Science and Arts (MANU), Hydrobiological Institute from Ohrid and others.

- Non-governmental organisations (operational on a national or local level) have important role for biodiversity conservation, monitoring and research as well.

- Different agencies - Roads Agency, Agency for Spatial Planning, and Agency for Real Estate Cadastre have also important role for biodiversity management.

b) Local level. Public enterprises for water management and public enterprises for communal affairs are the most important players on local level.

III. Biodiversity users

- Different civil society organizations and community groups - hunters, fishermen, plant and mushroom collectors, animal collectors, mountaineers.

- Private sector entities/business sector – small and medium by-out enterprises of non-timber forest products as well as processing and trade companies, electricity production and distribution companies, other natural resources exploitation companies, tourism operators etc.

1.2.3 Sector documents

The most important national strategic documents in relation to biodiversity conservation are the National Spatial Plan, NBSAP, NEAP as well as strategic documents in the related sectors (agriculture, forestry and waters, in particular).

Spatial Plan of the Republic of Macedonia (2002–2020). The Spatial Plan is an integral strategic development document defining the spatial organization and the goals and

concepts of the spatial development of certain areas, as well as the conditions for the implementation thereof. A Synthesis Concept for the organization, regulation and use of the space for the period 2002–2020 has been drawn up by the Public Enterprise for Spatial and Urban Planning (now Agency for Spatial Planning) in coordination with the Ministry of Environment and Physical Planning, based on 12 expert studies as a professional and scientific basis. The Spatial Plan was adopted by the Parliament in 2004 (however the Study for Natural Heritage was prepared in 1996).The part of the Synthesis Concept describing the natural heritage deals only with the network of national protected areas (processed according to the former categorization) and the areas planned for protection. The protected areas system presented in the Spatial Plan was revised in the project *Development of representative national system of protected areas* (see below). Establishment of the Macedonian national ecological network represents an amendment of the Spatial Plan, as well.

National Biodiversity Strategy and Action Plan of the Republic of Macedonia (MEPP, 2004). The National Biodiversity Strategy and Action Plan (NBSAP) is a fundamental strategic document for the protection of biodiversity adopted by the Government of Macedonia in 2004.The overall aim of the NBSAP is conservation of biological diversity and ensuring its sustainable use for the welfare of the people, taking into consideration Macedonia's unique natural values and rich tradition. The Strategy explains the goals, objectives and tasks for biodiversity conservation, i.e. it is a document with an integral approach based upon many strategic components: *in-situ* and *ex-situ* conservation, sustainable use of biodiversity, institutional improvement, investigation and monitoring, public awareness and education, impact assessment, incentive measures, legislation, financial resources, and coordination and implementation of the NBSAP. The Action Plan for the conservation of biodiversity consists of specific actions and detailed activities with a precisely defined time frame and budget for each strategic approach to achieving the main aim and the general guiding objectives. One of the specific activities (E.2.5) refers to monitoring of the climate change impact on biodiversity.

Second National Environmental Action Plan (NEAP2). The Second National Environmental Action Plan (NEAP2) is a strategic document providing general instructions and directions for Macedonia in the field of the environment for the period 2006–2011. It defines the problems of the environment, establishes priorities and goals for different media and sectors that affect the environment, and provides special measures and actions for overcoming the problems. The obligation to draw up the NEAP arose from the Law on Environment. The section entitled 'Nature and Biodiversity', which aims at the achievement of the main goal of establishing an integral system for nature protection and biodiversity preservation according to EU standards and international agreements, provides special actions for 'establishment of national ecological network' as well as the action 'Preparing of documents and analysis for establishment of Natura 2000'. Implementation of these actions is to assist in overcoming the problems identified in this field, especially the lack of a national monitoring system, unsustainable use of forests, wild plant species and fungi, excessive hunting and fishing, the lack of information on managing the process of nature conservation, inappropriate use of the land and uncontrolled urbanization, etc., as well as the process of the approximation of Macedonia to the EU.

Agriculture and Rural Development Strategy. Agriculture and rural development are the key elements on which the Republic of Macedonia should put more attention in the pre-

accession process to the European Union. As a basis for formulation of the agricultural policy, the Ministry of Agriculture, Forestry and Water Economy (MAFWE) has adopted the following strategic objective:' *to strengthen the ability of Macedonian agriculture to compete in the integrated regional markets of the European Union and South-Eastern Europe through measures to increase the efficiency of agricultural production, processing and marketing, and to build appropriate, effective public and private institutions; to improve farm incomes; to ensure that consumers have access to safe, healthy food; to optimize the use of scarce land, forest and water resources, in an environmentally sustainable manner; and to build viable rural communities through sustainable rural development*.' One of the six strategic policy focal issues that should be addressed in the period 2007–2013 in order to achieve the strategic objective outlined below is to achieve sustainable resource management, in order to comply with the EU Common Agricultural Policy and effective introduction of agro-ecological measures. The main aspect covered by the agri-environmental policy in the Republic of Macedonia should be to protect and improve physical, chemical and biological soil conditions, to reduce the water-related environmental problems in agriculture, to preserve traditional low-input farming systems and traditional landscapes, to provide alternative use for areas with low potential, but also, to preserve valuable grassland habitats and arable land through extensive cultivation methods or landscape management on high nature value areas preserving and protecting biodiversity, sensitive/endangered habitat types and rare and threatened species. The need to ensure and provide effective tools for implementation of the Nitrate Directive, Water Framework Directive and the future Natura 2000 Network is particularly emphasized.

Strategy for sustainabledevelopment of forestry inthe Republic of Macedonia. Forestry Strategy does not address forest biodiversity properly. It deals mainly with economic aspects of forests: standing biomass and production, forest fires prevention and management. However, it calls upon forest certification based on standard international criteria which takes biodiversity into account to a great extent.

Strategy for Energetic Development in the Republic of Macedonia to 2030 - prepared for the period 2010-2020 with the vision to 2030. It defines the most suitable long-term development of energetic sector in Macedonia aiming to ensure permanent and quality energy supply to the consumers. **Strategy for Renewable energy use in the Republic of Macedonia to 2020** wasadopted in 2010 with the main goal to collect and present all relevant information about the potential and possibilities for exploitation of renewable energy sources in Macedonia.

Maximum use of renewable energy sources is the priority activity of the energy sector, as defined in the Strategy for energetic development. The following renewable energy sources are used in Macedonia: hydroenergy (for production of electricity), biomass (mostly wood used for heating in households), geothermal energy (mainly used for heating of greenhouses), and low percentage of solar energy (for heating water in households).

The Strategy elaborates 3 possible scenarios with different growth rate of electricity consumption. The basic scenario to 2020 (with anticipated consumption growth rate of 2,5%) envisages finishing of reconstruction and use of existing hydro-electric power plants (9 big and 13 small hydropower plants) as well as construction of new ones: Sv. Petka (under construction), Boshkov Most, Galishte, Chebren, Lukovo pole, Gradec and Veles with the total 690 MW installed capacity. Also, 121 small hydro-electric power plants are already put in tender procedures with the total installed capacity 93MW. About 400 small hydropower

plants are planned for construction in Macedonia according to the Study for small hydro power plants in Macedonia, with the total capacity of 255 MW

According to the data from 2005, Macedonia belongs to the group of countries with relatively high level of use of renewable energy sources with 13.8% contribution in the total energy consumption, out of which 38% belongs to the hydroenergy (94% fall out on big and 4% on small hydropower plants). The Strategy envisages rising of the renewable energy use from 13.5% in 2005 to 21% in 2020. According to the analysed scenarios for energy supply in the period 2020-2030, construction of new production capacities are planned, among which construction of one hydroelectric power plant Veles with 89 MW installed capacity as well as construction of a number of small hydropower plants with the total capacity 160-240 MW and production of 420 – 620 GWh (36 – 53 ktoe) annually.

Additionally, several other strategies are of importance for biodiversity conservation – National Strategy for Sustainable Development in the Republic of Macedonia (2010-2030, Water Strategy of the Republic of Macedonia (2012-2042), Strategy for Energetic Development in the Republic of Macedonia to 2030, Strategy for Renewable energy use in the Republic of Macedonia to 2020, National Transport Strategy (2007-2017),Poverty Eradication and Social Exclusion Strategy of the Republic of Macedonia (2010-2020), etc.

It has to be noted that the process of elaboration of new national biodiversity strategy was initiated since the existing NBSAP expired in 2009.Finally, elaboration of the strategy started in 2013. The project is financed by GEF and will be implemented by UNEP and MoEPP.

Elaboration of Strategy for nature is based in the Article 159 of the Law on Nature Protection (Official Gazette of RM, 67/04). Nature strategy will deal mainly with physical nature (biodiversity part will rely on its elaboration in the biodiversity strategy). The elaboration of the nature strategy will start this year as a part of the nature conservation programme in Macedonia financed by the Swiss government through Swiss Development and Cooperation Agency.

Except for the action plans in FNC and SNC there is no national strategy for dealing with climate impacts.

1.2.4 Data availability

The availability of data concerning climate change in general and climate change impact on biodiversity discussed in previous communications to CCC remain the same to date. Nothing was done to overcome this problem during last five years. The recommendations and actions proposed in the SNC were not implemented. Thus, the lack of cartographic data on vegetation types' distribution in the country is evident and it hampers the possibility for modelling of possible vegetation changes provoked by the climate change. The same stands for distribution ranges for sensitive species.

However, some progress was made, especially in relation to large carnivores (see chapter 1.3.2 below), ecological network structure and requirements for its functioning etc.

The problems of uncertainty of the regional models for climate change (temperature and precipitation) due to the gaps in data ranges may cause eventual errors in future modelling of the climate change impacts on biodiversity.

1.3 Review of recent research and other projects

In recent years (2007-2012) some progress was made in terms of biodiversity research and conservation. The information on all available projects and research results is presented below.

1.3.1 Scientific projects

Only few scientific projects aiming at biodiversity research were conducted in the past years, due to the lack of national science funding. However, some of the realized projects are very important since they provide the necessary baseline data on biodiversity and some have direct connections with climate change assessments.

1) Reconstruction of past environmental variations in ancient lake Ohrid, diatom inferred perspective. Institute of Biology, Faculty of Natural Sciences and Mathematics, Ss. Cyril and Methodius University, Skopje
2) Wetlands diversity along longitudinal gradient in Macedonia. Institute of Biology, Faculty of Natural Sciences and Mathematics, Ss. Cyril and Methodius University, Skopje
3) Population studies of the reptiles on the island of Golem Grad. Institute of Biology, Faculty of Natural Sciences and Mathematics, Ss. Cyril and Methodius University, Skopje
4) Vegetation of the steppe zone in Macedonia. Institute of Biology, Faculty of Natural Sciences and Mathematics, Ss. Cyril and Methodius University, Skopje
5) The Vegetation of thermophilic trampled habitats rich in C_4 plants in Slovenia and Macedonia and its position in the broader European scale. Institute of Biology, Faculty of Natural Sciences and Mathematics, Ss. Cyril and Methodius University, Skopje; Slovenian Academy of Sciences and Arts.
6) Forest vegetation of the Galichica mountain range in Macedonia (Matevski et al., 2011)
7) Evaluation of forest communities of conservational importance on Belasitsa mountain (Bulgaria and Macedonia) based on invertebrate indicator groups. Institute of Biology, Faculty of Natural Sciences and Mathematics and Bulgarian Academy of Sciences.
8) Landscape Ecology - landscapes of Osogovo Mt, Mariovo area.
9) Flora of the Republic of Macedonia. Macedonian Academy of Sciences and Arts
10) Ecology and land tenure system of the critically endangered Balkan lynx *lynx lynx martinoi* . Macedonian Ecological Society, KORA-Switzerland.

1.3.2 Conservation and applicative projects

The period after the drafting of the National Biodiversity Strategy (MEPP, 2004) was marked by implementation of many important projects on biodiversity conservation:

- **Development of representative national protected areas system**. Project activity Ref. RFP 79/2009), as part of the "Strengthening the *Ecological, Institutional and Financial Sustainability of Macedonia's National Protected Areas System" (Project00058373 - PIMS 3728). Funded by UNDP. Implemented by Macedonian Ecological Society.* Macedonian Ecological Society (MES), in the frames of the Project Activity has developed and recommended representative national network of protected areas and areas proposed for protection, that will contribute to more efficient preservation of

species and habitats/ecosystems of national and global importance in the Republic of Macedonia. The results of this project activity shall assist the MEPP to fulfil its obligations deriving from several legal and strategic documents (Spatial Plan of the Republic of Macedonia, Law on Nature Protection, etc.), and implement the provisions of the Convention on Biological Diversity (NBSAP) and other conventions in the area of environment and nature protection ratified by the Republic of Macedonia. Besides this, the results will help the MEPP to implement the actions defined towards transposition and implementation of the two main directives in nature conservation, namely Directive on the conservation of natural habitats and of wild fauna and flora (92/43/EEC) and Directive on the conservation of wild birds (2009/147/EC ex. 79/409/EEC), specified in the National Programme for Adoption of the Acquis of the EU (NPAA), in the Chapter 27 "Environment". In the frames of this project activity, GIS layers were developed during the first project phase for the designated areas (Important Bird Areas – IBAs, Important Plant Areas – IPAs and Prime Butterfly Areas – PBAs), as well as areas included in the Ramsar List, UNESCO List of the world natural and cultural heritage, Emerald network and all nationally protected areas with known boundaries (designated or in a process of re-designation). In parallel with this, database of species and areas was created (distribution of selected rare, endemic and important species, assessment of threats, etc.).During the second phase of the Project implementation, field and laboratory investigations were carried out for the purpose of collecting and establishing the basic data on selected species (selection of species important for conservation and production of maps of the distribution of selected species), as well as finalization of the elaboration of GIS layers with nationally protected areas the boundaries of which have been unknown and map of areas proposed for protection was produced. Additionally, virgin forests in Macedonia were identified, map of areas sensitive to climate change was produced and assessment of land transformation on two pilot sites was conducted. During the third phase, consolidated map of priority areas for conservation was produced with presented conservation goals of the country. Apart from protected areas and areas proposed for protection, the map also contains the ecologically important areas identified by the expert team on the basis of the prior developed GIS layers. Also, sites important for management of certain species were identified and their borders were delineated on the map.

- **Development of the national ecological network in Macedonia (MAK-NEN).** *Funded by BBI Matra fund of the Netherlands Ministry of Agriculture, Nature and Food Quality and the Ministry of Foreign Affairs. Implemented by ECNC–European Centre for Nature Conservation and MES-Macedonian Ecological Society.* The main objective of this project was to develop a National Ecological Network (NEN) in Macedonia as a contribution to the development of the Pan-European Ecological Network (PEEN). This project also assists Macedonia in fulfilling its obligations as a signatory country of the Pan-European Biological and Landscape Diversity Strategy (PEBLDS).Building up a coherent ecological network of core areas, corridors, buffer zones and nature development areas is seen as one of the most effective measures for the protection of species and habitats and the sustainable use of nature and biodiversity, as well as providing an effective tool for mitigating (and adapting to) the effects of climate change. The implementation of this project will therefore represent a significant contribution to the fulfilment of the main goal of the National Biodiversity Strategy and Action Plan, as well. In the frames of the project intensive public participation campaign

on national level was undertaken, involving all relevant stakeholders. Two publications (background study and brown bear study), a poster and a number of leaflets were produced aiming at different sectors (forestry, agriculture, infrastructure development, particularly traffic, water supply, energy sector, etc.). Brown bear was taken as a model species for identification of core areas, corridors, buffer zones and restoration areas. The main output of the project was a map of Macedonian ecological network and published Bear Corridor Management Plan, both of them disseminated to the relevant ministries and other state institutions and organisations. In connection to climate change impact this project has very important outcomes and methodology. Identified corridors for movement of animals should be the key topic in mitigation of climate change impacts. Furthermore, ecological modelling that was used in the project might well serve in modelling of other species in relation to altered climate (e.g. temperature, precipitation, humidity) and other ecological factors.

- **Balkan lynx recovery programme (BLRP).** *Finanaced by MAVA - Switzerland. Implemented by: Euronatur - Germany, KORA - Switzerland, Macedonian Ecological Society, PPNEA – Albania.* The project had two phases (2006-2009 and 2009-2012). It consists of two main component, not aiming at conservation of the unique Balkan lynx (*Lynx lynx balcanicus*): 1. Direct conservation and monitoring activities for the Balkan lynx, other large carnivores and large ungulates (education, awareness raising, camera-trapping, etc.) and 2. Establishment of new protected areas (Jablanica, Shar Planina and Ilinska-Plakenska mountain range).
- **Ecology and land tenure system of the critically endangered Balkan lynx *Lynx lynx martinoi.*** *Financed by Swiss National Foundation. Implemented by: KORA - Switzerland, Macedonian Ecological Society, PPNEA – Albania. Research goals and objectives* of the project were: Goal 1. Study the land tenure system, social organization, habitat preferences, and distribution of the Balkan lynx in order to understand the species as an integral part of the landscape on the individual and population level. Goal 2. Investigate the feeding ecology of the lynx in order to make sensible recommendations for wildlife management measures enhancing and securing the prey base. Goal 3. Develop the capacity in wildlife research and monitoring in both countries and train young researchers in the relevant methodologies and field techniques. All of the projects concerning lynx have developed sound schemes for wildlife monitoring and have gathered important ecological information on lynx, other large carnivores and their prey - this is a basis for assessment of the species vulnerability from different impacts, including climate change.
- **Management plans of Mavrovo National Park, Galichica National Park and Multipurpose area Jasen.** After the preparation and adoption of the management plan for Pelister National Park, several others management plans were elaborated in the recent period. Both Galichica and Mavrovo National Parks prepared management plans (not adopted yet), with reference to climate change impact and adaptation. Management plan was prepared for Jasen Multipurpose Area, as well. Another management plan that was prepared and adopted is for Ezerani Nature Park. Two other management plans for Canyon Matka Monument of Nature and Tikvesh Strict Nature Reserve were drafted - both sites are not re-proclaimed yet hence management plans are not adopted yet.
- **Osogovo mountains in the Balkan green belt.** *Funded by Frankfurt Zoological Society and ProNatura - Friends of Earth - Switzerland. Implemented by Macedonian Ecological*

Society. This on-going project (started in 2007) is aiming at establishment of protected area on Osogovo Mt. (the most suitable to be category V, protected landscape). The project is transboundary and the protected area on Macedonian side should be complementary.

- **Integrated Ecosystem Management in the Prespa Lakes Basin of Albania, Macedonia and Greece.** A number of projects were implemented in the frames of the transboundary Prespa project (coordinated and financed by UNDP): Integrated Ecosystem Management in the Prespa Lakes Basin of Albania, Macedonia and Greece. The overall goal of this project is the conservation of globally significant biological diversity and transboundary water resources of the Prespa lakes Basin. The project's objective is to catalyze the adoption of integrated ecosystem management (IEM) in the transboundary Prespa Lakes Basin of Macedonia, Albania, and Greece to conserve globally significant biodiversity, mitigate pollution of the transboundary lakes, and provide a sustainable basis for the Basin's further social and economic development. During these project monitoring schemes were developed, conservation action plans for some species and habitats, public awareness campaign was undertaken, trilateral tourism strategy was initiated, etc.

1.3.3 Invasive species

The importance of invasive species problem in the world was reflected in Macedonia in the recent period. There were three projects on allochtonous and invasive species implemented:

- **ESENIAS - east and south European network for invasive alien species.** *Albania, Macedonia, Croatia, Romania, Bulgaria, Turkey, Kosovo, Bosnia and Herzegovina, Greece, Serbia.* All of the Balkan countries are part of this project. Its main goal is to provide scientific base for monitoring of invasive alien species, risk assessment and risk management. This is an on-going project that attempts to compile a list of alien invasive species, provide distribution maps, identification tools etc. The progress of the project can be followed on its website: www.esenias.org.
- **Non-indigenous insects and their threat to biodiversity and economy in the Balkans.** CABI Bioscience Switzerland Centre– Delémont, Switzerland; University of Forestry - Sofia, Bulgaria; Ss Cyril and Methodius University, Skopje, Macedonia, Agriculture University of Tirana**,** Albania. **Main objective of the project were a)** To provide the three target countries with information on invasive alien insects in the Balkans and to develop local expertise in the field of invasive alien species management. This will allow the development of national strategies against invasive alien insects, and other invasive organisms in general. Both the economic and environmental aspects on invasive species will be considered, b) The basis of the project is the development of a database on non-indigenous insects present in the region, or about to enter the countries, with information on pathways, habitats, environmental and economic impact, etc., c) The main species will be detailed in more complete datasheets which will also include recommendation on management, d) These data will be incorporated into European datasets presently developed in two European projects (ALARM and DAISE) for analyses of invasion mechanisms and risk/impact assessment. This is one of the project that improves our knowledge on alien species in Macedonia. The project focuses on insects, especially from forestry point of view. In terms of climate change, many of these alien

species will be important for monitoring and prevention of damages to the natural forest ecosystems.

- **Asian tiger mosquito (*Aedes albopictus*** Skuse, 1894**) in Macedonia.** *Funded by World Health Organization, Office in Skopje. Implemented by Macedonian Ecological Society.* The main goal of the project was to determine the presence/absence of Asian tiger mosquito in Macedonia. The investigation resulted in three main conclusions: 1) The species *Aedes albopictus* (Skuse 1894) was **not detected in R. Macedonia**, 2) The existence of 51 species from Culicidae family on the territory of R. Macedonia was recorded, 3) In total twelve vector species occur in R. Macedonia: *Anopheles claviger*, *Anopheles maculipennis*, *Anopheles superpictus*, *Aedes vexans*, *Ochlerotatus geniculatus*, *Ochlerotatus communis*, *Ochlerotatus excrucians*, *Culex modestus*, *Culex pipiens*, *Culex tritaeniorhynchus*, *Culex univittatus* , *Coquillettidia richiardii*. Also, two main recommendations were proposed in terms of 1) Capacity building (human capacities, financial means and experts' database) and 2) Monitoring of the presence of *A. albopictus* and other invasive species in Macedonia. This project is clearly connected to climate change and human health. The spreading of vector species is undoubtedly a consequence of global warming and is expected to have profound impact on human health in Macedonia. Since the completion of the project a number of yellow fever cases were registered in Macedonia. However, not much of the prevention activities were undertaken - this should be of interest when dealing with climate change impact on the spread of alien species.

1.4 National protected areas

There is a big confusion in relation to the protected areas' system in Macedonia due to the absence of functional data base and PAs cadastre. Additional shade is posed by the re-proclamation process which is an obligation from the Law on Nature Protection from 2004. Protected areas have to be revalorised and re-proclaimed, the process which is undergoing, and the status of separate PAs can hardly be traced outside the MoEPP.

Table 2. Number of protected areas by category of protection (current status)(source: MES report for the UNDP/MoEPP project mentioned above)

Category of protection underIUCN	Number of PAs	Area (ha)	% of the national territory
Strict Nature Reserve	3	11480.73	0.45
National Park	3	115713.2	4.50
Natural Monument	57*	70423.97	2.74
Park of Nature	14	1457.53	0.06
Protected Landscape	3	5387.12	0.21
Multy-Purpose Area	1	26923.03	1.05
Total	**81**	**231385.6**	**9.00**
Total (without ovrlaps)		**226087.4**	**8.79**

* It has to be noted that recently one PA (Monument of Nature Alshar) was excluded from the list by Parliametary decision

Anyway, currently there are 81 PAs in Macedonia (Tab.2, Fig. 1) from different categories (which are more or less harmonized with the IUCN system) but individual PAs carry various names according to the old categorisation system (according to the old Law on Natural Rarities). The number and the respective land area for all PAs by categories (transposed according to the new Law on Nature Protection) is given in the table below (Tab. 2).

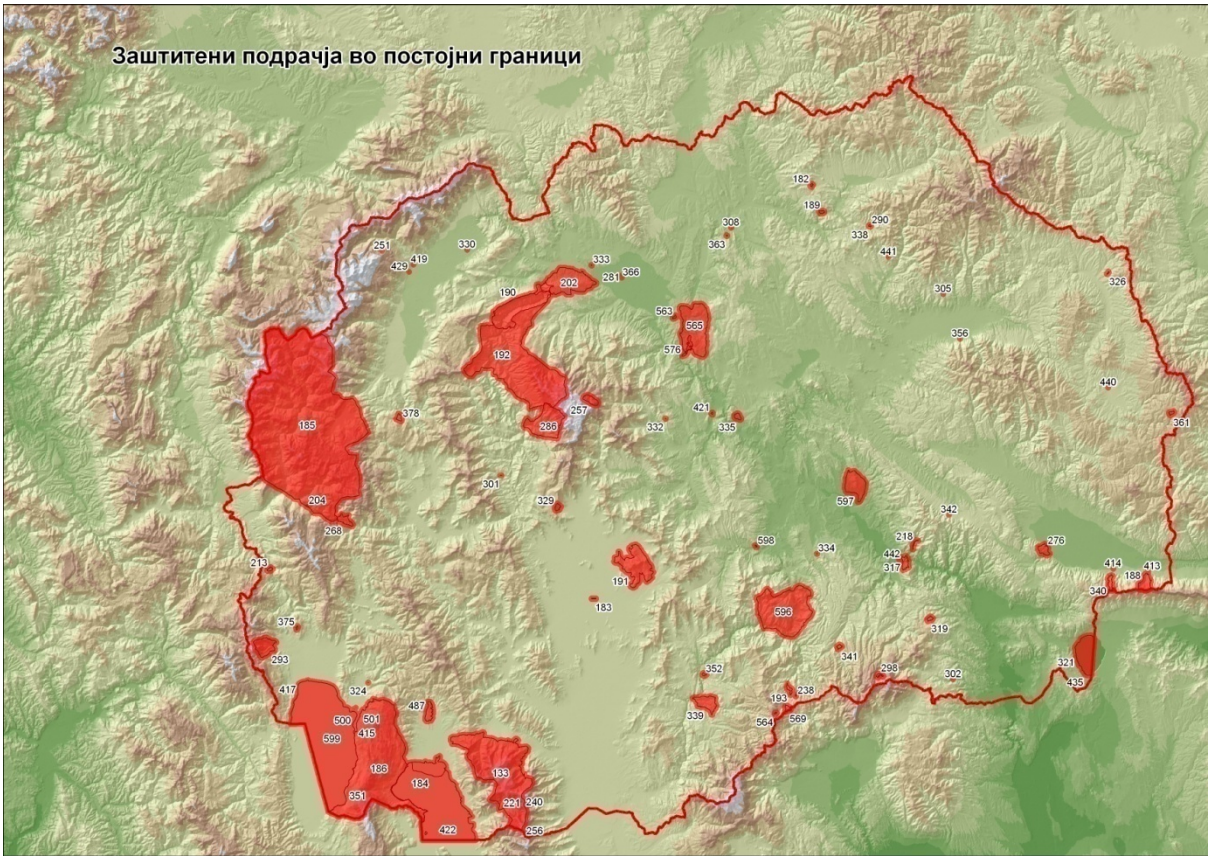

Figure 1. Map of current protected areas in Macedonia (source: MES report for the UNDP/MoEPP project mentioned above)

In order to overcome this situation, MoEPP in cooperation with UNDP-Skopje conducted a project on creation of a representative protected area network in the Republic of Macedonia* during 2010 and 2011. According to the results of that project 34 PAs in Macedonia appeared to be representative (Tab. 3 and Fig. 2). The number was shrunken by:

- incorporating of seven PAs into other larger PAs in which they are already situated;
- incorporating of 10 PAs into larger areas that are proposed for protection (according the National Spatial Plan)
- proposing of 27samll PAs for designation as natural rarities (a newly introduced category that incorporates PAs smaller than 100 ha and are designated by the ministerial decision); and
- deleting three PAs from the list (due to the fact that they lost the values for which they were proclamed)

*GEF Project implemented by UNDP and the Ministry of Environment and Spatial Planning of the Republic of Macedonia "Strengthening of ecological, institutional and financial sustainability of the system of protected areas in the Republic of Macedonia"Project Activity Ref. RFP 79/2009"Development of representative protected areas network" – Macedonian Ecological Society: Final report, Part I.

Table 3. Representative protected areas – total number and area by category(source: MES report for the UNDP/MoEPP project mentioned above)

Representative protected areas	Number of areas	Area
Strict Nature Reserve	2	470.8
National Park	3	115713.2
Nature Monument	20*	85517.0
Park of Nature	7	3164.1
Multipurpose Protected Area	2	31529.4
Total	**34**	**236394.5**

* It has to be noted that recently one PA (Monument of Nature Alshar) was excluded from the list by Parliametary decision

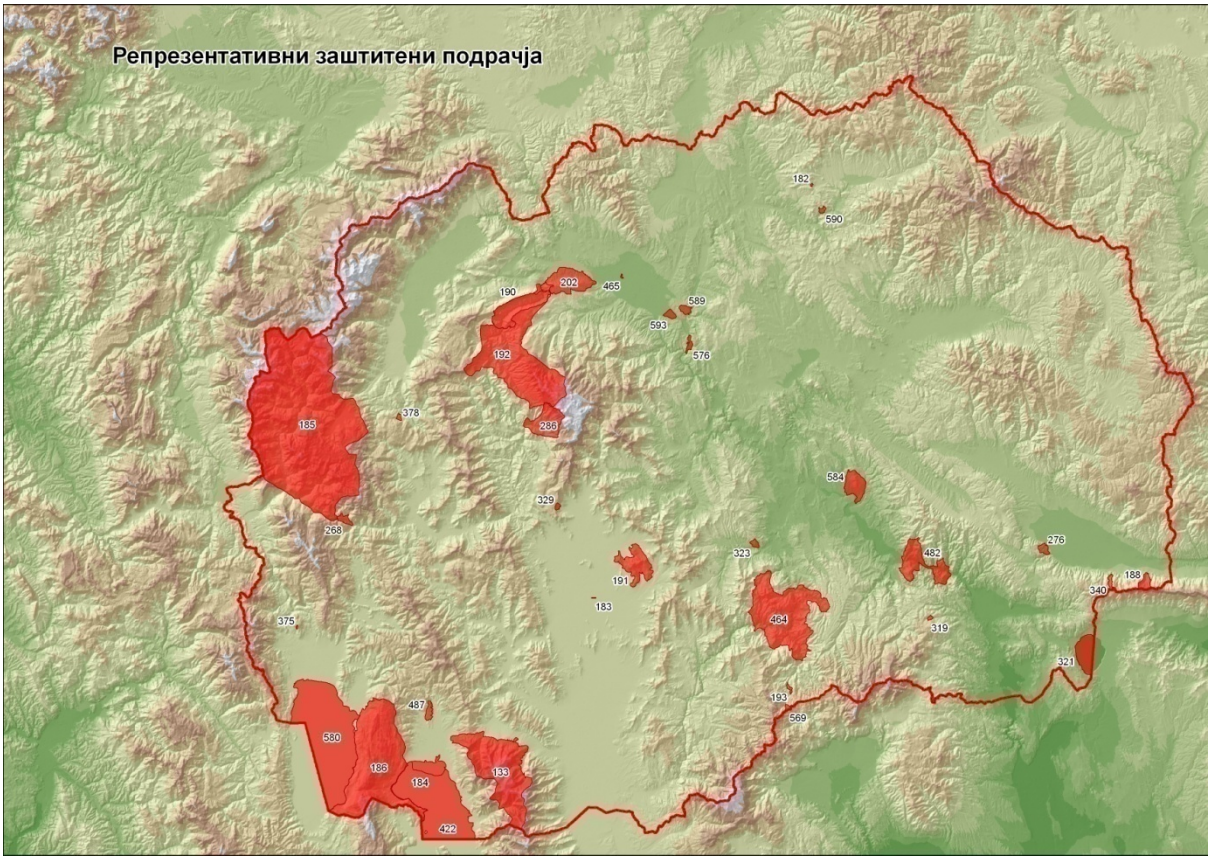

Figure 2. Map of representative protected areas in Macedonia (source: MES report for the UNDP/MoEPP project mentioned above)

It can be seen from the map on the figure above that the PAs in Macedonia are not evenly distributed. Most of PAs are in western Macedonia (both by number and by surface). Additionally they are not connected, even more – there are large gaps between them. Thus, PAs in Macedonia cannot serve to mitigate climate change impacts.

However, in course of the project mentioned above an effort was done to improve the situation. Analysis of all proposed PAs in National Spatial Plan for their suitability to be proclaimed was performed. Additionally, extensive analyses for the needs of species and

habitats conservation were conducted and new PAs were proposed. The needs for climate change adaptation of important habitats and species were taken into consideration to a certain extent during that process. The result was a proposal for a comprehensive and representative PAs network in Macedonia shown on the map on Fig. 3. For more details, see: GEF Project implemented by UNDP and the Ministry of Environment and Spatial Planning of the Republic of Macedonia "Strengthening of ecological, institutional and financial sustainability of the system of protected areas in the Republic of Macedonia" Project Activity Ref. RFP 79/2009 "Development of representative protected areas network" – Macedonian Ecological Society: Final report, Part I.

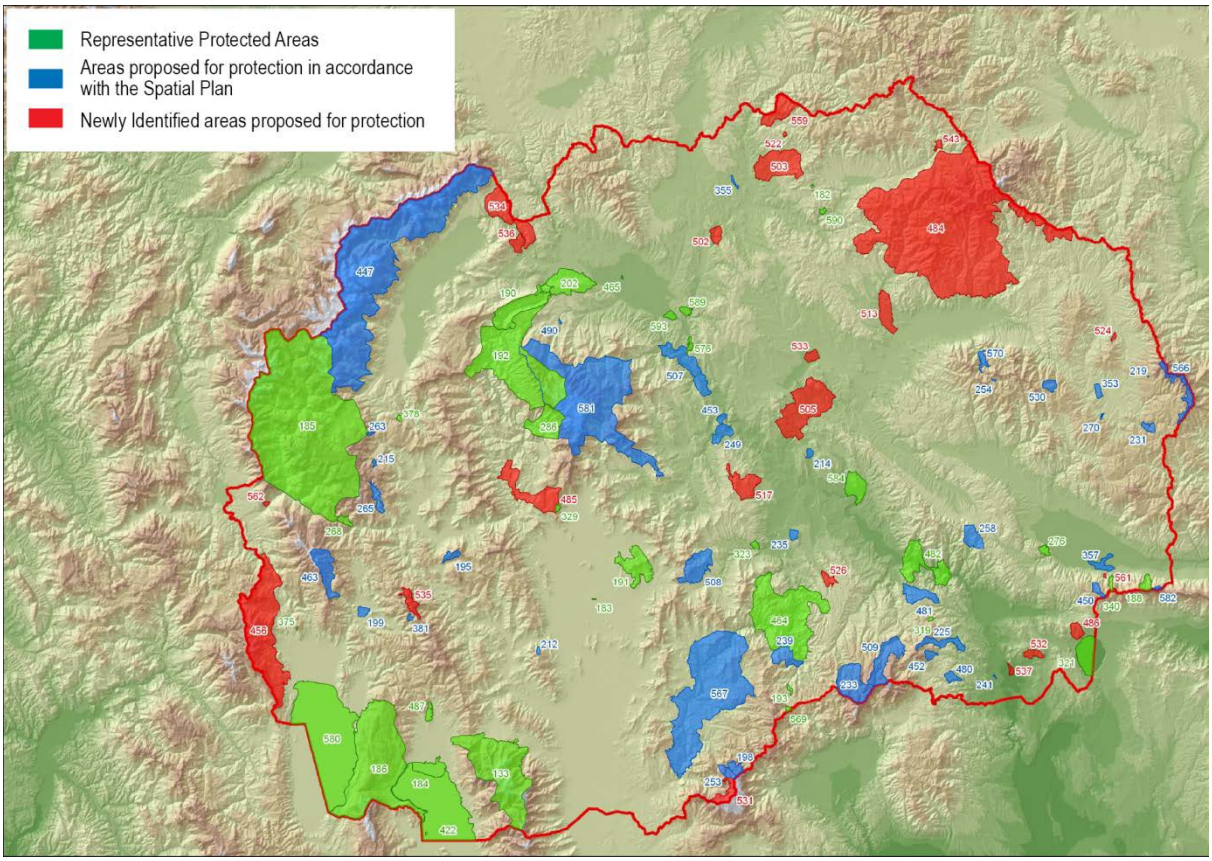

Figure 3. Map of the proposed representative PA system in Macedonia (source: MES report for the UNDP/MoEPP project mentioned above)

1.5 International obligations

1.5.1 UNFCCC and other international conventions

The main international framework for addressing and combating climate change is the **United Nations Framework Convention on Climate Change** (UNFCCC) of 1992. The Republic of Macedonia is one of the 195 Parties to the Convention, has ratified the Convention in 1998 and belongs to the non-Annex I Parties. UNFCCC is the parent treaty of the Kyoto Protocol adopted in 1997 with more than180 member Parties. The ultimate objective of both treaties is to stabilize greenhouse gas concentrations in the atmosphere at a level that will prevent dangerous human interference with the climate system. The Republic of Macedonia, as a country that has ratified the Kyoto Protocol in 2004, recognizes the

possibilities of achieving the goals of sustainable development by taking advantages for carbon funding through availing one of the mechanisms of the Protocol, so called Clean Development Mechanism. It is considered to be the only relevant mechanism for the non-Annex countries. In February 2007, the National Strategy for the Clean Development Mechanism was adopted by Government of the Republic of Macedonia, for the first period of obligations 2008-2012 based on the Kyoto Protocol. Nationally appropriate mitigation measures for GHG emissions reduction are defined for agriculture and forestry sector.

Convention on Biological Diversity (CBD) is the most important international framework for biodiversity conservation at a global scale, opened for signature at the Earth Summit in Rio de Janeiro in 1992 together with UNFCCC. The CBD has three main objectives: (i) conservation of biodiversity; (ii) sustainable use of its components; and (iii) equitable sharing of the benefits of the genetic resources.

In the Convention's first Strategic Plan, adopted in 2002 (Decision VI/26), the Parties committed themselves "to a more effective and coherent implementation of the three objectives of the Convention, to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth". The vision of the Strategic Plan for Biodiversity 2011-2020 (adopted at CBD/COP 10, Nagoya, 2010) is a world of "Living in harmony with nature" where "By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people." The Strategic Plan includes 20 headline targets for 2015 or 2020 (the "Aichi Biodiversity Targets"), organized under five strategic goals, among which the global Target 15 refers to "ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification by 2020".

Besides the CBD, biodiversity policy in Macedonia is driven by a number of conventions related to nature conservation ratified by the country. These include: Ramsar Convention on the conservation and wise use of wetlands of international importance (1971), Bonn Convention on migratory species (1979), Bern Convention on the conservation of European wildlife and natural habitats (1979), UNESCO Convention, etc.

The Standing Committee of the Bern Convention on its 32nd meeting in 2012recommends Contracting Parties to take urgent practical actions related to minimising negative effects of climate change on biodiversity, "1. ... more particularly focus on implementing adaptive management practices and strategies, enhancing the adaptive capacity of vulnerable species (rare/endemic/threatened), minimising pressures and threats on species and habitats that are most vulnerable to climatic change, and implementing monitoring of inter alia species' population trends, species behaviour, including phenology, and climatic change impacts upon critical areas; 2. ...to develop ecological networks, to enhance the permeability of landscapes generally, and also enhance their protected areas networks, as appropriate, by increasing the extent of existing sites, designating new sites and establishing buffer zones, and ensuring they are sustainably managed; 4. Adopt, as appropriate, a more holistic approach when formulating strategies and plans for ecological networks or protected areas, and when developing conservation or recovery plans for individual species."

1.5.2 EU

At a strategic policy level, the European Union has taken important steps in response to commitments under the CBD. European Commission launched the EC Biodiversity Action Plan, as part of the Communication 'Halting the loss of biodiversity by 2010 – and beyond' in 2006. EU leaders recognized. In March 2010, EU leaders recognized that the 2010 biodiversity target would not be met despite some major successes, such as establishing Natura 2000 the world's largest network of protected areas (based on provisions of the Birds and Habitats Directives). Therefore, the long-term vision by 2050 and ambitious headline target were endorsed in 2011. An EU biodiversity strategy to 2020 "Our life insurance, our natural capital" includes six mutually supportive and inter-dependent targets that respond to the objectives of the 2020 headline target. Target 2 focuses on maintaining and enhancing ecosystem services and restoring degraded ecosystems (at least 15%) by incorporating green infrastructure in spatial planning. This will contribute to the EU's sustainable growth objectives and to mitigating and adapting to climate change, while promoting economic, territorial and social cohesion and safeguarding the EU's cultural heritage. Republic of Macedonia, as an EU candidate country, has an obligation to implement both Birds and Habitats Directives. On the other hand, "the EU will reinforce its dialogue and cooperation on biodiversity with key partners, in particular candidate countries and potential candidates, to develop or adjust their policies to meet the 2020 biodiversity targets", as stated in the Strategy.

1.5.3 Other

At the **Sixth Ministerial Conference 'Environment for Europe'** in Belgrade (2007), the Ministers of 53 European countries stressed the importance of reaching the 2010 target, of combating climate change and prioritizing the establishment of European ecological networks to increase the resilience of habitats and ecosystems. Recognizing the importance of climate change for sustainable development and poverty eradication in the SEE region and the importance of integrating climate change considerations into the development of key economic sectors in SEE countries, the Belgrade SEE Climate Change Initiative (BCCI) was adopted by the Sixth Ministerial Conference 'Environment for Europe'. This Initiative has as its main goal to facilitate partnership and cooperation between the SEE countries and other countries in the United Nations Economic Commission for Europe (UNECE) region in climate change related programs. The main BCCI policy recommendations are related to: (a)development of the SEE Climate Change Framework Action Plan; (b) establishment of a Sub-regional, Virtual Climate Change Related Centre in Belgrade for research and systematic observation, education, training, public awareness and capacity building; and (c) developing partnerships.

Regional conference "**Conservation of Biodiversity in the Balkan Region within Sustainable Development principles and in Climate Change conditions**" was organized in June 2010 on the initiative of the Macedonian Ministry of Environment and Physical Planning. *Declaration for Joint Regional Action for Biodiversity conservation in the Balkan and neighboring regions with Sustainable Development Principles and in Climate Change Conditions* was signed by responsible ministries for the environment from Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Kosovo, Montenegro and Serbia.

1.6 Policy and Legislation

The legal basis for nature protection is found in the Constitution of the Republic of Macedonia (Official Gazette no. 52/91) that provides 'the right to a healthy living environment and duty to protect and improve the environment and the nature' and determines 'natural resources of the country, the flora and fauna, and amenities in common use are goods of common interest enjoying specific protection'. The Law on Environment is a framework law regulating the protection and improvement of the environment; in addition the provisions of the special laws regulating specific environmental areas and media including biological diversity are applied. Also, international agreements ratified by the Republic of Macedonia (CBD, Bern, Bonn, Ramsar, UNESCO conventions etc.) are important legal base for nature conservation in the country.

Almost 10 years ago, an attempt was made to consolidate and update the previous laws affecting species and habitats protection: Law on Natural Rarities Protection (Official Gazette of the Republic of Macedonia no. 41/1973), Law on Protection of National Parks (Official Gazette of the Republic of Macedonia no. 33/80) and Law on Protection of Ohrid, Prespa and Dojran lakes (1977) in accordance with the new global trends in nature conservation (adopted CBD 2010 Targets), global categorization of protected areas prescribed by International Union for Conservation of Nature (IUCN), sustainable development principles, obligations from relevant ratified international agreements as well as the process of approximation of national legislation to the EU legislation, including transposition of relevant directives for nature protection – Birds Directive (2009/147/EC ex. 79/409/EEC) and Habitats Directives (92/43/EEC).

Thus, in 2004, the Law on Nature Protection (Official Gazette of the Republic of Macedonia no. 67/04) was adopted as a general law that regulates the protection of nature by protecting the biological and landscape diversity, and the protection of the natural heritage, in protected areas and outside of protected areas, as stated in Article 1. Since its adoption, the Law has already been amended 6 times (Official Gazette of the Republic of Macedonia no. 14/06, 84/07, 35/10, 47/11, 148/11 and 59/12). Full implementation of the Law would be achieved only after adopting of the secondary legislation (about 50 by-laws are foreseen to be prepared). However, development of secondary legislation requires significant efforts, especially by-laws for which previous scientific/expert work needs to be undertaken, and only 10 by-laws were adopted so far.

In addition to the provisions of this Law, the use of natural resources for economic purposes shall also be regulated by the provisions of sectoral laws (Art. 1) of particular relevance are the following:

- Law on Hunting (Official Gazette of the Republic of Macedonia no. 26/09, 136/11 and 01/12),
- Law on Forests (Official Gazette of the Republic of Macedonia no. 64/2009, 24/2011 и 53/2011),
- Law on Pasture Management (Official Gazette of the Republic of Macedonia no. 3/98, 101./2000, 89/08, 105/09, 42/10),
- Law on Waters (Official Gazette of the Republic of Macedonia no. 87/08, 06/09, 161/09, 83/10 и 51/11),
- Law on Fishery and Aquaculture (Official Gazette of the Republic of Macedonia no. 7/08, 67/10, 47/11, 53/11 and 95/12),
- Law on agriculture and rural development (Official Gazette of the Republic of Macedonia no. 49/10),

- Law on stockbreeding (Official Gazette of the Republic of Macedonia no. 07/08, 116/10), etc.

Following the subject of regulation, the Law defines the scope of work (article 3) in the following 3 directions:

1. **Protection of biological diversity** - shall be carried out through establishment and implementation of a system of measures and activities for protection of wild species, including their genetic material, habitats and ecosystems, for the purpose of providing for a sustainable use of the components of biological diversity and maintenance of natural balance.
2. **Protection of landscape diversity** - shall be carried out through establishment and implementation of a system of measures and activities for conservation and maintenance of characteristic values of the landscape that derive from its natural configuration and/or the type of human activity.
3. **Protection of natural heritage -** shall be carried out through establishment of a system that shall specify the measures, procedures and methods for acquiring the status of natural heritage and for implementation of its protection. The Law defines natural heritage as parts of the nature and sites consisting of geologic, physical and geographic or biological formations or a group of such formations, which have extraordinary value from the aesthetic, conservation or scientific point of view. Natural heritage includes protected areas, strictly protected or protected wild species, characteristic minerals and fossils, speleological objects and natural rarity.

The main objectives of the Law on Nature Protection are defined in the Article 4:

1. Determination and monitoring of the state of nature;

2. Conservation and restoration of the existing biological and landscape diversity in a state of natural balance;

3. Establishment of a network of protected areas for the purpose of protection of the features on the basis of which they have acquired the status of natural heritage;

4. Providing for sustainable use of natural wealth in the interest of the present and future development, without significant damage of parts of the nature and with the least possible disturbance of natural balance;

5. Prevention of harmful activities of individuals and legal entities and disturbance in nature as a result of technological development and performance of activities, i.e. providing for the best possible conditions for protection and development of the nature;

6. Providing for the citizen to exercise their right to healthy environment.

1.6.1 Protection of species

General measures i.e. prohibited activities for the purpose of species protection are: extermination of indigenous wild species; reduction of the populations of wild species, destruction of their habitats, or modification of their living conditions to an extent that would cause a state of danger; deliberate disturbance of wild animals, especially during mating, breeding or hibernation, as well as capturing, hurting or shooting of wild animals; deliberate removal of wild plants and fungi from their habitats, reduction of their population, or destruction in any way; deliberate damaging or destruction of habitats of wild species; and using the non-selective means for wild species collection and hunting.

a) Special protection of species

In accordance with the extent to which the flora, fungi and fauna species are threatened they shall be categorized as: extinct, extinct in wild, critically endangered, endangered,

vulnerable, near threatened, least concerned and data deficient (Article 34). However, Red List and Red data book have not been prepared yet. Threatened wild species i.e. those that are categorized as critically endangered, endangered, vulnerable may be proclaimed as strictly protected or protected wild species (Article 35). **The lists of strictly protected and protected wild species** were adopted in 2011 (Official Gazette of the Republic of Macedonia no. 139/2011) without prior categorization of species based on their threat status. The list of strictly protected wild species includes 194 species (9 fungi species, 51 flora and 134 fauna species) and 820 species are put on the list of protected wild species, of which 75 species of fungi and lichens, 151 flora and 594 fauna species. It is prohibited to destroy, collect, cut or uproot the strictly protected plants and fungi, while the strictly protected animals the following activities are prohibited: deliberate capture, keeping and shooting; deliberate damaging or destruction of their developmental forms, nests, homes, as well as of their habitats or parts of habitats; deliberate disturbing, especially during the breeding and gestation period, raising of the cubs, migration, hibernation, if that disturbance threatens their future survival; deliberate destruction or taking of eggs from the nature or keeping of deaf eggs; and hiding, keeping, raising, selling, buying and transferring or any other form of acquiring and stuffing (Article 38). With regard to the protected wild species, the measures and activities for protection and the manner and extent of use of protected wild species shall be prescribed in the rulebook (Article 42), that is not prepared yet.

Protection of some species nominated as game (110 birds and 23 mammal species, of which only 14 species are game without protection) is provided by the Law on Hunting. Three ways of protection are prescribed for the protected game: closed season, temporary and permanent protection (Articles 11, 12 and 13). A coherent link between the two laws must be provided in order to avoid duplications that might jeopardise the legal certainty based on a thorough legal review for both laws. Such analyses were undertaken as part of EC funded project “Wings across Balkans”, implemented by MES.

b) Collection and trade

Collection and trade of threatened and protected wild species of plants, fungi and animals and their parts shall be conducted only upon prior acquisition of license for collection (article 23) or licence/certificate for trade (Article 29), issued by the Minister of Environment and Physical Planning (MEPP). The lists of threatened and protected wild species of plants, fungi and animals and their parts were adopted in 2012 (Official Gazette of the Republic of Macedonia no. 15/12) including the species listed in the annexes of the CITES, annexes of the EU Regulation on the protection of species of wild fauna and flora by regulating trade therein (338/97/EC) as well as national list of species whose trade is regulated with licensing procedure (D4 licence). According to the Law, the total quantity of endangered and protected wild species of plants, fungi, animals and their parts that are collected for commercial purposes shall be established on the basis of preceding assessment of the species status and opinion obtained from scientific and professional organizations about the density of endangered species' population in natural habitats every year and it is not implemented in practise.

Restriction or prohibition of use of certain species in case when the favourable conservation status of the species or habitat types is endangered due to unreasonable use, the Minister managing the body of state administration responsible for the affairs of nature protection shall limit or fully prohibit the use of the natural resource for as long as the state of danger

is lasting (Article 14). Collection and trade of *Gentiana lutea* and *Gentiana punctata* is prohibited with Ministerial decree since 2006.

1.6.2 Protection of habitats/ecosystems

General measures for protection of ecosystems and habitats are prescribed in the Law on Nature Protection. It shall be carried out by way of implementing measures and activities for nature protection, by using the natural resources in a sustainable manner and by spatial planning and spatial development (Article 47) ensuring their favourable conservation status (Article 48). Provisions of the sectoral laws are also relevant for different ecosystems. Preparation of national list of habitat types including habitats map, their importance, assessment of threat status, as well as measures for preserving the types of habitats in a favourable conservation status shall be prescribed by the Minister responsible for nature conservation. Preparation of these by-laws requires urgent attention and efforts.

According to the Law on Nature Protection the use of **forest ecosystems** within the protected areas is prohibited (Article 54). The conservation of the biological diversity of the forest ecosystems shall be carried out by way of protecting the forests within the frames of the protected areas, through the Programme for management of forest habitats within protected areas that is a part of the protected area management plan. The conservation and protection of forest ecosystems shall be provided according to the principles of sustainable development, conservation and maintenance of the natural composition of the species and their natural renewal, as well as maintenance of ecosystem services. The content of the Programme for management of forest habitats within protected areas shall be prescribed by the Minister responsible for nature protection (MEPP).

These provisions are overlapping and opposing with the Law on Forests that regulates the issues related to planning, management, use, protection of forests and its provisions are applied to all forests and forest land regardless of the ownership and purpose of the forest (Article 1). Specific obligation is given to the management authorities of protected areas - the measures prescribed in the general and specific plans for management and protection of forests shall be incorporated in the protected area management plan, and the content, preparation and adoption of the special plan for protection of forests within protected areas shall be prescribed by the Minister responsible for forestry (Article 29).

General provisions for protection of waters and conservation of biological and landscape diversity in the **water habitats** are give in the Law on nature protection, articles 55-59. More specific conservation measures are prescribed in the Law on waters.

Protection of biological and landscape diversity of **pasture habitats and grasslands** are secured through their traditional use, as prescribed by the Law on Nature Protection, article 60. The manner of use and the protection of important or endangered types of pasture habitats shall be prescribed by the Minister responsible for nature protection, in consent with the Minister responsible for the affairs of agriculture and forestry. Additionally, protection measures for grasslands should be prescribed by the Law on pasture management. However, the existing law is very old and needs complete revision.

In order to protect the biological and landscape diversity of the **high-mountain habitats** and ecosystems, any anthropogenic activity shall be forbidden, except the one related to the traditional stockbreeding, as well as ecotourism in compliance with the principles of sustainable development.

1.6.3 Protected areas and ecological networks

a) At present Macedonia's **protected areas** network (comprising of about 80 protected areas) do not form a coherent system. It is a collection of sites designated at various times

and for various reasons. The Law on Nature Protection provides a good legal basis to create a balanced, representative and effective system of protected areas in line with the IUCN categorization. Article 65 specifies the establishment of the system of protected areas for the purpose of protection of biological diversity within the frames of the natural habitats, the processes occurring in the nature, as well as the abiotic features and the landscape diversity. Also, cross border connection with the protected areas on the territories of the neighbouring countries is encouraged (article 67).

Newly adopted categorisation (Article 66) implies the obligation for the MoEPP to carry out re-proclamation of all previously protected areas under the old national categorization (including making adjustments to boundaries and zoning) within six years.The content of the act for (re)proclamation is specified in the Rulebook (Official Gazette of the Republic of Macedonia no. 26/12). The (re)proclamation act of protected area defines the outer boundaries and specifies zoning (zone of strict protection, active management, sustainable use and buffer zone according to articles 93, 104, 105, 106 and 107). Activities and actions that may be carried out within the zones established shall be stipulated by the proclamation act. The process by which (re)proclamation should take place is described in Articles 92-97 and it includes a clear requirement for public consultation.

Development of management plan for the protected area is an obligation of the management authority. The content of the management plan is prescribed in the Rulebook (Official Gazette of the Republic of Macedonia no. 26/12). The process of preparation and procedure for adoption of the management plan requires public consultation and involvement of all relevant stakeholders.

The Law also prescribes the rules for direct protection of protected areas i.e establishment of ranger service (articles 108-112), management of protected areas (articles 135-144) as well as financial sources for nature protection (article 161).

b) Ecological networks

Establishment of a coherent national ecological network is prescribed by the Law on Nature Protection (article 53) for the purposes of conservation, maintenance or restoration to a favourable conservation status of the ecologically important areas as defined in articles 51 and 52. Apart from the ecologically important areas, the network includes the system of ecological corridors, protected areas and areas proposed for protection as well as ecologically important areas for the EU – Natura 2000.

c) A new form of protection – **designation of natural rarities** was introduced with the amendments of Law on Nature Protection enacted in March 2010, defined as parts of living nature (rare, threatened and endemic plant and animal species and their parts and communities) and inanimate nature (relief forms, geological profiles, paleontological and speleological objects, if their area is less than 100 ha) which as objects of nature, owing to their scientific, aesthetic, health and other significance, cultural, training and educational and tourist and recreational functions, are placed under special protection of the state (Article 90-a). Given the fact that natural rarities are designated by the minister managing the body of the state administration responsible for the performance of the affairs in the area of nature protection, the time required for the completion of the procedure for their designation is much shorter, and thus the application of specific measures for protection of these areas may start very soon. Besides, the procedure for their designation itself does not require major financial expenditures. As part of the UNDP/GEF project for development of RPAN, 27 old protected areas were proposed to be proclaimed as natural rarities (mainly

individual trees or group of trees, paleontological sites and caves). No sites are designated as natural rarity, so far.

1.6.4 Nature impact assessment

As prescribed in the Law on Nature Protection, nature impact assessment of certain strategies, plans and programmes (article 15) and certain public and private projects (article 18) shall be performed in accordance with the stipulations of the Law on Environment. The procedure for assessment of the impact on nature of the planned activities in nature shall be carried out in order to avoid or minimize the degradation of the nature. Depending on the anticipated or caused degradation of nature, as well as on the possibility for compensation thereof, compensatory measures shall be prescribed.

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2 Methodology, Tools and Indicators (Hristovski Slavčo*, Matevski Vlado*, Melovski Ljupčo*)

Global climate change will have and has a significant impact on different environmental components. Biological diversity, as the most dynamic environmental segment, is constantly exposed to the climate change impact which makes it particularly vulnerable. On the other hand biodiversity reacts on climate change impacts according to its own adaptation capacity. The direction of adaptations, migrations and successions of different biodiversity components at a certain area or region depends on many factors. Above all, these are heterogeneity, differentiation, zoning, richness and complexity and similar parameters of particular biodiversity components. No matter the costs, it is considered that for market and social systems there is considerable adaptation potential, while for biodiversity there is lack of technical, financial and institutional capacities (Schneider et al. 2007) in many regions (Macedonia included). Coupled with non-climate related stressors, biodiversity loss will be even more severe though accompanied with various uncertainties (Schneider et al. 2007). New research suggests that projected biodiversity loss due to climate change could be higher than previously thought (Rosenzweig 2007 – IPCC IV Assessment Report).

The Republic of Macedonia has specific geographic position on Balkan Peninsula where different climatic influences (continental and Mediterranean) on a small area in separate parts of the country intertwine. In combination with other ecological and historic factors they have led to development of a specific and very rich biological diversity. Beside its intrinsic value, biodiversity in Macedonia has other values, especially economic, and it provides a lot of goods and services.

In that sense, we try to assess and find explanation for the impact of the current global climate changes on the most sensitive components of flora, vegetation and fauna, along with their vulnerability, in this report. These assessments are mostly based on habitat and species modelling, but expert judgment was also an important approach due to the lack of data and continual monitoring of biodiversity components. This assessment builds on previous assessments and especially on Second National Assessment (2008). All available data on climate parameters were taken into consideration in the assessment.

Definition of the used terms (Schneider et al. 2007 and Klein et al. 2007 – IPCC IV Assessment Report):

Impact describes a specific change in a system caused by its exposure to climate change. Impacts may be judged to be harmful or beneficial.

Vulnerability *to climate change is the degree to which the systems are susceptible to, and unable to cope with, adverse impacts. The concept of risk, which combines the magnitude of the impact with the probability of its occurrence, captures uncertainty in the underlying processes of climate change, exposure, impacts and adaptation.* ***Mitigation*** *is an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases.*

Adaptation *is an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.*

* Institute of Biology, Faculty of Natural Sciences and Mathematics, Ss. Cyril and Methodius University, Skopje, Republic of Macedonia

2.1 Overview of methods

The climate change impact on biodiversity might be analyzed in different scopes, on many different levels. One of the basic levels is assessing the climate change impact on particular plant or animal species - future distribution and shifts in range, population size and trends, aspects of ecophysiology, etc. The next level in ecological hierarchical system is the community level which should be assessed from the aspects of species composition and dominance, alpha and gamma diversity etc. Ecosystem level provides an infinite processes, conditions and forms to be assessed from the climate change impact. The diversity of ecosystem itself and their specificity is another criterion that facilitates the development of an array of different methods to be used (Malcolm et al. 1998; Cochard 2011). In previous Macedonian National Communications (First and Second) refugial sites and regions were pointed out as susceptible to climate change impacts and vulnerable to various degree which requires tailored-made methods as would be the case with higher-than-ecosystem ecological systems.

Malcolm et al. (1998) have presented a comprehensive manual of the groups of methods to be used on different ecological levels in terms of biodiversity impacts assessment. This guideline was followed to structure the presentation of the existing methods for species, communities, ecosystems, refugial sites, biomes and landscapes.

2.1.1 Species

The first approach in species impact assessment is selection of suitable (model) species. Than these species can be modelled for climate change impacts or potential impacts can be assessed by using an expert judgment.

Such species could be the once with narrow resource/habitat requirements and inflexible biology (Dennis 1993). A second approach similarly avoids uncertainty about climate change and focuses on species or ecosystems already in danger. The reasoning here is that organisms and ecosystems already threatened by human activities may be more vulnerable to the additional stress of a changing climate (Peters, 1990; Markham and Malcolm, 1996). The third, and probably the best approach would be to select species that are known to be directly impacted by climate change with severe consequences. Experimental studies of climate change impact or vulnerability of species have not been conducted yet in Macedonia disabling the use of the third approach for selection of species. The second approach requires only already existing knowledge which was developed in the last 10-15 years, especially after the elaboration of the National Biodiversity Strategy in 2004 (MEPP, 2004). The first approach might be hampered by certain gaps in knowledge, but it looks quite appealing in the case of certain mountainous/alpine species, endemics, relict species or stenovalent organisms.

Mokra Mt. (=Jakupica Mt.) is situated in the central part of the Republic of Macedonia. It is one of the highest mountains in Macedonia (Solunska Glava peak, 2540 m a.s.l.) and unlike many other mountains it is not shared with any other of the neighbouring countries (research would be easier and consistent). There is a meteorological station on Solunska Glava peak which provided climate data (Fig. 5) for almost six decades. This mountain also holds an important biodiversity, both within plants and animals with many endemic, stenovalent and threatened species. All of this makes Mokra Mt. a suitable locality to carry on impact assessment on sensitive species.

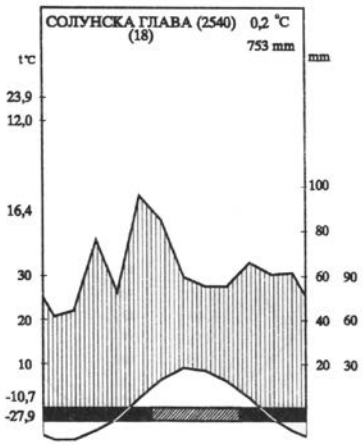

Figure 4. Climate diagram of Walter for Solunska Glava based on 18-years interval (Filipovski et al. 1996)

Figure 5. *Trechus goebli matchai* Jeannel, 1927 - an endemic ground beetle on Mokra Mt.

Methods for impact assessment include the use of expert judgement, climate "envelope" modelling, dynamic population modelling, and analogue and monitoring studies (Malcolm et al. 1998).

Expert judgement is a relatively simple way to generate ideas and discussion about potential climate change impacts. Typically, a climate change scenario is assumed, the opinion of experts as to impacts on the species of interest is solicited, and a workshop or other forum is organised to present and discuss results.

The use of *climate envelopes and profiles* capitalises on the fact that the geographic distributions of many species are highly correlated with climate. The potential impacts of a changing climate are investigated by comparing the current geographic distribution with future distributions under one or more climate change scenarios. Several dynamic population models have been developed that model tree community dynamics within forest stands; unfortunately, they usually do not incorporate the spatial component required to model changes in species distributions (models that explicitly model the dynamics of individual species in response to climate change are still rare). Recent research however confirmed that modelling of the changes of large vegetation complexes (e.g. biomes – bioclimatic modelling) may result with significant underestimation of potential impacts to species (Midgley et al. 2002). Thus combination of species and communities modelling is required for more accurate assessment.

Climate models (CMs) are frequently used to define effects of climatic change on native and invasive species based on their present geographic distribution. However, CMs have limited possibilities because they only consider species-climate relations and cannot account for other factors such as competition, nutrient use, or dispersal. Although some climatic models have been found to perform better than others (Elith et al. 2006), there is no consensus on the ''best'' model to use (Mark Andersen 2010).

Environmental niche models also known as Species Distribution Models (SDMs) are methods that use presence data together with the environmental data distributed in space and time to predict species distribution and habitat suitability based on the combination of

environmental factors (variables) that conditioned the species presence (Phillips et al. 2006; Warren & Seifert 2011).

MaxEnt is one of the models used recently for various ecological studies, including climate change (Guisan and Thuiller 2005; Phillips et al. 2006; Phillips and Dudik 2008).

Monitoring is an important research priority, both for biodiversity conservation and because plant and animal populations serve as barometers of ecosystem integrity. Losses of species indicate inappropriate and, quite likely, dangerous management practices. From a climate change perspective, monitoring is required to establish current population levels and distributional limits, and to detect climate-induced change that is already under way. Valuable information can be found in the EuMon (2013) project which focuses on monitoring of 456 species (and 177 habitats).

Understanding the past responses of natural populations to spatial and temporal climate variability provides important insights into the possible effects of future climate change. These *analogue studies* provide information on the kinds of climate changes that have influenced resources of interest in the past. Our ability to detect and respond to global climate change is improved with an increased understanding of the present-day role of climate in natural systems.

Lepetz et al. (2009) recommend a combination of the different methodologies as the most promising approach for assessment of biological responses to climate change. They stress that ecotoxicological research faced same problems and uncertainties as in the case of climate change predictions and thus, we should improve methods and analyses considering mistakes, misinterpretations and solutions from ecotoxicological research.

2.1.2 Communities

The impact of climate change on communities can be analyzed on the species level and then combine the results of particular species (e.g. impacts on pseudomaquis community can be assessed by analyzing specific impacts on the characteristic species: Kermes oak – *Quercus coccifera*, Phyllirea – *Phyllirea latifolia*, *Amanita vitadinii*, etc.). Better approach would be to assess the changes in functional and structural characteristics of the communities (species composition, biodiversity indices, index of homogeneity, index of dominance, biomass indices, age and sex structure, dispersal abilities, life forms spectrum etc.). However, significant and high quality data are needed in order to perform such analyses which lack in Macedonia. Current status of the knowledge concerning communities in Macedonia is presented below.

There is substantial amount of information on the characteristics of animal communities in oak forests on Galicica Mt. and degraded oak forests on Veles hills (Prelik & Georgievska 1999; Prelik 2002; Vidinčeva & Hristovski 2000/01), montane beech forests on Bistra Mt., Mavrovo National Park (Prelik 2002; Hristovski et al. 2004/05), beech forests on Osogovo Mt., urban and rural sites in Skopje area (Gorgievska et al. 2008a, 2008b, 2009) and lately there are on-going activities for altitudinal forest gradient on Belasica Mt.

The diversity of phytocoenoses on the territory of the Republic of Macedonia is represented by a large diversity of syntaxa (approximately 30 vegetation classes, 60 orders, 90 alliances and over 260 associations).

The vegetation on the territory of the Republic of Macedonia is explored on different level. Aquatic and lowland marsh vegetation are considered quite well studied vegetation types (Micevski 1963a, 1963b, 1966, 1967, 1968, 1969, 1988), meadows (Micevski 1964, 1966), halophytic vegetation (Micevski 1965, 1970, 1971; Matevski et al. 2008), vegetation of dry grasslands (Micevski 1970, 1972, 1977; Micevski & Matevski 1984; Matevski & Kostadinovski 1997; Matevski et al. 2007), "saum" vegetation (Carni et al. 2000), ruderal vegetation (Matvejeva 1982; Carni et al. 2001, 2003; Matevski & Carni, 2003), while mountain vegetation (grassy and marshy) is less known (Horvat 1960; Horvat et al. 1974). Forest vegetation is quite researched (Em 1978, 1981, 1986; Em & Dzekov 1969; Rizovski 1974; Carni et al. 2009; Matevski et al., 2010; and others), but some of the syntaxonomic units need additional research to be harmonized with the International Code for phytosociological nomenclature. In past period several vegetation monographs have been published for vegetation of Males and Pijanec (Micevski1978) Mountain Bistra (Micevski 1994; Rizovski & Dzekov 1990) Macedonian steppe (Micevski 1971; Matevski et al. 2007), Forest vegetation of the Galičica mountain range in Macedonia (Matevski et al. 2011) e.t.c.

The vegetational investigation was carried out using the method of the Central-European phytocoenological school (Braun-Blanquet 1928, 1932, 1964). According this methodology, lots of data are collected while identifying plant communities (phytocenoses, associations) compiled in synthetic tables. The association's synthetic table was structured after the methodology proposed by Braun-Blanquet (1964) and developed by Ellenberg (1974). Therefore, in the column header of the vegetation table for the association analyzed, the following have been entered: the serial number of releves, altitude (m.s.m.), exposition, slope, surface (m^2), coverage (%). For each species the values of abundance-dominance and frequency is provided, as well as their constancy within the samplings. Synthetic phytocoenologic index of constancy (K) whose classes are included between I-V values, that expresses the degree of coenotic fidelity compared to phytocoenoses environment of the association has been entered and calculate on the right of the table. After Braun-Blanquet & Pavillard (1928), the medium abundance and dominance (mAD) shows percentually the average coverage realized in the association's phytocoenoses by the phytoindividuals of each recorded species. Species names are noted using Flora Europaea. The following have been considered in the structure of the phytocoenologic table: illustrating or dominant species, characteristic species of the association, species for the recognition or differentiation of the suballiance, alliance, order and class. Differential species allowed us to set limits in the association for the taxa that are hierarchically superior to the alliance, order and class. The associations are analyzed and characterized physiognomically, coenologically and ecologically. All these data can be used for analyses of climate change induced variations.

Various models used for assessment of climate change impacts on species can be used for communities as well.

2.1.3 Ecosystems, biomes and refugial sites

The list of globally sensitive ecosystems to climate change include coastal wetlands, mangrove forests, island ecosystems, coral reefs, arctic ecosystems, mountain/alpine mountain ecosystems, boreal forests and tropical forests (Markham and Malcolm 1996). The most sensitive ecosystems/biomes in Macedonia identified so far are the mountain/alpine ecosystems, wetlands, sub-alpine forests of beech, spruce and fir as well as

the pseudomaquis in the southern parts of the river Vardar valley (MEPP 2004; Second National Communication 2008). The shifts in distribution range of these ecosystems can be well explained by the same spatial models used for species and communities. However, the assessment of the impact on structure and functioning of these ecosystems is demanding task requiring a wide spectrum of analyses:

- Ecosystem hydrology (quantity and quality)
- Cycling of nutrients
- Gross and net ecosystem production (especially primary productivity)
    - Aboveground and belowground productivity
    - Productivity of different layers/strata in the ecosystem (herb, shrub, tree layers)
    - Litter production (dynamics, quantity and quality)
- Litter decomposition rates, forest floor biomass and dynamics
- Overall carbon budget and its sequestration/release in the ecosystems
- Humus and soil nutrient availability
- Biodiversity within ecosystems
- Fires, calamities and diseases

So far, there are data available (that can be used for climate change issues) for very limited number of forest ecosystems (beech and oak forests), but not for other ecosystems such as grasslands/pastures, wetlands and pseudomaquis. Good examples are the complex projects on functioning of two oak and one beech forest ecosystems undertaken by the Institute of Biology (Faculty of Natural Sciences and Mathematics) in the period from late 1970s to 2005 (Mulev et al. 1999; Grupce & Melovski 1999). These projects were aiming at estimation of the biomass and primary production, belowground (Hristovski & Melovski 2012) and aboveground (Grupče et al. 1995; Melovski et al. 1994, 2003, 2004a; Hristovski et al. 2008) including litter-fall processes (Melovski et al. 1995a, 1995b, 1995c, 1995d; Šušlevska et al. 2001), forest floor biomass (Melovski et al. 2004b) and litter decomposition (Hristovski et al. 2001), characteristics of animal community (Vidinčeva & Georgievska 1996; Prelik 2002), dendrochronology (Hristovski et al. 2006/7; Hristovski & Melovski 2010), water percolation in the soil and this combined with the estimation of inputs (atmospheric deposition) and outputs enabled definition of overall nutrient cycling in the ecosystems. From the applicative point of view these data are very important in assessing the impacts and adaptation of ecosystems to climate change. Particularly, carbon sequestration was estimated (Grupce 2008), soil respiration, chemical quality of the litter (palatability).

There are number of computer based models that allow predictions of the impact of climate change on certain ecosystem processes (the first two methods are recommended by UNFCC: http://unfccc.int/files/adaptation/nairobi_workprogramme/compendium_on_methods_tools/application/pdf/20080307_compendium_m_t_sector.pdf). Such is the **Terrestrial Ecosystem Model (TEM)** which is a process-based ecosystem model that describes carbon and nitrogen dynamics of plants and soils for terrestrial ecosystems. The TEM uses spatially referenced information on climate, elevation, soils, vegetation, and water availability as well as soil- and vegetation-specific parameters to make monthly estimates of important carbon and nitrogen fluxes and pool sizes of terrestrial ecosystems (Pinto et al. 2008). **Carnegie-Ames-Stanford Approach (CASA) Model** enables calculation of monthly terrestrial NPP based on the concept of light-use efficiency modified by temperature and moisture stress scalars. Soil carbon cycling and Rh flux components of the model are based on a compartmental pool structure, with first-order equations to simulate loss of CO_2 from decomposing plant residue

and surface soil organic matter (SOM) pools. Model outputs include the response of net CO_2 exchange and other major trace gases in terrestrial ecosystems to interannual climate variability (Pinto et al. 2008). Another popular model is **Integrated Modelling of Global Environmental Change (IMAGE)** which was used in modelling of carbon and nitrogen cycles, ecosystems' biodiversity, land use and land cover changes, etc. (Kram & Stehfest 2011). Biodiversity is decreasing at high rates due to a number of human impacts. Based on IMAGE 2.4, the **GLOBIO3** model has been developed to assess human-induced changes in terrestrial biodiversity at national, regional, and global levels (Alkemade et al. 2009).

2.2 Proposed methodology for TNC

Further identification of climate change impacts on species and communities and their vulnerability, on the bases of vulnerability assessment in the previous national communication to the UNFCCC (Second National Communication 2008) will be performed using expert judgment method. Additionally impacts on several species and communities will be tested by modelling of the potential changes of distribution ranges as influenced by the anthropogenic climate change.

The methodology for modelling presented below was selected having in mind the: 1) main goal of the project for preparation of Third National Communication to Climate Change and its short duration; 2) the national circumstances in biodiversity sector and data availability; 3) suitability of methods for modelling of species and communities distribution presented in scientific literature. Up to three species (animals and plants) and one community will be selected and than their present and future distribution range (2050 and 2100) will be modelled using the MaxEnt software.

2.2.1 Species and communities to be modelled

For the purposes of the Third National Communication to Climate Change careful selection process of species and communities was performed. The following selection criteria were used: data availability, distribution range (incl. invasive species ranges), taxonomy, ecological characteristics (phenology, habitats/geologic preference, climate preferences) and threat status.

From the vegetational and floristic point of view some plant communities will be analyzed from the submediterranian part of the Republic of Macedonia (submediterranean forest community - ass. Querco cocciferae-Carpinetum orientalis Oberd. 1948 em. Ht. 54) that would be sensitive to the impact of global climate change. Other plant community (mountain pine shrubland - Pinetum mugho macedonicum calcicolum (H-at 1950) Em 1962) assessed as sensitive in Second National Communication (2008) will be modelled as well.

Some species with limited distribution will be modelled to check for the climate change impacts identified previously (Second National Communication 2008). It is considered that local plant endemic species of the mountain belt will be suitable (*e. g. Pedicularis ferdinandii* from the mountain Jakupica). Among animal species, insect species *Trechus goebli* (ground beetle) was selected (Fig. 5).

2.2.2 Modelling software (MaxEnt) for shift in distribution ranges of species and communities

Climate is one of the most important limiting factors at regional and continental scales defining species spatial distribution (Walker et al. 1993; Guisan and Thuiller 2005; Pearson and Dawson 2003). In general, species' geographic ranges are expected to shift depending to their habitat preferences and the ability to adapt to new conditions.

MaxEnt is a maximum entropy based machine learning program found to perform best among many different modelling methods (Elith et al. 2006; Ortega-Huerta & Peterson 2008; Kumar & Stohlgren 2009). MaxEnt uses presence points to define species distributions based on simple functions related to each climate variable (Phillips et al. 2006). Maximum entropy methods are based on the idea that there is a logical and mathematical correspondence between the thermodynamic entropy of statistical mechanics and the information entropy of information theory. Of many advantages that MaxEnt have, one is that model can be developed with presence data only. In some sense this releases us from unreliable absence records which are used by other models. To overcome the "disadvantage" of having no absence data, MaxEnt model creates back-ground data or "pseudo absences" chosen randomly from the study area. So, the prediction can be understood as probability that a randomly chosen presence site is ranked above a random background site (Phillips et al. 2006). Another advantage of MaxEnt model is possibility to run both types of variables: continuous and categorical. Continuous variables have real values which correspond to measurable quantities like elevation, "distance to", temperature or precipitation. Categorical variables contain a limited number of discrete values like land use categories, soil or vegetation type etc. (Phillips & Dudik 2008). Detailed customization of the parameters is another positive attribute of the MaxEnt software. By selecting an appropriate cut-off value, this continuous map can be converted to a binary map of predicted species presence or absence.

Modelling species' current and future geographic range requires three types of data:

- information on the species' current geographic distribution,
- data on current climatic conditions,
- data on predicted future climatic conditions.

Species presence data can be obtained from herbaria, museum's collections and various studies – the extensive literature data are presented above. Climatic data are free to download from (http://www.worldclim.org/bioclim)(Hijmans et al. 2005) where 19 bioclimatic variables (Tab. 4) are available with past, current and future conditions (IPCC 4) with original resolution of 1 km x1 km. These data are convenient since they provide spatial distribution of numerous present and future climate parameters based on the models recommended by IPCC 4: A1B, A2A, B2A, A1 and B1. The same models were used for the climate change scenarios in Macedonia (Karanfilovski 2012) – however they cannot be downscaled to 1x1km grid and used in spatial-modelling softwares.

Table 4. Bioclimatic variables

Bio_1	Annual Mean Temperature
Bio_2	Mean Diurnal Range (Mean of monthly (max temp – min temp))
Bio_3	Isothermality (P2/P7)*(100)
Bio_4	Temperature Seasonality (standard deviation*100)
Bio_5	Max Temperature of Warmest Month
Bio_6	Min Temperature of Coldest Month
Bio_7	temperature Annual Range (P5-P6)
Bio_8	Mean Temperature of Wettest Quarter
Bio_9	Mean Temperature of Driest Quarter
Bio_10	Mean Temperature of Warmest Quarter
Bio_11	Mean Temperature of Coldest Quarter
Bio_12	Annual Precipitation
Bio_13	Precipitation of Wettest Month
Bio_14	Precipitation of Driest Month
Bio_15	Precipitation of Seasonality (Coefficient of Variation)
Bio_16	Precipitation of Wettest Quarter
Bio_17	Precipitation of Driest Quarter
Bio_18	Precipitation of Warmest Quarter
Bio_19	Precipitation of Coldest Quarter

Sometimes, environmental variables can contain similar information. This similarity or correlation should be avoided and usually one of the correlated variables is excluded from the model. Environmental variables that will be used for the modelling need to be tested for multi-colinearity by examining cross-correlation matrix.

2.2.3 Ecosystem modelling

Modelling of the ecosystem changes induced by the climate change require huge amount of data, time and human resources and will be not performed for this report.

2.3 Indicators for monitoring of biodiversity vulnerability

In order to propose suitable indicators for effective monitoring of changes of biodiversity status due to climate change (which reflects the vulnerability of biodiversity components) the following criteria were taken into account:

- Existing knowledge (the species and communities for which the most data are available concerning the distribution range should be considered for monitoring, i.e. should be proposed as indicators; it is also important that the data are

contemporary, reliable and with high quality; preferably there should be a knowledge about the expected impacts of climate change on selected indicators based on modelled vulnerability if possible);
- Available human capacities (species and communities selected for indicators for monitoring of climate change impacts and biodiversity vulnerability should be easy to recognise and easy accessible in order to avoid excessive trainings and creation of capacities);
- Economic feasibility, including equipment (one should have in mind the financial implications while selecting the indicators in order to safeguard sustainability of the monitoring; this includes expenses for travel and field work, equipment etc.);
- Representativeness (a range of species' and communities' responses to climate change impacts should be taken into account, including horizontal and vertical shifts of distribution ranges; plant communities and ecosystems expected to gain the distribution range as well as species and communities that are expected to lose range or are threatened to extinction have to be monitored).

Indicators to follow the relations among biodiversity and economic sectors that use biodiversity or have direct and/or indirect impacts on biodiversity were not considered.

Having in mind the above criteria the following indicators are proposed:
- Timberline in mountains (Jakupica Mt. should be taken into consideration since some other species listed below are distributed there; sites free of grazing have to be selected in order to avoid human impact)
- Kermes oak ecosystem / plant community (direction and extent of the changes in distribution range have to be followed)
- Mountain pine ecosystem / community (*Pinus mugo*) (vertical shift of the distribution range should be monitored)
- Selected mountainous wetland habitats (preferably on Shar Planina)
- Plant species: *Pedicularis ferdinandi*, *Crocus cvijicii* (vertical shift of the distribution range has to be monitored)
- Animal species:
    - For vertical shifts in distribution range: *Dinaromys bogdanovi, Dendrocopus syriacus, Trechus goebli, Paradeltomerus paradoxus*.
    - For horizontal shifts in distribution range: *Testudo graeca, Coluber najadum, Burrhinus oedicnemus, Buteo rufinus, Podarcis taurica, Vormela peregusna.*
    - For monitoring of changes in the reproductive cycles: *Montifringilla nivalis.*
    - Species connected to lowland wetlands: *Vanellus vanellus, Ciconia ciconia, Triturus vulgaris, Rana balcanica, Diacyclops pelagonicus, Lycaena dispar.*

Special protocols have to be elaborated for monitoring of biodiversity changes based on each of the proposed indicators.

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3 Climate Change Impact and Vulnerability Assessment of Biodiversity (Melovski Ljupčo*, Hristovski Slavčo*, Ivanov Gjorgje† and Matevski Vlado*)

3.1 Introduction

The vulnerability of the biodiversity sector in Macedonia as affected by the anthropogenic climate change was assessed in Second National Report (SNC) to United Nations Framework Convention on Climate Change (UNFCCC). This assessment was based on expert judgment and comparisons with literature data. The review of assessment in SNC is presented in Chapter 2.1., while additional assessment on the bases of literature data and expert judgment is presented in chapters 2.2 to 2.7.The aim of this report is however, to improve the assessment by using modeling software in order to make the predictions more reliable (Chapter 2.8).

As stated in the SNC, modelling of ecosystem changes in sense of their structure and functions requires considerable amount of knowledge and data that are not available in Macedonia at the moment. On the other hand, prediction about the shift of the distribution range of ecosystems as a reaction to climate change impact is possible on the basis of the assessment of the plant community that defines the respective ecosystem.

The constraints concerning the available data pointed out in SNC still remain more or less the same.

3.2 Vulnerability assessment

Climate change vulnerability assessments provide two essential contributions to adaptation planning. Specifically, they help in (Glick et al., eds. 2011):

- Identifying which species or systems are likely to be most strongly affected by projected changes; and
- Understanding why these resources are likely to be vulnerable, including the interaction between climate shifts and existing stressors.

Determining which resources are most vulnerable enables managers to better set priorities for conservation action, while understanding why they are vulnerable provides a basis for developing appropriate management and conservation responses.

As pointed out in SNC, global climate change on a regional level could affect it through changes of the temperature and precipitation in different zones due to the zonal character of the biodiversity in Macedonia. For certain zones, the changes of the temperature regime might be more important factor causing the disturbances of the characteristics and the composition of the ecosystems (in the mountains), while for others, that factor might be the change of the precipitation quantity, i.e. the available humidity (in the valleys). Especially

* Institute of Biology, Faculty of Natural Sciences and Mathematics, Ss. Cyril and Methodius University, Skopje, Republic of Macedonia
† Macedonian Ecological Society, Skopje, Republic of Macedonia

important factor for the biodiversity in individual areas in Macedonia will be the redistribution of the precipitation throughout the year.

The SNC stated that considerable movement of plant and animal species in south - north direction (basically significant only for submediterranean oak ecosystem), as well as along the vertical gradient (for majority of other ecosystems) is expected, regardless of which scenario for climate change in the next 100 years should be taken into consideration. In any case, large dislocations of vegetation zones will happen, or a certain redistribution of ecosystems and organisms along with the zones. The size of damages and species loss will depend on the rate of the changes of the climate, since the change of the species distribution depends on their adaptation ability and mobility, or the possibility of coupled shift of the range with the climate change. This is especially important for the long-life plant perennial species as trees, which actually determine the ecosystem to the highest degree and along with it almost all other species.

As stated above, the assessment was done on the bases of expert judgment and literature data. Anyhow, the exact prognosis of changes cannot be driven since there are too many uncertainties, possible unpredictable shift of human life-styles during the next 100 years which will impact the land use pattern, conservation efforts etc. Despite that, this report tries to put some more objectivity to biodiversity vulnerability assessment by involving modeling in the assessment. As for the whole exercise, modeling is also hampered by the lack of biodiversity data. Thus, only selected plant communities and species were modeled, for which the knowledge is satisfactorily.

3.2.1 Short review of the assessment in SNC

The possible impact of the climate change on major ecosystem types in Macedonia was assessed in SNC and their most likely vulnerability responses were envisaged. Short summary is presented below while concrete identified vulnerabilities are listed in the Tab. 5 and 6.

Second National Communication identified, on the bases of expert judgment and on the basis of relevant literature, that subalpine and alpine pastures (grassland ecosystems) would be the most threatened. Alpine grasslands, rocky habitats, screes and rock vegetation are distributed only on the highest parts of mountain summits and occupy very small areas (only 0.5% of the country's territory). Vertical movement of these communities will be hindered by many relief related obstacles, ecological preferences and especially available space. Conical shape of the mountain summits means smaller area on the higher elevation. And not the whole area will be available. Only north faced slopes would offer suitable ecological conditions since alpine zone in Macedonian mountains will disappear.

Another significant threat to the biodiversity in Macedonia in relation to climate warming and predicted drop of precipitation is the danger of disappearing of the vegetation and other species in the refugia centers (SNC 2006). They are very important for biodiversity in Macedonia due to the extraordinary species richness, especially endemic and relict species, which have found shelter there as a response to the climate changes in the former epochs.

Other azonal plant communities /ecosystems in the river gorges and valleys etc. will be affected as well. It is very difficult in this stage to predict to what extent they are threatened by the global warming. However, it is an important issue for Macedonian biodiversity.

Climate change impact to biodiversity (species and natural ecosystems) and possibilities for adaptation and vertical movement of species and communities will be different in different regions due to many reasons, including geology, relief, general geographical characteristics etc. (SNC 2006). Past and present human impact, especially agriculture and infrastructural object will have crucial role in that process.

The impact of climate change on different plant and animal species in Macedonia cannot be correctly assessed due to the lack of data – described in SNC in more details. It can only be concluded, based on similar studies performed in different mountainous regions (especially in the Mediterranean region - Sanz-Elorza et al. 2003; Stanisci et al. 2005), that significant perturbations in species ecology will happen. This includes: changes in vertical migration periods – birds; disturbances in the start of activities of hibernating animals – mammals; decreased food availability (insects on the edges of snow patches for birds); earlier egg-laying of birds; loss or restriction of habitats for many plant and animal species (could lead to extinction of cryophilous species); unsuitable habitat available for vertical movement of different plant species; etc. (based on various literature sources).

The survival of natural ecosystems is to a large extent left to natural adaptation, unlike farming and forestry that can be adjusted to changing climate. The most important mechanisms are acclimatization (mostly related to genetic variability) and beside that migration as a response to climate change. Therefore, (i) the importance of conservation of genetic diversity as an integral part of biodiversity is again stressed, and (ii) since fragmentation of habitats may hamper the migration, evaluation of habitat fragmentation and biocorridors for Macedonia is needed! The lack of precise distributional data has to be exceeded by analysis and discussion on climatic and biogeographic division of Macedonia and existing altitudinal differences.

3.2.1.1 Communities

The response of natural ecosystems to climate change is complex. It is however known that smaller, fragmented and isolated ecosystems, which do not have the genetic potential, required for adaptation and the spatial capacities for relocating to a new location are particularly vulnerable.

More or less a detailed assessment, in the frame of available knowledge and data, of the climate change impact on major ecosystem types in Macedonia was done in the scope of SNC. The reasons for the changes and the basic problems (mainly of an anthropogenic origin) that influence the decreased potential of natural ecosystems for adaptation and shifting of their range is presented in Tab. 5 (extracted from SNC with minor adaptations).

As mentioned before (see Chapter 2 on Methods), the constraints concerning the available data still remain and in this occasion the precise quantitative assessment of climate change impact on ecosystems and habitats or plant communities characteristic for Macedonia is not possible for several reasons:

1. Distribution map of the major ecosystem types does not exist (nor a map of biomes). Only the map of potential distribution of the basic climate-vegetational-soil zones (Filipovski et al. 1996) - they correspond to biomes (Matvejev & Puncer 1989) - which does not represent their present distribution. The situation with habitat mapping is even worse (even theoretical and terminological adjustment of habitats in Macedonia with internationally accepted classifications for habitat types: EUNIS,

Habitats from Annex I from EC Habitat Directive etc. does not exist). Mapping of vegetational types (plant communities) has never been considered.

2. The network of meteorological stations is not developed enough in order to serve for precise determination of climate conditions on meso- and microclimatic level, which is the starting point for modeling of the future changes (imprecise input data for the models). Meteorological stations along the altitudinal gradient are almost absent. The time span of existing measurements is very short in most of the stations. Thus, available climate data (see Chapter 2.2.2.) have to be used.

Due to this, modeling was restricted only to very limited number of plant communities (marked in the table below with asterisk).

Table 5. The impact of the regional climate changes on plant communities (ecosystems) in Macedonia (source: SNC)

Plant community (ecosystem type)	Impact/vulnerability	Main reason for the sensitivity in relation to climate change	Coupled anthropogenic impact
Xerothermophilous ecosystem with Kermes oak*	Positive / expansion	Temperature	Fragmentation, agriculture
Thermophilous ecosystems of Pubescent oak and Oriental hornbeam	±Positive / Expansion	Temperature, precipitation, distribution of precipitation	Fragmentation, agriculture; exploitation
Thermophilous forests with Greek juniper	±Positive / Expansion	Temperature, precipitation, distribution of precipitation	Currently not exploited
Riparian forests - Oriental plane, willow, alder, tamaris	Negative / Restriction/ destruction	Water level and flow/ irregular floods and dry periods	Water sector (water captures and dams)
Steppe-like grassland ecosystems	±Neutral up to positive/Expansion - indirectly	Temperature, precipitation - indirectly / erosion	Abandonment of agricultural practices / infrastructure development
Hill pastures - grassland ecosystems	±Neutral up to positive/Redistribution	Temperature, precipitation, distribution of precipitation - indirectly / erosion	Different impacts and abandonment of agricultural practices
Rocky habitats in the river gorges and valleys	Not sensitive?		
Thermo-mesophilous forest of Italian and Turkey oak	Negative / Restriction	Temperature, precipitation, distribution of precipitation	Fragmentation, over-exploitation
Mesophilous Sessile oak forests	Negative / Restriction	Temperature, precipitation, distribution of precipitation	Over-exploitation
Beech forests - sub-montane and montane	Positive /Expansion	Temperature, precipitation, distribution of precipitation	Exploitation
Sub-alpine beech forests	?neutral / Probably expansion	Temperature	
Sub-alpine Molika pine forests	Positive /Expansion	Temperature	Conservation
Sub-alpine spruce forests	Negative / Restriction/reduction of population	Precipitation, humidity	Water extraction, exploitation
Sub-alpine fir and Scots	Positive or neutral /	Temperature	Exploitation

pine forests	Similar like beech forests		
Sub-alpine Mountain pine scrub-land*	Negative / Restriction	Temperature	Irrelevant
Sub-alpine pastures and pastures on rocky sites	Sensitive/ negative	Temperature/ Precipitation?/ Competition/ Smaller area	Abandonment of traditional sheep farming
Alpine pastures and pastures on rocky sites	Negative / Reduction of populations/ Loss of species	Temperature/ Precipitation?/ Competition/ Loss of area	Abandonment of traditional sheep farming
Alpine rocks and rocky habitats	Negative / Reduction of populations/ Loss of species	Temperature/ Precipitation?/ Loss of area	

The two communities (ecosystems) marked with asterisk in the table will be modelled in order to check whether the expert predictions were relevant and correct (see below).

3.2.1.2 Flora

The assessment of the global climate change impact (regardless the scenario) on the vegetation and flora in SNC was based only on subjective expert judgment including the analysis of historical and recent data. Having in mind that there is no biodiversity monitoring system in Republic of Macedonia (with the exception of natural lakes) it was assumed that the impacts will result in:

- expansion of the thermophilous (Mediterranean and sub-Mediterranean) flora and vegetation from the southern to the central and northern parts of Macedonia and
- shift of the forest belts towards higher altitudes.

However, modeling of the sub-mediterranean Kermes oak community in this report (Third national Communication – TNC) proved that subjective assessment can lead to misjudgment (see below – Chapter 3.2.8.3.5)

The vulnerability of flora is summarized in the Tab. 6 below on the basis of assessment in SNC and amended in this report. Only plant species that are important for Macedonian biodiversity (high mountainous and wetland species, endemic and relict species and some typical representatives for major vegetation types) were assessed.

The review of the vulnerability of plant species shown on the bases of different vegetation belts is given below.

Lowland belt. Various impacts are possible – decrease of humidity in the habitat, increase of temperature, drying of habitats etc. The following species are the most vulnerable: *Thymus oehmianus, Ramonda nathaliae, Ramonda serbica, Adianthum capillus-veneris*, *Drosera rotundifolia, Blackstonia perfoliata, Cladium mariscus, Carex elata, Marsilea quadrifolia, Salvinia natans*.

Mountain belt. The increase of temperatures will lead to shorter snow pack lasting on the mountains, which are without typical alpine belt (bellow 2300 m a.s.l. - Galichica, Bistra, Jablanica and others). Changed ecological conditions in sub-alpine region, will affect the species that grow around the melting snow patches. Such species are Macedonian high mountain local endemic floristic species: - *Crocus cvijici* (Galichica), *Colchicum pieperianum* (Bistra), *Fritillaria macedonica* (Jablanica) and others: *Ranunculus degenii, Saxifraga stellaris* subsp*. alpigena, Sphagnum spp., Crocus scardicus, Crocus pelistericus, Trollius europaeus,*

Salix retusa, Salix reticulata, Salix herbacea, Salix alpina, Rhododendron myrthifolium, Pedicularis ferdinandi , Rhododendron ferrugineum, Empetrum nigrum, Loiseleuria procumbens, Dryas octopetala, Listera cordata (due to the spruce forest decline and dye back); *Ranunculus degenii* on Shar Planina Mt., *Silene pusilla*, *Sphagnum* species (water capture).

Dojran Lake. These changes particularly affect the Common reed (*Phragmites australis*) zone and other aquatic macrophytic vegetation (ass. *Myriophyllo-Nupharetum* is completely extinct). Vulnerable plant species are: *Nuphar lutea, Nymphaea alba, and Salvinia natans*.

Prespa lake. Endangered plant species are: *Aldrovanda vesiculosa, Salvinia natans* and *Trapa natans.*

Ohrid lake: Endangered plant species: *Carex elata, Senecio paludosus, Ranunculus lingua*

In course of this report (TNC) only two high-mountain plant species will be modeled: *Crocus cvijici* and *Pedicularis ferdinandi*.

Table 6. Review of the plant species in Macedonia vulnerable to climate change.

	Species	**Taxonomic group**	**Ecosystems/biomes**	**Remarks**
LYCOPSIDA				
	Lycopodium clavatum	Lycopodiaceae	Mountain wetlands	Species to be affected by the changes in mountain wetlands
	Hupezia sellago	Lycopodiaceae	Mountain wetlands	Species to be affected by the changes in mountain wetlands
	Diphasium alpinum	Lycopodiaceae	Mountain pastures	Species to be affected by the changes in mountain wetlands
	Selaginella selaginoides	Selaginellaceae	Mountain wetlands	Species to be affected by the changes in mountain wetlands
	Isoetes phrygia	Isoetaceae	Submediterranean area, open habitats	Relict species, vulnerable species to climate change
OPHIOGLOSIDAE				
	Ophioglossum vulgatum	Ophioglossidae	lowland wetlands	Species to be affected by the changes in lowland wetlands
	Osmunda regais	Osmundaceae	lowland wetlands	Species to be affected by the changes in lowland wetlands
FILICINAE				
	Thelipteris palustris	Thelipteridaceae	lowland wetlands	Species to be affected by the changes in lowland wetlands
	Adiantum capillus-veneris	Adianthaceae		restricted distribution
GYMNOSPERMAE				

	Species	Taxonomic group	Ecosystems/biomes	Remarks
IUCN	*Pinus heldreichii* var. *leucodermis*	Pinaceae	Coniferous forests	Very rare species with restricted distribution
	Pinus mugo	Pinaceae	Coniferous forests	Altitudinal shift is expected
	Picea abies	Pinaceae	Coniferous forests	Boreal species sensitive to climate changes
	Juniperus excelsa	Cupressaceae	Coniferous shrub communities	Expected shift of the distribution range
ANGIOSPEMAE DICOTYLEDONAE				
IUCN-Ex/En	*Ranunculus degenii*	Ranunculaceae	Mountain wetlands	Species to be affected by the changes in mountain wetlands
	Ranunculus lingua	Ranunculaceae	lowland wetlands	Species to be affected by the changes in lowland wetlands
	Trollius europaeus	Ranunculaceae	Mountain wetlands	Species to be affected by the changes in mountain wetlands
	Pulsatilla vernalis	Ranunculaceae	Coniferous forests	Species sensitive to climate changes
	Quercus coccifera	Fagaceae	Submediterranean area, forests	Expected shift of the distribution range
	Rumex hydrolapathus	Polygonaceae	lowland wetlands	Species to be affected by the changes in lowland wetlands
	Salix reticulata	Salicaceae	low mountain shrub communities	Alpine species, Shar Planina, Jakupica
	Salix herbacea	Salicaceae	low mountain shrub communities	Alpine species, Shar Planina, Korab
	Salix retusa	Salicaceae	low mountain shrub communities	Alpine species, Shar Planina
	Salix alpina	Salicaceae	low mountain shrub communities	Alpine species, Shar Planina, Jakupica
IUCN	*Viola brachyphylla*	Violaceae		(Sub) endemic species-Nidzhe
	Rhododendron myrthifolium	Ericaceae	low mountain shrub communities	Expected shift of the distribution range
	Rhododendron ferrugineum	Ericaceae	low mountain shrub communities	Expected shift of the distribution range
	Empetrum nigrum	Ericaceae	low mountain shrub communities	Expected shift of the distribution range
	Loiseleuria procumbens	Ericaceae	low mountain shrub communities	Expected shift of the distribution range
IUCN	*Soldanella pindicola*	Primulaceae	Mountain wetlands	Species to be affected by the changes in mountain wetlands

	Species	Taxonomic group	Ecosystems/biomes	Remarks
	Dryas octopetala	Rosaceae	In places where the snow melts	Species to be affected by the changes in alpine belt
	Saxifraga stellaris subsp. *alpigena*	Saxifragaceae	Mountain springs and bogs	Species to be affected by the changes in mountain wetlands
	Drosera rotundifolia	Droseraceae	Mountain wetlands	Species to be affected by the changes in mountain wetlands
	Aldrovanda vesiculosa	Droseraceae	Natural lake	will follow changes in oscillations in water levels in natural lakes
IUCN-Ex/En	*Astragalus physocalyx*	Fabaceae	Submediterranean area, forests	Sensitive species with very restricted distribution
	Astragalus cernjavskii	Fabaceae	Submediterranean area	Endemic of Central Macedonia - Negotino
IUCN	*Hedysarum macedonicum*	Fabaceae	Dry grasslands	Endemic of Central Macedonia - Negotino
	Trapa natans	Trapaceae	Natural lakes, rivers	will follow changes in oscillations in water levels in natural lakes
	Aesculus hippocastanum	Hippocastanaceae	Beech forests	Relict species with restricted distribution
	Phyllirea latifolia	Oleaceae	Submediterranean area, forests	Expected shift of the distribution range
IUCN	*Rindera graeca*	Boraginaceae	mountains rocky sites	Expected shift of the distribution range
IUCN	*Pedicularis ferdinandi*	Scrophulariaceae	Mountain pastures	Endemic species of Jakupica
IUCN	*Melampyrum heracleoticum*	Scrophulariaceae		Expected shift of the distribution range
IUCN	*Ramonda nathaliae*	Gesneriaceae	Lowland and mountains rocky sites	Relict species
IUCN	*Ramonda serbica*	Gesneriaceae	Lowland and mountains rocky sites	Relict species
IUCN	*Thymus oehmianus*	Lamiaceae	River gorges	Endemic and relict species
IUCN	*Centaurea soskae*	Asteraceae	cliffs	Endemic species Galichica
	Senecio paludosus	Asteraceae	lowland wetlands	Species to be affected by the changes in lowland wetlands
ANGIOSPEMAE MONOCOTYLEDONAE				
IUCN	*Colchicum pieperianum*	Liliaceae	Mountain pastures	Expected shift of the distribution range
IUCN	*Fritillaria macedonica*	Liliaceae	Mountain wetlands Mountain pastures	Endemic of Jablanica, Deshat
IUCN	*Narthecium scardicum*	Liliaceae	Mountain wetlands	Species to be affected by the

Species	Taxonomic group	Ecosystems/biomes	Remarks
			changes in mountain wetlands
Crocus scardicus	Iridaceae	In places where the snow melts	(Sub) Endemic, north and west part of Macedonia
Crocus pelistericus	Iridaceae	In places where the snow melts	Endemic of Pelister, Nidzhe
Crocus cvijici	Iridaceae	In places where the snow melts	Endemic of Galichica
Leucojum aestivum	Amaryllidaceae	lowland wetlands	Species to be affected by the changes in lowland wetlands
Listera cordata	Orchidaceae	Coniferous forests	Will follow the changes in the belt of common spruce
Carex elata	Cyperaceae	lowland wetlands	Species to be affected by the changes in lowland wetlands
Cladium mariscus	Cyperaceae	lowland wetlands	Species to be affected by the changes in lowland wetlands
Alopecurus creticus	Poaceae	lowland wetlands	Species to be affected by the changes in lowland wetlands

3.2.1.3 Fauna

Climate change impact will provide for vulnerability to global and regional fauna. So far, there have been well demonstrated changes in the distribution of certain animal species. Parmesan et al. (1999) found out that 60% of the studied butterfly species have shifted their distribution towards north for 35-240 km. Also, population calamities of *Lymantria dispar* have been linked to the climate change in Europe (Wolf and Graser 1996). Although birds are less vulnerable to climate change due to their high mobility, there has been evidenced case of birds of Britain where it has been observed that the egg-laying is eight days earlier in average (Crick et al. 1997).

The most vulnerable fauna species of the Republic of Macedonia to the climate change impact were already identified in the First and Second National Communication. Both of these reports focus on the species connected to the refugial sites in Macedonia, species of the mountain ecosystems, especially those associated to mountainous wetlands (glacial lakes, mountain streams), natural lakes as well as lowland wetlands. The summarized review of these species is presented in Tab. 7. However, a number of vulnerable species were identified additionally in this report, based on their ecology, present population size and distribution. They are also presented in the Tab. 7.

Table 7. Review of the animal species in Macedonia vulnerable to climate change.

No	Species	Taxonomic group	Ecosystems/biomes	Remarks

No	Species	Taxonomic group	Ecosystems/biomes	Remarks
1	*Euxinella alpinella*	Snails	Mountain ecosystems, endemic for Kajmakchalan	Endemic of calcareous alpine ecosystems of Kajmakchalan
2	*Euxinella subai*	Snails	Mountain ecosystems, endemic for Kozhuf	Endemic species of mesophyllous forests of Kozhuf Mt.
3	*Helix dormitoris*	Snails	Mountain ecosystems	Balkan endemic species distributed on pastures and rocky sites on Shar Planina
4	*Helix secernenda*	Snails	Mountain ecosystems	Balkan endemic species distributed on calcareous areas of the south-west Macedonian mountains
5	*Montenegrina stankovici*	Snails	Rocky sites and cliffs	Endemic species of the rocky sites in the foothills of Galichica Mt., next to Ohrid lake
6	*Tandonia macedonica*	Snails	Mountain ecosystems	Endemic species of Galichica Mt.
7	*Latrodectus tredecimguttatus*	Spiders	Open grasslands in submediterranean area	Thermophilous species of hill pastures in the submediterranean area
8	*Cyphophthalmus gjorgjevici*	Opiliones	Caves and endogean habitats	Endemic species
9	*Cyphophthalmus markoi*	Opiliones	Endogean habitats	Endemic of endogean habitats in Demir Kapija gorge
10	*Allocyclops kieferi*	Crustaceans	lowland wetlands	
11	*Alona elegans*	Crustaceans	Glacial lakes	Shar Planina
12	*Alona intermedia*	Crustaceans	Glacial lakes	Arctic-alpine species, Shar Planina and Pelister
13	*Alpioniscus macedonicus*	Crustaceans	caves	Endemic of Jakupica Mt.
14	*Alpioniscus slatinensis*	Crustaceans	caves	Endemic for the caves in Poreche
15	*Alpioniscus vardarensis*	Crustaceans	caves	Endemic of caves in Demir Kapija gorge
16	*Arcticocamptus abnobensis*	Crustaceans	Mountain springs and bogs	Arctic-alpine species, Mokra Mt.
17	*Arctococamptus macedonicus*	Crustaceans	Glacial lakes and temporary waters	Relict species, Pelister, Shar Planina, Mokra
18	*Arctodiaptomus niethammeri*	Crustaceans	Glacial lakes and temporary waters	Pelister, Galichica
19	*Arctodiaptomus osmanus*	Crustaceans	Glacial lakes and temporary waters	Pelister, Galichica
20	*Austropotamobius torrentium macedonicus*	Crustaceans	Mountain streams	
21	*Bogidiella albertimagna glacialis*	Crustaceans	Mountain springs and bogs	relict-endemic taxon of Mokra Mt. (Jakupica)
22	*Branchipus intermedius*	Crustaceans	Temporary pools	Relict species, Toni Voda (Bistra Mt.)

No	Species	Taxonomic group	Ecosystems/biomes	Remarks
23	*Chirocephalus pelagonicus*	Crustaceans	Ponds	Endemic of Pelagonia wetlands
24	*Cypridopsis concolor*	Crustaceans	lowland wetlands	Rare species, known only from Negorci wetlands
25	*Diacyclops pelagonicus*	Crustaceans	Submediterranean area	Very restricted distribution
26	*Dociostaurus maroccanus*	Crustaceans	Submediterranean area	Usually solitary, but in some cases aggregates and causes devastation of crops
27	*Eucypris heinrichi*	Crustaceans	Submediterranean area, open habitats	Expected shift of the distribution range
28	*Eudiaptomus gracilis*	Crustaceans	temporary waters	Relict species, Toni Voda (Bistra Mt.)
29	*Eudiaptomus hadzici*	Crustaceans		Indicator of overgrowth of Dojran lake
30	*Heterocypris erikae*	Crustaceans	lowland wetlands	Species to be affected by the changes in lowland wetlands
31	*Heterocypris gevgelija*	Crustaceans	temporary waters	Galichica
32	*Heterocypris hartwigi*	Crustaceans	lowland wetlands	Endemic species
33	*Hypocamptus brehmi*	Crustaceans	Mountain springs and bogs	arctic-alpine species, Bistra Mt.
34	*Macedonethes skopjensis*	Crustaceans	Endogean habitats	Troglobiont species of Matka caves
35	*Macedonethes stankoi*	Crustaceans	Endogean habitats	Troglobiont species of caves in Babuna source area on Jakupica Mt.
36	*Mixodiaptomus tatricus*	Crustaceans	Glacial lakes and temporary waters	Relict species, Shar Planina, Mokra and Jablanica
37	*Mladenoniscus belavodae*	Crustaceans	Endogean habitats	Troglobiont species of Demir Kapija caves, the only representative of the genus Mladenoniscus
38	*Niphargus pancici jakupicae*	Crustaceans	Mountain springs and bogs	relict-endemic taxon of Mokra Mt. (Jakupica)
39	*Niphargus pancici peristericus*	Crustaceans	Mountain springs and bogs	relict-endemic taxon of Osogovo Mt.
40	*Niphargus tauri osogovensis*	Crustaceans	Glacial lakes	Local endemic of Golemo Ezero on Pelister Mt.
41	*Potamon ibericum*	Crustaceans	Rivers and streams in sumbediterranean areas	Commons species of the streams in south Macedonia; expected shift in distribution range
42	*Psychrodromus fontinalis*	Crustaceans	Mountain springs and bogs	arctic-alpine species, Mokra Mt.
43	*Psychrodromus olivaceus*	Crustaceans	Mountain springs and bogs	arctic-alpine species, Shar Planina, Mokra and Nidzhe Mt.
44	*Psychrodromus peristericus*	Crustaceans	Mountain springs and bogs	Local endemic of Pelister Mt.
45	*Tanymastix motasi*	Crustaceans	lowland wetlands	Endemic of Pelagonia wetlands

No	Species	Taxonomic group	Ecosystems/biomes	Remarks
46	*Trichoniscus semigranulatus*	Crustaceans	Endogean habitats, subendemic species	Troglophile species, endemic for Macedonia and Bulgaria
47	*Brachydesmus henrikenghoffi*	Myriapods	Endogean habitats	Endemic species
48	*Brachydesmus macedonicus*	Myriapods	Endogean habitats	Endemic of Jakupica Mt.
49	*Brachydesmus peristorensis*	Myriapods	Endogean habitats	Endemic of Pelister Mt.
50	*Leptoiulus macedonicus*	Myriapods	Endogean habitats	Endemic of endogean habitats on Korab and Shar Planina
51	*Leptoiulus storkani*	Myriapods	Endogean habitats	Endemic species of endogean habitat on Korab Mt.
52	*Typhloglomeris ljubotensis*	Myriapods	Endogean habitats	Endemic endogean species
53	*Typhloglomeris varuna*	Myriapods	Caves	Endemic troglobiont species
54	*Typhloiulus albanicus*	Myriapods	Caves	Endemic troglobiont species
55	*Typhloiulus giganteus*	Myriapods	Caves	Endemic troglobiont species
56	*Cordulegaster heros*	Dragonflies	Rivers	Threatened species
57	*Epallage fatime*	Dragonflies	Rivers and streams in sumbediterranean areas	Thermophilous species in submediterranean areas; expected horizontal shift in distribution
58	*Calliptamus italicus*	Orthopterans	Submediterranean area, open habitats	Expected shift of the distribution range
59	*Paracoloptenus caloptenoides*	Orthopterans	Submediterranean area	Expected shift of the distribution range
60	*Poecilimon jablanicensis*	Orthopterans	Mountain pastures	Endemic of Jablanica Mt.
61	*Poecilimon vodnensis*	Orthopterans	Meadows and pastures, endemic for Vodno	Endemic species of Vodno Mt.; not recorded in the last 50 years
62	*Saga pedo*	Orthopterans	Pastures	Isolated population of the species exist on Galichica Mt.; otherwise its main distribution range is north of Danube
63	*Carabus variolosus nodulosus*	Beetles	Riparian habitats along mountain streams	Threatened species, vulnerable to climate change
64	*Ceutophyes bukoviki*	Beetles	caves	Endemic species of Ubavica cave
65	*Ceutophyes karamani*	Beetles	caves	Endemic species of caves on Galichica Mt.
66	*Deltomerus sterbai*	Beetles	mountains streams	Endemic of Pelister Mt., relict species with very restricted distribution
67	*Dorcadion borisi*	Beetles	Mountain pastures	Endemic of subalpine ecosystems of

No	Species	Taxonomic group	Ecosystems/biomes	Remarks
				Belasica Mt.
68	*Dorcadion heyrovskyi*	Beetles	Mountain pastures	Endemic of subalpine ecosystems of Kozhuf
69	*Dorcadion kaimakcalanum*	Beetles	Mountain pastures	Endemic of alpine ecosystems of Kajmakchalan
70	*Dorcadion ljubetense*	Beetles	Mountain pastures	Endemic of alpine ecosystems of Shar Planina, Korab, Bistra, Jakupica and Jablanica
71	*Dorcadion macedonicum*	Beetles	Mountain pastures	Endemic of subalpine open habitats of Galichica Mt
72	*Dorcadion purkynei*	Beetles	Mountain pastures	Endemic of Kajmakchalan Mt.
73	*Duvalius fodori*	Beetles	mountains rocky sites	Endemic of Shar Planina
74	*Duvalius karaormanicus*	Beetles	caves	Endemic of Mlechnik cave (Karaorman)
75	*Duvalius macedonicus*	Beetles	Endogean habitats	Endemic of alpine endogean habitats of Pelister Mt.
76	*Duvalius peristericus*	Beetles	Endogean habitats	Endemic of alpine endogean habitats of Pelister Mt.
77	*Duvalius strupii*	Beetles	mountains rocky sites	Endemic of Korab Mt.
78	*Duvalius vignai*	Beetles	beech forests and rocky sites	Endemic of Galichica Mt.
79	*Duvlaius gogalai*	Beetles	Endogean habitats	Endemic of caves in Tresonechka Reka catchment
80	*Hydroporus macedonicus*	Beetles	mountain streams	Endemic of Kozhuf
81	*Lathrobium ivokaramani*	Beetles	Endogean habitats	Endemic species of endogean habitats in Zheden foothills
82	*Lathrobium jakupicense*	Beetles	Endogean habitats	Endemic species of endogean habitats on Jakupica Mt.
83	*Lathrobium matchai*	Beetles	Endogean habitats	Endemic species of endogean habitats on Pelister Mt.
84	*Ochridiola marinae*	Beetles	Endogean habitats, endemic for Galichica Mt.	Endemic of endogean habitats on Galichica Mt.
85	*Omphreus albanicus*	Beetles	forests	Relict species
86	*Omphreus gracilis*	Beetles	mountains rocky sites	Relict species, Endemic of Shar Planina
87	*Osmoderma eremita*	Beetles	Old forests	Threatened species; rare in Macedonia; prefers old oak and beech forests
88	*Otiorhynchus shardagensis*	Beetles	Mountain pastures	Endemic of Shar Planina
89	*Paradeltomerus paradoxus*	Beetles	mountains streams	Endemic of Shara and Korab

No	Species	Taxonomic group	Ecosystems/biomes	Remarks
90	*Petkovskiella stygia*	Beetles	Caves	Endemic genus and species of Jakupica Mt.
91	*Potamonectes macedonicus*	Beetles	Glacial lakes	Endemic of Shar Planina
92	*Trechus galicicaensis*	Beetles	mountains rocky sites	Endemic of Galichica Mt.
93	*Trechus goebli goebli*	Beetles	mountains rocky sites	Endemic of Pelister Mt.
94	*Trechus goebli matchai*	Beetles	mountains rocky sites	Endemic of Mokra Mt.
95	*Trechus hajeki*	Beetles	Beech forests	Endemic of Pelister Mt.
96	*Trechus ljubetenis*	Beetles	Beech forests	Endemic of Shar Planina Mt.
97	*Trechus midas*	Beetles	mountains rocky sites	Endemic of Mokra Mt.
98	*Trechus pachycerus*	Beetles	mountains rocky sites	Endemic of Mokra Mt.
99	*Erebia* (different species)	Butterflies	lowland wetlands	Species to be affected by the changes in mountain ecosystems
100	*Eremophila alpestris*	Butterflies	Mountain ecosys-tems, pastures	Relict species, vulnerable to climate change
101	*Euphydryas aurinia*	Butterflies	Rivers, lakes	Ohrid lake system
102	*Lycaena dispar*	Butterflies	lowland wetlands	Threatened species
103	*Papilio alexanor*	Butterflies	Grasslands and rocky sites	Rare species in Macedonia
104	*Parnassius apolo*	Butterflies	Mountain ecosys-tems, pastures	Threatened species, suitable for monitoring
105	*Eudontomyzon stankokaramani*	Lampreys	Glacial lakes	Relict species, Jablanica
106	*Acantholingua ohridana*	Fish	Natural lakes	Endemic of Ohrid lake and threatened species
107	*Alburnus belvica*	Fish	Natural lakes	Threatened species
108	*Alosa fallax*	Fish	Rivers, lakes	Ohrid lake system
109	*Barbus prespensis*	Fish	Natural lakes	Endemic of Prespa lake and threatened species
110	*Chondrostoma prespense*	Fish	Natural lakes	Endemic of Prespa lake and threatened species

No	Species	Taxonomic group	Ecosystems/biomes	Remarks
111	*Cobitis meridionalis*	Fish	Natural lakes	Threatened species
112	*Cyprinus carpio*	Fish	Natural lakes	Threatened species
113	*Pachychilon macedonicum*	Fish	Natural lakes	Endemic of Dojran lake and threatened species
114	*Phoxinellus epiroticus*	Fish	Natural lakes	Endemic of Ohrid lake and threatened species
115	*Phoxinellus prespensis*	Fish	Natural lakes	Endemic of Prespa lake and threatened species
116	*Rutilus ohridanus*	Fish	Natural lakes	Endemic of Ohrid lake and threatened species
117	*Rutilus prespensis*	Fish	Natural lakes	Endemic of Prespa lake and threatened species
118	*Sabanejewia doiranica*	Fish	Natural lakes	Endemic of Dojran lake and threatened species
119	*Salaria fluviatilis*	Fish	Natural lakes	Threatened species, Dojran lake
120	*Salmo aphelios*	Fish	Natural lakes	Endemic of Ohrid lake and threatened species
121	*Salmo balcanicus*	Fish	Natural lakes	Endemic of Ohrid lake and threatened species
122	*Salmo letnica*	Fish	Natural lakes	Endemic of Ohrid lake and threatened species
123	*Salmo lumi*	Fish	Mountain streams	Endemic of Ohrid lake system; dubious taxonomic status
124	*Salmo pelagonicus*	Fish	Mountain streams	Endemic of Pelister Mt.
125	*Salmo peristericus*	Fish	Mountain streams	Endemic of Pelister Mt.
126	*Bombina variegata*	Amphibians	lowland wetlands	Common species in Macedonia
127	*Pelobates syriacus balcanicus*	Amphibians	lowland wetlands	Species to be affected by the changes in lowland wetlands
128	*Rana balcanica*	Amphibians	lowland wetlands	Species to be affected by the changes in lowland wetlands
129	*Rana temporaria*	Amphibians	Mountain wetlands	Inhabits mountainous areas
130	*Triturus alpestris*	Amphibians	Glacial lakes and temporary waters	
131	*Triturus carnifex macedonicus*	Amphibians	lowland wetlands	Species to be affected by the changes in lowland wetlands
132	*Triturus karelinii*	Amphibians	lowland wetlands	Species to be affected by the changes in lowland wetlands
133	*Triturus vulgaris*	Amphibians	lowland wetlands	Species to be affected by the changes in lowland wetlands

No	Species	Taxonomic group	Ecosystems/biomes	Remarks
134	*Ablepharus kitaibelii*	Reptiles	Submediterranean area	Widespread in Macedonia
135	*Coluber caspius*	Reptiles	Submediterranean area	Widespread in Macedonia
136	*Coluber najadum*	Reptiles	Submediterranean area	Widespread in Macedonia
137	*Cyrtopodion kotschyi*	Reptiles	Submediterranean area	
138	*Elaphe situla*	Reptiles	Submediterranean area	Widespread in Macedonia
139	*Lacerta agilis*	Reptiles	Mountainous areas	expected shift of the distribution range
140	*Lacerta trilineata*	Reptiles	Submediterranean area	expected shift of the distribution range
141	*Lacerta vivipara*	Reptiles	High-mountain pastures	Isolated populations on high mountains in Macedonia
142	*Ophisaurus apodus*	Reptiles	Submediterranean area	expected shift of the distribution range
143	*Podarcis erhardii*	Reptiles	Submediterranean area	Widespread in Macedonia
144	*Podarcis taurica*	Reptiles	Submediterranean area	Widespread in Macedonia
145	*Testudo graeca*	Reptiles	Submediterranean area	Widespread in Macedonia
146	*Testudo hermanii*	Reptiles	Submediterranean area	Widespread in Macedonia
147	*Typhlops vermicularis*	Reptiles	Submediterranean area	expected shift of the distribution range
148	*Vipera berus*	Reptiles	High-mountain pastures	Isolated populations on high mountains in Macedonia
149	*Vipera ursinii*	Reptiles	High-mountain pastures	Isolated populations on high mountains in western Macedonia
150	*Accipiter brevipes*	Birds	Submediterranean area	Small population of 40-100 breeding pairs in Macedonia
151	*Alauda arvensis*	Birds	Submediterranean area, open habitats	expected shift of the distribution range
152	*Anas acuta*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
153	*Anas clypeata*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
154	*Anas crecca*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands

No	Species	Taxonomic group	Ecosystems/biomes	Remarks
155	*Anas penelope*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
156	*Anas platyrhynchos*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
157	*Anas querquedula*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
158	*Anas strepera*	Birds	lowland wetlands	Rare species in Macedonia (5-30 breeding pairs)
159	*Anser anser*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
160	*Anthus campestris*	Birds	Submediterranean area, open habitats	Widespread in Macedonia
161	*Anthus spinoletta*	Birds	Mountain pastures	Widespread in Macedonia
162	*Aquila heliaca*	Birds	Submediterranean area, open habitats	There are 30-40 breeding pairs in Macedonia (~3% of European population)
163	*Ardea cinerea*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
164	*Ardea purpurea*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
165	*Ardeola ralloides*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
166	*Botaurus stellaris*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
167	*Burhinus oedicnemus*	Birds	Submediterranean area, open habitats	Distribution not well known
168	*Buteo rufinus*	Birds	Submediterranean area, open habitats	Widespread in Macedonia
169	*Calandrella cinerea*	Birds	Submediterranean area, open habitats	expected shift of the distribution range
170	*Ciconia ciconia*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
171	*Circus aeruginosus*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
172	*Circus macrourus*	Birds	Submediterranean area, wetlands	Species rarely occurring in Macedonia
173	*Delichon urbica*	Birds	Urban areas	Expected changes in phenology; suitable for public communication
174	*Dendrocopus syriacus*	Birds	Submediterranean area	expected shift of the distribution range
175	*Egretta alba*	Birds	Mountain rocky sites and pastures	Widespread in Macedonia

No	Species	Taxonomic group	Ecosystems/biomes	Remarks
176	*Egretta garzetta*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
177	*Elaphe quatuorlineata*	Birds	lowland wetlands	Widespread in Macedonia
178	*Emberiza melanocephala*	Birds	Submediterranean area	Widespread in Macedonia
179	*Emys orbicularis*	Birds	Submediterranean area	Widespread in Macedonia
180	*Erinaceus concolor*	Birds	Submediterranean area	Widespread in Macedonia
181	*Falco naumanni*	Birds	Mountain ecosys-tems	Threatened species, 6% of the European population is in Macedonia
182	*Falco vespertinus*	Birds	Submediterranean area	Migratory with small breeding population in Macedonia
183	*Galerida cristata*	Birds	Submediterranean area	Widespread in Macedonia
184	*Gallinago gallinago*	Birds	Submediterranean area, open habitats	
185	*Glareola pratincola*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
186	*Himantopus himantopus*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
187	*Hirundo rustica*		Rural areas	Expected changes in phenology; suitable for public communication
188	*Ixobrychus minutus*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
189	*Limosa limosa*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
190	*Locustella luscinioides*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
191	*Melanocorypha calandra*	Birds	Submediterranean area, open habitats	expected shift of the distribution range
192	*Montifringila nivalis*	Birds	Mountain pastures	Vulnerable species (taxon) to climate change
193	*Motacilla flava*	Birds	Submediterranean area	Expected shift of the distribution range
194	*Numenius arquata*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
195	*Nycticorax nycticorax*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
196	*Parus lugubris*	Birds	Submediterranean area	
197	*Passer hispalionensis*	Birds	Submediterranean area	

No	Species	Taxonomic group	Ecosystems/biomes	Remarks
198	*Platelea leucorodia*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
199	*Prunella collaris*	Birds	Mountain pastures	
200	*Pyrrhocorax graculus*	Birds	Rocky sites and cliffs	
201	*Pyrrhocorax pyrrhocorax*	Birds	Rocky sites and cliffs	
202	*Recurvirostra avosetta*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
203	*Sturnus roseus*	Birds	Submediterranean area	Vagrant species; expected changes in phenology
204	*Tetrax tetrax*	Birds	Submediterranean area, open habitats	Last records in Macedonia data from the 1970s
205	*Tichodroma muraria*	Birds	Rocky sites and cliffs	Vulnerable species (taxon) to climate change
206	*Tringa hypoleucos*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
207	*Tringa nebularia*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
208	*Tringa stagnalis*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
209	*Tringa totanus*	Birds	lowland wetlands	Species to be affected by the changes in lowland wetlands
210	*Vanellus vanellus*	Birds	lowland wetlands	Severe reduction in breeding population
211	*Apodemus flavicollis*	Mammals	Forests	Forest-dwelling species in general
212	*Dryomys nitedula*	Mammals	Submediterranean area, open habitats	Distributed in western Macedonia
213	*Dynaromis bogdanovi*	Mammals	Submediterranean area	Expected shift of the distribution range
214	*Eryx jaculus*	Mammals	Submediterranean area	Distributed along river Vardar and south-east Macedonia
215	*Lutra lutra*	Mammals	Mountain streams	Widespread in Macedonia

No	Species	Taxonomic group	Ecosystems/biomes	Remarks
216	*Lynx lynx balcanicus*	Mammals	forests	Threatened taxon (critically endangered)
217	*Martes foina*	Mammals	Submediterranean area	Widespread in Macedonia
218	*Meles meles*	Mammals	Forests	Widespread in Macedonia
219	*Microtus guentheri*	Mammals	Submediterranean area	Distributed in Vardar valley and Bitola area
220	*Nannospalax leucodon*	Mammals	Submediterranean area	Widespread in Macedonia
221	*Rupicapra rupicapra balcanica*	Mammals	Forests, mountain pasture	Strong pressure of poaching is evident
222	*Spermophilus citellus karamani*	Mammals	Mountain and lowland pastures	Distributed on Jakupica Mt.; another subspecies present in south-east Macedonia
223	*Talpa stankovici*	Mammals	Mountain ecosystems and lowlands	Distributed in western Macedonia
224	*Vormela peregusna*	Mammals	Submediterranean area	Distributed in Vardar valley and eastern Macedonia

Only one of these likely vulnerable species was modelled in course of this report – the ground beetle *Trechus goeblii matchai* (see below).

3.2.2 Protected areas and species distributions

Macedonia has established a system of protected areas. For most of the vulnerable species, these protected areas represent strongholds or hold their core populations (Melovski et al. 2011).

The protected areas (PAs) system in Macedonia covers a variety of large and small sites representing different habitat types and various rare, endemic or relict species. Almost all of the PAs were proclaimed during the 1950s, 1960s and 1970s. The threat status of habitats and species was hardly considered during their designation and proclamation. Some of the protected areas were designated for conservation of geodiversity or fossils. The categories of protected areas in Macedonia and their corresponding management objectives are defined in Articles 66–90 of the Law on Nature Protection (Official Gazette of RM, No. 67/04): **I. Strict Natural Reserve, II. National Park, III. Natural Monument, IV. Nature Park, V. Protected Landscape, VI. Multipurpose Area**. Besides these categories, a new category - **Natural rarity** was introduced in order to cover very small areas important for their geology, geomorphology, palaeontology etc. Other articles regulate other administrative procedures connected to protected areas (proclamation, register, cadastre, supervision, etc.). The names of categories in the national Law were kept the same as those of the IUCN categorization, were slightly modified, or completely changed (for categories IV and VI the old names were taken since they correspond better to the language peculiarities or to keep

already domesticated terms). However, they all more or less correspond to the respective IUCN categories.

The most comprehensive source of data for the time being can be found in the Physical (Spatial) Plan of Macedonia. The data are confusing since areas that are recommended for protection are placed in the same table. According to the Spatial Plan, expansion of the total surface of designated areas is envisaged to rise from the current of about 7.3% to 11.6% of the national territory in the period 2000–2020 (Macedonian Ecological Society 2011).

A specific problem for Macedonia is that the existing protected area system is still not harmonized with the existing legislation. The Law on Nature Protection stipulates that harmonization and re-proclamation of all PAs have to be done in a six-year period (starting in 2004). Not much has been done so far. Additionally, for some categories it is not clear what the management objectives are (or why were they designated?) and it is not easy to ascribe some of the categories in force to the existing PAs. The process is led by the Nature Sector established within the Administration of Environment in the Ministry of Environment and Physical Planning, but it is proceeding very slowly and has no priority plan. Most of the existing PA categories will definitely serve as a backbone for the future Natura 2000 Network (Habitats Directive requirement). They will also serve as core areas in the future National Ecological Network (which is also a legal obligation).

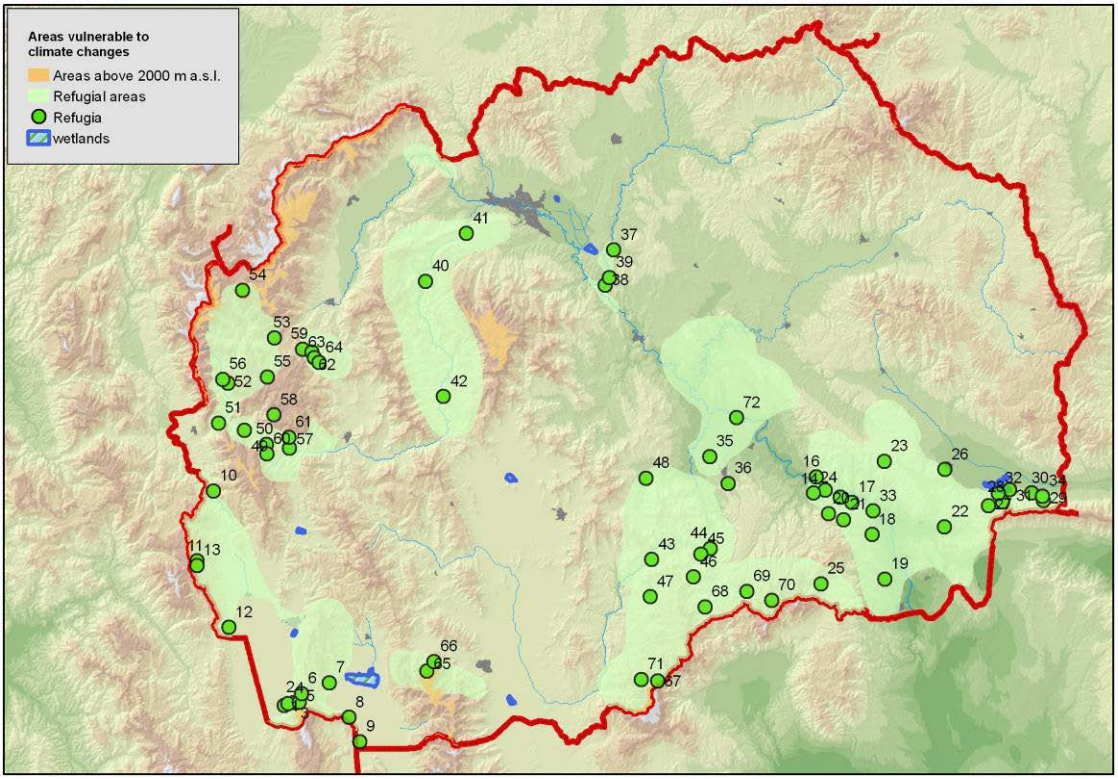

Figure 6. Map of the areas in Macedonia that are sensitive to climate change (from Brajanoska et al. 2011)

Most of the protected areas (or proposed for protected) represent core areas of many important and threatened species. The vulnerability to climate change has not been decisive factor in designing the boundaries or management objectives of the protected areas, yet. However, Brajanoska et al. (2009) elaborated the significance of protected areas for the

climate change adaptation. This analysis took into consideration both the First and Second National Communication to Climate Change. The following areas were included in the map of areas sensitive to climate change:

Alpine zone of the mountains above 2000 m a.s.l

Refugial regions (areas)

Major swamps and marshes

Emerald Network represents a network of Areas of Special Conservation Interest (ASCI) designated with the aim to conserve the network of natural habitats. It is developed on the territory of the parties to the Bern Convention (Convention on the Conservation of European Wildlife and Natural Habitats). Republic of Macedonia in the period from 2002-2008 developed its national Emerald network which contains 35 sites of interest for conservation. Four sites in the National Emerald Network are categorized as type A (Areas important for the protection of birds), 5 sites are categorized as type B (Areas important for other species and/or habitats) and the largest number of Emerald sites i.e. 26 sites are included in the type C (Areas important for birds, other species and/or habitats).

The total area of the proposed Emerald sites is 752,223 ha, representing about 29% of the territory of the Republic of Macedonia. The sites are fairly diverse in size: the smallest covers about 625 ha (Negorci marsh) and the largest site is Jakupica, which covers about 76,740 ha.

There is only one Ramsar site in Macedonia (Prespa Lake) and one UNESCO world heritage site - Ohrid (two more sites were proposed: cave Slatinski Izvor and Markovi Kuli).

Other internationally designated areas such as Important Bird Areas, Important Plant Areas and Prime Butterfly Areas also contain a number of threatened species, some of them vulnerable to climate change. Good quantitative analysis of the populations of important birds in Macedonian IBAs was presented by Velevski et al. (2010). The distribution if IPAs and important plant species can be found in Melovski et al (2010). Both IBAs and IPAs were used to identify Key Biodiversity Areas - KBA (Melovski et al. 2012).

All of the described protected or designated areas serve as core areas for populations of wildlife species. In most of the cases, animal and plant species were targeted, however in some of them (e.g. IPAs) other organisms were taken into account. Unfortunately, only few protected areas have management plans that are implemented. The majority of protected areas have neither management body or management plan. Effective protection of these areas will certainly lead to conservation of core populations of threatened species and species vulnerable to climate change. It cannot serve as a definite measure for safeguarding viable populations of climate change vulnerable species but it can certainly provide ground for adaptation measures.

3.2.2.1 Representation of vulnerable habitats and species in the national protected areas' system

In this chapter an analysis of the conservation status of major habitat types (ecosystems) and nationally and internationally important species that are vulnerable to the climate change was made. The list of vulnerable habitat types is taken from SNC and modified from the standpoint of the current state of knowledge where appropriate and amended with the modeling results from this report. The lists of vulnerable plant and animal species were

compiled on the bases of the SNC assessment and amended were necessary. It has to be noted that these lists are not definite, i.e. they are not exhaustive.

3.2.2.1.1 Habitats

The results of the analysis of habitats' representativeness in the national protected areas' system are shown in Tab. 8. First column represents the list of habitats assessed to be vulnerable in SNC; the second column gives the type of vulnerability as assessed in SNC and modified for this purpose; the protected areas and areas proposed for protection (Macedonian Ecological Society 2011) which covers entire range of the habitat in Macedonia, or parts of its range, is presented in the third column; the fourth column shows the status of the protected area(s) and current threats for the concerned habitat type; potentials for adaptation of the concerned habitat type in relation to the proposed national ecological network (MAKNEN) (Brajanoska et al. 2011) are given in the fifth column.

Table 8. Representation of the vulnerable habitat types in the national protected areas' system

Plant community (ecosystem type)	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
Xerothermophilous ecosystem with Kermes oak*	2050: shrink of the range and limited redistribution 2100: Redistribution of the range – toward eastern mountains	Cham Chiflik; Demir Kapija Gorge	Protected, but no administration in place (Demir Kapija gorge); Proposed for protection (Cham Chiflik and Chalakli); Threats: wild fires; overexploitation (indirectly)	Landscape corridors Malesh, Istibanja, Goten, Smrdesh and Vlaina Planina, Stepping-stone corridor Smrdesh-Goten. Status: not established in practice and not managed; probably not sufficient and not efficient
Thermophilous ecosystems of Pubescent oak and Oriental hornbeam	±Positive / Expansion (very uncertain – fragmentation, agriculture; exploitation)	Demir Kapija Gorge, Matka, Jasen, NP Galichica, Tikvesh	Protected, but no administration in place; Threats: wild fires; overexploitation	Landscape corridors Selechka Planina, Luben; Istibanja, Goten, Smrdesh; Stepping-stone corridor Smrdesh-Goten, Steppic corridors Kampur, Karatmanovo-Ivankovci, Shtipski Koridor
Thermophilous forests with Greek juniper	±Positive / Expansion (very uncertain: lack of knowledge; lack of space for redistribution)	NP Galichica; Tikveshko Ezero, Chalakli, Radusha, Demir Kapija Gorge; Badar Gorge, Jasen, Matka	Protected (NP Galichica, Tikveshko Ezero, Matka); Protected, but no administration in place (Demir Kapija); Proposed for protection (Badar, Chalakli and Radusha) Threats: wild fires	Not relevant – the sites are too fragmented naturally (bedrock and other ecological requirements)
Riparian forests -	Negative / Restriction/	Demir Kapija Gorge,	Protected (NP	Preserved river

Plant community (ecosystem type)	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
Oriental plane, willow, alder, tamaris	destruction (very likely – decline in water courses flow in south Macedonia)	Belchishko Blato, NP Mavrovo	Mavrovo and Demir Kapija - but no administration in place) or not protected (Belchishko Blato); Threats: water sector (water captures and dams)	corridors along rivers
Steppe-like grassland ecosystems	±Neutral up to positive / Expansion – indirectly (uncertain – too many ecological variables for expert judgment, coupled with anthropogenic factor)	Ljubash, Slan Dol, Orlovo Brdo	Protected, but no administration in place (Orlovo Brdo); Proposed for protection (Ljubash and Slan Dol) Threats: Abandonment of agricultural practices / infrastructure development	Steppic corridors Kampur, Karatmanovo-Ivankovci, Shtipski Koridor Dolno Povardarie, Dolna Bregalnica-Mangovica Status: not established in practice and not managed; probably not sufficient and not efficient
Hill pastures - grassland ecosystems	±Neutral up to positive / Redistribution (uncertain – too much dependent on human impact)	Vodno, NP Galichica, Jasen, Matka, Tikvesh, Markovi Kuli, Demir Kapija, Mariovo	Protected (Vodno, Jasen, Tikvesh, Demir Kapija and Galichica); not protected (Markovi Kuli, Mariovo) Different impacts and abandonment of agricultural practices Threats: Abandonment of agricultural practices / infrastructure development (Vodno)	MAK-NEN does not consider hill pastures (not relevant)
Rocky habitats in the river gorges and valleys	Not vulnerable? (totally uncertain – need research)	Demir Kapija Gorge, Babuna-Topolka, Raec – Kozjak, Mariovo, Taor, NP Mavrovo,	Protected (NP Mavrovo); Protected but no administration in place (Demir Kapija); Proposed for protection (Babuna-Topolka, Raec – Kozjak, Mariovo, Taor) Threats: Quarries	MAK-NEN does not consider hill pastures (not relevant)
Thermo-mesophilous forest of Italian and Turkey oak	Negative / Restriction (uncertain – too many ecological variables for expert judgment, coupled with anthropogenic factor)	NP Galichica, NP Pelister, NP Mavrovo, Smolarski Vodopad; Other areas proposed for protection (e.g. Shar Planina, Kozhuf, Jablanica, Salandzhak, Jakupica, Osogovo, etc.)	Protected (NP Galichica, NP Pelister, NP Mavrovo, Smolarski Vodopad); Proposed for protection (Shar Planina, Kozhuf, Jablanica, Salandzhak, Jakupica, Osogovo, etc.) Threats: Exploitation	Numerous linear and landscape corridors which are more or less efficient; redistribution will most likely be possible
Mesophilous Sessile oak forests	Negative / Restriction (uncertain – too many	NP Galichica, NP Pelister, NP Mavrovo, Smolarski	Protected (NP Galichica, NP Pelister, NP Mavrovo, Smolarski	Numerous linear and landscape corridors which are more or less

Plant community (ecosystem type)	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
	ecological variables for expert judgment, coupled with anthropogenic factor)	Vodopad; Other areas proposed for protection (e.g. Shar Planina, Kozhuf, Jablanica, Salandzhak, Jakupica, Osogovo, Maleshevski Planini, etc.)	Vodopad); Proposed for protection (Shar Planina, Kozhuf, Jablanica, Salandzhak, Jakupica, Osogovo, Maleshevski Planini, etc.) Threats: Exploitation	efficient; redistribution will most likely be possible
Beech forests - sub-montane and montane	Positive / Expansion (uncertain – possibly lack of space, coupled with anthropogenic factor – overuse)	NP Galichica, NP Pelister, NP Mavrovo, Smolarski Vodopad; Other areas proposed for protection (e.g. Shar Planina, Kozhuf, Jablanica, Salandzhak, Jakupica, Osogovo, Maleshevski Planini, etc.)	Protected (NP Galichica, NP Pelister, NP Mavrovo, Smolarski Vodopad); Proposed for protection (Shar Planina, Kozhuf, Jablanica, Salandzhak, Jakupica, Osogovo, Maleshevski Planini, etc.) Threats: Exploitation	Several linear (Bukovik-Sretkovo, Istok Planina, Krushevo, Baba Sach, Dren-Vitolishte, Kozjak-Pletvar, Deve Bair) and landscape (Bukovik-Kolari, Vlaina Planina, Selechka Planina, Malesh, Goten) corridors which are more or less efficient; redistribution will most likely be possible
Black pine forests	Negative / Restriction, loss (uncertain – too many ecological variables for expert judgment, coupled with anthropogenic factor)	Jasen, Cham Chiflik, Redir, Kartal, Kozhuf, Meshnik, Maleshevski Planini	Protected (Jasen; Cham Chiflik - but no administration in place) Proposed for protection (Redir, Kartal, Kozhuf, Meshnik, Maleshevski Planini) Threats: wild fires, exploitation	Core areas Nidzhe-Kozjak-Kozhuf and Jakupica-Babuna; Landscape corridor Goten, Vlaina Planina and Malesh
Sub-alpine beech forests	Neutral / Probably expansion (uncertain – possibly lack of space, coupled with anthropogenic factor – grazing due to sheep breeding)	NP Galichica, NP Pelister, NP Mavrovo, Smolarski Vodopad, Jablanica, Shar Planina, Jakupica, Kozhuf, Osogovo	Protected (NP Galichica, NP Pelister, NP Mavrovo, Smolarski Vodopad); Proposed for protection (Jablanica, Shar Planina, Jakupica, Kozhuf, Osogovo) Threats: not significant currently	Irrelevant – too high altitudes and low human pressure; only core areas identified in already protected or proposed areas.
Sub-alpine Molika pine forests	Positive / Expansion (very likely – expansion in all directions, process which is currently underway on several mountains)	NP Pelister, Belo Grotlo, Jablanica, Shar Planina	Protected (NP Pelister); Proposed for protection (Belo Grotlo, Jablanica, Shar Planina) Threats: not significant currently – conservation	Irrelevant – too high altitudes and low human pressure; only core areas identified in already protected (NP Pelister) or proposed areas (Shar Planina)
Sub-alpine spruce forests	Negative / Restriction/reduction of population (very likely – the	NP Mavrovo, Shar Planina	Protected (NP Mavrovo); Proposed for protection (Shar Planina)	Irrelevant – only one representative stand currently under low human pressure; only

Plant community (ecosystem type)	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
	southern border of general distribution range in Europe)		Threats: Water extraction (NP Mavrovo – Adzhina Reka), exploitation (Shar Planina)	core areas identified in already protected (NP Mavrovo) or proposed areas (Shar Planina)
Sub-alpine fir and Scots pine forests	Positive or neutral / Similar like beech forests (very uncertain – possibly lack of space, coupled with anthropogenic factor – overuse)	NP Mavrovo, NP Galichica, NP Pelister, Jasen, Kozhuf, Jakupica, Redir	Protected (NP Mavrovo, NP Galichica, NP Pelister, Jasen) Proposed for protection (Kozhuf, Jakupica, Redir) Threats: exploitation	Irrelevant – too high altitudes and not considered in MAKNEN, but core areas identified (Nidzhe-Kozjak-Kozhuf).
Sub-alpine Mountain pine scrub-land*	2050: Significant shrink of the range 2100: Complete loss of the most representative site – Juruchica and Solunska Glava); possible redistribution of the range – toward Shar Planina and Osogovo	Jakupica	Proposed for protection (Jakupica) Threats: Fires – low significance	Irrelevant – too high altitudes and not considered in MAKNEN (natural redistribution impossible – too far and disconnected)
Sub-alpine pastures and pastures on rocky sites	Sensitive/ Negative (most likely – lack of space)	NP Galichica, NP Pelister, NP Mavrovo, Jasen, Shar Planina, Jakupica, Osogovo, Kozhuf, Belo Grotlo, Kajmakchalan, Jablanica, Stogovo, Ilinska Planina	Protected (NP Galichica, NP Pelister, NP Mavrovo, Jasen); Proposed for protection (Shar Planina, Jakupica, Osogovo, Kozhuf, Belo Grotlo, Kajmakchalan, Jablanica, Stogovo, Ilinska Planina) Threats: not significant currently – overgrazing and abandonment	Irrelevant – too high altitudes
Alpine pastures and pastures on rocky sites	Negative / Reduction of populations/ Loss of species (most likely – lack of space)	NP Pelister, NP Mavrovo, Shar Planina, Jakupica	Protected (NP Pelister and Mavrovo); Proposed for protection (Shar Planina, Jakupica) Threats: not significant currently – overgrazing and abandonment	Irrelevant – too high altitudes; establishment of corridors is impossible
Alpine rocks and rocky habitats	Negative / Reduction of populations/ Loss of species (most likely – lack of space)	NP Pelister, NP Mavrovo, Shar Planina, Jakupica	Protected (NP Pelister and Mavrovo); Proposed for protection (Shar Planina, Jakupica) Threats: not significant currently	Irrelevant – too high altitudes and too fragmented naturally; establishment of corridors is impossible

* Vulnerability of the habitat was assessed on the bases of the modeling (MaxEnt software)

One has to bear in mind that there are lots of uncertainties imminent to the assessment and considerable weakness of the assessment based mainly on expert judgment method for proper analysis. Anyhow, it can be concluded that even with these shortcomings, the severe predicted impact of climate change on major habitat types will result in significant changes in vegetation distribution in Macedonia. Current system of PAs is not sufficient to cope with these changes and is not sufficient to allow for appropriate adaptations. Most of the sites supporting vulnerable habitats are in the protected areas which are without any kind of management. In addition, significant portion of vulnerable habitats are out of protected areas.

3.2.2.1.2 Species

The results of the analysis of species' representativeness in the national protected areas' system are shown in Tab. 9 and 10. The relevance of the columns is same as in Tab. 8.

Table 9. Representation of the vulnerable plant species in the national protected areas' system

Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
Lycopodium clavatum	Extinction – due to the habitat loss; (very likely)	Osogovo	Proposed for protection	Irrelevant – only one site in Macedonia
Huperzia sellago	Extinction – due to the habitat loss; (very likely)	Shar Planina Jakupica Pelister Kajmakchalan Jablanica	Protected (NP Pelister); Proposed for protection (Shar Planina, Jakupica, Pelister, Kajmakchalan and Jablanica)	Irrelevant – high altitude and not treated in MAKNEN
Diphasium alpinum	Extinction – due to the habitat loss; (most likely)	NP Mavrovo; Shar Planina	Protected (NP Mavrovo); Proposed for protection (Shar Planina)	Irrelevant – high altitude and not treated in MAKNEN
Selaginella selaginoides	Extinction – due to the habitat loss; (very likely)	Shar Planina Jakupica Jablanica	Proposed for protection (Shar Planina, Jakupica and Jablanica)	Irrelevant – high altitude and not treated in MAKNEN
Isoetes phrygia	Extinction – due to the habitat loss; (very likely)	Markovi Kuli Monospitovsko Blato	Protected (Markovi Kuli); Proposed for protection (Monospitovsko Blato)	Not treated in MAKNEN
Ophioglossum vulgatum	Decline of the distribution range – due to the habitat loss;	Markovi Kuli Monospitovsko Blato;	Protected (Markovi Kuli , NP Mavrovo); Proposed for protection	Not treated in MAKNEN

Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
	(likely)	Negorska Banja NP Mavrovo Jablanica Alshar Kozhuf	(Monospitovsko Blato, Negorska Banja, Jablanica, Kozhuf); (Alshar was recently delisted from PAs' system)	
Osmunda regais	Extinction – due to the habitat loss; (very likely)	Monospitovsko Blato	Proposed for protection (although the species itself was protected by the Strumica municipality)	Species to be affected by the changes in lowland wetlands
Thelipteris palustris	lowland wetlands	Monospitovsko Blato, Kozhuf	Proposed for protection	Species to be affected by the changes in lowland wetlands
Adiantum capillus-veneris	Permanently wet places	Babuna, Pelister, Kozhuf	Protected (NP Pelister); Proposed for protection (Babuna and Kozhuf)	restricted distribution
Pinus heldreichii var. *leucodermis*	Coniferous forests	Shar Planina, Galichica, Kajmakchalan	Protected (NP Galichica); Proposed for protection (Shar Planina and Kajmakchalan)	Very rare species with restricted distribution
Pinus mugo	Coniferous forests	Shar Planina, Jakupica, Kajmakchalan	Proposed for protection	Altitudinal shift is expected
Picea abies	Coniferous forests	Shar Planina NP Mavrovo	Protected (NP Mavrovo); Proposed for Protection (Shar Planina)	Boreal species sensitive to climate changes
Juniperus excelsa	Coniferous shrub communities	NP Galichica; Tikveshko Ezero, Chalakli, Radusha, Demir Kapija Gorge; Badar Gorge	Protected (NP Galichica, Tikveshko Ezero); Protected, but no administration in place (Demir Kapija); Proposed for protection (Badar, Chalakli and Radusha)	Expected shift of the distribution range
Ranunculus degenii	Mountain wetlands	Shar Planina, NP Mavrovo, Jablanica	Protected (NP Mavrovo); Proposed for protection (Shar Planina and Jablanica)	Species to be affected by the changes in mountain wetlands
Ranunculus lingua	Probably already extinct	Studenchishko Blato, Bansko	Proposed for protection	Species to be affected by the changes in lowland wetlands
Trollius europaeus	Mountain wetlands	Shar Planina, NP Mavrovo, NP Pelister, Kajmakchalan	Protected (NP Mavrovo and NP Pelister); Proposed for protection (Shar Planina and Kajmakchalan)	Species to be affected by the changes in mountain wetlands

Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
Pulsatilla vernalis	Coniferous forests	Shar Planina, Jablanica	Proposed for protection	Species sensitive to climate changes
Quercus coccifera	Submediterranean area, forests	Cham Chiflik; Chalakli Demir Kapija Gorge	Protected, but no administration in place (Demir Kapija gorge); Proposed for protection (Cham Chiflik and Chalakli)	Same corridors as for the Kermes oak community
Rumex hydrolapathus	lowland wetlands	Ohridsko Ezero, Studenchishko Blato, Belchishko Blato	Protected (Ohridsko Ezero), Proposed for protection (Studenchishko Blato and Belchishko Blato)	Species to be affected by the changes in lowland wetlands
Salix reticulata	low mountain shrub communities	Shar Planina, NP Mavrovo and Jakupica	Protected (NP Mavrovo); Proposed for protection (Shar Planina and Jakupica)	Alpine species, Shar Planina, Jakupica
Salix herbacea	low mountain shrub communities	Shar Planina, NP Mavrovo	Protected (NP Mavrovo); Proposed for protection (Shar Planina)	Alpine species, Shar Planina, Korab
Salix retusa	low mountain shrub communities	Shar Planina, NP Mavrovo	Protected (NP Mavrovo); Proposed for protection (Shar Planina)	Alpine species, Shar Planina
Salix alpina	low mountain shrub communities	Shar Planina, Jakupica	Proposed for protection	Alpine species, Shar Planina, Jakupica
Viola brachyphylla		Kajmakchalan	Proposed for protection	(Sub) endemic species-Nidzhe
Rhododendron myrthifolium	low mountain shrub communities	Jakupica	Proposed for protection	Expected shift of the distribution range
Rhododendron ferrugineum	low mountain shrub communities	Shar Planina	Proposed for protection	Expected shift of the distribution range
Empetrum nigrum	low mountain shrub communities	Shar Planina, NP Mavrovo	Protected (NP Mavrovo); Proposed for protection (Shar Planina)	Expected shift of the distribution range
Loiseleuria procumbens	low mountain shrub communities	Shar Planina	Proposed for protection	Expected shift of the distribution range
Soldanella pindicola	Mountain wetlands	Shar Planina, Jablanica	Proposed for protection	Species to be affected by the changes in mountain wetlands
Dryas octopetala	In places where the snow melts	Shar Planina, NP Mavrovo, NP Galichica, Jakupica, Kajmakchalan	Protected (NP Mavrovo, NP Galichica); Proposed for protection (Shar	Species to be affected by the changes in alpine belt

Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
			Planina, Jakupica and Kajmakchalan)	
Saxifraga stellaris subsp. *alpigena*	Mountain springs and bogs	NP Pelister, Jakupica, Kajmakchalan	Protected (NP Pelister); Proposed for protection (Jakupica and Kajmakchalan)	Species to be affected by the changes in mountain wetlands
Drosera rotundifolia	Mountain wetlands	Judovi Livadi, NP Mavrovo	Protected (NP Mavrovo); Protected without administration (Judovi Livadi)	Species to be affected by the changes in mountain wetlands
Aldrovanda vesiculosa	Probably already extinct	Ezerani	Protected	will follow changes in oscillations in water levels in natural lakes
Astragalus physocalyx	Submediterranean area, forests	Bogdanci-Curculum		Sensitive species with very restricted distribution
Astragalus cernjavskii	Submediterranean area	Orlovo Brdo	Protected, but no administration in place (Orlovo Brdo)	Endemic of Central Macedonia - Negotino
Hedysarum macedonicum	Dry grasslands	Ljubash, Slandol, Orlovo Brdo	Protected, but no administration in place (Orlovo Brdo); Proposed for protection (Ljubash, Slan Dol)	Endemic of Central Macedonia - Negotino
Trapa natans	Natural lakes, rivers	Dojransko Ezero, Prespansko Ezero, Ezerani, Monospitovsko Blato, Katlanovsko Blato	Protected (Dojransko Ezero, Prespansko Ezero, Ezerani); Proposed for protection (Monospitovsko Blato, Katlanovsko Blato)	will follow changes in oscillations in water levels in natural lakes
Aesculus hippocastanum	Beech forests	NP Galichica, NP Pelister, Suvi Dol, Jablanica	Protected NP Galichica, NP Pelister, Suvi Dol, Jablanica	Relict species with restricted distribution
Phyllirea latifolia	Submediterranean area, forests	Demir Kapija, Taor, Badar, Chalakli, Kozhuf, Orlovo Brdo, Tikveshko Ezero, NP Galichica	Protected (NP Galichica, Demir Kapija, Tikveshko Ezero); Protected, but no administration in place (Orlovo Brdo) Proposed for protection (Chalakli, Kozhuf)	Expected shift of the distribution range
Rindera graeca	mountains rocky sites	NP Galichica	Protected	Expected shift of the distribution range
Pedicularis ferdinandi	Mountain pastures	Jakupica	Proposed for protection	Endemic species of Jakupica

Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
Melampyrum heracleoticum		Jasen, Matka, Jablanica, NP Galichica, Mariovo	Protected (Jasen, Matka, NP Galichica); Proposed for protection (Jablanica, Mariovo)	Expected shift of the distribution range
Ramonda nathaliae	Lowland and mountains rocky sites	Matka, Taor, Badar, Demir Kapija, Babuna, Kozhuf, Jakupica, Jasen,	Protected (Jasen, Matka, NP Galichica); Proposed for protection (Taor, Badar, Babuna, Jakupica)	Relict species
Ramonda serbica	Lowland and mountains rocky sites	NP Mavrovo, Jablanica, NP Galichica	Protected (NP Mavrovo, NP Galichica); Proposed for protection (Jablanica)	Relict species
Thymus oehmianus	River gorges	Jasen	Protected	Endemic and relict species
Centaurea soskae	cliffs	NP Galichica	Protected	Endemic species Galichica
Senecio paludosus	lowland wetlands	Studenchishko Blato	Proposed for protection	Species to be affected by the changes in lowland wetlands
Colchicum pieperianum	Mountain pastures	NP Mavrovo	Protected	Expected shift of the distribution range
Fritillaria macedonica	Mountain wetlands Mountain pastures	NP Mavrovo, Jablanica	Protected (NP Mavrovo); Proposed for protection (Jablanica)	Endemic of Jablanica, Deshat
Narthecium scardicum	Mountain wetlands	Shar Planina, NP Mavrovo, Jakupica, Jablanica	Protected (NP Mavrovo); Proposed for protection (Shar Planina, Jakupica, Jablanica)	Species to be affected by the changes in mountain wetlands
Crocus scardicus	In places where the snow melts	Shar Planina, NP Mavrovo	Protected (NP Mavrovo); Proposed for protection (Shar Planina)	(Sub) Endemic, north and west part of Macedonia
Crocus pelistericus	In places where the snow melts	NP Pelister	Protected	Endemic of Pelister, Nidzhe
Crocus cvijici	In places where the snow melts	NP Galichica	Protected	Endemic of Galichica
Leucojum aestivum	lowland wetlands	Studenchishko Blato	Proposed for protection	Species to be affected by the changes in lowland wetlands
Listera cordata	Coniferous forests	Shar Planina, NP Mavrovo	Protected (NP Mavrovo); Proposed for protection (Shar Planina)	Will follow the changes in the belt of common spruce
Carex elata	lowland wetlands	Studenchishko Blato	Proposed for protection	Species to be affected by the changes in lowland wetlands
Cladium mariscus	lowland wetlands	Negorska Banja	Proposed for protection	Species to be affected by the changes in lowland wetlands

Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
Alopecurus creticus	lowland wetlands	Monospitovsko Blato	Proposed for protection	Species to be affected by the changes in lowland wetlands

Table 10. Representation of the vulnerable animal species in the national protected areas' system (n/a – not assessed and requires further studies)

No	Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
1	*Euxinella alpinella*	Changes in phenology and distribution	Kajmakchalan	Proposed for protection	n/a
2	*Euxinella subai*	Changes in phenology and distribution	Kozhuf	Proposed for protection	n/a
3	*Helix dormitoris*	Changes in phenology and distribution	Shar Planina	Proposed for protection	n/a
4	*Helix secernenda*	Changes in phenology and distribution	Jablanica, Jakupica, NP Galichica	Protected (NP Galichica); Proposed for protection (Jablanica, Jakupica)	n/a
5	*Montenegrina stankovici*	Changes in phenology and distribution	NP Galichica	Protected	n/a
6	*Tandonia macedonica*	Changes in phenology and distribution	NP Galichica	Protected	n/a
7	*Latrodectus tredecimguttatus*	Changes in phenology and distribution	Slan Dol, Osogovo	Proposed for protection	n/a
8	*Cyphophthalmus gjorgjevici*	Changes in phenology and distribution	Rashche	Proposed for protection	n/a
9	*Cyphophthalmus markoi*	Changes in phenology and distribution	Demir Kapija	Protected without administration	n/a
10	*Allocyclops kieferi*	Extinction might be expected	Not included in any protected area (present in Pelagonija)		n/a
11	*Alona elegans*	Extinction might be expected	Shar Planina	Proposed for protection	n/a
12	*Alona intermedia*	Extinction might be expected	Shar Planina, NP Pelister	Protected (NP Pelister); Proposed for protection (Shar Planina)	n/a
13	*Alpioniscus macedonicus*	Changes in phenology and distribution	Jasen	Protected	n/a
14	*Alpioniscus slatinensis*	Changes in phenology and distribution	Beleshnica, Poreche	Proposed for protection	n/a
15	*Alpioniscus*	Changes in phenology and	Demir Kapija	Protected without	n/a

No	Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
	vardarensis	distribution		administration	
16	*Arcticocamptus abnobensis*	Mountain springs and bogs	Jakupica	Proposed for protection	n/a
17	*Arctococamptus macedonicus*	Extinction might be expected	Shar Planina, NP Pelister, Jakupica	Protected (NP Pelister); Proposed for protection (Shar Planina and Jakupica)	n/a
18	*Arctodiaptomus niethammeri*	Extinction might be expected	NP Pelister, NP Galichica	Protected	n/a
19	*Arctodiaptomus osmanus*	Extinction might be expected	NP Pelister, NP Galichica	Protected	n/a
20	*Austropotamobius torrentium macedonicus*	Reduction of the population	Present in many protected areas and proposed areas for protection		n/a
21	*Bogidiella albertimagna glacialis*	Extinction might be expected	Jakupica	Proposed for protection	n/a
22	*Branchipus intermedius*	Extinction might be expected	NP Mavrovo		n/a
23	*Chirocephalus pelagonicus*	Extinction might be expected	Not included in any protected area (present in Pelagonija)	Protected	n/a
24	*Cypridopsis concolor*	Extinction might be expected	Negorci	Proposed for protection	n/a
25	*Diacyclops pelagonicus*	Extinction might be expected	Not included in any protected area (present in Pelagonija)	Not protected	n/a
26	*Dociostaurus maroccanus*	Calamities might be expected	Vodno, Cham Chiflik	Protected	n/a
27	*Eucypris heinrichi*	Extinction might be expected	NP Mavrovo	Protected	n/a
28	*Eudiaptomus gracilis*	Extinction might be expected	Dojransko Ezero	Protected	n/a
29	*Eudiaptomus hadzici*	Extinction might be expected	Jablanica	Proposed for protection	n/a
30	*Heterocypris erikae*	temporary waters	NP Galichica	Protected	n/a
31	*Heterocypris gevgelija*	Extinction might be expected	Negorci	Proposed for protection	
32	*Heterocypris hartwigi*	Extinction might be expected	Ploche Litotelmi	Protected	n/a
33	*Hypocamptus brehmi*	Extinction might be expected	NP Mavrovo	Protected	n/a
34	*Macedonethes skopjensis*	Possibly already extinct	Matka	Protected	n/a

No	Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
35	*Macedonethes stankoi*	Changes in phenology	Jakupica	Proposed for protection	n/a
36	*Mixodiaptomus tatricus*	Extinction might be expected	Shar Planina, Jakupica, Jablanica	Proposed for protection	n/a
37	*Mladenoniscus belavodae*	Changes in phenology	Demir Kapija	Protected without administration	n/a
38	*Niphargus pancici jakupicae*	Extinction might be expected	Jakupica	Proposed for protection	n/a
39	*Niphargus pancici peristericus*	Extinction might be expected	NP Pelister	Protected	n/a
40	*Niphargus tauri osogovensis*	Extinction might be expected	Osogovo	Proposed for protection	n/a
41	*Potamon ibericum*	Changes in phenology and distribution	Demir Kapija, Dojransko Ezero, Kozhuf	Protected without administration (Demir Kapija); Protected (Dojransko Ezero); Proposed for protection Kozhuf)	n/a
42	*Psychrodromus fontinalis*	Extinction might be expected	Jakupica	Proposed for protection	n/a
43	*Psychrodromus olivaceus*	Extinction might be expected	Shar Planina, Jakupica, Kajmakchalan	Proposed for protection	n/a
44	*Psychrodromus peristericus*	Extinction might be expected	NP Pelister	Protected	n/a
45	*Tanymastix motasi*	Extinction might be expected	Not included in any protected area (present in Pelagonija)		n/a
46	*Trichoniscus semigranulatus*	Changes In phenology	Osogovo	Proposed for protection	n/a
47	*Brachydesmus henrikenghoffi*	Changes in phenology and distribution	Katlanovo	Proposed for protection	n/a
48	*Brachydesmus macedonicus*	Changes in phenology and distribution	Jakupica	Proposed for protection	n/a
49	*Brachydesmus peristorensis*	Changes in phenology and distribution	NP Pelister	Protected	n/a
50	*Leptoiulus macedonicus*	Changes in phenology and distribution	Shar Planina, NP Mavrovo	Protected (NP Mavrovo); Proposed for protection (Shar Planina)	n/a
51	*Leptoiulus storkani*	Changes in phenology and distribution	NP Mavrovo	Protected	n/a
52	*Typhloglomeris ljubotensis*	Changes in phenology and distribution	Shar Planina	Proposed for protection	n/a
53	*Typhloglomeris varuna*	Changes in phenology and distribution	Mlechnik cave	Protected	n/a

No	Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
54	*Typhloiulus albanicus*	Changes in phenology and distribution	Shar Planina, Jasen	Proposed for protection	n/a
55	*Typhloiulus giganteus*	Changes in phenology and distribution	Beleshnica	Proposed for protection	n/a
56	*Cordulegaster heros*	Changes In phenology and distribution	NP Galichica, NP Mavrovo, NP Pelister, Jasen, Jablanica, Jakupica, Kozhuf	Protected (NP Galichica, NP Mavrovo, NP Pelister, Jasen); Proposed for protection (Jablanica, Jakupica, Kozhuf)	n/a
57	*Epallage fatime*	Changes In phenology and distribution	Kozhuf, Dojran	Proposed for protection	n/a
58	*Calliptamus italicus*	Changes in phenology - calamities might be expected	Demir Kapija, Dojran, NP Mavrovo, Vodno, NP Pelister	Protected	n/a
59	*Paracoloptenus caloptenoides*	Changes in phenology and distribution	Demir Kapija, Kozhuf, Matka, Jasen, Dojran	Protected (Demir Kapija, Matka, Jasen, Dojran); Proposed for protection (Kozhuf)	n/a
60	*Poecilimon jablanicensis*	Extinction might be expected	Jablanica	Proposed for protection	n/a
61	*Poecilimon vodnensis*	Probably already extinct	Vodno	Protected	n/a
62	*Saga pedo*	Extinction might be expected	NP Galichica	Protected	n/a
63	*Carabus variolosus nodulosus*	Sensitive to changes in water regime; extinction might be expected	Shar Planina	Proposed for protection	n/a
64	*Ceutophyes bukoviki*	Sensitive to changes in caves hydrology; changes in phenology	Bukovik	Proposed for protection	n/a
65	*Ceutophyes karamani*	Sensitive to changes in caves hydrology; changes in phenology	NP Galichica	Protected	n/a
66	*Deltomerus sterbai*	Extinction might be expected	NP Pelister	Protected, entire population within NP Pelister	n/a
67	*Dorcadion borisi*	Extinction might be expected	Belasica	Proposed for protection	n/a
68	*Dorcadion heyrovskyi*	Extinction might be expected	Kozhuf	Proposed for protection	n/a
69	*Dorcadion kaimakcalanum*	Extinction might be expected	Kajmakchalan	Proposed for protection	n/a

No	Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
70	*Dorcadion ljubetense*	Extinction might be expected	Shar Planina, NP Mavrovo, Jakupica, Jablanica	Protected (NP Mavrovo); Proposed for protection (Shar Planina, Jakupica, Jablanica)	n/a
71	*Dorcadion macedonicum*	Extinction might be expected	NP Galichica	Protected	n/a
72	*Dorcadion purkynei*	Extinction might be expected	Kajmakchalan	Proposed for protection	n/a
73	*Duvalius fodori*	Extinction or change in species phenology	Shar Planina	Proposed for protection	n/a
74	*Duvalius karaormanicus*	Extinction or change in species phenology	Mlechnik cave	Protected	n/a
75	*Duvalius macedonicus*	Extinction or change in species phenology	NP Pelister	Protected	n/a
76	*Duvalius peristericus*	Extinction or change in species phenology	NP Pelister	Protected	n/a
77	*Duvalius strupii*	Extinction or change in species phenology	NP Mavrovo	Protected	n/a
78	*Duvalius vignai*	Extinction or change in species phenology	NP Galichica	Protected	n/a
79	*Duvlaius gogalai*	Extinction or change in species phenology	NP Mavrovo	Protected	n/a
80	*Hydroporus macedonicus*	Sensitive to the changes in mountain streams	Kozhuf	Proposed for protection	n/a
81	*Lathrobium ivokaramani*	Extinction or change in species phenology	Rashche	Proposed for protection	n/a
82	*Lathrobium jakupicense*	Extinction or change in species phenology	Shar Planina, Jakupica	Proposed for protection	n/a
83	*Lathrobium matchai*	Extinction or change in species phenology	NP Pelister	Protected	n/a
84	*Ochridiola marinae*	Extinction or change in species phenology	NP Galichica	Protected	n/a
85	*Omphreus albanicus*	Extinction or change in species phenology	NP Mavrovo	Protected	n/a
86	*Omphreus gracilis*	Extinction or change in species phenology	Shar Planina	Proposed for protection	n/a
87	*Osmoderma eremita*	Severe reduction in distribution range	Mavrovo, Mariovo, Ilinska Planina	Protected (NP Mavrovo); Proposed for protection (Mariovo, Ilinska Planina)	n/a
88	*Otiorhynchus shardagensis*	Extinction might be expected	Shar Planina	Proposed for protection	n/a
89	*Paradeltomerus paradoxus*	Extinction might be expected	Shar Planina, NP Mavrovo	Protected (NP Mavrovo); Proposed	n/a

No	Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
				for protection (Shar Planina)	
90	*Petkovskiella stygia*	Extinction or change in species phenology	Jakupica	Proposed for protection	n/a
91	*Potamonectes macedonicus*	Sensitive to the changes in glacial lakes	Shar Planina	Proposed for protection	n/a
92	*Trechus galicicaensis*	mountains rocky sites	NP Galichica	Protected, entire population within NP Galichica	n/a
93	*Trechus goebli goebli*	mountains rocky sites	NP Pelister	Protected, entire population within NP Pelister	n/a
94	*Trechus goebli matchai*	mountains rocky sites	Mokra (Jakupica)	Proposed for protection	n/a
95	*Trechus hajeki*	Extinction or change in species phenology	NP Pelister	Protected, entire population within NP Pelister	n/a
96	*Trechus ljubetenis*	Extinction or change in species phenology	Shar Planina	Proposed for protection	n/a
97	*Trechus midas*	Extinction or change in species phenology	Mokra (Jakupica)	Proposed for protection	n/a
98	*Trechus pachycerus*	Extinction or change in species phenology	Mokra (Jakupica)	Proposed for protection	n/a
99	*Erebia* (different species)	Changes in phenology and distribution; extinction might be expected for some species	All national parks, Jasen and proposed areas such as Jakupica, Shar Planina, Osogov, Kozhuf, Kajmakchalan	Protected or proposed for protection	n/a
100	*Eremophila alpestris*	Changes in phenology and distribution/extinction	Shar Planina, NP Mavrovo, Jakupica	Protected (NP Mavrovo); Proposed for protection (Shar Planina, Jakupica)	n/a
101	*Euphydryas aurinia*	Changes in phenology and distribution	NP Galichica, Jablanica, Jasen, NP Mavrovo, NP Pelister, Osoogov, Shar Planina, Jakupica	Protected (NP Galichica, NP Mavrovo, NP Pelister and Jasen); Proposed for protection (Jakupica, Jablanica)	n/a
102	*Lycaena dispar*	Sensitive to the changes in lowland wetlands	Dojran, Ezerani, Galichica, Taorska Klisura, Ostrovo, Redir, Ljubash, Kozhuf, Shar Planina, Slan Dol, Vodno, Belchishko Blato	Protected (Dojran, Ezerani, Galichica, Ostrovo, Vodno); Proposed for protection (Taorska Klisura, Redir, Ljubash, Kozhuf, Shar Planina, Slan Dol, Belchishko	n/a

No	Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
				Blato)	
103	*Papilio alexanor*	Changes in phenology and distribution/extinction	Jasen, Matka, Babuna, Radusha	Protected (Jasen, Matka); Proposed for protection (Babuna, Radusha)	n/a
104	*Parnassius apolo*	Changes in phenology and distribution/extinction	Shar Planina, NP Mavrovo, NP Pelister, NP Galichica, Jablanica, Kozhuf, Chalakli	Protected (NP Galichica, NP Mavrovo, NP Pelister); Proposed for protection (Jablanica, Kozhuf, Chalakli, Shar Planina)	n/a
105	*Eudontomyzon stankokaramani*	Changes in phenology	MN Ohridsko Ezero	Protected	n/a
106	*Acantholingua ohridana*	Dependent on the status of the lake Ohrid and fishing	MN Ohridsko Ezero	Protected	n/a
107	*Alburnus belvica*	Dependent on the status of the lake Prespa and fishing	MN Prespansko Ezero	Protected	n/a
108	*Alosa fallax*	Dependent on the status of the lake Ohrid and Crn Drim	MN Ohridsko Ezero	Protected	n/a
109	*Barbus prespensis*	Dependent on the status of the lake Prespa and fishing	MN Prespansko Ezero	Protected	n/a
110	*Chondrostoma prespense*	Dependent on the status of the lake Prespa and fishing	MN Prespansko Ezero	Protected	n/a
111	*Cobitis meridionalis*	Dependent on the status of the lakes	MN Prespansko Ezero, MN Ohridsko Ezero	Protected	n/a
112	*Cyprinus carpio*	Dependent on the status of the lakes and fishing	MN Ohridsko Ezero, MN Prespansko Ezero, MN Dojransko Ezero	Protected	n/a
113	*Pachychilon macedonicum*	Dependent on the status of the lake Dojran and fishing	MN Dojransko Ezero	Protected	n/a
114	*Phoxinellus epiroticus*	Dependent on the status of the lake Ohrid	MN Ohridsko Ezero	Protected	n/a
115	*Phoxinellus prespensis*	Dependent on the status of the lake Prespa	MN Prespansko Ezero	Protected	n/a
116	*Rutilus ohridanus*	Dependent on the status of the lake Ohrid and fishing	MN Ohridsko Ezero	Protected	n/a

No	Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
117	*Rutilus prespensis*	Dependent on the status of the lake Prespa and fishing	MN Prespansko Ezero	Protected	n/a
118	*Sabanejewia doiranica*	Dependent on the status of the lake Dojran	MN Dojransko Ezero	Protected	n/a
119	*Salaria fluviatilis*	Dependent on the status of the lake Dojran	MN Dojransko Ezero	Protected	n/a
120	*Salmo aphelios*	Dependent on the status of the lake Ohrid and fishing	MN Ohridsko Ezero	Protected	n/a
121	*Salmo balcanicus*	Dependent on the status of the lake Ohrid and fishing	MN Ohridsko Ezero	Protected	n/a
122	*Salmo letnica*	Dependent on the status of the lake Ohrid and fishing	MN Ohridsko Ezero	Protected	n/a
123	*Salmo lumi*	Changes In phenology	Ohridsko Ezero		n/a
124	*Salmo pelagonicus*	Extinction might be expected	NP Pelister		n/a
125	*Salmo peristericus*	Extinction might be expected	NP Pelister	Protected	n/a
126	*Bombina variegata*	Sensitive to changes In ponds and temporary waters	Present in many protected areas and proposed areas for protection	Protected or proposed for protection	n/a
127	*Pelobates syriacus balcanicus*	Senstive to changes in lowland wetlands	Dojransko Ezero, Ezerani, Galichica, Taorska Klisura, Ostrovo, Prespansko Ezero, Radusha, Monospitovsko Blato	Protected (Dojransko Ezero, Ezerani, NP Galichica, Ostrovo, Prespansko Ezero); Proposed for protection (Monospitovsko Blato, Radusha)	n/a
128	*Rana balcanica*	Senstive to changes in lowland wetlands	Prespansko Ezero, Monospitovsko Blato	Protected (Prespansko Ezero); Proposed for protection (Monospitovsko Blato)	n/a
129	*Rana temporaria*	Altitudinal shift is expected	NP Mavrovo, Jakupica, Jablanica, Maleshevski Planini, Shar Planina, NP Pelister, Kajmakchalan, Doshnica	Protected (NP Mavrovo, NP Pelister); Proposed for protection (other areas)	n/a

No	Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
130	*Triturus alpestris*	Sensitive to changes in glacial lakes and ponds; extinction might be expected	Shar Planina, NP Mavrovo, Jablanica	Protected (NP Mavrovo, NP Pelister); Proposed for protection (Jablanica, Shar Planina)	n/a
131	*Triturus carnifex macedonicus*	Senstive to changes in wetlands	NP Galichica	Protected	n/a
132	*Triturus karelinii*	Senstive to changes in wetlands	Prespansko Ezero, Monospitovko Blato	Protected (Prespansko Ezero); Proposed for protection (Monospitovsko Blato)	n/a
133	*Triturus vulgaris*	Senstive to changes in wetlands	Studenchishko Blato, NP Galichica, NP Mavrovo	Protected (NP Galichica, NP Mavrovo); Proposed for protection (Studenchishko Blato)	n/a
134	*Ablepharus kitaibelii*	Changes in phenology and distribution	Demir Kapija, Kozhuf, NP Galichica, Jablanica, Jasen, Osogovo, Tikvesh, Matka, Dojran, Babuna	Protected (Demir Kapija, NP Galichica, Jasen, Osogovo, Tikvesh, Matka, Dojran); Proposed for protection (Kozhuf, Jablanica, Babuna)	n/a
135	*Coluber caspius*	Changes in phenology and distribution	Present in many protected areas and proposed areas for protection		n/a
136	*Coluber najadum*	Changes in phenology and distribution	Demir Kapija, Dojran, Kozhuf, Tikvesh	Protected	n/a
137	*Cyrtopodion kotschyi*	Changes in phenology and distribution	Kozhuf, Matka, Dojran	Protected	n/a
138	*Elaphe situla*	Changes in phenology and distribution	Demir Kapija, Dojran, Jasen, Orlovo Brdo, Babuna, Radusha, Rasche, Tikvesh, Katlanovski Predel, Vodno	Protected (Demir Kapija, Dojran, Jasen, Tikvesh, Vodno, Katlanovski Predel); Proposed for protection (Orlovo Brdo, Radusha, Babuna)	n/a
139	*Lacerta agilis*	Changes in phenology and distribution	Shar Planina, NP Mavrovo, NP Pelister, Jakupica, Kajmakchalan, Kozhuf	Protected (NP Mavrovo, NP Pelister); Proposed for protection (Shar Planina, Jakupica, Kajmakchalan,	n/a

No	Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
				Kozhuf)	
140	*Lacerta trilineata*	Changes in phenology and distribution	Present in many protected areas and proposed areas for protection		n/a
141	*Lacerta vivipara*	Extinction might be expected	NP Mavrovo, Shar Planina, Osogovo	Protected (NP Mavrovo), Proposed for protection (Shar Planina, Osogovo)	n/a
142	*Ophisaurus apodus*	Changes in phenology and distribution	Demir Kapija	Protected in Demir Kapija, but no administration in place	n/a
143	*Podarcis erhardii*	Changes in phenology and distribution	Present in many protected areas and proposed areas for protection		n/a
144	*Podarcis taurica*	Changes in phenology and distribution	Present in many protected areas and proposed areas for protection		n/a
145	*Testudo graeca*	Changes in phenology and distribution	Present in many protected areas and proposed areas for protection		n/a
146	*Testudo hermanii*	Changes in phenology and distribution	Present in many protected areas and proposed areas for protection		n/a
147	*Typhlops vermicularis*	Changes in phenology and distribution	Demir Kapija, Ljubash, Osogovo, Rasche, Kozhuf, Jasen, Slan Dol, Matka	Protected without administration (Demir Kapija); proposed for protection (Ljubash, Osogovo)	n/a
148	*Vipera berus*	Changes in phenology and distribution	Jakupica, Shar Planina, Jablanica, Kajmakchalan, Osogovo, Pelister, NP Mavrovo	Protected (NP Pelister, NP Mavrovo); Proposed for protection (Jakupica, Shar Planina, Osogovo, Kajmakchalan)	n/a
149	*Vipera ursinii*	Changes in phenology and distribution; extinction might be expected for some species	Shar Planina, NP Mavrovo	Protected (NP Mavrovo), Proposed for protection (Shar Planina)	n/a
150	*Accipiter brevipes*	Changes in phenology	Demir Kapija, Tikvesh, Slan Dol, Raec	Protected (Demir Kapija, Tikvesh); Proposed for	n/a

No	Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
				protection (Slan Dol)	
151	*Alauda arvensis*	Changes in phenology	Present in many protected areas and proposed areas for protection	Protected or proposed for protection	n/a
152	*Anas acuta*	Changes in phenology	MN Ohridsko Ezero, MN Prespansko Ezero, MN Dojransko Ezero, Monospitovo	Protected in monuments of nature, proposed for protection (Monospitovo)	n/a
153	*Anas clypeata*	Changes in phenology	MN Ohridsko Ezero, MN Prespansko Ezero, MN Dojransko Ezero, Monospitovo	Protected in monuments of nature, proposed for protection (Monospitovo)	n/a
154	*Anas crecca*	Changes in phenology	MN Ohridsko Ezero, MN Prespansko Ezero, MN Dojransko Ezero, Monospitovo	Protected in monuments of nature, proposed for protection (Monospitovo)	n/a
155	*Anas penelope*	Changes in phenology	MN Ohridsko Ezero, MN Prespansko Ezero, MN Dojransko Ezero, Monospitovo	Protected in monuments of nature, proposed for protection (Monospitovo)	n/a
156	*Anas platyrhynchos*	Changes in phenology	Present in many protected areas and proposed areas for protection	Protected or proposed for protection	n/a
157	*Anas querquedula*	Changes in phenology	MN Ohridsko Ezero, MN Prespansko Ezero, MN Dojransko Ezero, Monospitovo	Protected in monuments of nature, proposed for protection (Monospitovo)	n/a
158	*Anas strepera*	Changes in phenology	MN Ohridsko Ezero, MN Prespansko Ezero, MN Dojransko Ezero, Monospitovo	Protected in monuments of nature, proposed for protection (Monospitovo)	n/a
159	*Anser anser*	Changes in phenology	MN Ohridsko Ezero, MN Prespansko Ezero, MN Dojransko Ezero, Monospitovo	Protected in monuments of nature, proposed for protection (Monospitovo)	n/a
160	*Anthus campestris*	Changes in phenology	Present in many protected areas and proposed areas for protection	Protected or proposed for protection	n/a

No	Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
161	*Anthus spinoletta*	Extinction or change in species phenology	NP Mavrovo, Shar Planina, NP Pelister, NP Galicica, Jablanica, Jakupica	Protected or proposed for protection	n/a
162	*Aquila heliaca*	Changes in phenology and distribution	Tikvesh, Taorska Klisura, Mariovo	Protected (Tikvesh); Proposed for protection (Taor, Mariovo)	Steppic corridors in Ovche Pole and along river Vardar valley
163	*Ardea cinerea*	Changes in phenology and distribution	Present in many protected areas and proposed areas for protection	Protected or proposed for protection	n/a
164	*Ardea purpurea*	Sensitive to the changes in lowland wetlands	MN Ohridsko Ezero, MN Prespansko Ezero, MN Dojransko Ezero, Monospitovo	Protected in monuments of nature, proposed for protection (Monospitovo)	n/a
165	*Ardeola ralloides*	Sensitive to the changes in lowland wetlands	MN Ohridsko Ezero, MN Prespansko Ezero, MN Dojransko Ezero, Monospitovo	Protected in monuments of nature, proposed for protection (Monospitovo)	n/a
166	*Botaurus stellaris*	Sensitive to the changes in lowland wetlands	MN Ohridsko Ezero, MN Prespansko Ezero, MN Dojransko Ezero, Monospitovo	Protected in monuments of nature, proposed for protection (Monospitovo)	n/a
167	*Burhinus oedicnemus*	Changes in phenology and distribution	Slan Dol, Osogovo	Proposed for protection	Steppic corridors in Ovche Pole and along river Vardar valley
168	*Buteo rufinus*	Changes in phenology and distribution	Demir Kapija, Drenovska Klisura, Taorska Klisura, Mariovo, Babuna, Tikvesh	Protected (Tikvesh) or without administration (Demir Kapija); Proposed for protection (Taor, Mariovo, Babuna)	Steppic corridors in Ovche Pole and along river Vardar valley
169	*Calandrella cinerea*	Changes in phenology and distribution	n/a	n/a	n/a
170	*Ciconia ciconia*	Sensitive to the changes in lowland wetlands	Present in many protected areas and proposed areas for protection	Protected or proposed for protection	n/a
171	*Circus aeruginosus*	Sensitive to the changes in lowland wetlands	Present in many protected areas and proposed areas for protection	Protected or proposed for protection	n/a
172	*Circus macrourus*	Sensitive to the changes in lowland wetlands	n/a	n/a	n/a

No	Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
173	*Delichon urbica*	Changes in phenology	Present in many protected areas and proposed areas for protection	Protected or proposed for protection	
174	*Dendrocopus syriacus*	Changes in phenology and distribution	Present in many protected areas and proposed areas for protection	Protected or proposed for protection	Forested corridors
175	*Egretta alba*	lowland wetlands	MN Ohridsko Ezero, MN Prespansko Ezero, MN Dojransko Ezero, Monospitovo	Protected in monuments of nature, proposed for protection (Monospitovo)	n/a
176	*Egretta garzetta*	Sensitive to the changes in lowland wetlands	MN Ohridsko Ezero, MN Prespansko Ezero, MN Dojransko Ezero, Monospitovo	Protected in monuments of nature, proposed for protection (Monospitovo)	n/a
177	*Elaphe quatuorlineata*	Changes in phenology and distribution	Present in many protected areas and proposed areas for protection	Protected or proposed for protection	n/a
178	*Emberiza melanocephala*	Changes in phenology and distribution	Present in many protected areas and proposed areas for protection		n/a
179	*Emys orbicularis*	Sensitive to the changes in lowland wetlands	Present in many protected areas and proposed areas for protection	Protected or proposed for protection	n/a
180	*Erinaceus concolor*	Changes in phenology and distribution	Present in many protected areas and proposed areas for protection	Protected or proposed for protection	n/a
181	*Falco naumanni*	Submediterranean area	Mariovo, Markovi Kuli, Tikvesh	Protected (Tikvesh, Markovo Kuli); Proposed for protection (Mariovo)	n/a
182	*Falco vespertinus*	Changes in phenology and distribution	Demir Kapija, Babuna	Protected without administration (Demir Kapija); Proposed for protection (Babuna)	n/a
183	*Galerida cristata*	Changes in phenology and distribution	Present in many protected areas and proposed areas for protection	Protected or proposed for protection	n/a
184	*Gallinago gallinago*	Sensitive to the changes in lowland wetlands	Present in many protected areas and	Protected or proposed for	n/a

No	Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
			proposed areas for protection	protection	
185	*Glareola pratincola*	Sensitive to the changes in lowland wetlands	Present in many protected areas and proposed areas for protection	Protected or proposed for protection	n/a
186	*Himantopus himantopus*	Sensitive to the changes in lowland wetlands	MN Ohridsko Ezero, MN Prespansko Ezero, MN Dojransko Ezero, Monospitovo	Protected in monuments of nature, proposed for protection (Monospitovo)	n/a
187	*Hirundo rustica*	Changes in phenology	Present in many protected areas and proposed areas for protection	Protected or proposed for protection	
188	*Ixobrychus minutus*	Sensitive to the changes in lowland wetlands	MN Ohridsko Ezero, MN Prespansko Ezero, MN Dojransko Ezero, Monospitovsko Blato, Katlanovsko Blato, Studenchishko Blato)	Protected in monuments of nature, proposed for protection (Monospitovsko Blato, Katlanovsko Blato, Studenchishko Blato)	n/a
189	*Limosa limosa*	Sensitive to the changes in lowland wetlands	Prespansko Ezero, Ezerani	Protected	n/a
190	*Locustella luscinioides*	Sensitive to the changes in lowland wetlands	n/a	n/a	n/a
191	*Melanocorypha calandra*	Changes in phenology and distribution	Mariovo, Ljubash, Babuna, Katlanovsko Blato	Proposed for protection	n/a
192	*Montifringila nivalis*	Changes in phenology and distribution/extinction	Shar Planina, NP Mavrovo, Jakupica	Protected (NP Mavrovo); Proposed for protection (Shar Planina, Jakupica)	n/a
193	*Motacilla flava*	Sensitive to the changes in lowland wetlands	Present in many protected areas and proposed areas for protection	Protected or proposed for protection	n/a
194	*Numenius arquata*	Sensitive to the changes in lowland wetlands	n/a	n/a	n/a
195	*Nycticorax nycticorax*	Sensitive to the changes in lowland wetlands	Prespansko Ezero, Dojranko Ezero, Katlanovo	Protected (Prespansko Ezero; Dojransko Ezero); Proposed for protection (Katlanovsko Blato)	n/a
196	*Parus lugubris*	Changes in phenology and distribution	Present in many protected areas and	Protected or proposed for	n/a

No	Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
			proposed areas for protection	protection	
197	*Passer hispalionensis*	Changes in phenology and distribution	Slan Dol, Babuna, Demir Kapija	Protected without administration (Demir Kapija); Proposed for protection (Slan Dol, Babuna)	Steppic corridors in Ovche Pole and along river Vardar valley
198	*Platelea leucorodia*	Sensitive to the changes in lowland wetlands	Prespansko Ezero, Dojranko Ezero, Ohridsko Ezero	Protected	n/a
199	*Prunella collaris*	Changes in phenology and distribution/extinction	Shar Planina, NP Mavrovo, Jakupica	Protected (NP Mavrovo); Proposed for protection (Shar Planina, Jakupica)	n/a
200	*Pyrrhocorax graculus*	Changes in phenology and distribution/extinction	Jakupica, NP Mavrovo, NP Pelister, Shar Planina, Osogovo, Galichica	Protected (NP Mavrovo; NP Pelister, NP Galichica); Proposed for protection (Shar Planina, Jakupica)	n/a
201	*Pyrrhocorax pyrrhocorax*	Changes in phenology and distribution/extinction	Jakupica, NP Mavrovo, NP Pelister, Shar Planina	Protected (NP Mavrovo; NP Pelister); Proposed for protection (Shar Planina, Jakupica)	n/a
202	*Recurvirostra avosetta*	Sensitive to the changes in lowland wetlands	Prespansko Ezero, Ezerani	Protected	n/a
203	*Sturnus roseus*	Sensitive to the changes in lowland wetlands	n/a	n/a	Steppic corridors in Ovche Pole and along river Vardar valley
204	*Tetrax tetrax*	Probably already extinct	n/a	n/a	Steppic corridors in Ovche Pole and along river Vardar valley
205	*Tichodroma muraria*	Changes in phenology and distribution/extinction	Jakupica, NP Mavrovo, Shar Planina	Protected (NP Mavrovo; NP Pelister); Proposed for protection (Shar Planina, Jakupica)	n/a
206	*Tringa hypoleucos*	Sensitive to the changes in lowland wetlands	n/a	n/a	Riparian corridors along river Vardar and other rivers
207	*Tringa nebularia*	Sensitive to the changes in lowland wetlands	n/a	n/a	Riparian corridors along river Vardar and other rivers

No	Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
208	*Tringa stagnalis*	Sensitive to the changes in lowland wetlands	n/a	n/a	Riparian corridors along river Vardar and other rivers
209	*Tringa totanus*	Sensitive to the changes in lowland wetlands	n/a	n/a	Riparian corridors along river Vardar and other rivers
210	*Vanellus vanellus*	Sensitive to the changes in lowland wetlands	Prespansko Ezero, Ezerani, Studenchishko Blato, Monospitovsko Blato, Katlanovsko Blato	Protected (Prespansko Ezero, Ezerani); Proposed for protection (Studenchishko Blato, Monospitovsko Blato, Katlanovsko Blato)	n/a
211	*Apodemus flavicollis*	Changes in phenology and distribution	Present in many protected areas and proposed areas for protection	Protected or proposed for protection	Could use the same corridors as the target species of MAK-NEN (Brown bear)
212	*Dryomys nitedula*	Changes in phenology and distribution	NP Mavrovo, NP Pelister, NP Galichica, Strazha, Shar Planina, etc.	Protected or proposed for protection	Could use the same corridors as the target species of MAK-NEN (Brown bear)
213	*Dynaromis bogdanovi*	Extinction might be expected	NP Mavrovo, NP Galichica, Shar Planina	Protected (NP Mavrovo); Proposed for Protection (Shar Planina)	n/a
214	*Eryx jaculus*	Changes in phenology and distribution	Demir Kapija, Dojran, Babuna	Proposed for protection	Steppic corridor Dolno Povardarie
215	*Lutra lutra*	Changes in phenology and distribution	Alshar, Demir Kapija, Ezerani, Jablanica, Dojransko Ezero, Ohridsko Ezero, Prespansko Ezero, Mariovo, Osogovo, Tikvesh, Belchishko Blato, Monospitovsko Blato	Protected or proposed for protection	Riparian corridors along rivers
216	*Lynx lynx balcanicus*	Changes in phenology and distribution	NP Mavrovo, NP Pelister, NP Galichica, Shar Planina, Jasen, Jakupica, Jablanica	Protected (NP Mavrovo, NP Pelister, NP Galichica, Jasen); Proposed for Protection (Shar Planina, Jakupica, Jablanica)	Could use the same corridors as the target species of MAK-NEN (Brown bear)
217	*Martes foina*	Changes in phenology and distribution	Present in many protected areas and	Protected or proposed for	Could use the same corridors as the

No	Species	Vulnerability	Representation in protected areas	Status of the PA	Potential corridors in MAKNEN
			proposed areas for protection	protection	target species of MAK-NEN (Brown bear)
218	*Meles meles*	Changes in phenology and distribution	Present in many protected areas and proposed areas for protection	Protected or proposed for protection	Could use the same corridors as the target species of MAK-NEN (Brown bear)
219	*Microtus guentheri*	Changes in phenology and distribution	Dojran	Proposed for protection	n/a
220	*Nannospalax leucodon*	Changes in phenology and distribution	Present in many protected areas and proposed areas for protection	Protected or proposed for protection	n/a
221	*Rupicapra rupicapra balcanica*	Changes in phenology and distribution	NP Mavrovo, NP Pelister, NP Galichica, Shar Planina, Ilinska Planina, Jablanica	Protected in national parks, proposed for protection in the other areas.	Could use the same corridors as the target species of MAK-NEN (Brown bear)
222	*Spermophilus citellus karamani*	Extinction might be expected	Jakupica, Jasen	Protected (Jasen); Proposed for protection (Jakupica)	n/a
223	*Talpa stankovici*	Changes in phenology and distribution	NP Pelister, Shar Planina, NP Mavrovo, Jablanica, Jakupica	Protected (NP Pelister, NP Mavrovo); Proposed for protection (Jakupica, Jablanica, Shar Planina)	n/a
224	*Vormela peregusna*	Changes in phenology and distribution	Tikvesh, Taor, Dojran	Protected (Tikvesh); Proposed for protection (Taor, Dojran)	n/a

3.2.3 Biocorridors

Building up a coherent ecological network of core areas, corridors, buffer zones and restoration areas is seen as one of the most effective measures for the protection of species and habitats and the sustainable use of nature and biodiversity, as well as providing an effective tool for mitigating (and adapting to) the effects of climate change. Macedonia has developed a National Ecological Network (MAK-NEN) as part of the Pan-European Ecological Network (PEEN). The implementation of MAK-NEN will therefore represent a significant contribution to the fulfillment of the main goal of the National Biodiversity Strategy and Action Plan, as well. During the elaboration of MAK-NEN two tasks were realized: 1. Identification and mapping of the ecological corridors and restoration areas of national importance in Macedonia and their connection to the existing core areas and buffer zones in order to provide ecological connectivity and 2. Promotion of the PEEN and ecological networks in general through the development of a Management Plan for an ecological corridor for large carnivores, with special focus on the Brown bear (*Ursus arctos*).

Integral part of MAK-NEN is the Bear Corridor Management Plan (Brajanoska et al. 2011). This document contains management objectives for all of the identified corridors, core areas, restoration areas and buffer zones. These objectives aimed primarily to maintain viable population of the brown bear, but also other large carnivores such as lynx and wolf and populations of other species dependent on forest habitats. In addition, an effort was made to identify core areas and corridors that serve to support survival of steppic and riparian species. However, this exercise (steppic and riparian corridors) was not all encompassing and it needs more to be done. Anyhow, this part of the network is functional at least for part of the territory of the country.

All of the identified corridors for movement of animals should be the key topic in adaptation of climate change impact. These biocorridors will enable both horizontal and vertical shifts of wildlife, especially animals. The maintenance of functional biocorridors will serve for safeguarding of viable populations of animals from conventional human threats such as hunting and poaching, habitat degradation and disturbance as well as climate change impact. For usfulness of MAK-NEN biocorridors for adaptation of climate change vulnerable species and habitats see Tab. 8, 9 and 10 – last column.

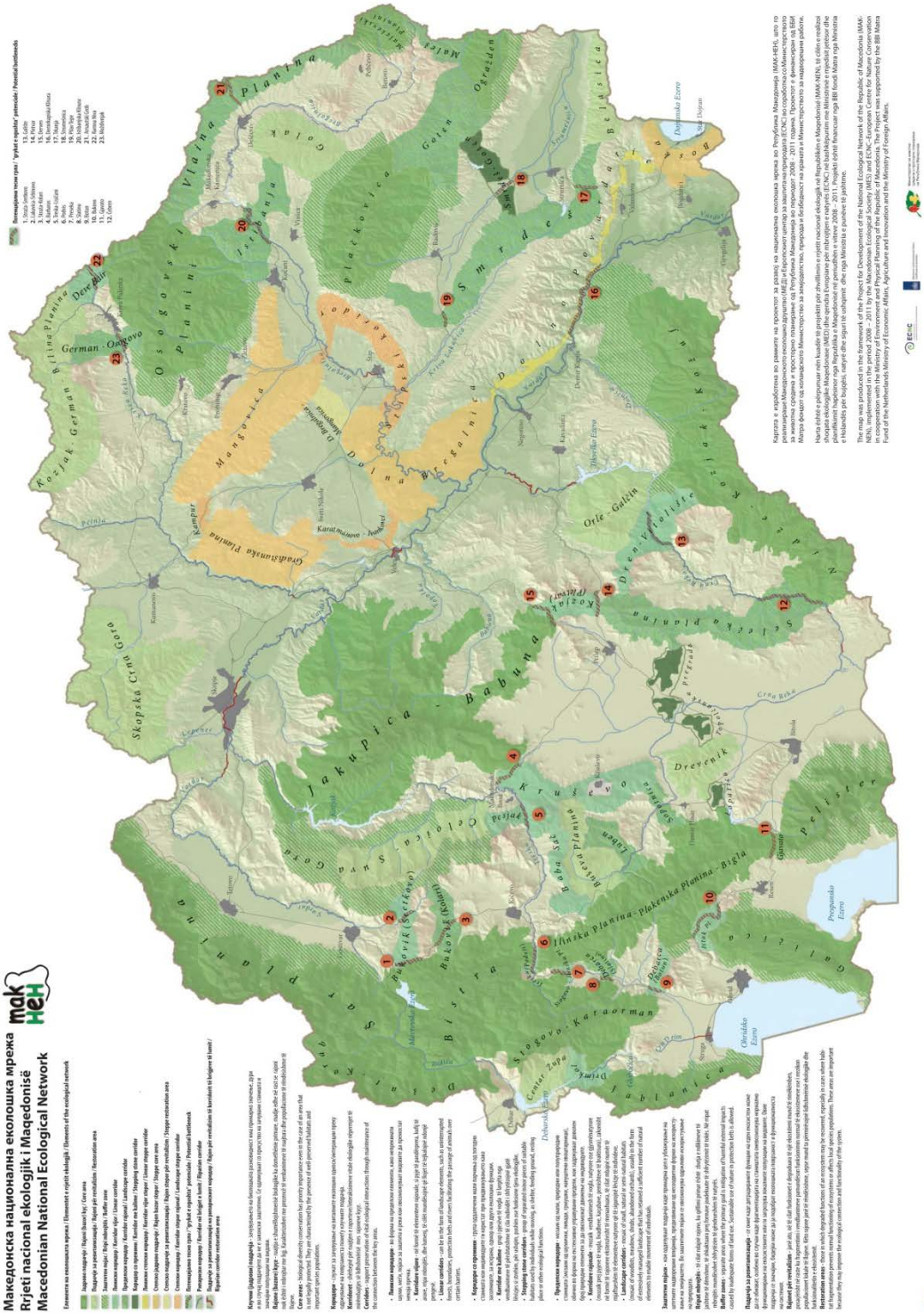

Figure 7. Macedonian Ecological Network (MAK-NEN) showing the corridors, core areas, restoration areas and buffer zones (from Brajanoska et al. 2011).

It has to be noted that MAK-NEN is national network and was designed primarily for large carnivors. Efficient clamate change adaptation concerning vulnerable biodivesity components needs regional and local approch as well, or finetuning of the network on finer scale.

3.2.4 Distribution of alien species, pathogens and parasites

Spatial-temporal species re-distribution of invasive alien species, pathogens and parasites distribution range is expected as in case with natural autochthonic flora and fauna. Response to warmer/cooler and drier/moister conditions, with possible migration in latitudinal and altitudinal directions is already happening, according to many studies.

The importance of invasive species problem in the world was reflected in Macedonia in the recent period. There were three projects on allochtonous and invasive species implemented: **1. ESENIAS - East and South European Network for invasive alien species; 2. Non-indigenous insects and their threat to biodiversity and economy in the Balkans** and **3. Asian tiger mosquito (*Aedes albopictus*** Skuse, 1894**) in Macedonia.** However, there is no significant progress related to knowledge and research in this field in Macedonia. The basic information on this subject in Macedonia was already elaborated in Chapter 1 (National circumstances).

3.2.5 Relation between climate change indicators and population trends of target species and habitats

Potential indicators (plant communities/ecosystems and plant and animal species) have been identified in previous chapters (Chapter 2 on methodology) based on the various criteria. The following text assesses the relation of these indicators and climate change impact. This assessment aims at providing ground for reaching decisions and setting better protocols for future monitoring.

3.2.5.1 Timberline in mountains

Jakupica Mt. (Mokra Mt. massif) should be taken into consideration since the territory of this mountain is entirely in Macedonia, than its highest peaks have conical shape, it has alpine zone (higher than 2200 m a.s.l. and it is accessible. Besides, some other indicator species (listed below) are distributed there (Mokra Mt. massif and Solunska Glava peak) which will contribute for decreasing of monitoring costs. Sites free of grazing have to be selected in order to avoid human impact.

There are numerous cases of shifting the timberline in subalpine and alpine regions of several mountains in Macedonia. However, these shifts cannot be attributed to climate change solely since these changes may be due to decrease or abandonment of grazing practices in mountain pastures. Such examples include extension of Molika pine in alpine zone of Pelister (however, Molika pines are spreading horizontally as well) and Jablanica Mt. Thus, beech forest will be more appropriate for monitoring.

3.2.5.2 Kermes oak ecosystem / plant community

Kermes oak community is distributed only in sub-mediterranean part of the country characterized by warm and arid conditions (summer). Since the climate change models predict further decrease of precipitation and increase of temperature, it was considered that this community will shift its distribution range toward north and higher up on the

neighboring hills and mountains (SNC). However, modeling of its distribution range in course of this report showed that these changes will be quite different than supposed (see Chapter 3.2.8 below).

3.2.5.3 Mountain pine ecosystem / community (Pinus mugo)

This community was selected due to the same reason as above – already modeled changes in course of this report. Vertical shift of the distribution range should be monitored. The modeling exercise for TNC showed that climate conditions in 100 years will not be suitable for this community even on the highest peak – Solunska Glava. Thus, mountain pine community will have to disappear.

3.2.5.4 Selected mountainous wetland habitats

High mountain wetlands (marshes and mires) are particularly susceptible to climate change. Less precipitation will be available in future, than shorter lasting of snow cover and its faster melting is predicted. The importance to monitor the changes of these ecosystems is even more pronounced due to increasing anthropogenic pressure on them (increase of mountain tourism and water extraction in mountainous areas). Wetlands on Shar Planina were pointed as target ecosystems for monitoring but Begovo Pole on Jakupica Mt. (Mokra Mt. massif) can also be considered since other monitoring activates are foreseen there as well.

3.2.5.5 Plant species

- *Pedicularis ferdinandi* - Vertical shift of the distribution range should be monitored. The modeling exercise for TNC showed that climate conditions in 50 years will not be suitable for this plant species even on the highest part of the peak Solunska Glava.
- *Crocus cvijicii* - Vertical shift of the distribution range on Galichica Mt. has to be monitored. It was expected that similar changes will happen as in the case of *Pedicularis ferdinandi* on Solunska Glava. However, modeling exercise showed that after significant decrease of the distribution range of *Crocus cvijicii* in 50 years, there will be expansion of its range in 100 years.

3.2.5.6 Animal species

- Vertical shifts in distribution range has to be monitored for the following animal specs: the mammal Balkan snow vole (*Dinaromys bogdanovi*), the bird Syrian woodpecker (*Dendrocopus syriacus*), the ground beetle *Trechus goebli* and *Paradeltomerus paradoxus*. Similar changes are expected as for the plant species.
- For horizontal shifts in distribution range: *Testudo graeca* (Greek tortoise), *Coluber najadum* (Dahli's whipsnake), *Burrhinus oedicnemus* (Eurasian Stone-curlew), *Buteo rufinus* (Long-legged Buzzard), *Podarcis taurica* (Balkan wall lizard), *Vormela peregusna* (Marbled polecat). Most of these species are connected to the submediterranean forest and shrubland communities of the Querco-Carpinetum orientalis zone (*Testudo graeca, Coluber najadum, Buteo rufinus* and *Vormela peregusna*). The shifts of the natural vegetation and changes of communities' composition will affect the distribution and population status of these animals. *Burrhinus oedicnemus* and *Podarcis taurica* are species of open habitats (steppe like habitats) and their distribution expansion might be expected.
- For monitoring of changes in the phenology: *Montifringilla nivalis* (White-winged Snowfinch). It is expected that this mountain species will change its reproductive cycle – earlier mating and nesting. The changes in the phenology of this species will

probably correspond to the snow cover duration in the high mountain zones. *Hirundo rustica* (Barn swallow), *Delichon urbica* (House martin), *Neophron percnopterus* (Egyptian vulture) and *Ciconia ciconia* (White stork) are species easy to monitor from the aspect of their migration (spring arrival and autumn departure dates) and changes in the reproduction biology (mating, nesting, reproduction success).

- Species connected to lowland wetlands: *Vanellus vanellus* (Northern Lapwing), *Triturus vulgaris* (Smooth newt), *Rana balcanica* (Balkan water frog), *Diacyclops pelagonicus* and *Lycaena dispar*. These species are sensitive to lowland wetlands hydrology which is expected to be disturbed significantly due to the climate change.

3.2.6 Changes in phenology

Many studies examining the impacts of global warming on terrestrial ecosystems reveal a consistent pattern of change, the response to warming by phenological change across the northern hemisphere seems to be especially well documented (IPCC 2001; Menzel et al. 2006). The timing of seasonal activities of animals and plants is perhaps the simplest process in which to track changes in the ecology of species in response to climate change (Gian-Reto et al. 2002). Most of the changes in phenology are observed during the spring period (arrival of migratory species, flowering of plants, breeding birds and amphibians, appearance of butterflies etc.). The spring phenological signal is considered to be a perfect indicator for climate change impacts (Menzel et al. 2006). Also, some of the changes can be observed in the autumn period (e.g. leaf senescence).

Birds, butterflies and wild plants, in particular, include popular and easily identifiable species and thus have received considerable attention from the public. As a result many long-term phenological data sets have been collected (Gian-Reto et al. 2002). Studies in Europe and North America have revealed phenological trends that very probably reflect responses to recent climate change. In general, spring activities have occurred progressively earlier since the 1960s (Gian-Reto et al. 2002).

Some evidence also indicates a later onset of autumnal phenological events, but these shifts are less pronounced and show a more heterogeneous pattern. Studies reveal different proportions of bird species which advance, delay or do not change autumn migration, and trends of leaf colouring of trees at neighbouring stations often show contradictory signals (Gian-Reto et al. 2002). Menzel et al. (2006) considered the changes in leaf colour as doubtful signal of the changes.

The impact of the climate change on the phenology of species has not been studied in Macedonia, although such activities could be very important as an indicator of the changes induced by climate change. Phenology can be easily observed, at least in some species and this should be reflected in the Action Plan for Climate Change Adaptation in Macedonia. Such an activity can be well used for communication with the wider public, as well.

Studying and monitoring of phenological changes can easily be integrated into national biodiversity monitoring system, but unfortunately such monitoring system in Macedonia does not exist. The only example in this relation is irregular/incomplete monitoring of some migratory bird species. Recently, the arrival of certain bird species in Macedonia was being recorded (swallows, storks) but the time series is very short to be used for analyses (Velevski, pers. comm).

3.2.7 Impacts of the increased atmospheric CO_2 on ecosystems

Scientific literature on climate change impact on ecosystems deals with effects of particular changes (increased atmospheric and soil CO_2, increased temperatures, soil water availability) on particular components/processes of the ecosystems. However, it is very difficult to perform an integral estimate of the climate change impact on ecosystems.

It is well known that the increased temperatures tend to stimulate photosynthesis and primary production i.e. carbon assimilation. Respiration and carbon release from ecosystems also increase with the temperature increase (Larcher 1995). The resulting effect whether carbon assimilation or release will prevail depends on number of ecological factors (some of them hard to predict) such as dominant plant species in the ecosystem, local topography, annual dynamics of temperature and humidity, soil properties, etc.

The effect of increased CO_2 is also well known. Plants tend to acquire atmospheric CO_2 to a certain level (carbon saturation) which again depends on number of factors, primarily the plant species. Increased atmospheric CO_2 has the potential to increase plant growth in a variety of ways: stimulation of photosynthesis, depression of respiration, relief of water and low light stresses, relief of nutrient stress by several mechanisms (greater nutrient use efficiency, increased nutrient uptake through root-microbial associations, increased symbiotic nitrogen fixation), and delay of leaf senescence that prolongs the growing season. Some of the mechanisms that promote increased growth could be particularly important in arid/semi arid and infertile areas. However there is great uncertainty about whether or not these mechanisms operate for prolonged periods in natural ecosystems (Mellilo et al. 1990).

One of the aspects to be discussed is the litter production and litter decomposition in the ecosystems. Litter decomposition and plant respiration (above- and belowground) are the primary sources of CO_2 efflux from the terrestrial ecosystems. Some studies show that the climate change will affect litter decomposition than the ecosystems' production (Kirschbaum 1995; Kätterer et al. 1998). Increased temperature stimulates the litter decomposition rates (Kirschbaum 1995; Pöhhacker & Zech 1995). On the other hand, increased temperature and increased atmospheric CO_2 stimulate production of "low-quality" litter that has lower decomposition rates i.e. lower carbon release (Hirschel et al. 1997; Moore et al. 1999). Basic litter decomposition rates in Macedonian ecosystems have been measured for the Italian and Turkey oak ecosystem on Galichica (Grupche et al. 1983) and for montane beech forest in Mavrovo National Park (Hristovski et al. 2001). However, the effects of climate change were not assessed.

Some aspects of the climate change impact on the primary production of ecosystems in Macedonia have been studied only in forest ecosystems. There are no targeted studies on the level of single plant organism. The best examples of ecosystem studies are the ones that concern montane beech forests and oak (Italian and Turkey) forests. Forests in Macedonia cover surface of 947653 ha with wood volume of 74,343,000 m^3 and annual increment of 2.02 $m^3 \cdot ha^{-1}$ (First National Communication to UNFCCC).Oak forests occupy 283,050 ha and beech forests about 226016 ha (Grupche 2009).

Grupche (2009) estimated the primary production and carbon sequestration in one oak and one beech forest community. Phytomass production in the Italian and Turkey oak ecosystem (Quercetum frainetto-cerris macedonicum) is 237 $t \cdot ha^{-1}$out of which 189.6 $t \cdot ha^{-1}$ is aboveground and 47.02 $t \cdot ha^{-1}$ is belowground phytomass. Annual net-primary production is 11,09 $t \cdot ha^{-1} \cdot y^{-1}$.Phytomass of the montane beech forest (Calamintho grandiflorae–

Fagetum) is 347 $t \cdot ha^{-1}$ (297 $t \cdot ha^{-1}$ is aboveground and 57.75 $t \cdot ha^{-1}$ is belowground). Annual net-primary production (19.7 $t \cdot ha^{-1} \cdot y^{-1}$) is higher than the one of the oak ecosystem. The total phytomass of the Italian and Turkey oak ecosystem and montane beech forest in Macedonia is 45800 and 34227 Kt, respectively. The aboveground phytomass of these two ecosystems is 36702 and 29390 Kt, respectively. The belowground phytomass was estimated to be 9102 and 5701 Kt, respectively. Total net-primary production is 2147 and 1945 $Kt \cdot y^{-1}$ for Italian and Turkey oak ecosystem and montane beech ecosystem, respectively. Aboveground net-primary production is 1725 and 1357 $Kt \cdot y^{-1}$, while the belowground is 421 и 583 $Kt \cdot y^{-1}$, respectively (excluding non-perennial tissues).The assimilation of CO_2 was estimated at 3927 and 3550 $Kt \cdot y^{-1}$ for Italian and Turkey oak ecosystem and montane beech ecosystem, respectively. Total reserves of carbon in the forest floor are 905 Kt in the oak ecosystem and 868 Kt in the beech ecosystem. These data show the importance of Macedonian forests as sinks for atmospheric carbon.

3.2.8 Modelling

For the modeling purposes three species (plants *Crocus cvijicii* and *Pedicularis ferdinandi*, and insect species *Trechus goeblii matchai*) and two plant communities (xero-termoophilous Kermes oak scrub and sub-alpine mountain pine shrubland) were selected. The main reason for this selection was not the importance of these species and communities, but the availability of data. (The lack of precise and comprehensive biodiversity data in Macedonia was stressed several times in this report.) Modeling of the vulnerability of the endangered Balkan lynx population was not finalized because the preliminary results showed that the results are not reliable since too many uncertainties concerning the forest changes exist.

3.2.8.1 Scenario

The assessment was performed according to the **A1B scenario** from Special Report on Emissions Scenarios (SRES) published by IPCC in 2000 (IPCC 2000). This scenario takes into account a market oriented world with fastest per capita economy growth. The scenario envisages world population maximum in 2050 and then decline. The governance will be with strong regional interactions and income convergence; the technology will relay on balanced use of fossil and non-fossil energy sources. It is rather pessimistic scenario but less pessimistic than A2 and A1FI. Assessment of impacts and vulnerability by use of multiple scenarios was not performed due to the lack of time (according to the project requirements).

3.2.8.2 Approach

As described in methodology chapter, MaxEnt software will be used to model the climate change induced distribution range changes of selected species and communities. MaxEnt is used to define the suitable habitat for certain species based on its preference for particular complex of abiotic ecological factors. It can be used for plant communities as well, since communities can be represented by the key-stone species which can be then modeled individually. MaxEnt uses presence points to define species distributions based on simple functions related to each climate variable (Phillips et al. 2006). Of many advantages that MaxEnt have, one is that model can be developed with presence data only. In some sense this releases us from unreliable absence records which are used by other models. Another advantage of MaxEnt model is possibility to run both types of variables: continuous and categorical. Continuous variables have real values which correspond to measurable

quantities like elevation, "distance to", temperature or precipitation. Categorical variables contain a limited number of discrete values like land use categories, soil or vegetation type etc. (Phillips & Dudik 2008).

Modeling species' current and future geographic range requires three types of data:

- information on the species' current geographic distribution (it also defines the current complex of ecological factors),
- data on current climatic conditions,
- data on predicted future climatic conditions.

Climatic data are free to download from (http://www.worldclim.org/bioclim) (Hijmans et al. 2005) where 19 bioclimatic variables (Tab. 4) are available with past, current and future conditions (IPCC 4) with original resolution of 1 km x1 km. These data are convenient since they provide spatial distribution of numerous present and future climate parameters based on the models recommended by IPCC 4: A1B, A2A, B2A, A1 and B1. The same models were used for the climate change scenarios in Macedonia (Karanfilovski 2012) – however they cannot be downscaled to 1x1km grid and used in spatial-modeling software's.

3.2.8.3 Modeling results

MaxEnt model was used to predict the possible changes in distribution of four plant species and one ground beetle according to the climate change scenario A1B (IPCC 4). The model was developed using current distribution data, 19 climatic variables representing the current and future climate (http://www.worldclim.org/bioclim) (Hijmans et al. 2005) and variables defining the terrain (elevation, aspect & slope). All environmental variables (Tab. 4) were rasterized using ESRI ArcGIS 9.2 in order to have the same pixel size (1x1 km), same geographic projection and datum (Lambert Azimuthal Equal Area with WGS '84 datum). All output models were find to perform with high prediction (AUC > 0.9). Models with performance measure values more than 0.75 are considered potentially useful (Elith 2002; Phillips & Dudik 2008).Evaluation of the models was done with *k*-fold cross-validation which consists of randomly dividing the dataset into *k (k=5* in our case*)* independent partitions, using *k*−1 of them to calibrate the model, and evaluate with the left-out partition.

Climate models were analyzed in ESRI ArcGIS 9.2 and the following results were produced:

- Predicted current distribution model (according current climate -Y2000);
- Projected climate distribution model Y2050;
- Projected climate distribution model Y2100;
- Spatial analysis of distribution area for the three periods (Y2000, Y2050 & Y2100).

To define the presence or absence with current and future projections, a suitability map for all five species was produced from the average probability of occurrence (MaxEnt output map) using Minimum Training Presence (MTP) logistic threshold value (Young et al.2011). MTP uses the suitability associated with the least suitable presence record as the threshold. In other words the species is predicted to be present in areas where suitability is better or equal with the minimum suitable conditions where species currently occurs. The resulted maps were afterwards tested if they encompass the recent confirmed species occurrence (Franklin 2011).

Results from the spatial analysis are presented in Tab. 11 and the climate distribution models are presented on maps [Figs. 10 (a-c), 13 (a-b), 14 (a-c), 16 (a-c) and 19 (a-c)] for each modelled species and each period respectively.

Table 11. Spatial analysis of observed and modeled (predicted) distribution.

Species	**Modeled distribution (area, km^2)**			**Observed distribution (area, km^2)**
	Y2000	Y2050	Y2100	
Pinus mugo	182	51	0	10,63
Trechus goebli	108	1	0	22,58
Quercus coccifera	1028	228	1884	805,17
Crocus cvijicii	8	5	29	2,81
Pedicularis ferdinandi	31	0	0	1,52

3.2.8.3.1 Crocus cvijicii

Crocus cvijicii is plant species (Fig. 8) known to occur only on Galichica Mt. - Stara Galichica (Fig. 9). It grows only in the high-altitude zone of the mountain on pastures (1800-2150 m) on limestone. It flowers during the late spring / early summer period, mostly in humid places (above timber line) or near the remaining snow patches.

Figure 8. *Crocus cvijicii* on Galichica Mt. (V. Matevski)

Figure 9. Stara Galichica with the peak Magaro – the site with *Crocus cvijicii* habitat

The present distribution of *Crocus cvijicii* is presented in Fig. 10a (polygon with green lines). The modelled range with MaxEnt is presented by red polygons (consisted of 1x1km squares) and covers total of 8 km^2 (Tab. 11). The modelled distribution range is larger than the real distribution since the model finds larger suitable habitat than the one currently occupied. However, the model does not consider all ecological factors (e.g. the soil and bedrock type) and especially historic and antropogenic factors. Thus the model presents the potential distribution range which might not be fully resized.

The change in climate in 2050 (Fig. 10b) will shrink the potential distribution range of the species to 5 km^2 (Tab. 11). According to the modelling for 2100 the potential distribution range (Fig. 10c) of the species will expand to 29 km^2 and will cover northern (lower) parts of Galichica Mt.

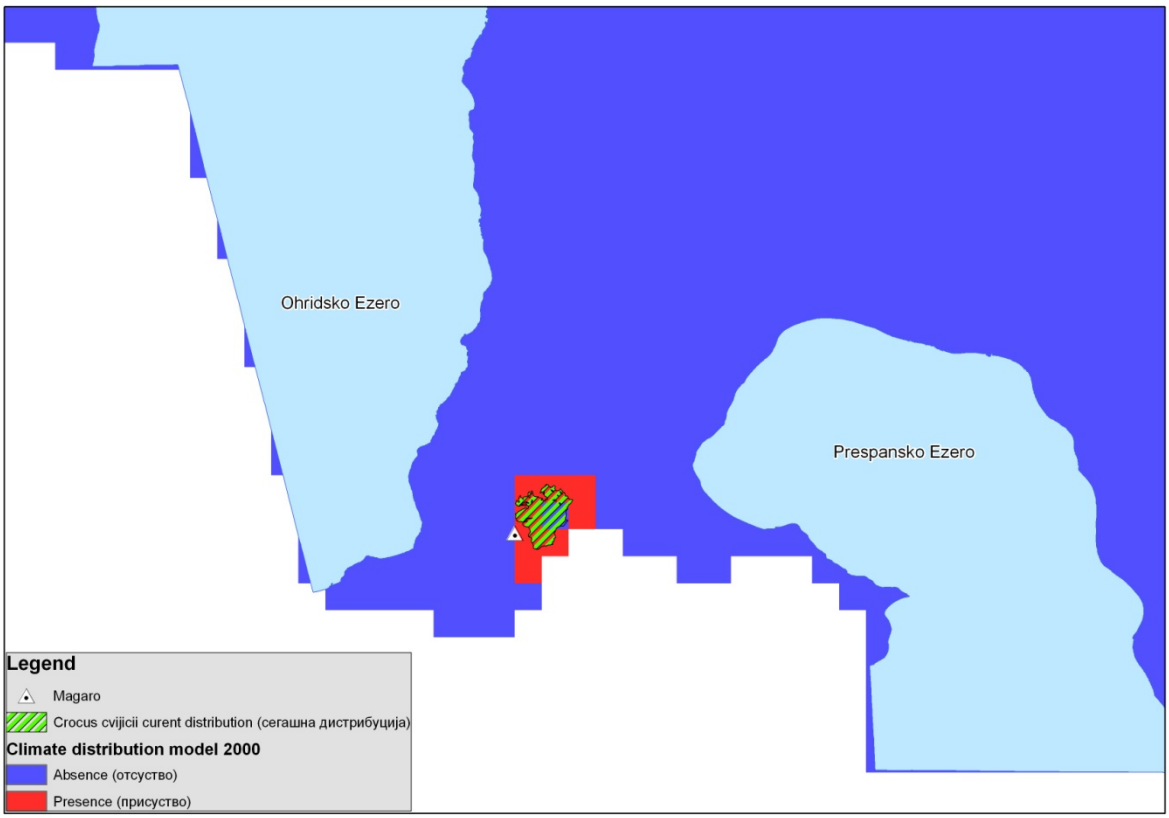

Figure 10-a Current distribution and modeled range on the bases of suitable habitat

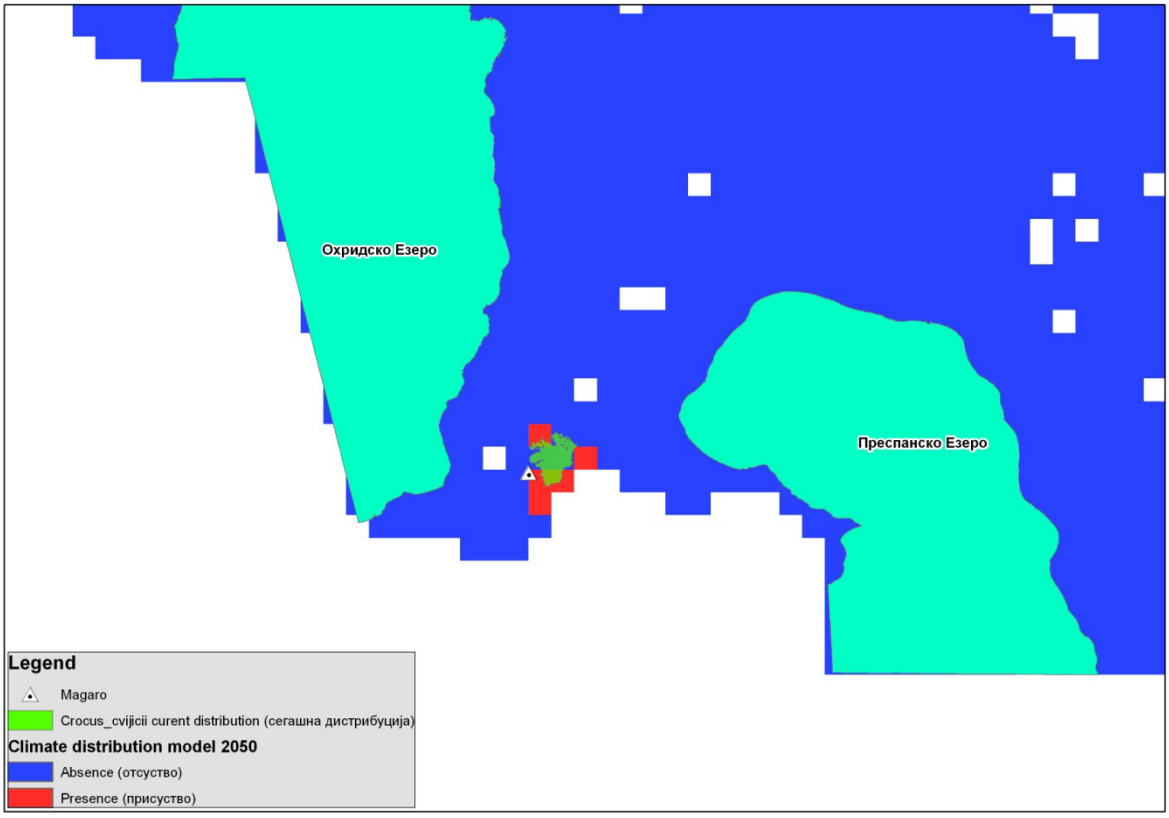

Figure 10-b Modelled distribution in 2050

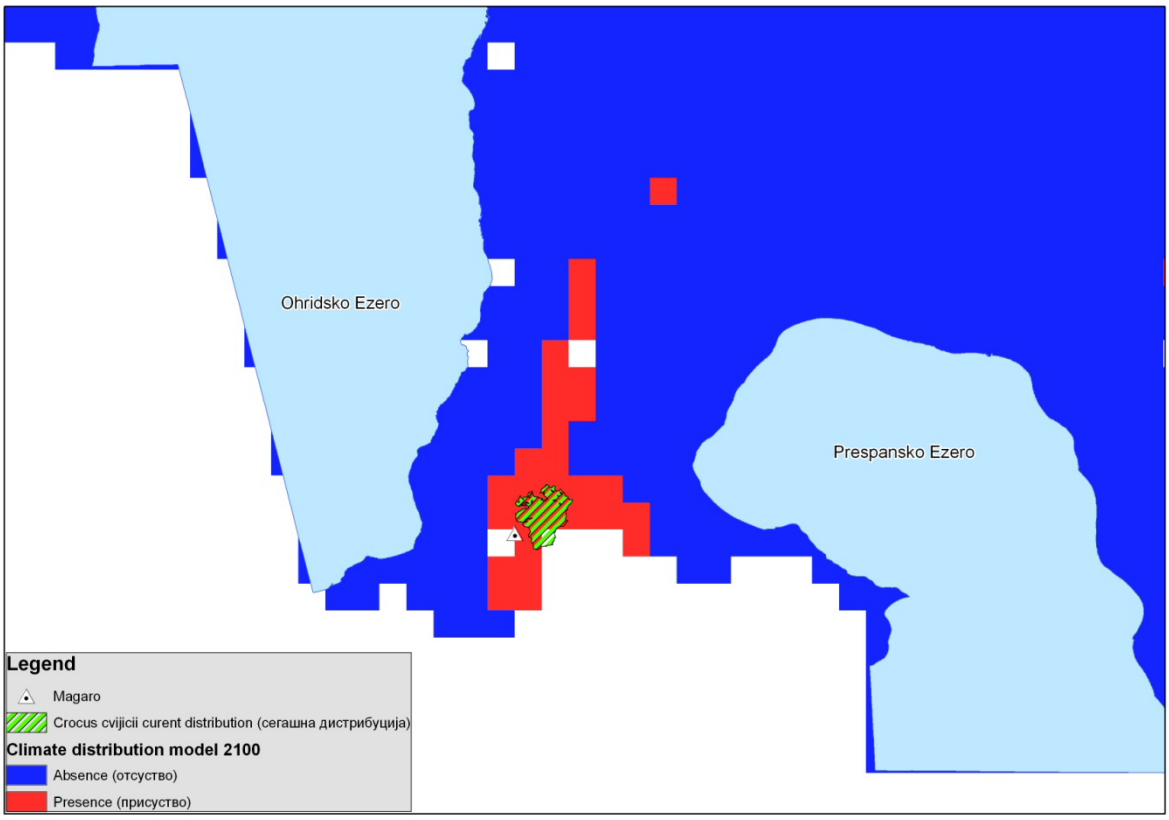

Figure 10-c Modeled distribution in 2100

Figure 10. Current and modelled distribution range of *Crocus cvijicii*

3.2.8.3.2 *Pedicularis ferdinandi*

Pedicularis ferdinandi (Fig. 11) is endemic plant species (fam. Scrophulariaceae) of Mokra (Jakupica) Mt. (Fig. 12). Its present distribution is consisted of scattered localities in the high altitude zone, at altitudes of 2100-2300m (Fig. 13a, green polygon). The modeled presented distribution is much larger i.e. suitable habitats and climate can be found in most of the alpine zone of Mokra Mt. (Fig. 13a, red polygon). According to the performed modeling, *Pedicularis ferdinandi* will disappear already in 2050 (Fig. 13b) due to the sever change in climate.

Figure 11. Pedicularis ferdinandi on Mokra Mt.

Figure 12. Solunska Glava, the highest peak of Jakupica (Mokra Mt. massif)

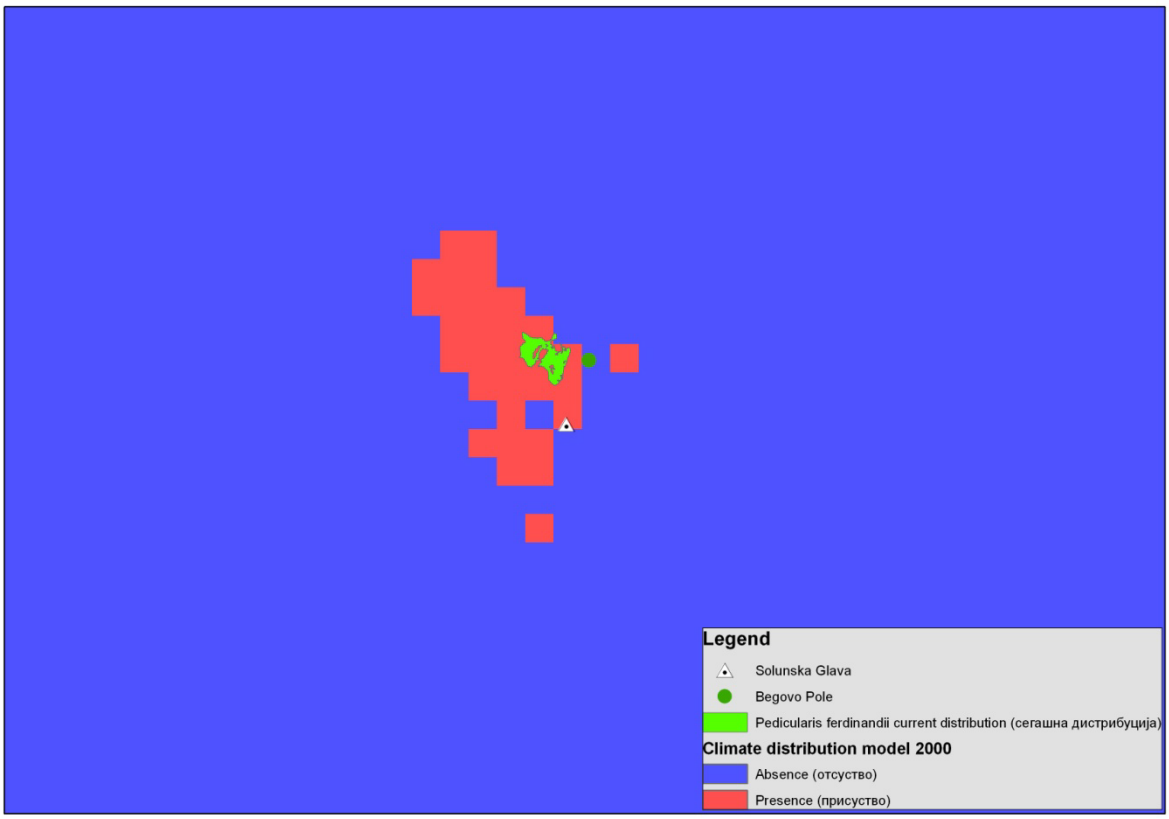

Figure 13-a Current distribution and modeled range on the bases of suitable habitat

Figure 13b Modeled distribution in 2050

Figure 13. Current and modelled distribution range of *Pedicularis ferdinandi*

3.2.8.3.3 *Trechus goebli matchai*

Trechus goebli matchai (Fig. 5) is small ground beetle species (Coleoptera, Carabidae) known to be an endemic for Mokra Mt. It occupies primarily rocky sites or pastures with rocks at the altitudes above 2200 m. So far, it is recorded from the following localities: Solunska Glava peak (Fig. 12), Marina Rupa, Solunsko Pole and Begovo Pole (Fig. 14-a, polygon with green lines). According to the model, it might occupy much larger area of 108 km^2 (Tab. 11) which might be expected (thorough field research will probably prove its occurrence in other high-altitude localities on Mokra Mt.) (Fig. 14-a, red color). A significant shrink of the distribution areas is expected in 2050 according to the model (Fig. 14-b) - suitable conditions for its survival will be matched only on the top of the Solunska Glava peak. In 2100 (Fig. 14-c) the species will disappear completely.

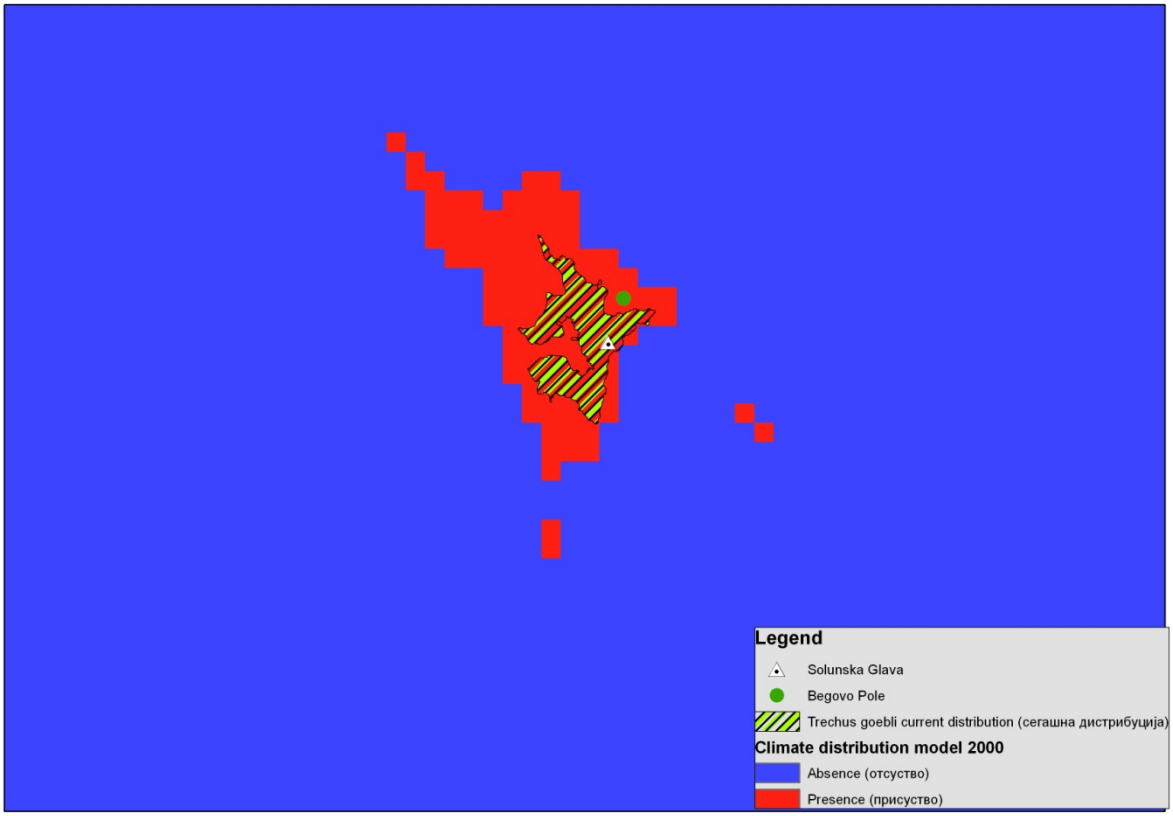

Figure 14-a Current distribution and modeled range on the bases of suitable habitat

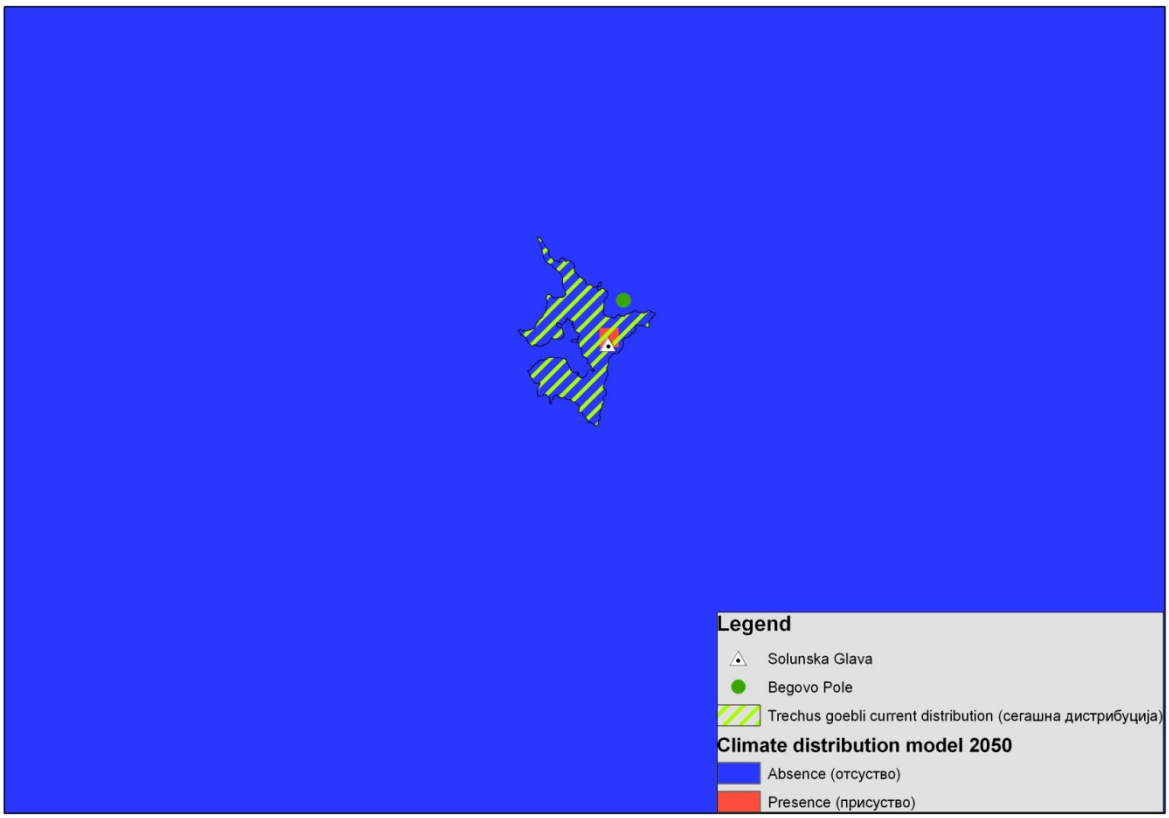

Figure 14-b Modeled distribution in 2050

Figure 14-c Modeled distribution in 2100 (the species has disappeared)

Figure 14. Current and modelled distribution range of *Trechus goeblii matchai*

The results of the modelling of the distribution of Trechus goebli matchai seem logical and expected. However, the model does not take into account the specific ecology of the species that is not well known. Trechus goebli matchai is part of the ground beetle species with affinity to inhabit underground habitats (endogean species). Another scenario for this species is that it will shift its phenology (earlier reproductive cycles) or more likely it will live deeper in the rocky ground and thus survive and adapt to the predicted climate change (expert judgment).

3.2.8.3.4 *Pinus mugo* community (Mountain pine)

Mountain pine is distributed on Mokra and Shar Planina mountains. However, it makes vast shrubby communities only on Mokra Mt. (Fig. 15). Here, it covers the biotopes in the subalpine and alpine zone. The present distribution of the Mountain pine (green color) is much smaller than the modeled one (Fig. 16-a, red color). The modeled distribution range is larger than the real distribution since the model finds larger suitable habitat than the one currently occupied. However, the model does not consider all ecological factors (e.g. the soil and bedrock type) and especially historic and antropogenic factors. Thus the model presents the potential distribution range.

A considerable shrink might be expected in 2050 (Fig. 16-b) while in 2100 it will completely disappear from Mokra Mt. (Fig. 16-c).

Figure 15. Mountain pine (*Pinus mugo*) scrubland on Solunska Glava and surrounding peaks and slopes (Mokra Mt. massif)

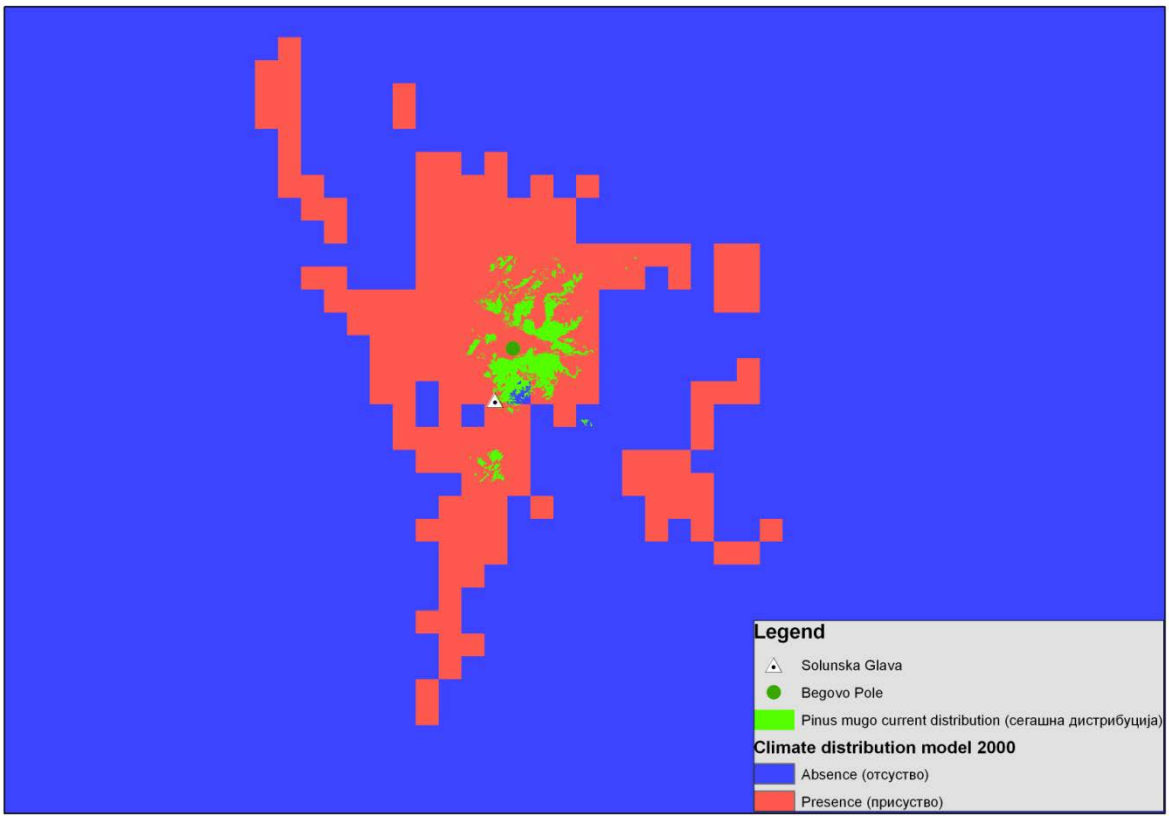

Figure 16-a Current distribution and modeled range on the bases of suitable habitat

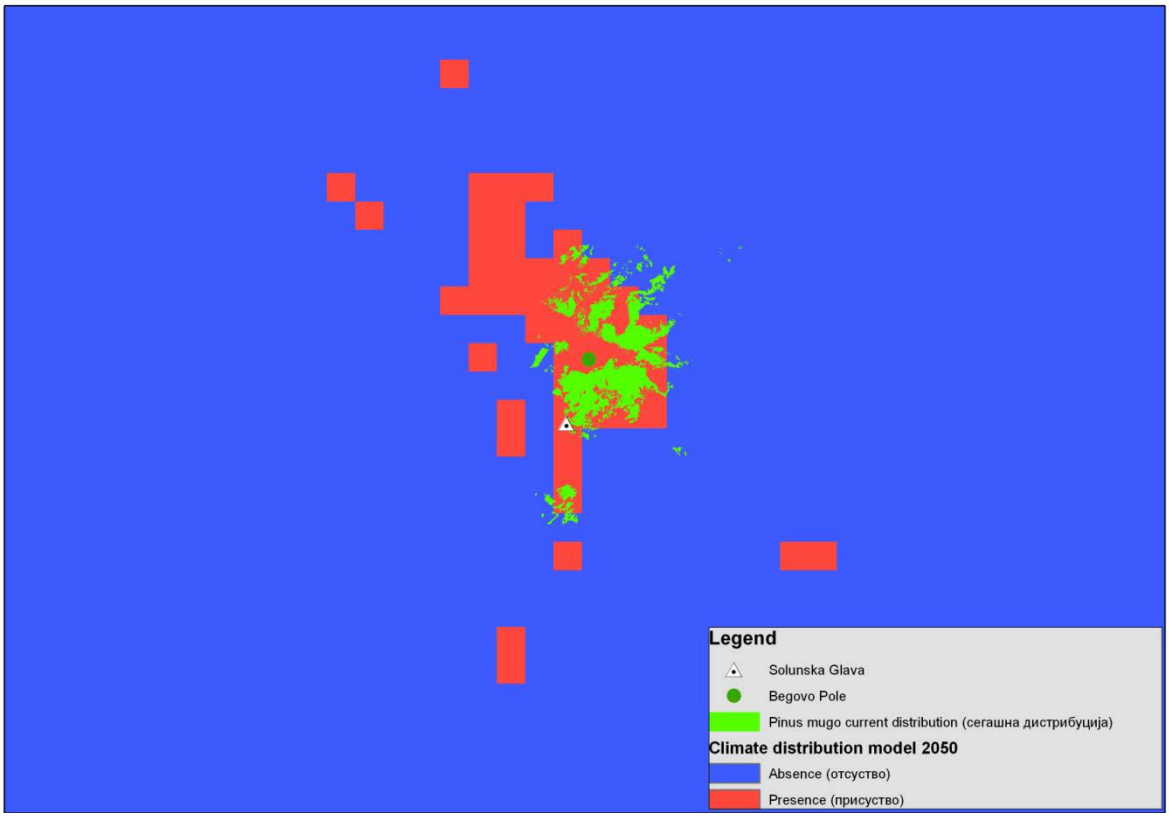

Figure 16-b Modeled distribution in 2050

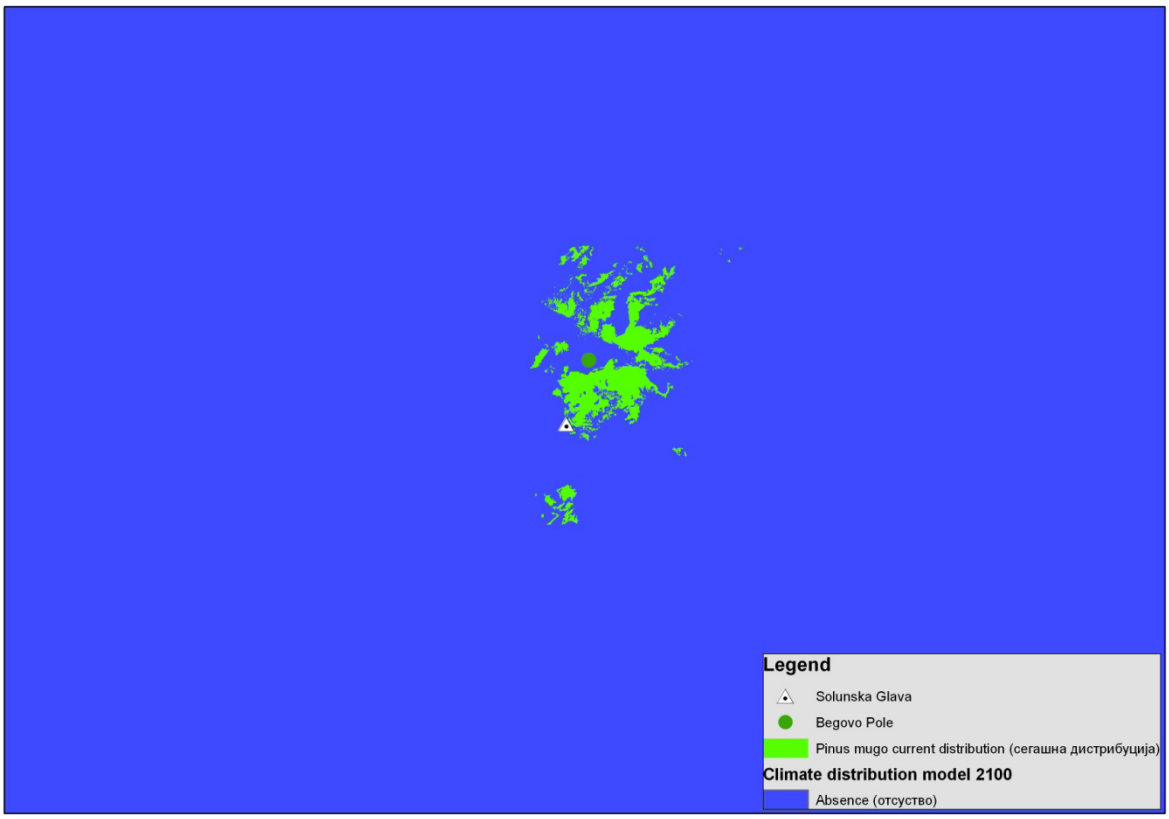

Figure 16-c Modeled distribution in 2100

Figure 16. Current and modelled distribution range of mountain pine community (*Pinus mugo*)

3.2.8.3.5 *Quercus coccifera* community (Kermes oak)

Kermes oak (Fig. 17) grows in south-east Macedonia in the area between Demir Kapija, Gevgelija and Strumica (Fig. 19-a, green color). Kermes oak, Oriental hop-hornbeam and Pubescent oak are the edifiers (main species) of the pseudomaquis vegetation represented by the association Querco cocciferae-Carpinetum orientalis (Fig. 18). The modeled present distribution (Fig. 19-a, polygon with green lines) corresponds well to the current field situation. A shift towards east (Strumica valley) should be expected in 2050 according to the presented model (Fig. 19-b). A remarkable and unexpected shift of the distribution range as shown in Fig. 19-c is expected for the year 2100 - the most suitable areas will be the ones in east Macedonia (Osogovo, Vlaina, Plachkovica, Ograzhden and Belasica mountains) and Mariovo. The shift of the distribution range of Kermes oak was already predicted in the First and Second National Communication, but in those reports the shift was expected towards north, along the river Vardar and its tributaries.

Figure 17. Kermes oak (Quercus coccifera)

Figure 18. Kermes oak (*Quercus coccifera*)community in the area around village Miravci

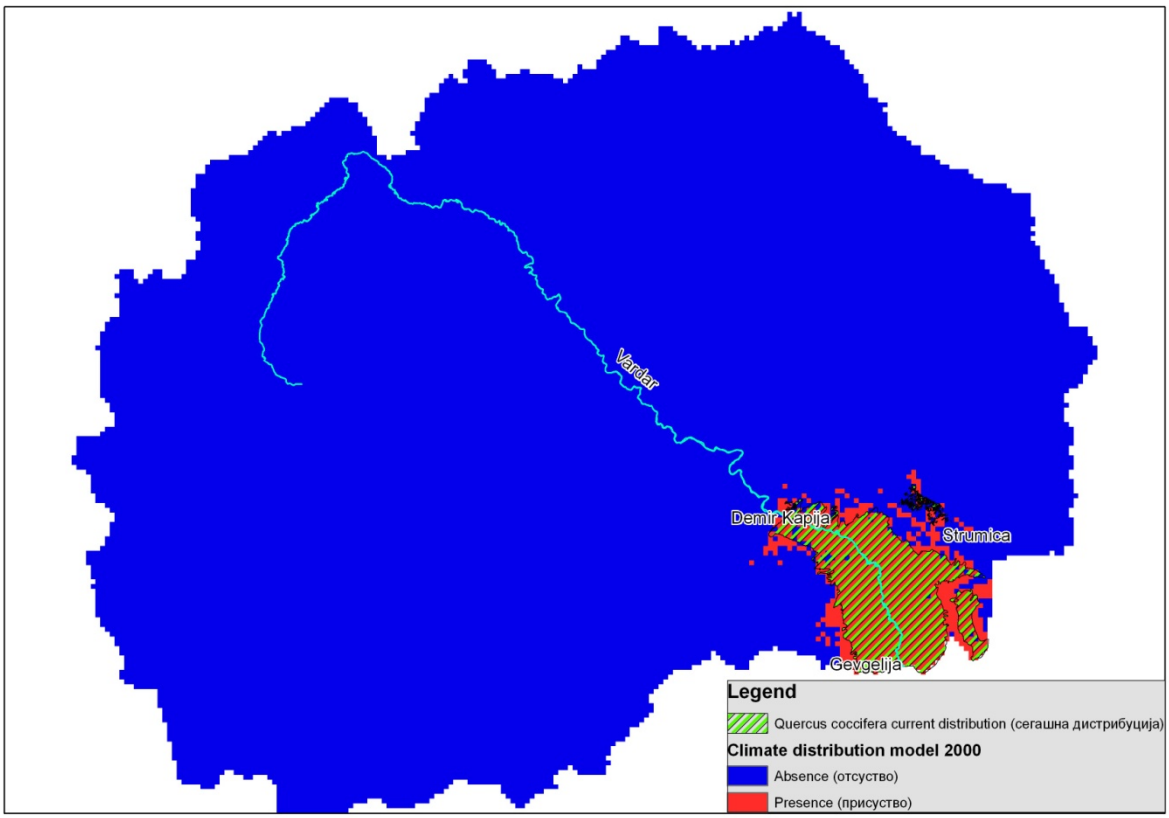

Figure 19-a Current distribution and modelled range on the bases of suitable habitat

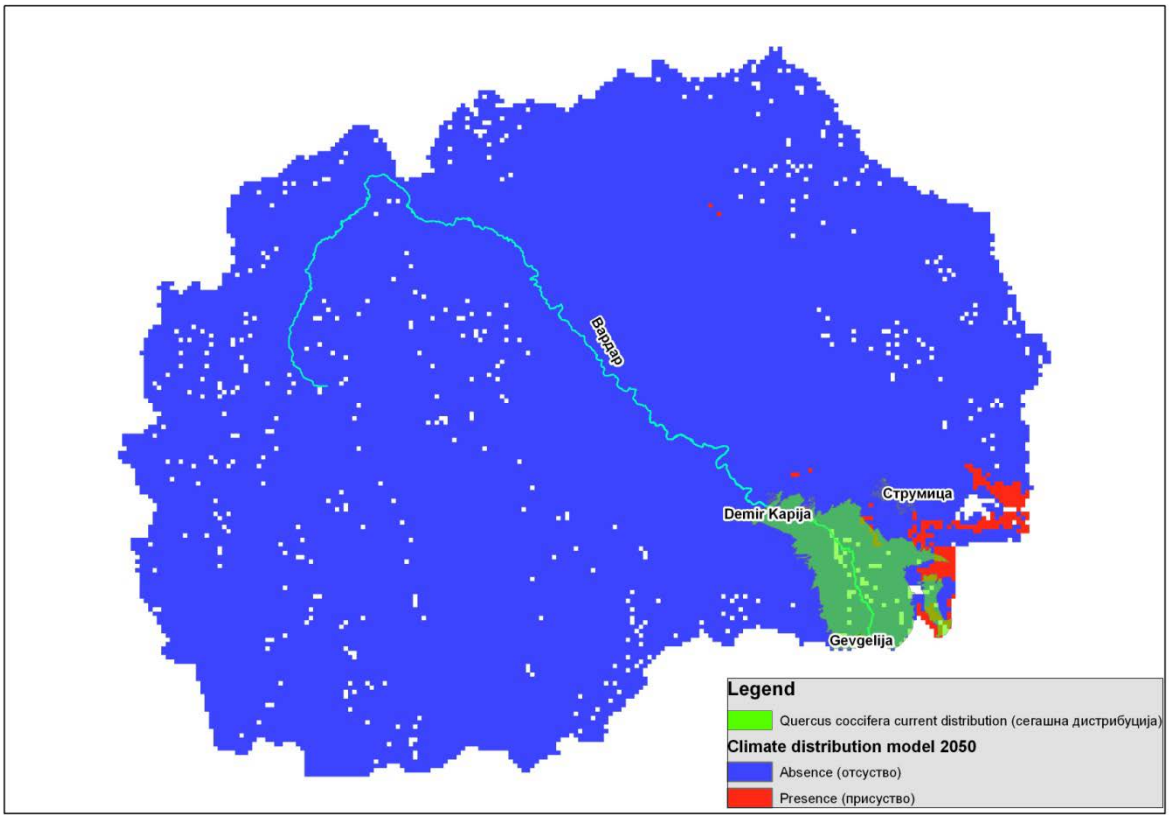

Figure 19-b Modeled distribution in 2050

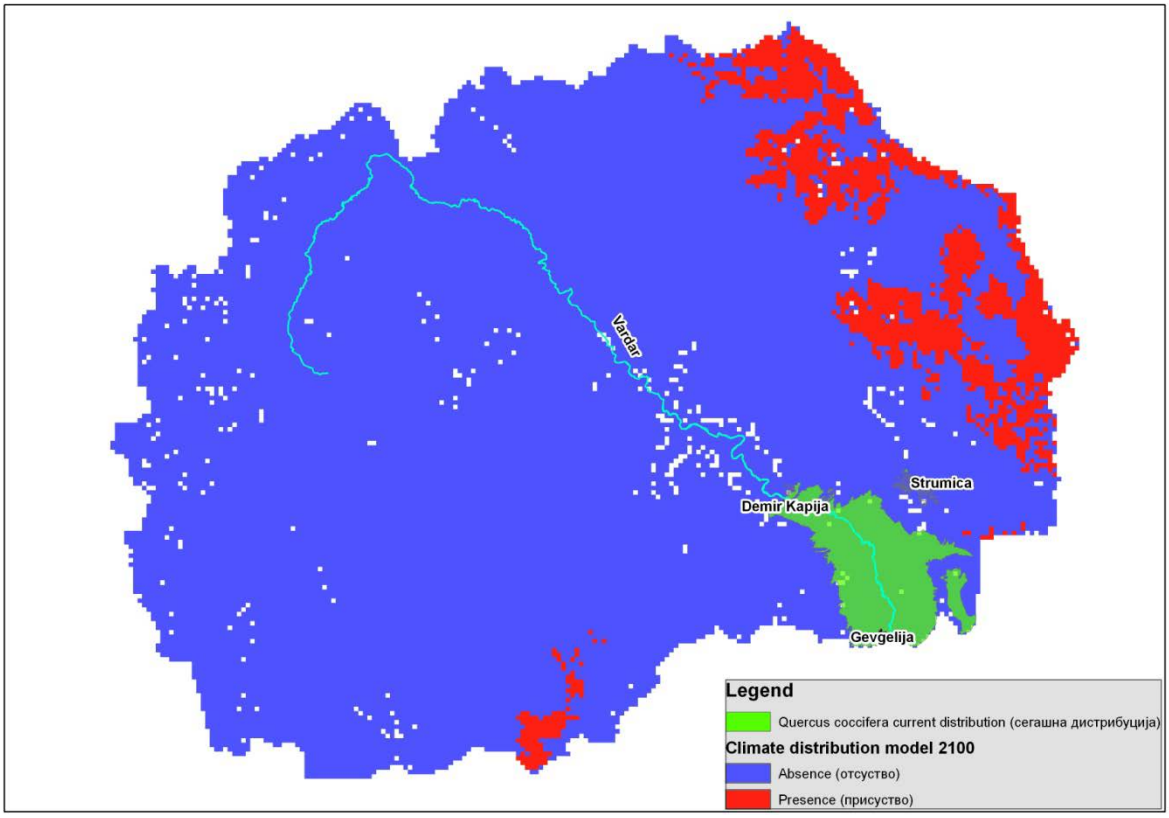

Figure 19-c Modeled distribution in 2100

Figure 19. Current and modelled distribution range of Kermes oak community (*Quercus coccifera*)

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4 Action plan for climate change adaptation in biodiversity sector (Melovski Ljupčo*, Hristovski Slavčo*, Matevski Vlado*)

Action plan for climate change adaptation in the sector of biodiversity was prepared in similar way as the action plan in SNC. Strategic planning was based on simple list of identified problems that prevents reaching the main goal – **to prevent excessive loss of biodiversity in Macedonia during this century due to the climate change impacts**. The basic tool will be to allow available adaptation processes to take place.

Second National Communication contained several actions aiming at collection of data on biodiversity in relation to climate change. However, some of these activities were partially fulfilled within the frame of the National Biodiversity Strategy (2004) or most probably will be part of the new national biodiversity strategy which is in preparation. Thus, the activities concerning basic data collection were modified in order to reflect better the needs for data on species and ecosystems, but in relation to climate change.

The Action Plan within the Second National Communication contained activities which were arranged according to the main identified problems. The Action Plan of the Third National Communication also follows these problems (although some of them modified to better reflect the recent changes in the biodiversity sector).

4.1 Identified problems

1. Lack of data for precise distribution of different species, population density and abundance; Vegetational map - communities and habitats; Insufficient definition of biogeographical characteristics of Macedonian territory – addresed in **Action 1**
2. Lack of data on vulnerable biodiversity components to climate change– addresed in **Actions 2-5**
3. Monitoring system of climate change impact on biodiversity does not exist – addresed in **Actions 6-11**
4. *Ex situ* conservation of wild species threatened by the climate change does not exist – addresed in **Action12**
5. Spatial plan does not consider consequences of climate change to biodiversity– addresed in **Action 13-17**
6. Problem of periodic natural and induced hydrological fluctuations; Water extraction is not regulated – addresed in **Action 18-23**
7. Impact of climate change on mountain ecosystems – addresed in **Actions 24-25**
8. Protected areas systems was not established to cope with the climate change impact – **Actions** addresed in **26-27**
9. Lack of good intersectoral cooperation– addresed in **Actions 28-29**
10. Insufficient capacities (human and knowledge)– addresed in **Actions 30**
11. Lack of awarenes about climate change impact on biodiversity – addresed in **Action 31**
12. Lack of financial mechanisms – addresed in **Action 32**

* Institute of Biology, Faculty of Natural Sciences and Mathematics, Ss. Cyril and Methodius University, Skopje, Republic of Macedonia

4.2 Short gap analyses of the implementation of the Action Plan of Second National Communication

Only few of the actions proposed in the Action Plan within the SNC were implemented. We identified only seven (7) actions that were completely or only partially elaborated – most of them within the separate reports of the Third National Communication. MAK-NEN project (Establishment of Macedonian Ecological Network) resulted in partial completion of two actions regarding the ecological network. MAK-NEN project focused primarily on Brown bear and only touched the species of steppic areas and riparian species. Identification of biocorridors, core areas, restoration areas and buffer zones for these species and habitats is pending.

Actions fully or partially completed from the Action Plan of Second National Communication	Comments	Reference
Defining sensitive species in relation to climate change	Most of the sensitive species were identified in SNC and TNC, thus we consider this action almost fulfilled, thou on the basis of expert judgment	Report on vulnerability within TNC
Detailed maping and modeling of the changes of Kermes oak and Pubescent oak forests as a pilot study for climate change	Mapping and modeling of Kermes oak was performed in TNC	Report on vulnerability within TNC
Elaboration of the list of bioindicator species on the basis of their biogeographic distribution	A list of bioindicatorspecies was proposed in TNC	Report on vulnerability within TNC
Assessment of ecosystems' fragmentation in RM as a tool for understanding of obstacles for adaptation of ecosystems against global climate change	Part of this activity was fulfilled within the MAK-NEN project (Establishment of Macedonian Ecological Network) with focus on Brown bear	Report on *national circumstances in biodiversity sector* within TNC
Definition of possible routes (biocorridors) for movement and migration of threatened plant and animal species by the climate change	This activity was fulfilled within the MAK-NEN project (Establishment of Macedonian Ecological Network) with focus on Brown bear	Report on *national circumstances in biodiversity sector* within TNC
Establishing of data base	Data base on biodiversity was established within MoEPP for the purposes of different projects, the last being the UNDP funded project Development of National Biodiversity Information System (NBIS) within Strengthening the Ecological, Institutional and Financial Sustainability of Macedonia's National Protected Areas System. However, the data base is not regularly updated.	Report on *national circumstances in biodiversity sector* within TNC
Assessment of the impact of periodic natural and induced hydrological fluctuations on biodiversity of three natural lakes in climate change context	During last decade several projects addressed the hydrological status of natural lakes in Macedonia, in particular Dojran Lake (for the needs of efforts to save Dojran Lake by additional supply of water) and Prespa Lake (in the frame of UNDP project for trilateral Prespa Park and individual scientific projects).	Several reports, scientific papers etc.

4.3 Action plan

	Action	Type	Stakeholders	Timeframe	Financing	Constraints (possible barriers and risks)	Comments / related sector - joint action is needed or preferable
1.	Icnlude climate change vulnerability in the process of threat status estimation of species, habitats and ecosystems within the activities of the National Biodiversity Strategy	Policy	MoEPP (Nature and Climate Change), Scientific Institutions,	Long term	A	So far, Macedonia has not prepared a National Red list of threatened species, mainly due to the lack of funds.	Inclusion of climate change vulnerability criteria should face no obstacles if funds are obtained / no related sector
2.	Elaboration of precise distribution maps of rare, endemic, relict species of plants, animals and fungi, sensitive to climate change	Research	Scientific Institutions	Short term	B	Lack of suitable research capacities in Macedonia; lack of funds	/ no related sector
3.	Modeling of sensitive species in relation to climate change	Research	Scientific Institutions	Short term	B	Lack of suitable research capacities in Macedonia	The first models were prepared within TNC / no related sector
4.	Protection of populations of economically important species in high mountain belt threatened by the climate change through elaboration of action plans for e.g. bilberries and chamois	Policy	MoEPP, National parks, Individual collectors, Hunting Societies	Short term	B	The collection of wild plants is still not legally well regulated. Poaching is serious problem for game animals.	/ no related sector
5.	Investigation of distribution of sensitive species, determination of their population density	Research	Scientific Institutions, MoEPP	Short term	B	Lack of suitable research capacities in Macedonia	/ no related sector
6.	Monitoring of the melting of snow patches and changes of the associated vegetation, flora and animals	Research	Scientific Institutions, MoEPP	Long term	B	Lack of historic data	/ no related sector
7.	Monitoring of population status of species vulnerable to climate change	Monitoring	Scientific Institutions, MoEPP	Continuous	B	Monitoring of wild species still not established within	/ no related sector

	Action	Type	Stakeholders	Timeframe	Financing	Constraints (possible barriers and risks)	Comments / related sector - joint action is needed or preferable
						MoEPP	
8.	Establishment of a pilot network of mountain meteorological stations (e.g. Jakupica Mt.) along vertical gradient		Scientific Institutions, MAFWE – Administration for hydro-meteorology	Short term	B	Lack of funds	/ Climate – Hydrometeorological administration
9.	Monitoring of the status of alien (and invasive) species of plants	Monitoring	Scientific Institutions, MoEPP	Continuous	B	Monitoring of alien species still not established within MoEPP	See Report on National Circumstances for the list of alien species / Health
10.	Monitoring of the status of animal species-vectors of diseases	Monitoring	Ministry of Health, Scientific Institutions	Continuous	B	Lack of suitable research capacities in Macedonia Lack of cooperation between Ministry of Health and relevant scientific institutions	See Report on National Circumstances for the project on Asian tiger mosquito / Health
11.	Study of the phenology of the defined indicator species	Monitoring	NGOs, Scientific Institutions, MoEPP	Long term	B	Lack of historic data	/ no related sector
12.	Elaboration of list of species for which "*ex situ*" conservation is necessary	Research	MoEPP, MAFWE, Scientific Institutions	Short term	A	/	So far, the only appropriate institutions for ex-situ conservation are the Skopje ZOO and the Botanical Garden of the Institute of Biology / Agriculture
13.	Adoption of policy instruments for implementation of corridors management plans into national and regional spatial planning	Policy	MoEPP, MAFWE, MTC, ME, MLS, municipalities, MF	Medium term	B	Lack of good cooperation between spatial planners, relevant ministries, scientists and public enterprises	/ Spatial planning; agriculture; Forestry; Transport

	Action	Type	Stakeholders	Timeframe	Financing	Constraints (possible barriers and risks)	Comments / related sector - joint action is needed or preferable
14.	Case study of implementation of the ecological network concept in regional planning based on inter-sectoral approach	Policy	MoEPP, MAFWE, MTC, ME, MLS, municipalities, MF	Short term	B	Lack of good cooperation between spatial planners, relevant ministries, scientists and public enterprises	/ Spatial planning; agriculture; Forestry; Transport
15.	Adaptation of forestry management plans in the main forested biocorridors to provide their better functionality in terms of climate change impacts	Policy	MAFWE, MF	Medium term	C	Forestry sector still not transformed according to the trends in EU	/ Forestry
16.	Cost-benefit study of the impact of energy production systems based on using alternative energy sources (hydrological systems, solar power, wind) on biodiversity	Research	MoEPP, MAFWE, MTC, ME, MLS	Short term	B	Lack of institutional commitment; Lack of suitable research capacities in Macedonia	/ Energy sector
17.	Definition of possible routes (biocorridors) for movement and migration of threatened plant and animal species by the climate change	Research	MoEPP, MAFWE, MF, Scientific Institutions, NGOs	Short term	B	Lack of suitable research capacities in Macedonia	/ Agriculture; Forestry
18.	Determination of ecological minimum for mountain water ecosystems	Research	MoEPP, MAFWE, ME, Scientific Institutions	Short term	B	Lack of institutional commitment	/ Water resources
19.	Hydrologic study for the vulnerability of lowland marshes, mountain mires and glacial lakes	Research	MoEPP, Scientific Institutions	Medium term	B	Lack of good hydrologic and biodiversity data	/ Water resources
20.	Assessment of the impact of periodic natural and induced hydrological fluctuations on biodiversity of glacial lakes in climate change context	Research	MoEPP, Scientific Institutions	Short term	A	Lack of capacity and knowledge	/ Water resources
21.	Assessment of the impact of periodic natural and induced hydrological	Research	MoEPP, Scientific Institutions	Short term	A	Lack of capacity and knowledge	/ Water resources

	Action	Type	Stakeholders	Timeframe	Financing	Constraints (possible barriers and risks)	Comments / related sector - joint action is needed or preferable
	fluctuations on biodiversity of mountain bogs and springs in climate change context						
22.	Assessment of the impact of periodic natural and induced hydrological fluctuations on biodiversity of lowland marshes and bogs in climate change context	Research	MoEPP, Scientific Institutions	Short term	A	Lack of capacity and knowledge	/ Water resources
23.	Assessment of the impact of induced floods on Tamaris shrublands, willow woodlands with poplar and Periploca in the region of Gevgelija	Research	MoEPP, Scientific Institutions	Short term	A	Lack of capacity and knowledge	/ Water resources
24.	Study of the historical and present timber line and modelling of future changes induced by the climate	Research	MoEPP, Scientific Institutions	Continuous	B	Lack of historic data	/ Forestry
25.	Detailed maping and modeling of the changes of some mountain pasture types as a pilot study for climate change	Research	MoEPP, MP, Scientific Institutions	Short term	B	Lack of suitable research capacities in Macedonia	/ Agriculture
26.	Detailed revision of the Macedonian protected areas system in connection to climate change adaptation.	Research	MoEPP, MAFWE, MF, Scientific Institutions, NGOs	Short term	C	Low institutional capacity	/ in cooperation with Forestry and agriculture sector
27.	Establishing protected areas of category IV, V and VI on the main corridors previously defined	Legislation/ Policy	MoEPP, MAFWE, MF, Scientific Institutions, NGOs	Short term	B	Low institutional capacity	An initiative is on-going for protection of IlinskaPlanina / no related sector
28.	Training of specialized staff in the MoEPP, scientific and professional insitutions for modelling of the climate	Capacity building	MoEPP, MAFWE, Scientific Institutions, NGOs	Long term	A	Low institutional capacity; including scientific institutions	/ no related sector

	Action	Type	Stakeholders	Timeframe	Financing	Constraints (possible barriers and risks)	Comments / related sector - joint action is needed or preferable
	change impact on biodiversity						
29.	Establishing of an intersectoral body among the administrations that have the responsibility for managing water resources and biodiversity, with a strategy for activities	Policy	MoEPP, MAFWE, MTC, ME, MLS, MF	Short term	A	Low awareness for the importance of biodiversity and threats imposed by water sector	/ water sector
30.	Inclusion of climate change adaptation measures into rural development schemes	Policy	MoEPP, MAFWE, Government	Medium term	B	Lack of commitment; Low institutional capacity	/ Agriculture
31.	Communication strategy for awareness rising about the vulnerability of biodiversity in relation to climate change	Policy	MoEPP, NGOs	Long term	A	/	/ no related sector
32.	Establishing a budget for climate change study, monitoring and adaptation	Policy	MoEPP, Government	Long term	A	Low priority of biodiversity and nature protection in Macedonia	/ no related sector

Acronyms

MoEPP – Ministry of Environment and Physical Planning
MAFWE – Ministry of Agriculture, Forestry and Water Economy
MTC – Ministry of Transport and Communications
ME – Ministry of Economy
MLS – Ministry of Local Self-government
MF – Macedonian Forests – Public Enterprise
MP –Public Enterprise for Management of Pastures

Financing

A – less than 100 000€
B – 100 000-300 000€
C – more than 300 000€

Timeframe

Long term - less than 2 years
Medium term - 2-5 years
Short term - more than 5 years