A thesis submitted to the Department of Environmental Sciences and Policy of Central European University in part fulfillment of the Degree of Master of Science

Climate Change Impact on Biodiversity and its Implications for Protected Areas Management

Case study of Dashtidjum Zakaznik, Tajikistan

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Author's declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ABSTRACT OF THESIS submitted by:

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for the degree of Master of Science and entitled: Climate change impact on biodiversity and its implications for protected areas management: Case study of Dashtidjum Zakaznik, Tajikistan

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Climate change is an unequivocal global problem that has many negative consequences and can become the dominant direct driver for the loss of biodiversity. Its impacts on species and ecosystems have already been observed worldwide and vary from species phenological changes, to shifts in their geographical distribution and to extinction. Species adaptive responses, in turn, pose various challenges for adequate management of protected areas that play a key role in biodiversity conservation, and require review of conservation goals and implementation of adaptation measures. This thesis focuses on Tajikistan as a mountainous country with unique biodiversity, and explores climate change impacts on the biodiversity of one of the most vulnerable reserves rich in biodiversity – *Dashtidjum Zakaznik*.

The current and potential impacts of climate change on the biodiversity of the *zakaznik* have been analyzed following the DPSIR approach and based on up-to-date knowledge, experts' assumptions and observations. An analysis of meteorological data has confirmed an increase of mean temperatures and anomalies in precipitation. The main factors of climate change impacts, as well as species vulnerability and adaptive responses, have been identified for the main taxa of flora and fauna, with a focus on rare and endangered species, and all represented ecosystems. A vulnerability assessment has shown potential population decline for the majority of species important for conservation, migration of some species northwards outside the area of the *zakaznik*, extinctions of some species and increases in population sizes for other species, mainly invasive species. An assessment of national policies and strategies has identified a number of prerequisites for the implementation of adaptation measures that may contribute to the mitigation of the climate change impacts on the biodiversity of *Dashtidjum Zakaznik*. They include expansion of the protected area, and establishment of buffer zones and migration corridors.

Keywords: climate change, biodiversity, protected areas, vulnerability assessment, adaptation measures, Tajikistan, Dashtidjum Zakaznik

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List of Abbreviations

CBD	Convention on Biological Diversity
DPSIR	Driver-Pressure-State-Impact-Response
EEA	European Environment Agency
ELIN	Electronic Library Information Navigator
GEF	Global Environment Facility
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
MPA	Marine Protected Areas
NEAP	National Environmental Action Plan
NBBC	National Biodiversity and Biosafety Center
NBSAP	National Biodiversity Strategy and Action Plan
NGO	Non-governmental organization
REDD	Reducing Emissions from Deforestation and Forest Degradation
SAH	State Administration for Hydrometeorology
SCBD	Secretariat of the Convention on Biological Diversity
SCEPF	State Committee for Environment Protection and Forestry
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention for Climate Change
WCMC	World Conservation Monitoring Centre
WMO	World Meteorological Organization
WWF	World Wide Fund for Nature

ha	hectares
masl	meters above sea level
pers.comm	personal communication

1. Introduction

1.1 Background

Climate change is an unequivocal global problem that has been confirmed by observations of an increase in global mean sea and air temperatures, ice melting and sea level rise (IPCC 2007). In its fourth assessment report, the Intergovernmental Panel on Climate Change (IPCC) stated that the global mean surface temperature has increased by 0.76°C from 1850 to 2000, with a linear warming trend of 0.13°C per decade, which is twice that recorded for the last century (IPCC 2007). Scenarios developed by the IPCC project that increase of global mean temperature by 2099 might reach up to 6.4°C, if greenhouse gas emissions and other anthropogenic changes, for instance land use change, continue at or above current rates. This would be among the highest temperature shifts experienced in the past 740,000 years (Fischlin *et al.* 2007).

Such rapid rate of the temperature increase has many negative consequences and can become the dominant direct driver for the loss of valuable ecosystems and their services at global level (Root *et al.* 2003; Guariguata 2008). Change in temperature and precipitation regimes, along with associated disturbances, like flooding, wildfire and drought, increases ecosystems vulnerability leading to their disruption and loss of biodiversity (Rosenzweig *et al.* 2007). Species respond to climate change by temporal shifts of life-cycle events, shifts of distribution ranges to higher latitudes and elevations seeking the suitable climates, and by extinctions if the adaptive capacity is lower than the pace of climate change (Parmesan and Yohe 2003; Thomas *et al.* 2004). Further rise of global mean temperature will likewise drive significant evolutionary changes in species and ecosystems with many more far-reaching effects (Walther *et al.* 2002).

Possessing a critical threat to biodiversity and ecosystems, climate change represents a real challenge for protected areas management, questioning the adequacy of current protected areas in the conservation of representative ecosystems and endangered species (Scott 2004). Existing protected area networks have been developed to protect static patterns of biodiversity, and thereby could not respond to the dynamic changes in ecosystem composition and distribution triggered by climate change impacts (Mawdsley *et al.* 2009). New management approaches and climate change adaptation measures have to be developed and integrated into protected areas planning and management to ensure biodiversity conservation, as well as mitigation of climate change impacts.

This paper focuses on climate change impacts on biodiversity of Tajikistan – the country that despite its small land area is characterized by a rich and unique biodiversity, with a high degree of endemism (Safarov *et al.* 2003). Specific mountain climatic conditions and isolation have enabled the formation of a considerable number of species of global significance represented by endemic, relic species and wild relatives of cultivated plants (NBBC 2009). The latter occur in Tajikistan on a scale found nowhere else in the world (Krever *et al.* 1998). Tajikistan is home for nearly 10,000 flora species, including nearly 1,000 species of wild relatives of cultivated plants and 1,132 endemic plants, and 20 types of vegetation that range from broadleaf forests and boreal meadows to subtropical and tropical deserts (NBBC 2003). The diversity of ecosystems and plant communities promoted the development of a rich fauna, which is represented by more than 13,000 species, including 800 endemic species (Safarov *et al.* 2003).

Similarly to other countries, the rich biodiversity of Tajikistan is experiencing different pressures, resulting mainly from anthropogenic activities, including unsustainable use of natural resources, habitat modification and fragmentation and environmental pollution (NBBC 2003; Safarov *et al.* 2003). As a result, ecosystems are degrading and losing their diversity and functionality, and species are threatened by population decline and extinction. Due to habitat destruction and poaching, 3 animal and 16 plant species have already disappeared from the territory of Tajikistan (Safarov *et al.* 2003). Species affected by anthropogenic activities also become more vulnerable to climate change, and have fewer chances for successful adaptation to its impacts (Millsap *et al.* 1990; Mkanda 1996). Climate change therefore poses a real threat for the biodiversity of Tajikistan and may considerably increase the loss of unique species.

Climate change has already been observed in most areas of Tajikistan, including high altitude zones (Makhmadaliev *et al.* 2008). The surface mean temperature has increased by 0.3-1.2°C for the last sixty years, with the linear warming trend of 0.1-0.2°C per decade. There are also changes in precipitation patterns, and in the intensity and frequency of extreme weather events and connected natural disasters (Makhmadaliev *et al.* 2003b; 2008). The further increase of the temperature could be 3.7°C on average by the end of 2099 (0.3-0.4°C per decade) according to the IPCC models (Christensen *et al.* 2007), or by 0.2-0.4°C by the end of 2030 (0.1-0.2°C per decade), according to the projections of the State Administration for Hydrometeorology (SAH) (Makhmadaliev *et al.* 2008). Taking into account these projections, the probability of ecosystem degradation and loss of species, in particular rare and endangered species is quite high (Makhmadaliev *et al.* 2003b).

Mountain ecosystems of Tajikistan are especially sensitive to climate change due to their low adaptive capacity (Makhmadaliev *et al.* 2003b); and has already been affected by climate change. In particular, increase of mean temperature and melting of snow patches were one of the reasons for the extinction of the endemic species Menzber's marmot (*Marmota menzbieri*) that inhabited the high altitude meadows in the northern Tajikistan until 1980-1990 (Makhmadaliev *et al.* 2008). Experts also claimed reduction of the population of several fish species due to the warming of water in reservoirs that created unfavourable conditions. Other impacts include the spread of invasive species and an increased number of pest infestations (Makhmadaliev *et al.* 2008).

It is evident that the threat from climate change on biodiversity of Tajikistan is already tangible and urges implementation of adaptation measures aimed at mitigation of its negative consequences and prevention of irreversible losses. Development of adaptation measures, in turn, requires comprehensive research for understanding species' and ecosystems' responses to climate change, as well as the main factors of their vulnerability. At the same time, there is a lack of research on the potential impacts of climate change on species occurring in Tajikistan. A few available studies focus on general issues of biodiversity vulnerability to climate change, rather than vulnerability of certain species within particular areas, which is important for the development of adaptation measures.

The Government of Tajikistan has undertaken a number of measures towards biodiversity conservation, including the development of protected areas network that covers 22% of the country's territory and represents almost all ecosystems and rare species (Safarov *et al.* 2003). In addition, a number of national strategies and programs have been developed to enhance biodiversity conservation and protected areas management. At the same time, none of these documents consider the climate change impacts on biodiversity, though they have unquestionable implications for protected areas, which play an important role in biodiversity conservation.

Meanwhile, the importance of assessing climate change impact on biodiversity is highlighted in the National Action Plan for the Mitigation of Climate Change (Makhmadaliev *et al.* 2003b). The document also stipulates as a priority measure a need to enhance the scientific understanding of climate change impact on ecosystems with a special focus on protected areas. This research is intended to contribute to the mitigation of the negative consequences of climate change impact on the biodiversity of Tajikistan and fill the existing gap in research on species and ecosystems vulnerability to climate change by studying climate change impacts on the biodiversity of one of the most vulnerable reserves rich in biodiversity – *Dashtidjum Zakaznik*.

1.2 Objectives and research questions

The overall goal of this research is to contribute to the mitigation of climate change impacts on the biodiversity of Tajikistan, and *Dashtidjum Zakaznik* in particular, by pursuing the following objectives:

- *Analyze* meteorological data and *identify* climate change trends on the territory of *Dashtidjum Zakaznik*.
- *Assess* vulnerability of different components of biodiversity of *Dashtidjum Zakaznik*, including fauna, flora and ecosystems, to climate change impacts and *identify* potential changes in their state under an altered climate.
- *Analyze* relevant national policies and programs and *identify* prerequisites for implementation of adaptation measures.
- *Identify* implications for protected areas management and d*evelop* recommendations for adaptation measures to climate change.

The following main questions have been addressed and constituted the basis for this research:

- What are the climate change trends on the territory of *Dashtidjum Zakaznik*?
- How does climate change affect different components of biodiversity of *Dashtidjum Zakaznik*, including fauna, flora and ecosystems?
- How can national policies and programs on protected areas, climate change, and biodiversity conservation contribute to implementation of adaptation measures?
- What are the consequences from climate change impact on biodiversity to protected areas management, and how can they be managed?

The results of this research contribute to the implementation of national strategies on biodiversity conservation and climate change mitigation. Therefore they may be of interest not only to scientists and protected areas managers, but also to policy and decision makers. Though the research is focused on *Dashtidjum Zakaznik*, the results of its vulnerability assessment may be relevant for other protected areas of Tajikistan with similar species and ecosystems. Meanwhile, the results of the analysis of national policies and programs and identified prerequisites for adaptation measures are applicable for all protected areas in Tajikistan.

1.3 Methodology

This research is based on a combination of complementary methods and approaches including archival reviews and interviews for data collection, quantitative methods for analysis of meteorological data and qualitative vulnerability assessment based on the DPSIR approach for data analysis. A case study approach was chosen to tackle the research problem and ensure its comprehensive exploration with a variety of data collection and analysis procedures. The study site selection was based on a review of a number of criteria, including sensitivity to climate change, data availability and site significance for biodiversity conservation, and resulted in this research's focus on *Dashtidjum Zakaznik* as one of the most vulnerable reserves to climate change impacts with high significance for biodiversity conservation.

Archival reviews involved review of publications and materials from various sources, such as academic, government, intergovernmental, international and non-governmental organizations. Interviewing experts not only provided additional insights into the issue, but also helped to obtain required data, as published materials on climate change impacts on biodiversity of Tajikistan are quite limited. Interviews also allowed obtaining experts' reflections on potential impacts of climate change on biodiversity of *Dashtidjum Zakaznik,* and identifying priority issues and conservation measures.

Data analysis was mainly based on qualitative assessment and followed the simplified Driver-Pressure-State-Impact-Response (DPSIR) assessment framework. This approach was chosen due to the lack of quantitative and qualitative data on biodiversity trends in Tajikistan, which makes implementation of other types of analysis difficult. The DPSIR approach allowed focusing on several aspects of biodiversity vulnerability to climate change and addressing the research problem from different angles. In addition to the descriptive analysis, the quantitative methods based on Ms Excel and SPSS software were employed to analyze climate change on the territory of *Dashtidjum Zakaznik*, as well as for the selection of representative meteorological data.

1.4 Scope and limitations

This research is a first step in analyzing climate change impacts on protected areas in Tajikistan. It employs a case study approach to gain a comprehensive view on the issue and only focuses on *Dashtidjum Zakaznik*. It also focuses only on climate change impacts on biodiversity and does not cover climate change impacts on human social and economic aspects, as well as other human-induced impacts on biodiversity such as habitat modification and poaching. The research also did not intend to analyze all taxa that inhabit *Dashtidjum Zakaznik*, but mainly focused on endangered species under protection and species of global importance. Being a first step research, it primarily focuses on species-climate interactions and does not consider interspecies interactions. The research was limited by lack of monitoring data and thus relies both on existing knowledge and various assumptions. At the same time, it was supported by the opinion of highly qualified and experienced experts in the relevant fields, which provided additional credibility to its results.

1.5 Outline of the study

The thesis consists of six chapters and starts from the introduction that presents the overall background for the research and introduces its goal and objectives. It also provides an overview of the methods employed, as well as the scope and limitations of this research. *The second chapter* constitutes the analytical framework for the research. It is divided into two sections and starts with the overview of climate change trends and its impacts on biodiversity in a global context. It also summarizes species responses to climate change and introduces implications for protected areas management along with the adaptation strategies developed worldwide to mitigate climate change impacts on biodiversity. The second section of the chapter is focused on Tajikistan and provides an overview of its biodiversity, protected areas, climate change trends, as well as national strategies and programs devoted to these issues. *The third chapter* introduces the methodological framework of this research and provides an overview of the methods employed along with the justification of their selection. It also describes the scope of the research and its main limitations.

The fourth chapter constitutes the main part of the research and introduces the results of the vulnerability assessment of *Dashtidjum Zakaznik*. It consists of five sections and starts from the brief introduction to the *zakaznik* itself. It is followed by the analysis of climate change trends on the territory of *Dashtidjum Zakaznik*, and an analysis of the climate change impacts on the main components of its biodiversity, including fauna, flora and all types of ecosystems. The chapter concludes with a short summary. *The fifth chapter* identifies implications for protected areas management, provides a brief assessment of the natural adaptation capacity of the *zakaznik* itself, and reviews national programs and strategies in terms of their potential contribution to the implementation of climate change adaptation measures. The thesis is concluded by a summary of the main findings of the research and provides recommendations for biodiversity conservation and mitigation of climate change impacts.

2. Analytical Framework

This chapter constitutes the analytical framework for the research. It not only presents the up-to-date information obtained from the various literature sources, but also identifies the main components of the research analysis. The chapter is divided into two main parts and starts with the overview of climate change trends and impacts on biodiversity in a global context. It also summarizes species responses to climate change and introduces implications for protected areas management along with the adaptation strategies developed worldwide to mitigate negative impacts of climate change on biodiversity. The second part of the chapter is focused on Tajikistan and provides an overview of its biodiversity, protected areas network and climate change trends, including observations and projections. It also reviews national strategies and programs devoted to biodiversity conservation, protected areas management and climate change mitigation. The chapter is concluded by a summary.

2.1 Global scene: Climate change and biodiversity

Biodiversity is defined as the variability among living organisms, including diversity within species, between species and of ecosystems (SCBD 2000). It plays an important role in sustaining human lives by providing different goods and services, and through its intrinsic, cultural and social values (MEA 2005). Biodiversity also plays a direct role in climate regulation affecting the ability of ecosystems to capture and store carbon dioxide and rates of evapotranspiration, which in turn affect climate both at local and global levels (Guariguata 2008). The loss of biodiversity, which is happening at an estimated rate one hundred times higher than the natural background rate, contributes to global warming, in turn affecting living organisms and enhancing the loss (Chaytor *et al.* 2002).

In its fourth assessment report, the IPCC stated that the global mean surface temperature had increased by 0.76°C from 1850 to 2000, with a linear warming trend of 0.13°C per decade, which is twice that recorded for the last century (IPCC 2007). According to the same report, in eleven of the last twelve years the global surface temperature has been the warmest on record. Scenarios developed by the IPCC project that increase of global mean temperature by 2099 might reach up to 6.4°C, if greenhouse gas emissions and other anthropogenic changes, for instance land use change, continue at or above current rates. This would be among the highest temperature shifts experienced in the past 740,000 years (Fischlin *et al.* 2007).

By the end of this century, climate change and its impacts could become the dominant direct driver for the loss of biodiversity and valuable ecosystem services at the global level (Guariguata 2008). Change in temperature and precipitation regimes, along with associated disturbances, like flooding, wildfire and drought, increases ecosystems' vulnerability leading to their disruption and loss of biodiversity. An increase of global mean temperature by 3°C will cause transformation of over one-fifth of Earth's ecosystems, and warming above 3°C will cause further loss of biodiversity and ecosystem services (Schneider *et al.* 2007). According to the IPCC report, if the increase of global mean surface temperature exceeds 2°C, many species will be at a greater risk than in recent geological past and up to 20-30% of species could become extinct (Thomas *et al.* 2004; Fischlin *et al.* 2007). Climate change has already been blamed for the extinction of 14 vertebrate species, including the golden toad (*Bufo periglenes*) that inhabited cloud forests of Costa Rica (IUCN 2010b).

2.1.1 Climate change pressures on biodiversity

Biodiversity is already being affected by climate change, which has been confirmed by numerous observations worldwide. The first research papers on the impacts of climate change caused by human activities on biodiversity were published more than 20 years ago (Felton *et al.* 2009). Since then it has been established that climate change is affecting biodiversity in a number of ways, changing the phenology of organisms (Walther *et al.* 2002; SCBD 2009), the composition of communities and ecosystems (Omann *et al.* 2009), and causing shifts of species distributions (Felton *et al.* 2009; Willis *et al.* 2009). At the same time, many potential impacts of climate change on biodiversity remain poorly understood (Auld and Keith 2009).

The main ways climate change affects biodiversity can be summarized as follows: a) shift of suitable habitats due to the change of temperature and precipitation regimes (Auld and Keith 2009; SCBD 2009), b) loss of habitats due to the rise of sea level (Auld and Keith 2009; Omann *et al.* 2009), c) increased frequency and intensity of extreme weather events (Auld and Keith 2009; Felton *et al.* 2009), d) disruption of communities as a result of the spread of invasive, alien species, and appearance of new predators and competitors (Auld and Keith 2009; Walther *et al.* 2009), e) desynchronization of dispersal events and other species interactions due to adaptive phenological changes (Thomas *et al.* 2004; Auld and Keith 2009), f) change of growth rate due to the changes in atmospheric and oceanic concentration of carbon dioxide (Auld and Keith 2009; SCBD 2009).

Species respond to these impacts by adaptation mechanisms, trying to adjust to changing conditions, to moderate potential damage from climate change and to cope with the consequences (Omann *et al.* 2009; Vitt *et al.* 2010). According to the IPCC, adaptation could be divided into two types: a) autonomous or natural adaptation, which is reactive and relates to the species responses after climate change impacts have been realized and b) planned or human-mediated adaptation, which is proactive and relates to the conservation of biodiversity in the face of climate change (IPCC 2002; Heino *et al.* 2009). The next section deals with responses related to natural adaptation, while the planned adaptation is the main focus of section 2.2.2.

2.1.2 Species responses to climate change

Species responses to climate change include adaptation *in situ* as a result of their capacity to tolerate some degree of change and/or migration to a more suitable location in response to the changes (Auld and Keith 2009). The former could include change of phenology or physiological responses or evolutionary adaptation (Vitt *et al.* 2010). It should be noted that the capacity of living organisms for adaptation is quite limited and many species will not have the capacity to disperse at the required rate (Felton *et al.* 2009; Omann *et al.* 2009). If the adaptation rate is slower than the pace of climate change, it might lead to decrease of populations and species extinctions, which is the ultimate threat of climate change (Thomas *et al.* 2004; Brook *et al.* 2008).

Phenological changes are more often demonstrated by the temporal shifts of life-cycle events, including leaf unfolding, flowering, migration arrival, egg laying and breeding (Crick 2004; Araujo *et al.* 2006; Lepetz *et al.* 2009; SCBD 2009). Studies have already confirmed a significant advance of spring events by 2.5 days per decade (Parmesan and Yohe 2003; Feehan *et al.* 2009). In spite of the adaptation nature of these changes, they pose a number of threats to species and could lead to population declines (Leech and Crick 2007; SCBD 2009). These threats include change in species interactions, e.g. relationships with competitors and herbivores, mistiming between the peak of food demand for reproducing animals and seasonal peak in food abundance, and lower breeding performance (Leech and Crick 2007; Rosenzweig *et al.* 2007; Auld and Keith 2009).

Geographical distributions of species are changing as a result of rapid shifts in suitable habitats that force species to shift their distribution range tracking regions of suitable climate (Auld and Keith 2009; Willis *et al.* 2009). It has been observed that habitats of many species, and thus species distribution range, are moving poleward to higher latitudes and altitudes from current locations, as well as to higher elevations (Thomas and Lennon 1999; Heino *et al.* 2009; Omann *et al.* 2009; Vitt *et al.* 2010). An analysis of 99 species of birds, butterflies and alpine herbs has shown the average range shift towards the pole by 6.1 km per decade (Parmesan and Yohe 2003). Other studies report even greater shifts by up to 23.5 km per decade for birds (Hitch and Leberg 2007), as well as much smaller shifts, for instance 23.9 m per decade for alpine herbs (Parolo and Rossi 2008).

Shifts in distribution depend not only on species' dispersal capacity but also vary in different landscapes. It has been noticed that the velocity of temperature change is the lowest in mountainous biomes due to a large change in temperature at different elevations; and the highest in flat areas presented by flooded grasslands, mangroves and deserts (Loarie *et al.* 2009). In general, because of the shifts, population sizes and species richness are changing, with an increase in some areas and decline in others (Rosenzweig *et al.* 2007; Parolo and Rossi 2008). As dispersal ability of different species varies, the composition of many ecosystems is changing, as species that live together in an ecosystem are unlikely to move synchronously (Burgmer *et al.* 2007; Rosenzweig *et al.* 2007).

Besides natural limitation in the adaptive capacity of species, there are a number of external climate-driven factors that restrict autonomous adaptation and cause biodiversity loss and disruption of ecosystem services. One of them is loss of habitats due to the ice melting and rise of sea level (Auld and Keith 2009). The most vulnerable ecosystems in this respect include coastal wetlands and coral reefs, which have already been significantly affected by climate change (Omann *et al.* 2009). Another cause of species loss is change in the frequency of extreme weather events (e.g. fires, floods, drought) that pose a direct threat to living organisms (Auld and Keith 2009). Small populations are in particular danger, as they are unlikely to be replenished after such events (Omann *et al.* 2009).

Expansion of invasive species and exposure of species to new competitors, predators and pathogens is yet another threat (Auld and Keith 2009; Walther *et al.* 2009). Alien species may benefit from climate change by being enabled to survive and reproduce in regions where they could not previously persist. It has been noticed, that as a result of climate change, native ecosystems have become less resistant to invasive species and more resilient to their impacts. This often leads to the transformation of ecosystems, with a domination of alien species and reduced diversity of native species (Walther *et al.* 2009). Among the potential consequences is easier spread of diseases and pests that might reproduce faster (Omann *et al.* 2009).

Climate change impact on biodiversity is exacerbated by other human-induced stressors, such as habitat modification and fragmentation (Birdlife International 2008; de Chazal and Rounsevell

2009; SCBD 2009). Even if the species are capable to shift their distribution range, the area that might have suitable climate may already be modified and turned into agricultural land, roads or human settlement (Brook *et al.* 2008). The stressors also weaken the overall capacity of species to cope with climate change making them more sensitive to its negative impacts and leading to the loss of biodiversity (Julliard *et al.* 2003).

2.2 Global scene: Climate change and protected areas

Protected areas[1] have been established around the world with the main goal to protect biodiversity and specific natural features, threatened by anthropogenic activities (Soto 2002; Burns *et al.* 2003; Lemieux and Scott 2005). Over the past 40 years, protected areas have been the primary means of biodiversity conservation, separating valuable ecosystems from adjacent human-induced stressors (Hagerman *et al.* 2010). Currently, protected areas cover about 12% of the Earth's land surface (SCBD 2010) and 1% of the world's oceans (IUCN 2010e). Their effectiveness and thus conservation success is measured by representation of ecosystems, persistence of species selected for conservation in specific places, as well as by the size of the area (in hectares) protected from adjacent stressors (Hagerman *et al.* 2010).

2.2.1 Overview of the impacts

Climate change impact on biodiversity and species responses to it pose a real challenge for protected areas management and achievement of conservation goals. Characteristics of the protected areas, such as fixed borders and protection of particular species assemblages and ecosystems within the borders, became the "Achilles' heel" of this conservation tool (Burns *et al.* 2003; Heller and Zavaleta 2009; Scott 2004). The main challenges are connected with species tendency to move poleward and to higher altitudes for suitable climatic conditions and thus landscape-level shifts in ecosystem structure and distribution (Lemieux and Scott 2005; Willis *et al.* 2009). Protected areas networks that have been developed to protect static patterns of biodiversity may not adequately respond to the dynamic nature of climate change effects on ecosystems (Mawdsley *et al.* 2009; Hagerman *et al.* 2010).

With the magnitude of changes caused by climate change, some target species and ecosystems will no longer be viable in the areas designated for their protection (Araújo *et al.* 2004). Species

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[1] According to Article 2 of the Convention on Biological Diversity (CDB), protected area is "a geographically defined area, which is designated or regulated and managed to achieve specific conservation objectives" (UN 1992).

might move out of national parks and reserves, and new species could move in, changing the ecosystem composition (Hannah *et al.* 2005). As a result the representation of ecosystems and species in protected areas is changing (Scott 2004). Among particular vulnerable protected areas are those located at high latitudes and elevations, as well as at low-elevations and in costal zones (Heller and Zavaleta 2009).

Another challenge is the location of protected areas bordering modified landscapes, with human infrastructure and associated stressors, which threaten the survival of many species, and raise the rate of projected extinction rates (Heller and Zavaleta 2009; Hole *et al.* 2009). A combination of different factors, including changes in ecosystem composition, limited capacity of some species to adapt to new climatic conditions, as well as lack of suitable habitats due to habitat modification and fragmentation hinder the ability of protected areas to fulfill their designation and to maintain habitats and species population in the future (Lemieux and Scott 2005).

2.2.2 Management responses

Climate change and increased pressure on biodiversity urge us to take appropriate adaptation measures for biodiversity conservation. Protection of biodiversity itself is the effective measure for mitigation of the adverse effects of climate change as it limits the concentration of carbon dioxide in the atmosphere, sequestering and storing it in forests, peat lands and other habitats (Cliquet *et al.* 2009; Dudley *et al.* 2010). Effective measures would not only contribute to climate change mitigation, but also ensure proper functioning of ecosystem services. At the same time existing measures do not respond to the threats from climate change and require adaptation of policies and development of new conservation approaches for a dynamic rather than static system (IPCC 2002; Hagerman *et al.* 2010).

A number of recommendations for adaptation strategies have been developed worldwide, based on the main responses of species to changing environments, and with the main focus on protected areas management as the primary tool for biodiversity conservation (Velarde *et al.* 2005; Mawdsley *et al.* 2009). Some strategies, including expanding protected areas networks, and improved management of the matrix and habitat restoration, have widespread adoption; others are more controversial, with varied opinions among scientists, NGOs and international organizations. They include assisted migration, increased connectivity, and others (Hodgson *et al.* 2009; Hagerman *et al.* 2010). A brief overview of some recommendations is presented below.

2.2.2.1 Expansion of protected areas network

Expansion of protected areas networks has been proposed as a tool to address the problem with the loss of species and ecosystems representation within current reserves and national parks (Hannah *et al.* 2002; Hagerman *et al.* 2010). It is believed that existing protected areas should be supplemented with additional coverage to ensure fulfillment of their conservation objectives and maintaining biodiversity representation targets in the face of shifts in the distribution ranges of species (Hannah *et al.* 2002; Hannah 2008; Hodgson *et al.* 2009).

Two approaches are noteworthy regarding the expansion of the protected areas network. One is based on the compensation of lost ecosystem and/or species representation and adding the area to the reserve network until the target level of representation is reached (Hannah 2008). Another is to improve representation of climatic conditions within protected areas networks, adding area with the climatic conditions poorly represented in the network. In the latter case, area is added until the climatic representation target is met (Hannah 2008).

It is believed that territories adjacent to protected areas, as well as other areas with low human impact, should be secured for species to ensure the presence of sufficient habitats and increase connectivity (Heino *et al.* 2009; Hodgson *et al.* 2009; Hagerman *et al.* 2010). It is also important to revise existing networks to identify shifts in species distributions and ecosystems composition, rethink conservation goals and adjust them to new population dynamics (Hannah *et al.* 2002). Though expansion of the network is not the panacea for climate change and there are a number of challenges, including availability of viable climatic ranges, there is sufficient evidence that it will substantially reduce climate change impacts on biodiversity (Hannah 2008).

2.2.2.2 Individual protected areas

Another strategy for adaptation to climate change impacts is the designation of new protected areas particularly as a response to climate change (Hannah 2008). This concept mostly refers to marine protected areas (MPAs), in particular coral reefs, and promotes either resilience (capacity to recover to a reference condition after being damaged) or resistance (capacity to withstand without substantial biological change) to climate change. Application of this strategy to terrestrial ecosystems has been less explored. At the same time, it is argued that the concept can also be applied for the design of terrestrial reserves, in particular to protect vulnerable montane vegetation zones where changes with warming are dependent on the topography of mountain chains (Halpin 1997), similar to the changes in marine habitat due to sea-level rise. The main suggestion in regard to montane reserves is that the demarcation of reserves should not be based on watershed boundaries, but instead include high-elevated habitats on both sides, to secure habitats when the species will shift their distribution to higher elevations (Hannah 2008).

2.2.2.3 Mobile reserves

Mobile reserves, or dynamic protected areas, are reserves whose level of protection and/or boundaries vary in time and space (Hannah 2008). In other words, they are moving along with the target species that they protect. Partly, the idea is similar to the existing practice for hunting and fisheries, where activities could be restricted, allowed or prohibited, depending on the time and based on species' life-cycles and trends in population size. At the same time, the spatial variations are quite new for conservation practice. The concept has been first proposed in regard to MPAs, but there is already a number of general recommendations for its application for terrestrial protected areas, including creation of a coordinated system of landholder agreements (Hannah 2008).

2.2.2.4 Increasing connectivity

The concept of connectivity has appeared from the assumption that we need safe pathways between protected areas to facilitate dispersal in response to climate change (Hannah 2008). The main idea is to create and maintain dispersal corridors that will connect suitable environments and will enable species to move towards suitable climatic conditions (Mackinnon 2008; Heino *et al.* 2009; Hodgson *et al.* 2009).

Opponents of the concept believe that its importance is being overemphasized, and there are many uncertainties in the quantification of the benefits. Implementation of such measures requires large investments and is not cost-efficient, as better results could be achieved by expanding the protected areas network and enhancing habitat quality, rather than creating corridors (Hodgson *et al.* 2009).

2.2.2.5 Development of matrix areas

This concept also focuses on increasing connectivity of the landscape outside of protected areas networks (Mawdsley *et al.* 2009). The idea is to manage areas surrounding protected areas in a way to enhance the mobility of species under suitable climatic conditions through the adjacent landscapes (IUCN 2004; Heino *et al.* 2009; Hagerman *et al.* 2010). Development of matrix area combines different existing management techniques, including agroforestry, dam removals, and has already been implemented in a number of countries in Europe and in the USA (Hannah 2008; Mawdsley *et al.* 2009). It allows enhancing the quality of the landscape, making it permeable and suitable for different species, rather than focusing on the movement of specific species or ecosystem types (Hannah *et al.* 2002).

Inappropriate management of the matrix area could make the landscape highly permeable for invasive weed species and damage vegetation on the edges of protected areas (Hannah 2008). The drawback of the approach is that it does not focus on rare and endangered species, and species with narrow habitat requirements, which could lead to their extinction if not combined with other conservation strategies (Mawdsley *et al.* 2009). Nevertheless, in changing conditions, the matrix is playing an important role in supporting species shifts and may contain the only habitat available for species (Hannah 2008; Willis and Bhagwat 2009).

2.2.2.6 Assisted migration

Assisted migration[2] is a highly controversial issue (Hagerman *et al.* 2010). Proponents of the idea believe that assisted migration has its importance in biodiversity conservation in the face of climate change, and its wise application will lead to the avoidance of undesirable consequences, which are the main arguments of the opponents. Assisted migration, or in other words mediated migration, assisted colonization or managed relocation, has been suggested by scientists as the way to overcome challenges implied by the limited natural migration due to habitat fragmentation, or, if natural migration rate is lower than the pace of climate change (Hannah 2008; Vitt *et al.* 2010). It may be the only chance for less mobile or adaptable species to survive.

Assisted migration as a management response to climate change suggests translocation of the species on relatively short distances poleward or to higher elevations and focuses on species with limited dispersal ability (Vitt *et al.* 2010). It considers intra-continental translocation only, and aims to protect species from threatening diseases. In contrast to the long distance relocation of species with mass dispersal potential, the potential of the intra-continental translocated plant to become invasive at a new place is about 1%, which is quite low (Vitt *et al.* 2010). Arguments of the opponents focus on the potential negative effects of assisted introductions, including genetic consequences to existing populations that can overlap with the human-relocated populations and

[2] Assisted migration is defined as the "purposeful movement of species to facilitate or mimic natural expansion, as a direct management response to climate change" (Vitt *et al.* 2010).

lead to the disruption of native populations (Vitt *et al.* 2010). They also question the availability of niche space, and believe that the first and the best option is to allow species to adapt naturally (Hagerman *et al.* 2010).

2.2.2.7 Other measures

One of the important prerequisite for effective and efficient biodiversity conservation is regional coordination of activities (Hannah *et al.* 2002). It is important to assess the impact of climate change not only at national level, but at regional level as well. Regional modeling includes use of regional climate models, sensitivity analysis and biotic response models to identify impacts on a regional scale. It is especially relevant to the conservation of rare and endangered species, when the overall population size at regional or global scale has more importance than the population size within specific protected area. In this case, regional coordination allows identifying appropriate conservation goals, and harmonization of efforts, as well as transfer of knowledge, experience and other resources (Hannah *et al.* 2002).

2.3 Local scene: Biodiversity and protected areas in Tajikistan

2.3.1 Biodiversity overview

Tajikistan is a small mountainous country in Central Asia with an area of 143,100 km^2 and high concentration of biodiversity (Safarov *et al.* 2003). Mountains occupy 93% of the country territory, half of which is situated at an elevation of ≥3,000 masl (Fritsch and Friesen 2009). Specific mountain climatic conditions and isolation has enabled the formation of unique biodiversity with high degrees of endemism (Safarov *et al.* 2003). In spite of the small land area Tajikistan contains 1.9% of the world's plant and 0.66% animal diversity, including species of global significance presented by endemic, relic species and wild relatives of cultivated plants (NBBC 2009). The latter occur in Tajikistan on a scale found nowhere else in the world (Krever *et al.* 1998).

Biodiversity richness is exhibited at all levels, including ecosystem, species and genetic. Ecosystems of Tajikistan are represented by 12 types and range from nival glacier ecosystems and high mountain deserts and meadows to foothill semi-desert and desert ecosystems and wetlands (Safarov *et al.* 2003). The most common natural ecosystems include high mountain desert ecosystems (24% of the country territory), high mountain meadow and steppe (22%) and nival glacier ecosystems (20%). The most valuable and diverse ecosystems include mid-high mountain conifer forest (6%), mesophylic forest (1%) and xerophytic forest (4%) that among other valuable functions provide habitat for endemic and rare species and protect unique genetic resources (Safarov *et al.* 2003; NBBC 2009).

Tajikistan is home for nearly 10,000 flora species (see Figure 2-1), including approx. 1,000 species of wild relatives of cultivated plants and 1,132 endemic plants, and 20 types of vegetation that range from broadleaf forests and boreal meadows to subtropical and tropical deserts (NBBC 2003). Vascular plants are represented by 4,511 species, including 882 endemics, which can be compared with 4,750 species and 550 endemics in Kazakhstan that has territory almost twenty times bigger than Tajikistan (NBBC 2003). This richness can be explained by the combination of arid, sub-arid, and humid conditions, and the fluctuation of precipitation from 70 to 2,000 mm a year (Safarov *et al.* 2003).

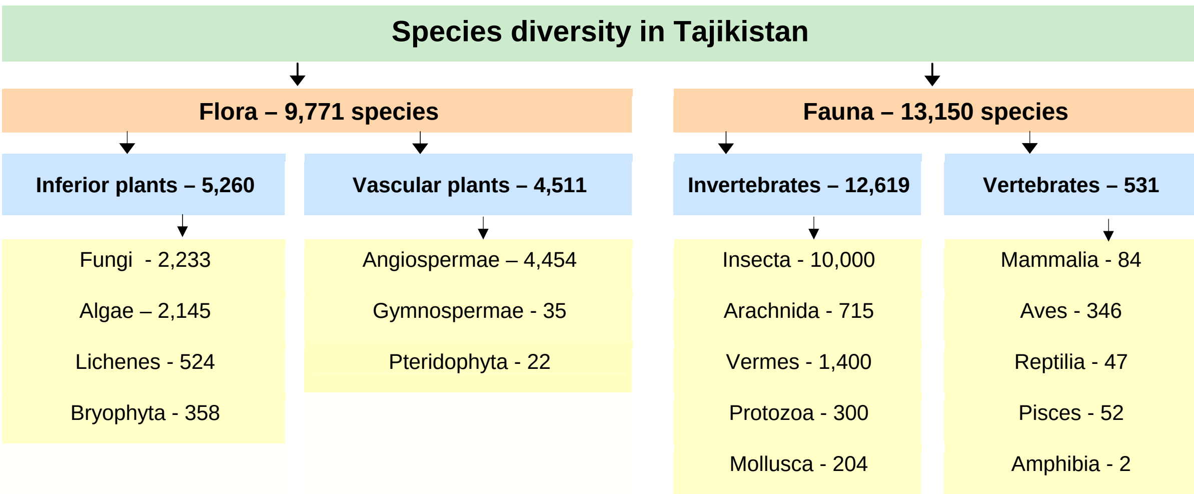

Figure 2-1. Species diversity in Tajikistan Source: Adapted from NBBC 2009

The diversity of ecosystems and plant communities promoted the development of a rich fauna, which is represented by more than 13,000 species (see Figure 2-1), including 800 endemic species (Safarov *et al.* 2003). The most numerous class of invertebrates, represented by 12,619 species, is insects, and of vertebrates – birds, represented by 346 species. The largest (and most famous) mammals include brown bear (*Ursus arctos isabellinus*), Bukhara red deer (*Cervus elaphus bactrianus*), argali or wild ram (*Ovis ammon polii*), snow leopard (*Uncia uncia*), and urial (*Ovis vignei bochariensis*).

Similarly to other countries, the rich biodiversity of Tajikistan is experiencing different pressures, resulting mainly from anthropogenic activities, including unsustainable use of natural resources, habitat modification and fragmentation, environmental pollution, and climate change (NBBC 2003; Safarov *et al.* 2003). As a result, ecosystems are degrading and losing their diversity and functionality, and species are threatened by population decline and risk of extinction. Due to habitat destruction and poaching, 3 animal and 16 plant species have already disappeared from the territory of Tajikistan, including the Turan tiger (*Panthera tigris virgata*) – a globally extinct species that gave the name for one of the reserves in Tajikistan – *Tigrovaya Balka* (Tiger Valley) (Safarov *et al.* 2003; Butorin *et al.* 2005).

A decline in species diversity is being observed in all natural ecosystems of Tajikistan (Safarov *et al.* 2003). More than 226 plant and 162 animal species have become rare and endangered due to human activities in the last few decades, and are included in the Red Data Book of Tajikistan (NBBC 2003, 2009). The most vulnerable taxa appear to be mammals and reptiles; nearly half of their species are endangered (Safarov *et al.* 2003). The most vulnerable ecosystems are mid-mountain forest ecosystems with approx. half of the flora and fauna species classified as endangered (UNECE 2004; Safarov *et al.* 2006). Eight fauna species (vertebrates) and three flora species are also listed in the International Union for Nature Conservation (IUCN) Red List of Threatened Species as 'endangered' and two fauna and seven flora species as 'critically endangered species' (see Annex 1) (IUCN 2010a).

2.3.2 Protected areas

A number of steps have been undertaken by the country to ensure *in-situ* conservation of threatened species, ecosystems and landscape. The major step includes the establishment of different protected areas, which are defined as "land or water areas that have special ecological, environmental, scientific, cultural, aesthetic and recreational values, completely or partially withdrawn from economic activities, and have special protection regime established by the Government of the Republic of Tajikistan" (Article 2) (*Law on Protected Areas* 1996). According to national legislation, protected areas should be regarded as a united system and may be owned only by the state (UNECE 2004). The Law on Protected Areas (1996) also specifies categories of protected areas based on the protection regime and land management, as well as conservation purposes. A brief description of the main categories, along with their reference to international IUCN categories is presented below:

- State strict nature reserves or *zapovedniks* (hereinafter referred to as reserves) are established to protect and study natural resources, processes, and gene pools of plants, animals, representative and unique ecosystems, and can not be used for any other purposes. This category corresponds to the IUCN category I – areas that possess some outstanding or representative ecosystems and managed for science and wilderness protection (IUCN 1994; *Law on Protected Areas* 1996).

- State natural parks or national parks are areas comprising complexes with special ecological, historical and aesthetic value and intended for use for environmental, recreational, educational, scientific and cultural purposes. They correspond to the IUCN category II – protected areas managed mainly for ecosystem protection and recreation and provide foundation for scientific, educational and recreational opportunities.
- State nature reserves, or species management sites, or *zakazniks* (hereinafter referred to as *zakazniks*) are designated for protection and rehabilitation of natural complexes or their components. They could be of republican or local importance, and correspond to the IUCN category IV – areas managed mainly for conservation through management intervention.
- State natural monuments are unique and irreplaceable natural objects that have ecological, scientific, cultural and aesthetic value. This category of protected areas corresponds to the IUCN category III – areas managed for conservation of specific natural features of outstanding or unique value (IUCN 1994; *Law on Protected Areas* 1996).

Development of the protected areas in Tajikistan began in 1938 when the first nature reserve "*Tigrovaya Balka*" was created to preserve unique wetlands and their inhabitants (Krever *et al.* 1998; Safarov *et al.* 2003). By the end of the 20th century the unique system of protected areas had been established and currently comprises four nature reserves, 14 *zakazniks* and three national parks (see Table 2-1)(NBBC 2009). The total area designated for the protection has reached more than 31 thousand km^2, which constitutes 22% of the total territory of the country (Safarov *et al.* 2006). This is twice higher that the 10% target, recommended by the IUCN guidelines (1994). Location of the established reserves, national parks and *zakazniks* can be seen in Figure 2-2, and additional information, including conservation goals, can be found in Annex 2.

Established protected areas represent most of the natural zones and ecosystems in Tajikistan (Meessen *et al.* 2003). They cover 50% of the total wetland area and 60% of high-mountain desert ecosystems, but only 0.5% of mid-mountain juniper forests, 0.2% of high mountain meadow and steppe and 0.01% of mid-mountain broadleaved forests (Safarov *et al.* 2003). More than 35% of flora and fauna species, including rare and endemic, and a considerable part of wild relatives of cultivated plants that represent valuable genetic resources, are concentrated within nature reserves (NBBC 2003, 2006).

Table 2-1. Protected areas of Tajikistan by category

Category	IUCN Category	Amount	Area (km²)	% from total protected area
Nature reserves	I	4	1,734	5.6
National parks	II	3	26,068	83.6
Zakazniks	IV	14	3,134	10
		21	**30,936**	**99.2**
Natural monuments	III	26	-	-
Botanic gardens	V	5	7	0.02
Botanic stations	-	13	100	0.3
Recreation zones	-	3	153	0.5
		47	260	0.8
Total		**68**	**31,196**	**100**
Percentage of country's territory				21.8

Source: Adapted from NBBC 2009

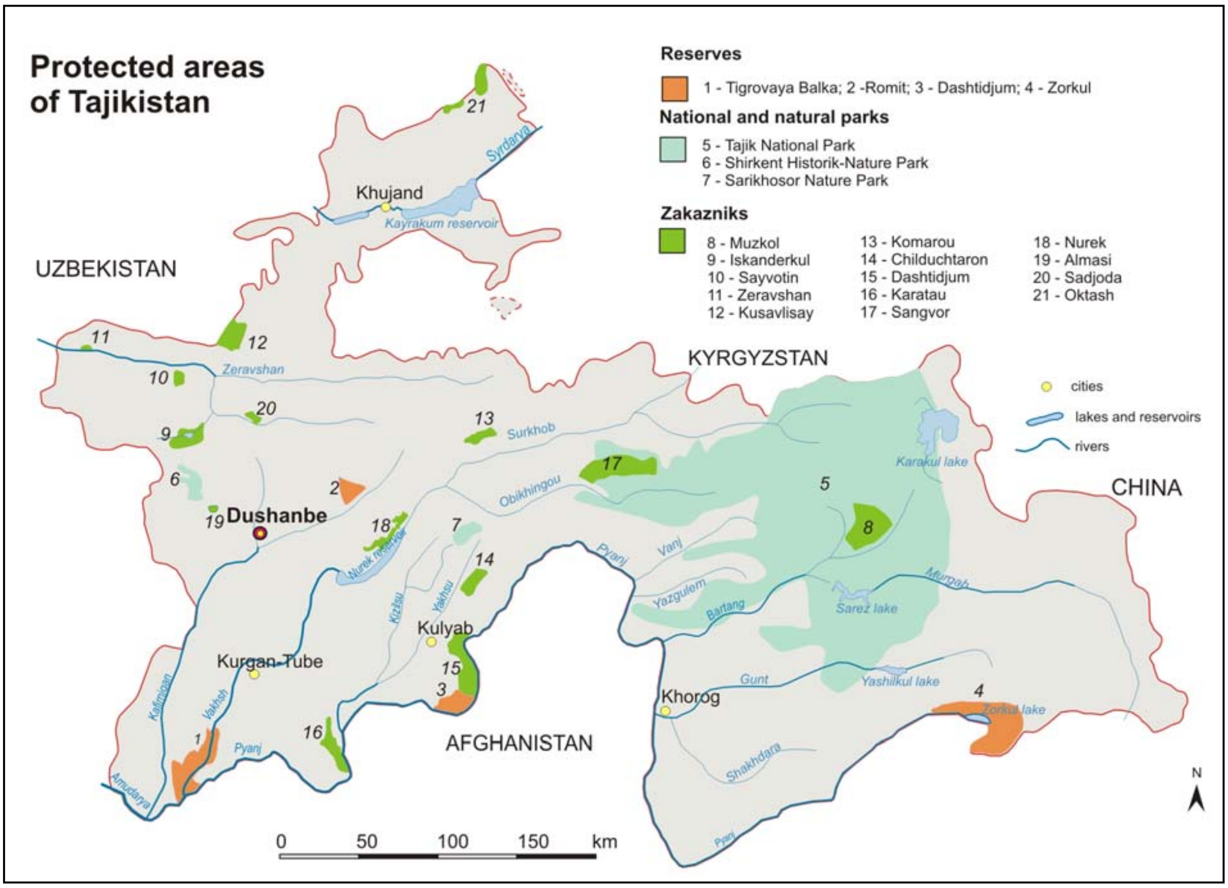

Figure 2-2. Protected areas of Tajikistan

Source: Adapted from NBBC 2009

However, the established protected areas network is far from ideal and has many problems with management and biodiversity conservation. Some of the drawbacks relate to the system itself and the fact that it does not cover all unique ecosystems and endangered species. According to Safarov *et al.* (2006), more than 10% of unique ecosystems and 85% of valuable species and their assemblages remain outside protected areas. Another problem is that the majority of *zakazniks* have very narrow conservation targets and focus on the protection of a few endangered species only, ignoring other associated species and valuable ecosystems (Safarov *et al.* 2006).

Other problems include the lack of financial and human resources that does not allow proper functioning of the environmental institutions and effective protection of biodiversity within designated protected areas. Due to the lack of funding, biodiversity monitoring within and outside protected areas has been significantly reduced, there is no updated data on the animal and plants numbers, and almost no research is carried out nowadays (Safarov *et al.* 2003). The situation has worsened by poor socio-economic conditions and low awareness. The protection regime is very often violated by local people who are forced to collect natural resources (e.g. wood) on the territory of the reserves in order to sustain their livelihoods (Safarov *et al.* 2006).

2.3.3 Policy and other measures

In response to problems with protected areas, Tajikistan has undertaken a number of steps towards the improvement of biodiversity conservation in general and protected areas management and efficiency in particular. The measures include the development of national strategies, programs and amendments to existing laws, as well as development and implementation of projects aimed at capacity building, raising awareness, and inventory and monitoring of biodiversity. A brief summary of the main measures and achievements is presented below.

2.3.3.1 National Biodiversity Strategy and Action Plan

A National Biodiversity Strategy and Action Plan (NBSAP) on conservation and sustainable use of biological diversity of the Republic of Tajikistan has been developed by the country to comply with its commitments under the CBD ratified in 1997, and to provide a policy instrument for biodiversity conservation in the country (Safarov *et al.* 2003). It contains not only comprehensive information on the current state of biodiversity and its components, main threats, trends and response conservation measures, but also specifies the main goals and objectives of biodiversity conservation, provides a strategy and action plans and identifies the main economic, political and financial mechanisms to achieve the envisaged goals. Adopted by the Government in 2003, the NBSAP constitutes the legal basis for biodiversity conservation in the country and requires implementation of identified measures by all competent authorities (Safarov *et al.* 2003).

The NBSAP provides detailed information on protected areas, their management and inefficiencies. It also identifies priority measures to overcome the problems and sets up a timeframe and mechanisms for their implementation. The main policy issues stipulated in the NBSAP include: a) enhancing the existing protected areas network by undertaking measures on protection of rare and endangered species and ecosystems, enhancing the monitoring systems and overall capacity building, b) expanding the current network of protected areas to include valuable and endangered species and ecosystems, c) development of national and regional protected areas network and ecological network, and d) harmonization of legislation with international requirements and obligations (Safarov *et al.* 2003).

In addition to the NBSAP the country has prepared four national reports on biodiversity conservation, with the last one submitted to the CBD Secretariat in 2009 (NBBC 2009). These reports provide up-to-date information on the state of biodiversity in Tajikistan (based on available data), as well as on the implementation of the Convention and its programs. Information about protected areas and progress of the implementation of the SCBD Programme of Work on Protected Areas in the country are also presented in the national reports.

2.3.3.2 National Environmental Action Plan

The National Environmental Action Plan (NEAP) was developed and adopted by the Government of Tajikistan in 2006 and aims to create the foundation for optimal nature management and conservation of valuable and fragile ecosystems to promote the sustainable development of the country (Safarov *et al.* 2006). The document provides comprehensive information on current environmental problems and identifies priorities, measures and mechanisms to overcome them. In addition to measures for coping with such problems as environmental pollution, deforestation, waste management and others, it provides measures on biodiversity conservation and protected areas management. The latter includes improvement of the protected areas system, training and raising the qualifications of protected areas management staff, revising the status of some reserves, organization of systematic monitoring, expanding the current protected areas network by establishing new micro-*zakazniks*, legislation harmonization and others (Safarov *et al.* 2006).

2.3.3.3 State Program on Protected Areas Development

One of the most important documents aimed at enhancing the protected areas system in Tajikistan is the State Program on Protected Areas Development in 2005-2015, adopted by the Government in 2005 as part of the NBSAP implementation process (NBBC 2006). The Program stipulates the main activities on the development of the protected areas in Tajikistan for the ten year period, and covers the most important issues in the area. Similarly to the national strategies, it emphasizes the need to harmonize the legislation to comply with international treaties and to expand the protected areas network to ensure the protection of valuable species and ecosystems (SCEPF 2005).

The Program envisages the establishment of new natural parks, *zakazniks* and reserves, as well as expanding the territory of existing natural parks and *zakazniks*, assigning buffer zones for the existing reserves and reorganization of the existing system based on the conservation goals and state of biodiversity (SCEPF 2005). It is also planned to create a transboundary national park with Afghanistan, China, and Pakistan. Other measures include the restoration of degraded habitats, renewal of scientific research and institutional capacity building. The Program provides detailed action plans, with the indication of responsible authorities and timeframe for implementation of activities, as well as concrete areas and places to be allocated for the creation of new protected areas (SCEPF 2005).

2.3.3.4 Ecological Network

A regional project has been implemented in Central Asia with the support of the World Wide Fund for Nature (WWF), United Nations Environment Programme (UNEP) and Global Environment Facility (GEF) and active participation of Tajikistan. The main goal of the project was the creation of a united scheme and strategy on the ecological network development in Central Asia for the long-term conservation of biodiversity and implementation of the agreement "On creation and management of the regional ecological network" signed in 2004 by the governments of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan (NBBC 2006; Pereladova *et al.* 2006). The project was also aimed at integration of the developed Ecological Network (Econet) into regional and national plans on sustainable development and establishing mechanisms for the long-term transboundary cooperation on biodiversity conservation (Pereladova *et al.* 2006).

The main outcome of the project was the development of an ecological network based on the complex integral approach with the use of GIS that allowed overlapping data on biodiversity, natural resources, existing protected areas network and socio-economic activities (Pereladova *et al.* 2006). The created comprehensive Econet of Tajikistan considers 82 animal and 80 plant indicator species and identifies the following components of the network: core areas of the first and second order, ecological corridors of the first and second order and buffer zones (NBBC 2006). Other project outcomes include the development of the Strategy and Action Plan on Econet Implementation at national and regional level, which *inter alia* provides necessary legal, structural, technical and financial mechanisms for its implementation (NBBC 2006).

2.3.3.5 Other activities

In addition to policy measures, a number of practical steps have been undertaken in the country and include the implementation of the projects on biodiversity conservation within protected areas, as well as strengthening the existing system of protected areas. The following protected areas were targeted by the projects:

- *Tigrovaya Balka Reserve*. Several projects were implemented on the territory of this reserve with the support of WWF and involvement of different stakeholders, including state agencies, scientists and NGOs. Undertaken activities comprise conservation of rare and endangered species, including reintroduction of Persian gazelle (*Gazella subgutturosa*), restoration of tugai forests, improvement of water balance, infrastructure rehabilitation and capacity building, and promotion of best water management practices among farmers (WWF 2008).

- *Dashtidjum Zakaznik* was the main target of the project funded by GEF and implemented with the support of the World Bank. The main outcomes of the project include development of the Management Plan for the *zakaznik*, institutional capacity building, implementation of the small grant program to ensure sustainable use of nature resources by local population, raising awareness on the value of biological resources and their sustainable use (Safarov *et al.* 2008).

- *Romit Reserve, Shirkent Natural Park* and *Almasi Zakaznik*, located on the southern slope of the Gissar Mountains, are covered by the ongoing project on protected areas and biodiversity management in the Gissar Mountains, which is being implemented with the support of United Nations Development Programme (UNDP) and GEF. The project aimed to improve management effectiveness and capacities in the selected protected areas and envisages activities on monitoring of endangered species and ecosystems, development of management plans, introduction of sustainable management practices on adjacent to protected areas territories, and many other activities (UNDP 2005).

The country has recently completed the UNDP-GEF project "Supporting country action on the CBD Programme of Work on Protected Areas". It has allowed to build capacity for the implementation of the following components of the CBD program: a) assessment of protected areas values by conducting national-level assessments of the protected areas environmental services and their integration into national processes, b) identification of the perverse incentives and their removal and/or mitigation of their negative effects, c) building capacity for protected areas by completing national capacity needs assessments, and d) development of a long-term monitoring program (UNDP 2010).

2.4 Local scene: Climate change in Tajikistan

Tajikistan belongs to the countries the least responsible for global climate change due to its low greenhouse gas emissions (Swarup 2009). Total CO_2 emissions in 2004 constituted only five megatons or 0.8 ton per capita, which can be compared with 20.6 ton per capita in the United States (UNDP 2007). This places Tajikistan as number 159 of 211 countries in the world, with the share of global emissions less than 0.1% (UNDP 2007; Makhmadaliev *et al.* 2008). Such a small share can be explained by insignificant use of fossil fuels, as 98% of the energy produced in Tajikistan is generated by hydropower plants. The main sources of greenhouse gases emissions in Tajikistan in 2002-2003 were agriculture (50%), fuel combustion (27%), industry (15%) and wastes (8%) (Makhmadaliev *et al.* 2008).

Though greenhouse gases emissions themselves are not of a big concern for the country, the consequences of climate change to its natural and socio-economic systems represent a real threat. Being a mountainous country with specific climatic conditions, landscapes and ecosystems, Tajikistan is very sensitive to global warming. Climate change and its negative consequences have already been observed, including an increase of surface temperatures leading to glaciers retreat, pest outbreaks, and biodiversity loss (Makhmadaliev *et al.* 2003a, 2003b, 2008). A brief overview of the climate change trends in Tajikistan as well as a summary of the observed and assumed impacts on biodiversity are presented below, along with the description of main policy measures on climate change mitigation and adaptation.

2.4.1 Observations and forecast

Analyses of climate change trends conducted by the SAH revealed that surface temperature in most areas of Tajikistan, including high altitude zones, is increasing (Makhmadaliev *et al.* 2003b, 2008). The average increase of mean surface temperature constitutes 0.1-0.2°C per decade for the last sixty years. The biggest increase in the mean surface temperature (1.2°C) was observed in a town located in the country's south. In the capital city, Dushanbe, this increase constitutes 1.0°C. Increase in mean surface temperature in the mountainous areas constitutes 0.3-0.5°C. Besides increase in mean surface temperatures, there is also an increase in minimum (by 0.5-2.0°C) and maximum (by 0.5-1°C) annual and seasonal temperatures. However in some areas of the country the minimum mean temperatures have decreased (by -0.1 °C). Duration of the frost-free period in most areas of Tajikistan has increased by 5-10 days (Makhmadaliev *et al.* 2008).

In contrast to increasing surface temperature, there is no general trend in precipitation patterns due to geographic and climatic diversity of the country (Makhmadaliev *et al.* 2003b, 2008). The observed trends vary for different elevations and landscapes. An insignificant increase of the annual amount of precipitations by 8% was observed on the territories located on elevations up to 2,500 masl, and a slight reduction by 3% was noted in the mountainous areas of the country. Though in some cases the intensity of precipitation has increased, the number of days with precipitation in general has decreased, with the maximum decrease of 48 days observed in some regions (Makhmadaliev *et al.* 2008). The trends in mean surface temperature and precipitation within Tajikistan are shown in Annex 3.

Climate change in Tajikistan can also be observed in the changing intensity and frequency of extreme weather events (Makhmadaliev *et al.* 2003b; 2008). The number of days with air temperature of 40°C and higher has increased at almost all flat areas of the country. Similar trends can be observed with the number of days with heavy rainfalls, especially in central mountainous and foothill areas, though the number of days when it snows has decreased. There is also increase in the frequency of natural disasters like floods and avalanches due to increase of mean surface temperatures (Makhmadaliev *et al.* 2003b; 2008).

According to the fourth IPCC report an increase in mean surface temperatures for Central Asia will constitute on average 3.7°C by the end of 21st century (0.3-0.4°C per decade), which is much greater than the global projected mean of 2°C (Christensen *et al.* 2007). The higher temperature increase in the models for high altitude areas is explained by the possible decrease in surface albedo due to snow and ice melting. The report also acknowledges that the projections for

Central Asia have many uncertainties due to the "complex topography and associated mesoscale weather systems of the high altitude areas" (Christensen *et al.* 2007, 81). Models project modest seasonal variations in the warming and a median decrease by 3% in the annual mean precipitation over Central Asia (Christensen *et al.* 2007).

Taking into account drawbacks of the global models that do not consider local landscape peculiarities and thus have high error probability, the State Agency for Hydrometeorology has employed a model developed by the Potsdam Institute for climate impact research, that takes into account geographical peculiarities of the country, to project climate change trends in Tajikistan until 2030 (Makhmadaliev *et al.* 2008). For this purpose, the reference data for the period from 1961 to 1990 collected from ten representative stations located in different climatic zones and altitudes of Tajikistan has been used. According to the developed scenarios a warming by 0.2-0.4°C is projected by the end of 2030 in most areas of Tajikistan. It means average temperature increase by 0.1-0.2°C per decade that coincides with the observed warming trends (Makhmadaliev *et al.* 2008).

2.4.2 Climate change and biodiversity

Despite the fact that mountain ecosystems and endemic species of Tajikistan are very vulnerable to climate change (Makhmadaliev *et al.* 2003b; Kassam 2009), research and information on climate change impacts on biodiversity are quite limited. It can be probably be explained by a general lack of monitoring and research activities in the country during the last twenty years, as well as by the relatively recent attention to the problem due to priorities given to other issues. Meanwhile, a number of observations and general knowledge have allowed experts to make first assumptions and conclusions on the negative impact of climate change on the country's biodiversity. A brief overview of the main studies and their results are presented below.

The first attempt to analyze climate change impact on biodiversity was undertaken during development of the National Action Plan of the Republic of Tajikistan for climate change mitigation in 2001-2003 (Makhmadaliev *et al.* 2003b). The study analyzed the overall vulnerability of ecosystems and their potential responses to global warming, and provided adaptation recommendations (section 2.4.3). The main projections presented in the report include: a) shift of the upper line of shrub and sub-shrub vegetation to higher elevations and degradation of this vegetation at the foothills, b) degradation of winter pastures and wetland ecosystems, and expansion of the area of deserts, c) flourishing of high mountain pastures and alpine meadows due to carbon dioxide fertilization effect, d) threats to the mid-mountain broadleaf forests from the increased frequency and intensity of the droughts, and e) negative impacts on water resources and thereby on inhabitants of water reservoirs (Makhmadaliev *et al.* 2003b).

The report also projects phenological changes in forest vegetation and fauna, alteration of flora and fauna species and spread of alien invasive species (Makhmadaliev *et al.* 2003b). The report emphasizes that increase of the surface mean temperature by more than 0.1°C per decade will exceed the capacity of mountain flora species for successful adaptation to climate change. Taking into account projections of surface mean temperature increase by 0.1-0.4°C per decade, the probability of mountain ecosystems degradation is quite high. Habitat loss as well as low adaptive capacity of the mountain species will lead to the loss of endangered and rare species (Makhmadaliev *et al.* 2003b).

The further study of the problem has resulted in the analysis of the most sensitive to climate change parameters and development of indicators for the assessment of climate change impact on ecosystems, reported in the Second National Communication on Climate Change (Makhmadaliev *et al.* 2008). Identified main indicators to climate change in different ecosystems include walnut trees for the deciduous forests of central Tajikistan, almond trees for southern Tajikistan, poplar for the tugai forests of *Tigrovaya Balka* and juniper forests as an indicator of long-term climatic fluctuations (Makhmadaliev *et al.* 2008).

The following parameters were identified as the most sensitive to climate change: impact on high mountain ecosystems and rare species of flora and fauna, outbreaks of pests and alien species, water and forest resources (Makhmadaliev *et al.* 2008). Climate change and related melting of snow patches were stated in the report as one of the reasons for the extinction of the endemic species Menzber's marmot (*Marmota menzbieri*) that inhabited the high altitude meadows in the northern Tajikistan until 1980-1990. Experts also claimed reduction of the population of several fish species (Amudarya trout, coast rainbow trout, etc.) due to the warming of water in reservoirs that created unfavourable conditions and affected migration routes (Makhmadaliev *et al.* 2008).

An increased number of pest outbreaks is another impact of the climate change mentioned in the Second national communication (Makhmadaliev *et al.* 2008). According to the report, a significant increase of pest outbreaks has been observed in Tajikistan in recent decades. In 2003-2005, increased number of cotton worm infestations caused harvest losses of up to 50%. Areas affected by locust (*Dociostaurus maroccanus*) in 2000-2007 increased from 16,000 to 85,000 hectares. Other negative impacts include threats to pistachios, almond trees and tugai forests of southern

Tajikistan, and associated biodiversity loss, from increased frequency and intensity of extreme weather events, including forest fires (Makhmadaliev *et al.* 2008).

The latest studies are focusing on the climate change impact on agricultural biodiversity, considering the fact that Tajikistan is the country of origin of many cultivated plants of global significance (Safarov *et al.* 2003). The project supported by UNDP and GEF seeks to embed agrobiodiversity of the country by removing barriers for its conservation and adaptation to climate change and enhancing current policy and practices (UNDP 2009). Along with other activities the project will focus on vulnerability and adaptation assessment of agrobiodiversity species to climate change and extreme weather events, as well as on identification of risk prone regions and stress resistant local endemic varieties for their reintroduction (UNDP 2009).

2.4.3 Policy measures

Taking into account the importance of climate change for the country, the Government of Tajikistan has undertaken several measures, including accession to the UN Framework Convention on Climate Change (UNFCCC) in 1998, and ratification of the Kyoto Protocol in 2000 (Makhmadaliev *et al.* 2008). In accordance with the obligations under the Convention, the country has developed several documents including a National Action Plan for Climate Change Mitigation and two National communications. A brief overview of these documents is presented below.

2.4.3.1 National Action Plan for Climate Change Mitigation

The National Action Plan for Climate Change Mitigation was adopted by the Government in 2003 and represents a strategic document on climate change issues (Makhmadaliev *et al.* 2003b). It provides a detailed overview of the climate change issues in the country, including problem background, climate change trends and scenarios, description of main sources and sinks of greenhouse gases, as well as overview of the potential and observed impact on various natural resources (including ecosystems), economy and public health. The document also identifies priorities and response measures for climate change mitigation, adaptation and for capacity building for further research and analysis (Makhmadaliev *et al.* 2003b).

Among various adaptation measures the document provides general recommendations on ecosystems adaptation to climate change (Makhmadaliev *et al.* 2003b). The following priority measures were identified with the involvement of various stakeholders: a) enhancing of scientific understanding of the climate change impact on ecosystems with a special focus on protected areas, b) systematic monitoring of the ecosystems, c) development and introduction of practices for sustainable use of natural resources, d) supporting natural corridors for the migration of species, e) protection of endangered species and their habitats, and f) expansion of the existing protected areas to cover ecosystems vulnerable to climate change (Makhmadaliev *et al.* 2003b).

2.4.3.2 National communications

The First National Communication on Climate Change was prepared by Tajikistan in 2003 and focuses on capacity building in priority areas (Makhmadaliev *et al.* 2003a). It provides comprehensive information on trends in greenhouse gases emissions and identifies potential for development and technology needs assessment in different economic sectors for emissions reduction and adaptation to climate change. It analyzes economic, environmental, legislative and institutional frameworks, determines barriers as well as suggests mechanisms and measures for the technology transfer and implementation of identified priority projects on climate change mitigation and adaptation (Makhmadaliev *et al.* 2003a).

The Second National Communication on Climate Change was completed in 2008 and aimed at providing up-to-date information on climate change issues in Tajikistan, including status of the implementation of UNFCCC (Makhmadaliev *et al.* 2008). It presents an updated inventory of greenhouse gases and sinks, vulnerability assessment by different sectors, as well as climate change adaptation and mitigation measures. The report also focuses on climate change impact on biodiversity (see section 2.4.2 for details) and emphasizes importance of protected areas and diverse and unique ecosystems of the country in studying impact of climate change on biodiversity at various altitudes and in different climatic zones (Makhmadaliev *et al.* 2008).

2.5 Summary

Climate change is an unequivocal global problem with many negative consequences including loss of valuable species, ecosystems and their services. It affects biodiversity in a number of ways, causing changes that lead to population decline and, in worst cases, to the extinction of species. From the review of species' adaptive responses to climate change, which include shifts of distribution ranges to higher latitudes and elevations, and changes in timing of life-cycle events, it is evident that climate change impacts on biodiversity have direct implications for protected areas management. Dynamic responses and constant changes in ecosystems' composition and distribution question the adequacy of the existing protected areas that serve as a primary tool for biodiversity conservation and urges for the development of climate change adaptation measures based on the biodiversity vulnerability assessment and available adaptation policies and strategies.

Climate change poses a real threat to the rich and unique biodiversity of Tajikistan represented by many rare, relict and endemic species and wild relatives of cultivated plants of global significance. Mountain ecosystems of Tajikistan are especially sensitive to climate change due to their low adaptive capacity. Increases of surface mean temperatures by more than 0.1°C per decade, which is already happening, could cause significant degradation of the mountain ecosystems and loss of their endangered inhabitants. Immediate adaptation measures are required to prevent the irreversible loss and should start with research on ecosystems' vulnerability to climate change in parallel with other measures including enhanced management of protected areas and minimized pressure on natural resources.

The Government of Tajikistan has already undertaken a number of measures towards biodiversity conservation, which includes development of a unique protected areas network that covers 22% of the country's territory and represents almost all ecosystems, rare and endemic species. Although the network experiences various problems in terms of management and effective biodiversity conservation, there are number of responsive measures aimed to overcome them. They include development of national strategies (NBSAP, NEAP), ecological network of the country and adoption of the State Program on Protected Areas Development. At the same time, none of these documents consider the issue of climate change impact on biodiversity that has undoubted implications for protected areas management.

Research on climate change impact on biodiversity of Tajikistan is quite limited and was mainly carried out during the development of the National Action Plan for Climate Change Mitigation and National communications on climate change. The latter provides an assessment of environmental parameters sensitive to climate change, including rare and endangered species, pest outbreaks, water and forest resources, and introduces indicator species that can be used to monitor climate change impact on ecosystems. The importance to assess climate change impact on biodiversity within protected areas is highlighted in the National Action Plan for Climate Change Mitigation, which is the strategic document for Tajikistan. The document also stipulates priority measures on ecosystems adaptation to climate change, which includes expansion of the existing protected areas to cover ecosystems vulnerable to climate change and enhancing the scientific understanding of climate change impact on ecosystems with a special focus on protected areas.

3. Methodological Framework

This research is based on a combination of complementary methods and approaches including archival reviews and interviews for data collection, quantitative methods for analysis of meteorological data and qualitative vulnerability assessment based on the DPSIR approach for data analysis (see Table 3-1). The research employs a case study that focuses on *Dashtidjum Zakaznik,* one of the most vulnerable reserves to climate change impacts with high significance for biodiversity conservation. A brief overview of the methods, including site selection, is presented below. This chapter also provides an overview of the scope and limitations of the research.

Table 3-1. Thesis methodological framework

Objective	Methods	Results
Analyze meteorological data and *identify* climate change trends on the territory of *Dashtidjum Zakaznik*	Archival review Pearson correlation Calculation of trend values	Meteorological data is obtained Representative dataset is chosen Climate change trends are identified
Assess vulnerability of different components of biodiversity of *Dashtidjum Zakaznik*, including fauna, flora and ecosystems, to climate change impacts and *identify* potential changes in their state under an altered climate.	Archival review Semi-structured expert interviews Qualitative assessment based on the DPSIR approach	Background information on biodiversity of *Dashtidjum Zakaznik* is collected Experts reflections on climate change impacts on biodiversity are obtained Vulnerability of biodiversity of *Dashtidjum Zakaznik* is assessed and main impacts of climate change are identified and prioritized
Analyze relevant national policies and programs and *identify* prerequisites for implementation of adaptation measures	Archival review Qualitative assessment based on the DPSIR approach	Information on national policies and legislation is obtained and analyzed. Prerequisites for implementation of adaptation measures are identified
Identify implications for protected areas management and *develop* recommendations for adaptation measures to climate change	Semi-structured expert interviews Qualitative assessment based on the DPSIR approach	Implications for protected areas management are identified and policy recommendations are developed and discussed

3.1 Site selection

A case study approach was chosen to tackle the research problem and ensure its comprehensive exploration with a variety of data collection and analysis procedures. The study site selection was based on a review of a number of criteria, including sensitivity to climate change, data availability and significance of site for biodiversity conservation, and resulted in this research's focus on *Dashtidjum Zakaznik* (see section 4.1 for a general description) as one of the most vulnerable reserves to climate change impacts with high significance for biodiversity conservation. A brief overview of the factors considered during the site selection is provided below.

Sensitivity to climate change is one criterion suggested by IPCC for site selection, and implies selection of a site where changes in climate are likely to be felt first and with the greatest effect (Parry and Carter 1998). According to (Makhmadaliev *et al.* 2008) *Dashtidjum Zakaznik* is located in an area 'significantly vulnerable' to climate change in ecological terms. This is explained by a significantly higher increase in the mean temperature (up to 1°C) in comparison with other regions of the country. In addition, the forest is prone to fires, and an increase in the number of forest fires due to warmer temperatures has been observed (Makhmadaliev *et al.* 2008).

Data availability is an important issue that could constrain any research (Parry and Carter 1998). *Dashtidjum Zakaznik* is one of the few reserves that have been studied in recent years, and the only one that has a Management Plan with detailed information on the current state of biodiversity, including data on species distributions (Safarov *et al.* 2008).

Significance of the site for biodiversity conservation is another factor considered for the site selection. *Dashtidjum Zakaznik* provides habitat for more than a 100 endemic flora species (Safarov *et al.* 2008). Forty animal and 43 plant species are listed in the Red Data Book of Tajikistan, and 14 plant and animal species are listed in the IUCN Red List (Safarov *et al.* 2008; IUCN 2010c). It also protects mid-mountain forest ecosystems, which are poorly represented in the protected areas network (section 2.3.2)(Safarov *et al.* 2003).

3.2 Data collection

A number of methods have been employed to gather data for the research, including archival reviews and semi-structured expert interviews. The former involved review of publications and materials from various sources, such as academic, government, intergovernmental, international, and non-governmental organizations. Interviewing experts not only provided additional insights into the issue, but also helped to obtain required data, as published materials on climate change impacts on biodiversity of Tajikistan are quite limited. Interviews also allowed to obtain experts' reflections on potential impacts of climate change on the biodiversity of the *zakaznik* and to identify priority issues and conservation measures. Field trip to *Dashtidjum Zakaznik* and interviews with the foresters helped collecting data on monitoring programs and observed climate change trends and impacts, and discussing potential adaptation measures. A brief overview of the methods is provided below.

3.2.1 Archival reviews

A detailed literature review was performed at the initial stage of the research and explored the problem from both global and national perspectives, to facilitate better understanding of the problem and to identify the criteria for the vulnerability assessment framework (section 3.3.1). This review also resulted in the identification of research gaps and the feasibility of using the proposed methods.

To address the research questions, documents were reviewed from internet sources, using Electronic Library Information Navigator (ELIN) of Lund University and Google Scholar. For the information from international, intergovernmental and non-governmental sources the official-websites of the organizations dealing with climate change, biodiversity conservation, and protected areas were accessed, including: UNFCCC, IPCC, CBD, UNEP and its World Conservation Monitoring Centre (UNEP-WCMC), IUCN, WWF and UNDP. The majority of country-level information, including official publications and internal reports, was retrieved from the databases of National Biodiversity and Biosafety Center (NBBC), SAH and UNDP.

An archival review was an important method in data collection during the research phase and also allowed obtaining data that is not available in published or electronic materials. It was used to gather information on temperature and precipitation trends recorded at Yol, the nearest meteorological station to *Dashtidjum Zakaznik,* as well as at mid-mountain meteorological stations (section 3.3.2). Another part of the archival review involved analysis of internal reports of the Academy of Science and its institutes, as well as those from the Research Laboratory for Nature Protection and other academic and state institutions, for any information on observations and analysis of climate change impacts on biodiversity of Tajikistan.

3.2.2 Expert interviews

Interviews with experts were an essential part of the research due to the lack of studies and published materials on observed and potential impacts of climate change on biodiversity of Tajikistan, and *Dashtidjum Zakaznik* in particular. Altogether, 18 experts with various backgrounds and from different institutions, including academic and governmental were interviewed (see Annex 4). A majority of interviews was conducted face-to-face during the research trip to Tajikistan; three interviews were conducted by phone. The interviews were held in a semi-structured form, with most of the questions prepared in advance. Generalized sample questions, as well as sample table that were filled during the interviews, are given in Annexes 5 and 6.

Interview data formed a basis for the analytical part of the research. They helped *inter alia* to identify (i) main pressures from climate change on various species of *Dashtidjum Zakaznik* and potential responses of species, (ii) observed impacts of climate change on biodiversity of the *zakaznik*, (ii) the most threatened species by climate change impacts, and (ii) priorities and recommendations for conservation measures. In addition to formal interviews, a number of consultations with experts in relevant fields were held to assist in selection of target species, as well as to discuss results of the research and suggested recommendations.

3.3 Data analysis

I analyzed data in several steps and employed the simplified DPSIR approach as the main framework for data analysis. Though there are a number of techniques to assess biodiversity vulnerability to climate change, including analogue studies, climate envelope modeling, and dynamic population modeling (Malcolm 1998; Parry and Carter 1998), the vulnerability assessment using the DPSIR framework was chosen due to the lack of quantitative and qualitative data on biodiversity trends in Tajikistan, which makes implementation of other types of analysis difficult.

The main components of the vulnerability assessment are presented below, in the section on DPSIR approach. In addition to qualitative analysis, I employed quantitative methods, including Pearson' R correlation for the selection of representative dataset and calculation of trend values for the analysis of meteorological data and identification of climate change trends on the territory of *Dashtidjum Zakaznik*. A brief overview of the methods employed for the analysis of meteorological data is presented in section 3.3.2

3.3.1 DPSIR approach

The DPSIR assessment framework was developed by European Environment Agency (EEA) in 1995 and adopted by many organizations worldwide as a tool to carry out environmental assessments (EEA 1998; Maxim *et al.* 2009). It has proved to be helpful in identifying and illustrating different elements, their references to each other, and implications for policy tools (Omann *et al.* 2009). The DPSIR approach therefore was chosen to address the research objectives from different angles and to obtain comprehensive view on vulnerability of *Dashtidjum Zakaznik* to climate change impacts and potential adaptation measures. It has been used to assess the vulnerability of the biodiversity of *Dashtidjum Zakaznik* to climate change impacts, identify implications for its management and develop recommendations on adaptation measures to mitigate climate change impacts on the biodiversity of the *zakaznik* (see Table 3-2).

The DPSIR approach was simplified in accordance with the research objectives and employed criteria identified at the literature review. The research started from a brief analysis of current trends and predictions for climate change in the study area (section 3.3.2) as one of the *drivers* for biodiversity loss. It was followed by the analysis of information on main *pressures* or factors of climate change impact on biodiversity, including direct and indirect factors, obtained through archival review and interviews. Species and ecosystems vulnerability was analyzed under the *state* component. It considered potential responses of species to climate change impacts, with a focus on sensitive species and ecosystems types, including those with limited geographical distribution, based on the assumption that species with narrow resource and habitat requirements, and already threatened by human activities, are more vulnerable to climate change impacts (Millsap *et al.* 1990; Mkanda 1996; Malcolm 1998), they also are the primary target of conservation measures.

Vulnerability assessment under the *state* component was supplemented with the analysis of available observations on species responses to climate change, collected through archival review and interviews (see Table 3-2). The vulnerability assessment of biodiversity helped to identify implications for the protected areas management, which constituted the basis for the *impact* component of the research along with the identified potential threats for biodiversity of the *zakaznik*. The *response* component included analysis of natural adaptation capacities of *Dashtidjum Zakaznik*. This analysis was done based on criteria suggested by several authors who argue that some characteristics of protected areas contribute to mitigation of climate change impacts or predispose to them (Malcolm 1998; Mackinnon 2008). These characteristics include topographic uniformity, connectivity with other components of a protected areas network, length of the south-north axis, and others (Malcolm 1998; Mackinnon 2008).

Another part of the <u>*response*</u> component was based on the analysis of national policies and programs on biodiversity conservation, protected areas development, and climate change mitigation. They were analyzed to identify prerequisites for the implementation of adaptation measures on the territory of *Dashtidjum Zakaznik* to mitigate climate change impacts. This analysis, as well as results of the vulnerability assessment, helped to address the fourth research question and develop recommendations for adaptation measures (see Table 3-2).

Table 3-2. Vulnerability assessment framework

Component	Research focus	Methods
Driver	Climate change on the territory of *Dashtidjum Zakaznik*: observations and forecast	Pearson correlation and calculation of trend values based on data obtained by archival review
Pressure	Direct and indirect factors of climate change impact on biodiversity	Vulnerability assessment based on data obtained by archival review and interviews
State	Fauna, flora, and ecosystems vulnerability Observed and potential responses of species and ecosystems to climate change	Vulnerability assessment based on data obtained by archival review, interviews and results of the research
Impact	Impacts on biodiversity and implications for management of *Dashtidjum Zakaznik*	Vulnerability assessment based on the results of the research
Response	Natural adaptation capacities of *Dashtidjum Zakaznik* Prerequisites for adaptation measures Recommendations for adaptation measures	Vulnerability assessment based on data obtained by archival review, experts interviews and the results of the research

3.3.2 Analysis of meteorological data

In order to analyze and characterize climate change on the territory of *Dashtidjum Zakaznik* I have used statistical data from the SAH database. In particular, I employed temperature and precipitation data with a monthly resolution for the period from 1961 to 2008. It should be noted that two separate datasets have been used within this research: one dataset to describe the <u>modern climate</u> on the territory of *Dashtidjum Zakaznik* and another representative dataset to identify the <u>climate change</u> trends. The latter is explained by the lack of meteorological observations at the study area.

To identify the modern climate on the territory of the *zakaznik*, I have used meteorological data for the baseline period 1961-1990 as recommended by the World Meteorological Organization (WMO) (McCarthy *et al.* 2001). For this purpose, I employed data from the meteorological station Yol, which is located on the territory of *Dashtidjum Zakaznik* at the altitude 1,283 masl and represents the climate of the most territory of the *zakaznik* (Asanova 2010b). To analyze the climate change on the territory of *Dashtidjum Zakaznik* for the period from 1961 to 2008 I have used the average data from mid-mountain meteorological stations that has been identified as a representative data for the study area (see explanations below).

A need to use the representative dataset was implied by the fact that the meteorological station Yol was closed in 1988 and there are no other meteorological stations located in the study area. The decision to use average data from the mid-mountain meteorological stations was taken after the consultations with the specialists of the SAH, comparative analysis of the temperature and precipitation trends generated both for the meteorological station Yol and for the mid-mountain meteorological stations, and Pearson's R correlation analysis.

Comparative analysis has been done using the Ms Excel by generating trend values to identify temperature and precipitation patterns for the period 1961-1987 for Yol area and mid-mountain stations, located at the altitudes from 1,000 to 2,500 masl. The generated graphs have shown a high synchronization of annual mean temperatures (see Figure 3-1). In particular, mean annual temperature has increased by 0.5°C for Yol area, and by 0.4°C for mid-mountain areas. Though the precipitation trend values have different signs: -0.2% for Yol area and +7% for mid-mountain area (Figure 3-2), the difference is insignificant for precipitation (Asanova pers.comm.).

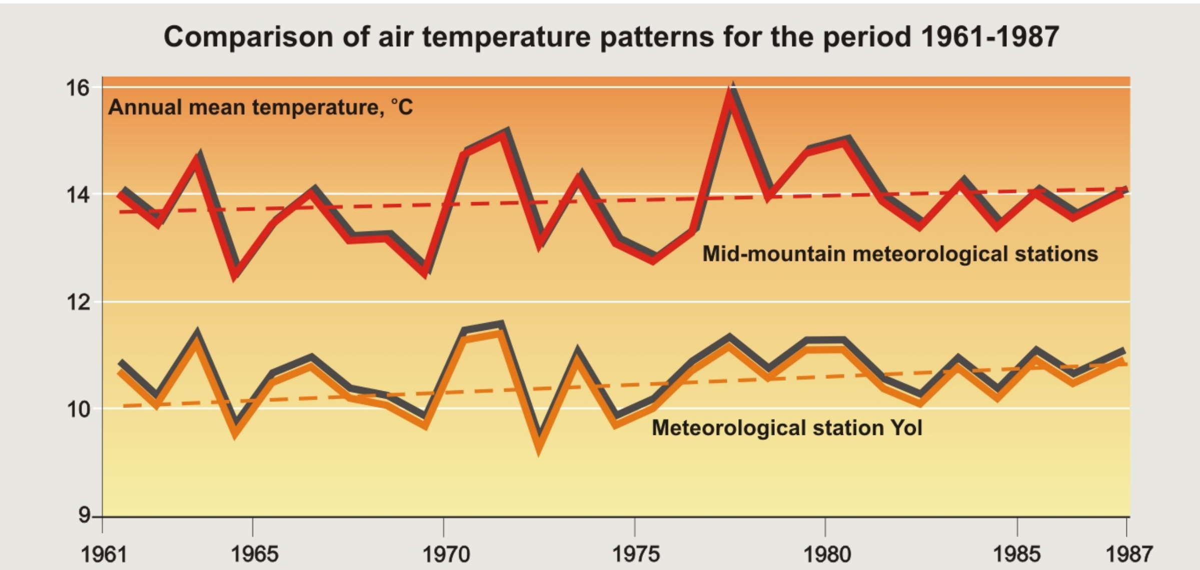

Figure 3-1.Comparison of air temperature patterns Data source: SAH 2010

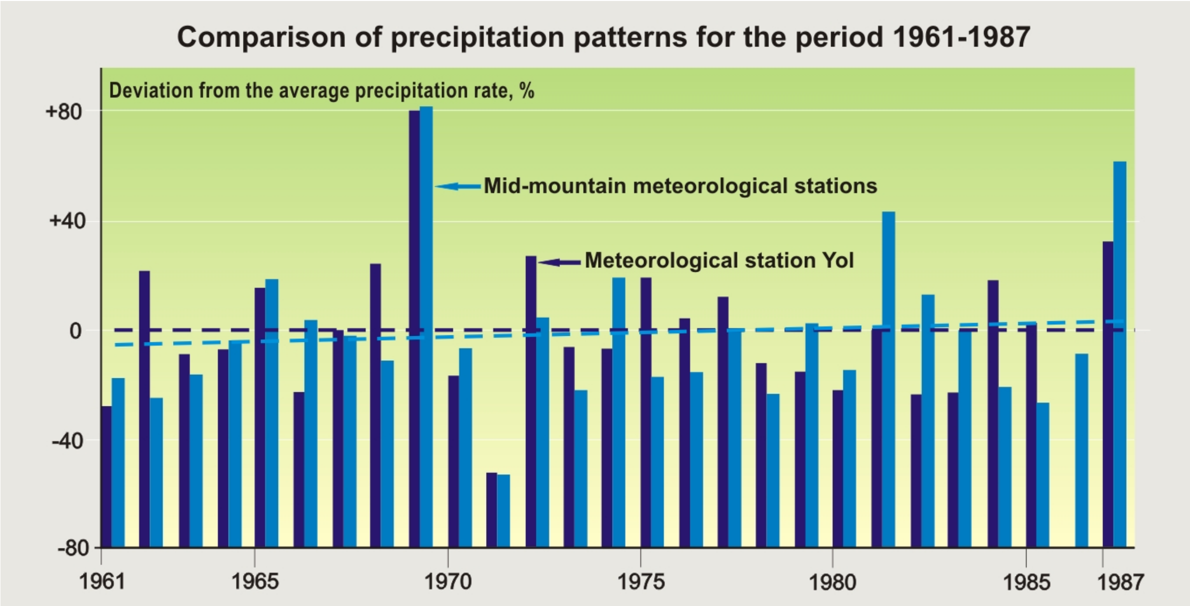

Figure 3-2. Comparison of precipitation patterns Data source: SAH 2010

The Pearson's R analysis has been done by using SPSS statistical package and has confirmed the correlation between two datasets. In particular, temperature correlation between Yol and mid-mountain stations for period 1961-1987 is positive and very highly significant ($r=0.890$, $p<.001$, $n=27$). Precipitation correlation between Yol and mid-mountain stations for period 1961-1987 is positive and highly significant ($r=0.598$, $p<.01$, $n=26$). Based on the results of the comparative and correlation analysis, the temperature and precipitation data from mid-mountain meteorological stations has been selected as the representative dataset and employed to analyze climate change trends on the territory of *Dashtidjum Zakaznik*.

To analyze climate change on the territory of *Dashtidjum Zakaznik* I have used quantitative method employing Ms Excel software. I have calculated annual and seasonal mean temperatures (°C) and annual and monthly rate of precipitations (deviation from the average rate for 1961-1990, %) for the baseline period and the following years up to 2008. I have generated graphs in Ms Excel, using the calculated temperature and precipitation values, to identify and characterize the linear trends. To calculate a trend value *(y)* I have used the equation: $y = coefficient *x$, where x equal to number of years minus one and coefficient is generated by Ms Excel program for each case. As a result, I obtained the trend values that allowed me to analyze changes of studied meteorological parameters, compare climate change during the baseline and following periods, and identify main factors that may have negative impact on the biodiversity of the *zakaznik*.

3.4 Scope and limitations

This research is a first step in analyzing climate change impacts on protected areas in Tajikistan. It employs a case study approach to gain a comprehensive view on the issue and only focuses on *Dashtidjum Zakaznik*. At the same time, however, recommendations provided here are relevant to other elements of the protected areas network in Tajikistan, especially those focusing on overall management and policy recommendations. The same can be stated regarding vulnerability assessment of species and ecosystems that occur in similar habitats in other reserves.

This research focuses only on climate change impacts on biodiversity and does not cover climate change impacts on human social and economic aspects, as well as other human-induced impacts on biodiversity such as habitat modification and poaching. The research also did not intend to analyze all taxa that inhabit *Dashtidjum Zakaznik* but focused mainly on endangered and rare species under protection, as well as ecosystems. Being a first step research, it primarily focuses on species-climate interactions and does not consider interspecies interactions.

The research focuses only on adaptation to climate change impacts and does not consider mitigation strategies aimed at reduction of greenhouse gases emissions, including the REDD initiative, though protected areas management and biodiversity conservation are also used as tools to mitigate consequences of climate change. Although it considers adaptation strategies to climate change, the main attention given here is to strategies relevant to protected areas, and other strategies aimed at biodiversity conservation are excluded.

The research was limited by data availability and thus relies both on existing knowledge and assumptions. At the same time, it was supported by opinion of highly qualified experts, which provided additional credibility to its results. Meanwhile, there are some uncertainties in the results of climate change analysis, in particular on precipitation trends, as the average representative data has been employed. Other uncertainties may refer to the results of the vulnerability assessment due to the combination of climate change and anthropogenic impacts at the study area.

It should also be noted that while various sources of information have been reviewed, they represent organizations and people dealing with environment protection. Thereby, the paper does not incorporate views of other parties, e.g. businesses that can have alternate opinions regarding climate change impacts in general and strategies to adjust protected areas management in particular. But this is a task for further, more detailed research.

4. Vulnerability Assessment of Dashtidjum Zakaznik

This chapter provides the results of the vulnerability assessment of *Dashtidjum Zakaznik* to climate change. It constitutes of six sections and starts from the brief introduction to the *zakaznik* itself, its location, history, and conservation goals. The main body of the chapter covers several aspects of the vulnerability assessment. It begins from the analysis of climate change trends on the territory of *Dashtidjum Zakaznik* for the period from 1961 to 2008. Based on the climate change trends, as well as future projections, the climate change impacts on the *zakaznik* are analyzed for the main components of biodiversity, including fauna, flora and all types of ecosystems. In the assessment, special attention is given to endangered species, as well as rare and endemic species and wild relatives of cultural crops of global significance, which are priority species for biodiversity conservation on the territory of *Dashtidjum Zakaznik*. The assessment covers the main aspects of species' vulnerability to climate change, observations of changes and assumptions for future changes, including distribution and population size. The vulnerability assessment of biodiversity components is followed by a short summary of the main findings.

4.1 Dashtidjum Zakaznik

Dashtidjum Zakaznik was established in 1972 with the objective of the conservation of the rare population of endangered species markhor (*Capra falconeri heptneri*), as well as other endangered species, including urial (*Ovis vignei bocharensis*), snow leopard (*Uncia uncia*) and Tien-Shan brown bear (*Ursus arctos isabellinus*), and unique mid-mountain forests (Annex 14) (NBBC 2003; Safarov *et al.* 2003). The total area of the *zakaznik* is 51,300 ha (Safarov *et al.* 2008). It is located in a mountainous area of southern Tajikistan (see Figure 4-1), on the southeast slopes of the Khazratisho range, between 37°40' and 38°20' north latitude and between 70°00' and 70°20' east longitude. The borders of *Dashtidjum Zakaznik* mainly pass along natural boundaries. In the north it is bordered by the Khodjidara river valley and on the south by the cam of Khazratisho range (Safarov *et al.* 2008). In the south, *Dashtidjum Zakaznik* borders with the state reserve of the same name. South-eastern and eastern borders of the *zakaznik* coincide with the state border of Tajikistan and Afghanistan along the Pyanj river (Figure 4-1)(Safarov *et al.* 2008).

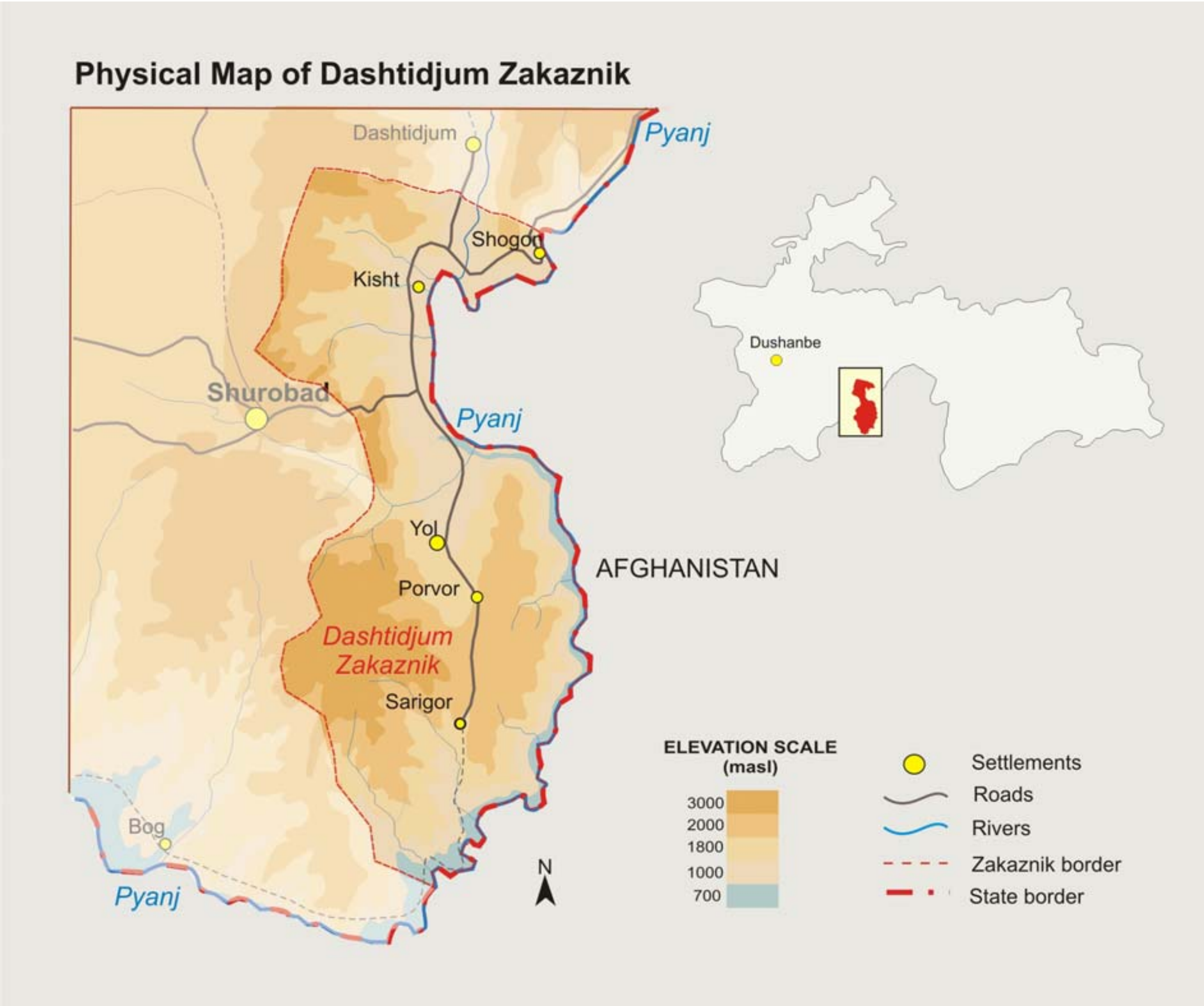

Figure 4-1. Location and physical map of Dashtidjum Zakaznik Source: Adapted from Noosfera 2008

The territory of the *zakaznik* comprises diverse elevations ranging from 700 to 2,911 masl (Safarov *et al.* 2008). The main orographic element of *Dashtidjum Zakaznik* is the Khazratisho range, with the highest peaks of Imam-Askari and Alanyzrak mountains: 2,911 and 2,843 masl respectively. In the north, the *zakaznik* encompasses a small part of the Darvaz range. The territory of *Dashtidjum Zakaznik* is characterized by a contrast relief and a dense hydrological network. An interesting feature of the *zakaznik* is the unique rocky conglomerate formations located in all vertical zones, from foothills and up to high mountains. They have diverse shapes and constitute one of the main elements that form the landscape of the *zakaznik* (Figure 4-2). These formations represent the main attractions for tourists, as well as provide shelter for many rare and endemic animal species similar to other parts of the *zakaznik* (Safarov *et al.* 2008).

Figure 4-2. Diverse landscapes of Dashtidjum Zakaznik

4.2 Climate change in Dashtidjum area

4.2.1 Modern climate

The climate of the area of *Dashtidjum Zakaznik* can be characterized as continental with frequent sudden changes of diurnal and seasonal temperatures (Safarov *et al.* 2008). A diverse and complex landscape sets conditions for the significant climatic variations at different places of the *zakaznik*, but, in general, the region can be characterized by hot and dry summers and warm and humid winters. According to observation data from the meteorological station Yol, mean monthly temperatures in the region are positive in the whole course of a year, with the mean annual air temperature 13.8°C (SAH 2010) (see Table 4-1). July and August are the hottest months of the year with the maximum temperature up to 40°C and the mean monthly temperature of 26°C and 26.8°C respectively. The coldest month of the year is January, with a mean monthly temperature 0.7°C and absolute minimum temperature -22°C (SAH 2010). It should be noted that at the high mountain areas of *Dashtidjum Zakaznik* (>2,000 masl) the temperatures are lower. The annual mean temperature there is 7.4°C, with the absolute maximum of 32°C and absolute minimum of -31°C (Safarov *et al.* 2008).

Table 4-1.Average climate parameters of the study area in 1961-1987

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	year
Air temperature, °C													
Mean	0.7	1.8	7.4	13.5	17.6	23.7	26.8	26.0	21.2	14.7	8.6	3.5	**13.8**
Maximum	13	18	22	31	37	39	40	40	37	33	27	20	**40**
Minimum	-22	-21	-13	-3	1	5	13	11	7	-3	-14	-18	**-22**
Sum of precipitations, mm													
Mean	51	66	100	116	83	20	18	3	4	27	29	37	**538**
Maximum	122	152	239	224	169	59	60	15	15	120	80	133	**966**
Minimum	3	13	7	68	19	0	0	0	0	0	1	0	**254**

Data source: SAH 2010

Annual average sum of precipitations is 538 mm, which indicates the aridity of the region (see Table 4-1) (SAH 2010). The maximum amount of precipitation falls in the spring season and is 55% of the annual amount of precipitations. A minimum amount of precipitation is observed in summer and autumn and is 4 to 12% of the annual amount (SAH 2010). Despite a low amount of annual precipitation in the major parts of the *zakaznik*, there are places where annual precipitation frequently amounts to 1,000-1,500 mm (Safarov *et al.* 2008). These are middle and high mountain canyons located within the wood and shrub zone and well protected by surrounding mountain ranges. On the territory of the *zakaznik*, there is almost no stable snow cover, except in harsh winters with a large amount of snow (Safarov *et al.* 2008). Usually a snow cover of low thickness can be observed from the middle of December to the middle of February. The maximum thickness of the snow cover constitutes 30 cm (Asanova 2010b). An exception is the high-mountain areas where a deeper snow cover can be observed for a longer period of time (Safarov *et al.* 2008).

4.2.2 Rate of climate change

Climate change on the territory of *Dashtidjum Zakaznik* is confirmed by the analysis of data from the meteorological stations located at altitudes of 1,000 to 2,500 masl (section 3.3.2). According to data processed, there are significant changes in air temperatures during the period analyzed, which resulted in some years being colder or warmer (Figure 4-3). At the same time, there is a clear trend of increase of the annual mean temperatures, which can be observed already during the baseline period (Figure 4-3). In particular, the annual mean temperatures for the period 1961-1990 have increased by 0.5°C or by 0.02°C per year. This increase is caused by the increase in monthly temperatures through the year, except February and March (Asanova 2010a). The analysis of seasonal changes in mean temperatures has revealed their increase during the winter (by 0.4°C), summer (by 0.3°C), and especially autumn (by 0.8°C). Spring, on the contrary, is characterized by a slight decrease, which constitutes -0.1°C.

Climate change in the following years up to 2008 is characterized by a further increase of air temperatures (Figure 4-3). The annual mean temperatures increased by 1.3°C for the period 1991 to 2008. The increase is 0.07°C per year, which is almost three times higher than for the baseline period. Similar to the baseline period, increase of annual mean temperatures is caused by the increase in monthly temperatures. Analysis of seasonal anomalies has shown significant changes in spring mean temperatures, which have increased by 3.2°C. While the summer temperatures have also considerably increased (by 0.9°C.), the autumn and winter temperatures have shown insignificant decrease if compared with the baseline period: by 0.7°C and 0.3°C respectively. In general, the change of annual mean temperatures for the period 1961 to 2008 is 0.8°C or 0.02°C per year. This is higher than the 0.5°C trend observed in the majority of the country's regions (section 2.4.1).

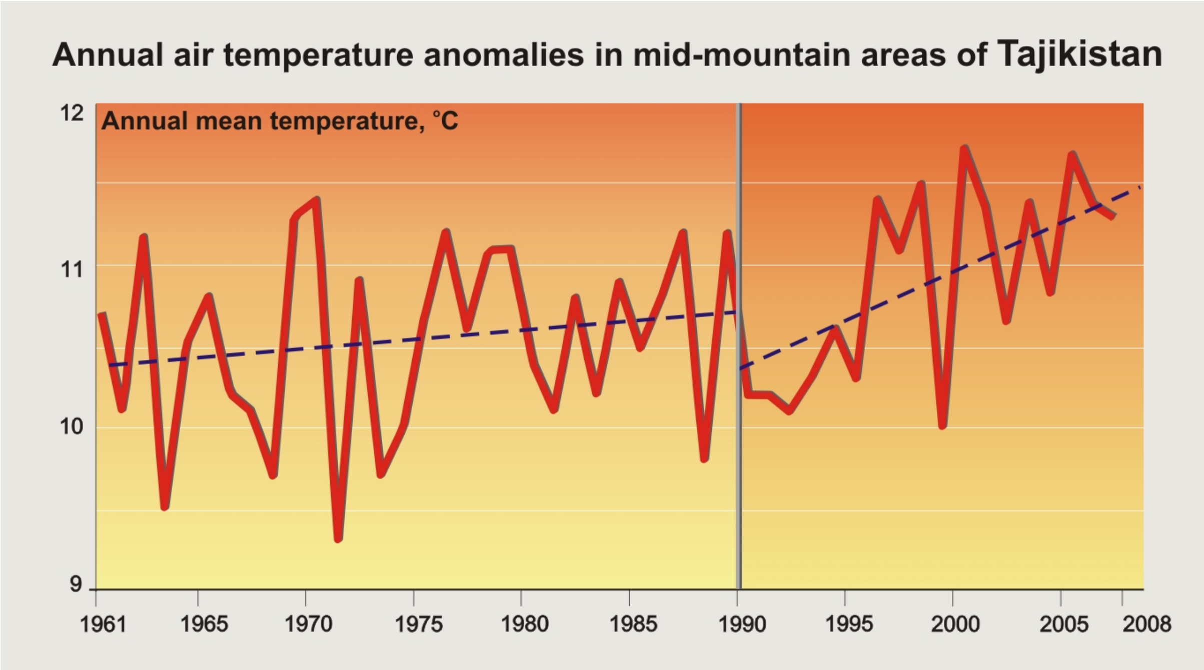

Figure 4-3. Annual air temperature anomalies in mid-mountain areas Data source: SAH 2010

Climate change on the territory of *Dashtidjum Zakaznik* is also confirmed by the changes in the amount of precipitation. Analysis of annual and monthly changes has revealed significant differences between the baseline period and the following 18 years. As can be seen from Figure 4-4, the baseline period is characterized by an insignificant increase of annual precipitation, which is 12% of the average precipitation rate for the period 1961-1990 (Figure 4-4). In a monthly analysis, the increase in precipitation has been observed in eight out of twelve months (see Table 4-2). In the following year up 2008, anomalies in precipitation patterns are characterized by the significant decrease in 32% (Figure 4-4). A monthly analysis has shown a decrease of precipitation for the majority of months, except of February, October and November. As can be seen from Table 4-2, the most significant decrease of precipitations was observed in September, as well as May and December.

Table 4-2. Monthly precipitation anomalies in mid-mountain areas of Tajikistan

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	year
Precipitation, deviation from the average precipitation rate in 1961-1990 (%)													
1961-1990	24	-20	1	-31	-23	13	23	11	17	36	-10	36	**12**
1991-2008	0	7	-2	-8	-70	-23	0	-40	-150	18	19	-29	**-32**

Data source: SAH 2010

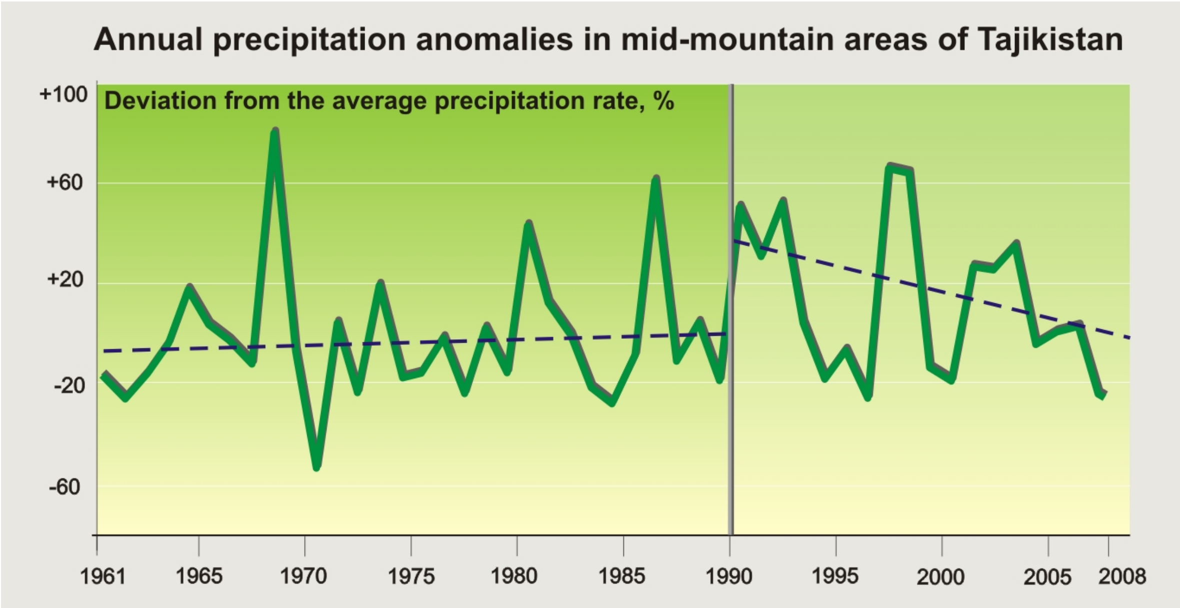

Figure 4-4. Annual precipitation anomalies in mid-mountain areas. The trends for both periods (1961-1990, 1990-2008) are compared to the average mean precipitation for 1961-1990 Data source: SAH 2010

Climate change on the territory of *Dashtidjum Zakaznik* has also been observed by its inhabitants who emphasize hotter and drier summers in the last decade, as well as a decrease of snow cover in winter time in valleys and mid-mountain areas, and its increase in high mountain areas (Boboev pers.comm.; Faizov pers.comm.). They have also noticed more frequent extreme weather events, in particular heavy rains, which very often lead to mudflows and unusual extremely cold temperatures during the last winters (Boboev pers.comm.; Faizov pers.comm.). Experts also highlight desiccation of 30-50% of springs, especially in the southern area of *Dashtidjum Zakaznik* and melting of snowfields on the top of the mountain ranges due to higher air temperatures (Safarov pers.comm.; Zagrebelnyi pers.comm.).

The identified climate change anomalies may have a significant negative impact on the biodiversity of *Dashtidjum Zakaznik*. The most adverse effect may be exerted by the decrease of spring precipitation important for plants vegetation, as well as the significant increase of spring air temperatures, which may lead to considerable changes in species phenology (sections 4.3 and 4.4). A further climate warming, which is projected to continue at the rate observed nowadays (Makhmadaliev *et al.* 2008; Asanova 2010a), may aggravate the consequences for the biodiversity of the *zakaznik*. According to SAH projections, an increase of annual mean temperature by the end of 2050 may be 1.8 to 2.9°C, while the decrease of the annual amount of precipitation may reach 20% for the last century (Asanova 2010a). It may considerably aggravate the consequences for Dashtidjum's biodiversity and lead to the loss of valuable species.

4.3 Fauna vulnerability to climate change

A unique geographical location of *Dashtidjum Zakaznik* between large mountain systems of Pamir-Alai and Hindu Kush, and their proximity to Himalayas and Tibet, has promoted the development of diverse fauna, which possesses characteristics of various mountainous regions (Safarov *et al.* 2008). Another factor that contributes to the species diversity is the location of the *zakaznik* on the southern branches of the Khazratisho range, which pass through the Tajik-Afghan Depression and constitute a part of the large migration corridor that connects this region with the Central Asian mountain-desert region. All these, combined with the variability of landscapes and climates, have resulted in the formation of rich fauna represented by nearly 4,000 species (see Figure 4-5) with a considerable amount of endemic and rare species, as well as relics of the Tertiary period (Safarov *et al.* 2008).

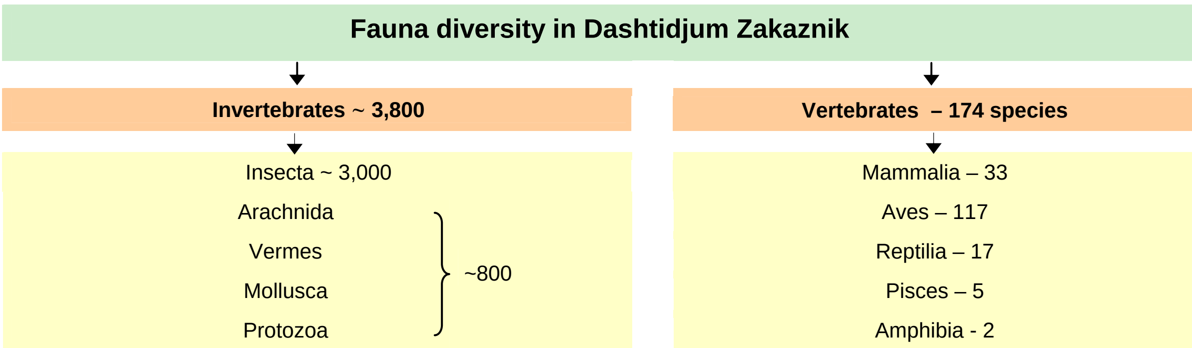

Figure 4-5. Fauna diversity in Dashtidjum Zakaznik Data source: Safarov *et al.* 2008

Dashtidjum Zakaznik provides habitat for many rare, vulnerable and endangered species of fauna (see Annex 7). Seven species of vertebrates are listed in the IUCN Red List; four have 'endangered' status and the other three are 'vulnerable' species (see Annex 8) (IUCN 2010c). Forty species of the *zakaznik* are included in the Red Data Book of Tajikistan (Safarov *et al.* 2008). Nine are listed as 'endangered' and one as 'critically endangered' species (Abdusaljamov *et al.* 1988) (see Annex 9). *Dashtidjum Zakaznik* is a zoological reserve and its priority measures are focused on the conservation of key species of global and regional importance, including markhor, urial, and snow leopard (Safarov *et al.* 2008). Despite the protection regime established on the territory of the *zakaznik*, its biodiversity experiences significant anthropogenic pressure, which leads to its decline. The main direct factors that affect fauna species include poaching and expansion of urban and agricultural areas. Among indirect factors are forest cutting for fuel wood and cattle grazing that lead to the degradation of suitable habitats (Safarov *et al.* 2008).

Climate change is yet another threat for the animal world of *Dashtidjum Zakaznik*. It not only aggravates the degradation of the habitats (see section 4.5), but also directly affects animals leading to changes in their phenology, population size and distribution range (see section 2.1.2). The main factors of the climate change impact include changes in food abundance and availability of suitable habitats, desynchronization of species interaction, as well as spread of invasive species (section 2.1.1). Species that are already endangered by anthropogenic factors, as well as rare and endemic species with narrow and scattered distribution ranges, are among the most vulnerable to climate change (Millsap *et al.* 1990; Mkanda 1996; Malcolm 1998). Species' responses to climate change have already been observed for several animals of the *zakaznik*. They are mainly represented by shifts in species' distribution ranges, as the lack of constant monitoring does not allow identifying other changes, including phenological. A brief overview of the species of *Dashtidjum Zakaznik*, as well as the assessment of their responses and vulnerability to climate change is presented below.

4.3.1 Mammals

Mammals of *Dashtidjum Zakaznik* include 33 species, which constitutes 39% from the total amount of mammal species in Tajikistan (NBBC 2003; Safarov *et al.* 2008). The key mammal inhabitants of the *zakaznik* include badger (*Meles meles*), fox (*Vulpes vulpes*), wolf (*Canis lupus*), stone marten (*Martes foina*), wild boar (*Sus scrofa*), Siberian ibex (*Capra sibirica*) (Figure 4-6), markhor (Figure 4-7), urial (Figure 4-8), Tien-Shan brown bear, Indian porcupine (*Hystrix leucura satunini*), tolai hare (*Lepus tolai*), and red marmot (*Marmota caudata*), as well as tree dormouse (*Dryomus nitedula*) and mice (Safarov *et al.* 2008). State of the population of the majority of mentioned species depends on the prosperity of mid-mountain forest ecosystems and forest productivity (Safarov *et al.* 2008). Thus, any factor that affects the state of these ecosystems, including climate change, affects the population of their mammal inhabitants.

Insectivores in *Dashtidjum Zakaznik* are represented by two species: long-eared hedgehog (*Hemiechinus auritus*) and lesser white-toothed shrew (*Crocidura suaveolens*), which mainly inhabit foothill zones with savannoid ecosystems (Safarov *et al.* 2008). From cheiroptera species, the most widely spread species are common pipistrelle (*Pipistrellus pipistrellus*) and lesser mouse-eared bat (*Myotis oxygnathus*). Four out of seven species of this order are listed in the Red Data Book of Tajikistan as 'rare' species, including lesser horseshoe (*Rhinolophus hipposideros*), greater horseshoe (*Rhinolophus ferrumequinum*), whiskered bat (*Myotis mystacinus*), and free-tailed bat (*Tadarida teniotis teniotis*) (see Annex 9) (Abdusaljamov *et al.* 1988; Safarov *et al.* 2008).

The only representative of lagomorphs - tolai hare (*Lepus tolai*) has a wide geographic range and occurs at the altitudes ranging from 1,200 to 2,800 masl (Safarov *et al.* 2008). Rodents are mainly represented by widely spread species, including forest mouse (*Apodemus sylvatycus)*, endemic Turkestan rat (*Rattus turkestanicus*) and Zaisan mole vole (*Ellobius tancrei)* (Safarov *et al.* 2008). The only endangered species of this order is the Indian porcupine (Figure 4-9), listed in the Red Data Book of Tajikistan (see Annex 9) (Abdusaljamov *et al.* 1988). It inhabits low and mid-mountain areas and is evenly distributed across the *zakaznik* (Safarov *et al.* 2008). Another representative of the rodents - red marmot occurs in sub-alpine and alpine zones in small scattered populations (Safarov *et al.* 2008).

The order of carnivores has the highest number of species among the mammals of *Dashtidjum Zakaznik* (Safarov *et al.* 2008). It comprises of ten species, but their majority is represented by small populations. Six out of ten carnivorous mammals are listed in the Red Data Book as 'rare', 'endangered' or 'declining' species, including Central Asian otter (*Lutra lutra seistanica)*, least weasel (*Mustela nivalis pallida*), marbled polecat (*Vormela peregusna koshevnikovi*), Tien-Shan brown bear, Turkestan lynx (*Felis lynx isabellina*), and snow leopard (Abdusaljamov *et al.* 1988; Safarov *et al.* 2008) (see Annex 9). The latter is also listed in the IUCN Red List as an 'endangered species' (see Annex 8) (IUCN 2010c). Ungulates of the *zakaznik* are represented by markhor, urial, Siberian ibex and wild boar. Two of them – markhor and urial are listed in the IUCN Red List (IUCN 2010c) and the Red Data Book of Tajikistan (Abdusaljamov *et al.* 1988). The wild boar is the most prevalent species of large animals on the territory of *Dashtidjum Zakaznik*; and the least prevalent is the Siberian ibex represented by a very small population (Safarov *et al.* 2008).

Climate change impact on the species of mammals varies for different species and depends mainly on their adaptive capacity as well as the state of their populations. Species that occur in various habitats and are able to migrate upwards are less vulnerable than species with specific habitat requirements and limited migration capacity. Similar to this, polytrophic species that feed on diverse group of plants or animals, and are possible to switch their nutritive base are less vulnerable than selective monophagous species. Species that are already threatened by other factors are also more vulnerable to climate change. The main climate change factors that affect the populations of mammals include feed abundance and availability of suitable habitats and water resources. Some species are also sensitive to temperature anomalies. The species of mammals, similar to other species, mainly respond to climate change by phenological changes, as well as by migration to higher elevations. A brief overview of the vulnerability of different representatives of mammals inhabiting *Dashtidjum Zakaznik* is presented below.


Figure 4-6. Siberian ibex Photo credit: Saidov 2008


Figure 4-7. Markhor Photo credit: Shakulo 2008

Figure 4-8. Urial Photo credit: Michel 2009

Figure 4-9. Indian porcupine Photo credit: Amirov 2009

Climate change impact on the insectivores of *Dashtidjum Zakaznik* is likely to be negative. The long-eared hedgehog inhabits dry steppes and areas with lighted shrubs (Stubbe *et al.* 2008), is very sensitive to the changes in ambient temperatures (Dustov pers.comm.). Laboratory research conducted by Dustov has shown that increase of the ambient temperature by 1.5-2°C triggers earlier awakening of this species, and leads to the disruption of its nervous system. Awaken hibernating animals are characterized by the sluggishness behaviour and trophic disturbances, which at the end leads to the disruption of reproductive function Another factor that constrains the adaptation of the hedgehog to climate change is its low migration capacity (Dustov pers.comm.). Despite its wide distribution, it is unlikely that this species will shift its distribution range and migrate to higher elevations or northwards. Therefore it is highly probable that climate change would negatively affect the long-eared hedgehog and may cause the decline of its population on the territory of *Dashtidjum Zakaznik* (Dustov pers.comm.).

Similar to insectivores, the cheiroptera species of *Dashtidjum Zakaznik* can be affected by the increase of air temperatures and earlier awakening from the hibernation (Saidov pers.comm.). At the same time adaptive capacities of the bats occurring on the territory of the *zakaznik*, in particular the common pipistrelle and the lesser mouse-eared bat, are higher than those of the insectivores, due to their ability to migrate to long distances and occupy habitats at higher elevation (Sokolov 1963; Hutson *et al.* 2008). The bats may also benefit from the climate-driven increase of the populations of pests that constitute their forage (Saidov pers.comm.). The most vulnerable to climate change species of bats are species already threatened by anthropogenic activities that have narrow distribution ranges and low-density populations, in particular lesser and greater horseshoes (Saidov pers.comm.).

The only representative of lagomorphs - the tolai hare is sensitive to the cold winters with heavy snow cover (Saidov pers.comm.). The latter constrains access to forage affecting survival rate of the population. A considerable decline of the tolai hare population has already been observed on the territory of the *zakaznik* during the snowy winters. At the same time, the reproduction rate of this species allows restoring the population in subsequent years. Another factor that may affect the population of the tolai hare is the decrease in forage abundance (Saidov pers.comm.). This species mainly inhabits mid-mountain forests (Safarov *et al.* 2008) and its reproduction rate and density depends on the availability of green fodder. Therefore decrease of forested areas and xerophytization of vegetation may affect the population of the tolai hare, causing its decline on the territory of *Dashtidjum Zakaznik* (Saidov pers.comm.).

The most vulnerable species of rodents to the climate change are those associated with mesophylic forests, in particular the Turkestan rat (Saidov pers.comm.). The population of this endemic species depends on the state and productivity of walnut forests. A decrease in productivity and reduction of forest areas due to climate aridization may negatively affect the population of the Turkestan rat and decrease its density. The red marmot that inhabits sub-alpine and alpine meadows requires significant amount of green fodder. Aridization of climate and xerophytization of vegetation negatively affect this species and cause changes in its phenology. Lack of green plants promotes earlier hibernation - up to two weeks in comparison with previous decades, and shortening of its activity period. The latter most probably would affect the reproduction rate, and lead to the decline of its populations (Saidov pers.comm.).

Another species of rodents that is highly dependent on forest habitats and availability of green fodder is the juniper vole (*Microtus carruthersi*). Similar to the Turkestan rat, this species is a selectively herbivorous, feeding only on specific varieties of plants, and may experience difficulties in adaptation to climate change. It is probable that climate change would also affect the population of the Indian porcupine and lead to its decline (Zagrebelnyi pers.comm.). Increase of air temperatures, as well as a lack of forage resources, forces this species to migrate at higher elevation. The expansion of the upper boundary of its distribution range has already been observed on the territory of *Dashtidjum Zakaznik*. Climate change impacts, combined with the anthropogenic pressure, may undermine the population of this endangered and rare species (Zagrebelnyi pers.comm.; Saidov pers.comm.).

A majority of the carnivores occurring in *Dashtidjum Zakaznik* has certain capacity to adapt to climate change. They migrate to long distances following the prey and thus will not experience difficulties in shifting their distribution ranges (Saidov pers.comm.; Zagrebelnyi pers.comm.). The main factor that affects carnivores is the decrease of forage resources, which constitute their main ration. In particular, the Tien-Shan brown bear may be affected by the reduction of fruit trees of mid-mountain mesophylic and conifer ecosystems (see sections 4.5.3 and 4.5.4). At the same time, this may not affect the magnitude of the population, but will cause the northward migration and decrease of the population density on the territory of the *zakaznik*. Climate change will also affect the phenology of this species and promote earlier hibernation and awaking and associated disturbances in animal physiology (Saidov pers.comm.). Climate-induced reduction of mountain forests, in particular broad-leafed forests, may also affect the population of the endangered Turkestan lynx (Zagrebelnyi pers.comm.).

Although the snow leopard is one of the carnivores occurring on the territory of *Dashtidjum Zakaznik*, its main habitats are located outside, at higher elevations (Saidov pers.comm.; Zagrebelnyi pers.comm.). In the *zakaznik* the species can be observed occasionally in the summers, mainly at high mountain meadows, and in the winters at lower elevations when it follows the ungulates (Safarov *et al.* 2008). The snow leopard is not particularly sensitive to temperature changes, but it can be affected by the heavy snow cover that prevents its seasonal migration to lower elevations, increasing death rate (Kokorin *et al.* 2001). Several harsh winters in a row can affect the offspring of the snow leopard and result in the undermining of the population (Kokorin *et al.* 2001). Climate-driven decrease of ungulates may also adversely affect the population of the snow leopard (Saidov pers.comm.). In general, it is most probable that this species would completely disappear from the territory of *Dashtidjum Zakaznik* and migrate northwards (Saidov pers.comm; Zagrebelnyi pers.comm.).

The ungulates of *Dashtidjum Zakaznik* are probably the most vulnerable group of mammals to climate change. The main factor that affects population of the two key species – markhor and urial – is the decrease of forage resources (Saidov pers.comm.). The feed of the markhor mainly constitutes herbaceous plants, such as meadow grass (*Poa relaxa*), pieplant (*Rheum maximoviczii*) and ferula (*Ferula kokanica*), and leaves and sprouts of juniper trees (Abdusaljamov *et al.* 1988). Climate change, in combination with anthropogenic factors including cattle grazing, has already affected the hydrophilous vegetation (section 4.5.4), leading to the decline of the markhor population (Safarov *et al.* 2008; Valdez 2008a). It is likely that the lack of forage recourses, and the temperature factor itself, would cause shifts in the distribution range of this species. The markhor may expand the upper boundary of its range and occupy territories above 2,500 masl represented by suitable for it rock landscapes (Saidov pers.comm.). Its occurrence in the lower zone of the range will decrease. The latter has already been observed on the territory of *Dashtidjum Zakaznik* (Zagrebelnyi pers.comm.).

The urial is the most vulnerable ungulate of *Dashtidjum Zakaznik* to climate change (Saidov pers. comm.). Though it mainly inhabits xerophytic ecosystems of the *zakaznik* (Abdusaljamov *et al.* 1988; Safarov *et al.* 2008), increased temperature and lack of precipitation affects its forage resources and forces to migrate upwards (Saidov pers.comm.). At the same time, the urial prefers lower rounded stony hills (Valdez 2008b), and it is unlikely that it will inhabit rocky landscapes of the upper elevations, similar to markhor (Saidov pers.comm.). Lack of suitable habitats and fodder, combined with the anthropogenic pressure, may completely undermine the population of the urial on the territory of the *zakaznik*. The urial is also one of the few species of Tajikistan listed in the IUCN Red List as a species which decline has been caused by climate change (IUCN 2010d). Mass death of this species has been observed in Tajikistan during the harsh winters in 1968-1969 and 1971-1972 (Valdez 2008b).

The main factor that may affect the population of the Siberian ibex is the lack of suitable habitats. At present, this species inhabits the high mountain nival zone of *Dashtidjum Zakaznik* at the elevation from 2,500 masl (Abdusaljamov *et al.* 1988). Increase of air temperatures creates unfavorable conditions for the presence of the Siberian ibex on the territory of the *zakaznik* and forces its migrations to higher latitudes, as there are no higher elevations available. Therefore, it is likely that climate change would cause complete disappearance of this species from the area of *Dashtidjum Zakaznik* (Saidov pers.comm.). The population of another representative of the *zakaznik*'s ungulates – wild boar, may be affected by the lack of walnuts and other nuts that constitute the main part of its forage (Saidov pers.comm.) The positive influence of the climate change on the population of this, as well as other species, may be represented by the increase of air temperatures in winters and springs and associated decrease of the animals' death rates and an increase in survival rates of the offspring (Zaumyslova 2006).

4.3.2 Birds

Birds are the most diverse class of the vertebrates of *Dashtidjum Zakaznik*, comprising 117 species within 15 orders (Safarov *et al.* 2008). The order of *Passeriformes* has the highest number of species – 69, followed by the birds of prey (*Falconiformis*) represented by 13 species. The avifauna of the *zakaznik* consists of species of the various origins, including European, Central Asian, Iran-Turkestan, Indo-African, Chinese, Tibetan and Mongolian. The considerable number of nesting birds belongs to the European fauna type. Among them are: golden eagle (*Aquila chrysaetus daphanea*), ring dove (*Columba palumbus casiotis*), nightjar (*Caprimulgus europaeusi*), tawny owl (*Strix aluco*), and blackbird (*Turdus merula*). Nesting species of Indo-African origins include: laughing dove (*Streptopelia senegalensis*), common myna (*Acridotheres tristis*), long-tailed shrike (*Lanius schach*), and paradise flycatcher (*Terpsiphone paradise leucogaster*). Among representatives of Himalayan and Tibetan complexes are: Himalayan snowcock (*Tetraogallus himalayensis*), white-winged grosbeak (*Mycerobas carnipes*), ibis bill (*Ibidorhyncha struthersii*), streaked laughing-thrush (*Garrulax lineatus bilkevitchi*), and blue whistling-thrush (*Myophonus caeruleus*)(Safarov *et al.* 2008).

Background species of the low-lying and open areas of *Dashtidjum Zakaznik* are represented by blue whistling-thrush, Indian golden oriole (*Oriolus oriolus kundoo*), and long-legged buzzard (*Buteo rufinus*) (Safarov *et al.* 2008). Species that are common for foothills include lammergeyer (*Gypaetus* *barbatus hemachalanus*), peregrine falcon (*Falco peregrinus babylonicus*) and ring dove. Rocky slopes with rare wood and shrub vegetation are the main habitats of keklik or chukar (*Alectoris kakelik kakelik)* that is one of the most prevalent bird species of the *zakaznik*. The ring dove is a common background bird of mountain forests; it mainly occurs in maple forests with fragments of juniper trees (Safarov *et al.* 2008).

Twelve species of the avifauna of *Dashtidjum Zakaznik* are listed in the Red Data Book of Tajikistan, including 'endangered' species saker falcon (*Falco cherrug coatsi*), as well as 'rare' and 'declining' snake-eagle (*Circaetus ferox heptneri*), Egyptian vulture (*Neophron percnopterus*), see-see partridge (*Ammoperdix griseogularis*), peregrine falcon, blue whistling-thrush, streaked laughing-thrush, little swift (*Apus affinis galilejensis*) and other species (see Annex 9) (Abdusaljamov *et al.* 1988; Safarov *et al.* 2008). Three species of birds of the *zakaznik* are listed in the IUCN Red List, including 'endangered' saker falcon and Egyptian vulture, and 'vulnerable' pale-backed pigeon (*Columba eversmanni*) (see Annex 8) (IUCN 2010c).

Climate change impact on different species of birds of *Dashtidjum Zakaznik* varies from positive to negative. It may be beneficial for the species that inhabit high mountain areas above 2,000 masl including alpine and sub-alpine zones (Murodov pers.comm.). These species are mainly represented by alpine chough (*Pyrrhocorax graculus forsythia*) and birds from *Fringillidae* and *Emberizidae* families, including Turkestan greenfinch (*Chloris chloris turkestanicus*), Turkestan linnet (*Cannabia cannabia bella*), Indian grosbeak (*Coccothraustes coccothraustes humi*), common bunting (*Emberiza calandra*), red-headed bunting (*Emberiza bruniceps*), and rock bunting (*Emberiza cia par*). Under an altered climate, they can expand their distribution ranges and occupy territories previously covered by snowfields. Increased population density of these species in high mountain areas has already been observed (Murodov pers.comm.).

A majority of the species of birds has sufficient migration capacities and is able to shift their distribution ranges, both upwards and northwards, and occupy available niches (Murodov pers.comm.). At the same time this can result in a disappearance of some species from the territory of *Dashtidjum Zakaznik*. The latter has already happened to the black kite (*Milvus korschun*) that previously nestled in mid-mountain areas of the *zakaznik* (Murodov pers.comm.). During the last twenty years its distribution range has significantly shifted northwards, which was most likely caused by the increase of air temperatures (Murodov pers.comm.). The same factor promotes the introduction on the territory of the *zakaznik* of new species, mainly from southern areas of Tajikistan (Saidov pers. comm.). Avifauna of *Dashtidjum Zakaznik* already comprises several species that previously inhabited areas with warmer climate, but significantly expanded their ranges, in particular iris bill and common sand-piper (*Tringa hypolevcos*) (Murodov pers.comm.)

Climate change has already affected the phenology of many species occurring in *Dashtidjum Zakaznik*. A comprehensive study that explored arrival of migratory birds has identified shifts in the time of spring arrival of these birds (Murodov pers.comm.). At present, arrival of migratory birds occurs from seven to ten days earlier than it was 25-30 years ago. For some species this shift constitutes up to two weeks. In addition to earlier arrival of migratory birds, scientists have noted wintering of some species, including barn swallow (*Hirundo rustica*), sand martin (*Riparia rupestris*), rock wagtail (*Motocilla cinerea caspica*), white wagtail (*Motocilla alba dukhunensis*), and tawny pipit (*Anthus camprestris griseus*). During the last warm winters these species did not leave the area of the *zakaznik* as they did in the past, which confirms the influence of climate change on the phenology of migratory birds (Murodov pers.comm.).

One of the positive effects of climate change on birds' populations is an increased abundance of insects, including pests that constitute nutritive base of the majority of species. It provides favorable conditions for birds' populations, leading to the increase of their density. Among negative effects are decrease of the area covered by mid-mountain forests (section 4.5.4), aridization of climate, as well as alternation of warm and cold years. The former has negative effect on population of one of the rare species – the ring dove, which inhabits mid-mountain forests of *Dashtidjum Zakaznik* and can lead to its decline (Murodov pers.comm.; Abdusaljamov *et al.* 1988). Another vulnerable species is the paradise flycatcher that requires dense forest and can be affected by the decrease of forest areas, as well as by lack of precipitation (Murodov pers.comm.; Abdusaljamov *et al.* 1988).

Harsh winters and associated increase of the snow cover can cause the decline of chukar populations (Saidov pers.comm.; Murodov pers.comm.). In a winter time this species migrates at higher elevations in a search of food, but is not able to walk on a deep snow (Abdusaljamov *et al.* 1988). Therefore deep snow cover constrains its migration leading to death of starvation. Mass death of the chukar has already been observed in extremely snowy winters (Saidov pers.comm.; Murodov pers.comm.). At the same time, this species is characterized by the high reproduction rate and is able to restore the population in subsequent years (Murodov pers.comm.). By the same reason, it is unlikely that climate change impact will cause the decline of such rare birds as blue whistling-thrush, streaked laughing-thrush and little swift (Murodov pers.comm.).

The birds of prey listed in the Red Data Book of Tajikistan, including lammergeyer, snake-eagle peregrine and saker falcons, are more vulnerable to climate change due to their low reproduction rate, as well as lower adaptive capacity (Murodov pers.comm.; Abdusaljamov *et al.* 1988). Abundance of the lammergeyer can be affected by the decrease in numbers of ungulates, as well as of chukar. Although the snake-eagle may benefit from the potential abundance of reptiles, it can be affected by the decrease of areas suitable for its nesting. Decline of chukar populations during snowy winters, as well as reduction of suitable habitats, can also affect populations of endangered saker and peregrine falcons (Murodov pers.comm.; Abdusaljamov *et al.* 1988).

4.3.3 Reptiles

Reptiles of *Dashtidjum Zakaznik* are represented by 17 species, which constitutes 36% from the total amount of reptile species in Tajikistan (NBBC 2003; Safarov *et al.* 2008). They comprises of several species that are endemic for the Pamir-Alai mountains, including Caucasian agama (*Agama caucasica),* Turkestan agama (*Agama lehmanni*)*,* and Central Asian lebetina viper (*Vipera lebetina turanica*) (Safarov *et al.* 2008). The background species are represented by naked-toed gecko (*Gymnodactylus fedtschenkoi*), Turkestan agama, Asian snake-eyed skink (*Ablepharus brandti*), mountain racer (*Coluber ravergieri*), Pallas' coluber (*Elaphe dione),* grass lizard (*Ophisaurus apodus)*, water snake (*Natrix tesselata*), and oriental boa (*Eryx tataricus*) (Safarov *et al.* 2008).

The order of *Serpentes* has the highest number of species and constitutes of 9 out of 18 species of snakes occurring in Tajikistan (Safarov *et al.* 2008). The majority of the species are considerably affected by human activities, in particular illegal catching aimed at receiving snake's venom or their medicinal use (NBBC 2003; Safarov *et al.* 2003). Five of the species of snakes are listed in the Red Data Book of Tajikistan as 'declining' and 'rare' species, including Central Asian cobra (*Naja oxiana*), blind snake (*Typhlops vermicularis*), oriental boa, lebetina viper, and striated wolf snake (*Lycodon striatus bicolor*) (see Annex 9) (Abdusaljamov *et al.* 1988; Safarov *et al.* 2008).

The only representative of *Testudines* order – Central Asian steppe tortoise (*Agreonomys horsfieldi*) was quite numerous in the past, but nowadays its populations experience considerable decline due to the conversion of the foothill habitats to cultivated farmlands, as well as poaching and illegal exporting (Safarov *et al.* 2003). It is listed in the IUCN Red List as 'vulnerable species' (see Annex 8) (IUCN 2010c). In general, the typical habitats of the most reptile species of *Dashtidjum Zakaznik* are shrinking due to human activities. Another representative of endangered species is the long-legged skink (*Eumesces schneideri)* from the *Sauria* order, which occurs mainly in the lower reaches of the Pyanj river (Safarov *et al.* 2003). It is listed in the Red Data Book of Tajikistan as 'rare' and 'declining' species (see Annex 9) (Abdusaljamov *et al.* 1988).

It is most probable that climate change impact on the majority of the reptiles of *Dashtidjum Zakaznik* would be positive, as they are represented by the species common for hot and arid climate (Nadjmidinov pers.comm.). That is why both temperature increase and decrease of precipitation may create favorable conditions for the majority of reptiles and may even lead to the increase of their populations. The main mechanism of such response is the increase of the forage resources represented by small rodents and pest insects, as well as expansion of suitable habitats mainly represented by loess and rock slopes with lighted and ephemerous vegetation. In particular, increase in ambient temperature can lead to the increase of such rare snakes as Central Asian cobra, lebetina viper, and blind snake. At the same time, it should be noted, that it may happen only if anthropogenic pressure (poaching) is minimized (Nadjmidinov pers.comm.).

Increase of air temperature can also promote the expansion of distribution ranges of reptiles and their occupation of upper territories with cooler in the past climate (Nadjmidinov pers.comm.). Such expansion has already been observed for the lebetina vipera. If in the past this species occurred at the elevations from 2,000 to 2,700 masl, last monitoring observations confirmed its occurrence on the territories up to 3,100 masl. At the same time, in a long-term perspective, the necessity to shift distribution range upwards might cause negative effect on some species of snakes and lizards that prefer habitats in the foothill areas around human settlements. It may be conditioned by a low capacity for vertical migrations, as well as by lack of optimal habitats, such as loess-type rocks and water bodies (Nadjmidinov pers.comm.).

Unlike snakes and some lizards, the Central Asian steppe tortoise may experience negative impact of climate change, mainly due to the changes in vegetation (Saidov pers.comm.). Increase of air temperatures shortens the vegetation period of savannoid plants, leading to the decrease of forage abundance for this herbivorous species. As a result it may shorten the period of activity of the steppe tortoise, which coincides with the vegetation period of plants, and provoke earlier aestivation of this species. Shorter period of activity and lack of accumulated nutrients may result in lower reproduction rates and lead to the population decline. It is also likely that increase of air temperatures and earlier plant vegetation would lead to the earlier awakening of steppe tortoise from hibernation (Saidov pers.comm.).

Among other negative impacts of climate change on the population of reptiles is an indirect effect of the projected increase in a number of days with heavy rains on the blind snake (Nadjmidinov pers.comm.). This species occurs mainly underground and significant amount of precipitation for a short period of time forces it to come up to the surface where it becomes an easy prey for predators, as well as humans. Although this factor is an indirect, it has significant impact on the population of the blind snake and can cause its decline (Nadjmidinov pers.comm.). Climate change impact on the representatives of lizards including long-legged gecko can be dual. From one side, temperature increase may have favorable effect on lizards' forage resources represented by various pest insects (see 4.3.5). From the other side, potential increase of their enemies, including snakes, may provide negative effect on the population of lizards. It is also likely that climate change would lead to the decline of the populations of endemic species with narrow distributions ranges, including Caucasian agama (Nadjmidinov pers.comm.).

4.3.4 Other vertebrates

Amphibians in *Dashtidjum Zakaznik* are represented by 2 species – marsh frog (*Rana ridibunda*) and green toad (*Bufo viridis*), which are the only species of amphibians that occur in Tajikistan (Safarov *et al.* 2008). They are widely spread on the territory of the *zakaznik* and constitute considerable part of the cenosis of natural and artificial water reservoirs. The watercourses that pass trough the territory of *Dashtidjum Zakaznik* are inhabited by five species of fishes, including common marinka (*Schizothorax intermedius*), Samarkand khramulya (*Varicarhinus heratensis*), Turkestan somik (*Glyptosternon reticulatum*), Tajik beardie (*Nemachilus pardalis*), and Tibetan beardie (*Nemachilus stoliczkai*) (Safarov *et al.* 2008).

It is unlikely that climate change will have significant negative impact on populations of the amphibians of *Dashtidjum Zakaznik*. The green toad is very tolerant to dry and hot conditions, and spends most of the time away from the water bodies (Kuzmin 1999). It is adapted to use for the spawning even irrigation ditches and other artificial water channels (Kuzmin 1999), which makes it quite invulnerable to the desiccation of natural water bodies. It can also benefit from the replacement of light forests and shrub vegetation by steppe vegetation (section 4.5) as it prefers open areas. Similar to the green toad, the marsh frog has very broad habitat range, but depends on the water bodies in a greater extend, spending there considerable part of the time (Kuzmin 1999). It makes the marsh frog more vulnerable to climate change impacts, and, at some point, can lead to the decrease of its population.

The main factors that can affect populations of the amphibians include the desiccation of small water reservoirs due to the general decrease in precipitation and higher air temperatures. It can decrease a number of breeding sites and suitable habitats, which can alter the populations of both species. The reduction of water habitats can also increase the density of the amphibians around available water sources, leading to the increased competition and a spread of the diseases (Maslova 2006; Bickford *et al.* 2010). The populations of the amphibians, in particular the green toad, can be also affected by the increased number of days with heavy rains that can wash away or damage eggs and tadpoles (Bickford *et al.* 2010). Meanwhile, a considerable decrease of the populations of the amphibians is unlikely due to the high adaptive capacities of the species dwelling in the *zakaznik*.

The ichthyofauna of the *zakaznik* can be also altered by the climate change impacts. The main factor that may affect populations of fishes is the increase of water temperatures due to the general increase of air temperatures, and associated decrease in the amount of dissolved oxygen (Saidov 2006a; Saidov pers. comm.). The latter can affect the survival rate of baby fishes, as well as the reproduction and growth rates of adult fishes and lead to the population decline. It should be noted that this may happen only in the small rivers and water bodies where water can be easily warmed up. It is unlikely to affect the fast-streamed and relatively wide Pyanj river (Saidov 2006a; Saidov pers. comm.). Another negative factor is a potential upstream migration of the invasive species, in particular snakehead that can outcompete native species, including the common marinka and the Samarkand khramulya (Saidov 2006a). However, probability of such invasion is very low (Saidov pers.comm.).

4.3.5 Invertebrates

There are around 3,800 species of invertebrates in *Dashtidjum Zakaznik* (Safarov *et al.* 2008). The major class is represented by insects, which comprise of nearly 3,000 species. Some species of the insects belong to endemic and relic species with narrow distribution range and declining populations. Nine of them are listed in the Red Data Book of Tajikistan, including: wood mantis (*Hierodula tenuidentata*), Bei-Bienko ground mantis (*Rivetina beybienkoi*), large-headed mantis (*Mantis macrocephala*), *Porphyrophora odorata*, *Dalpada pavlovskii*, *Mustha baranovi*, Kuhistan blue (*Polyommatus kogistana*), ashen hawk moth (*Dolbinopsis grisea*), and *Netelia fuscicornis* (see Annex 9) (Abdusaljamov *et al.* 1988; Safarov *et al.* 2008). The pest insects comprises 41 species belonging to six orders. The most harmful from them are codling moth, walnut moth, pear louse, apricot march-flies, cherry casebearer, Tajik casebearer, mountain lackey, raisin moth, apple-leaf blister moth and others that affect fruit and other trees on the territory of the *zakaznik* (Safarov *et al.* 2008).

Climate change impact on the insects of *Dashtidjum Zakaznik* may cause flourishing of some species, and the decline of others. The first group is represented by the pest insects that benefit from the climate warming and may expand their distribution ranges (Hellmann *et al.* 2008). Such expansion has already been observed on the territory of the *zakaznik*, where from 20 to 80% of the trees are affected by the pest insects (Safarov *et al.* 2008). This is almost ten times higher than the area affected in the previous decades (Sangov pers.comm.). Although one of the primary reasons of this expansion is the lack of anti-pest treatment and control, climate change contributes to the situation aggravating its consequences (Makhmadaliev *et al.* 2008). This contribution is evident from the changes in species composition and the dominance of xerophilous insects, for instance mountain lackey (Sangov pers.comm.). It is likely that under an altered climate the pest insects would invade new areas and their density will increase (Muminov pers.comm.; Saidov pers.comm.).

The main factors that promote distribution of pest and other insects include their high adaptive capacities, as well as high dispersal abilities (Hellmann *et al.* 2008; Beaumont *et al.* 2009). Most of the species are able to shift their distribution range following the shifts in vegetation (Saidov 2006a). They are also able to change their activity rhythm and shift it from the hot period of the day to morning or evening. Lack of precipitations can be overcome by many insects through increased consumption of green leaves or by slowing metabolic activities. Many of the insects dwelling in the *zakaznik* belong to the polytrophic species and can change their food preferences (Saidov 2006a; Muminov pers.comm.). Unlike pest and wide-spread polytrophic insects, climate change can cause the decline of the insects with narrow food and habitat requirements and low migration capacities (Saidov 2006a; Muminov pers.comm.). It also refers to the psychrophilic inhabitants of the nival zone that would most likely suffer population decline and extinction due to melting of snowfields and associated lack of suitable habitats (Muminov pers.comm.). Warm winters and decreased snow cover can affect populations of the species hibernating under the snow, leading to the fluctuations in their populations' density (Muminov pers.comm.).

Climate change will have adverse affect on the majority of the endangered and rare species, as well as endemic species with narrow distribution ranges (Muminov pers.comm.). One of the most vulnerable species listed in the Red Data Book of Tajikistan is *Porphyrophora odorata*. It inhabits roots of the plants and is very sensitive to soil dehydration. A withering of the plants' roots due to the lack of precipitation and increased air temperatures can drive this species to the extinction. Another highly vulnerable species is the large-headed mantis that inhabits the grass stands of mountain slopes and forest meadows (Abdusaljamov *et al.* 1988). It can be affected by xerophytization of vegetation cover that leads to decrease of suitable habitats, and associated decline of the insects that constitute its nutritive base (Muminov pers.comm.). A main reason for the decline of *Dalpada pavlovskii* under an altered climate is the decrease of mesophylic trees, such as walnut (*Juglans regia*) and birch (*Betula tjanshanica*) that constitute the main habitat for this relic endangered species (Abdusaljamov *et al.* 1988).

Reduction of areas occupied by mountain forests and their xerophytization may also affect the abundance of another rare and endemic inhabitant of these forests - *Mustha baranovi* (Abdusaljamov *et al.* 1988), leading to its decline and potential extinction. The Kuhistan blue that occur at the elevation from 2,150 to 2350 masl (Abdusaljamov *et al.* 1988) can disappear from the area of *Dashtidjum Zakaznik* due to increase of air temperature that will affect the availability of suitable habitats. The same factor will affect the rare and relic ashen hawk moth – a species that inhabit only a certain species of the ash tree (Abdusaljamov *et al.* 1988). In general, despite the potential increase of population density of many species, in particular pest insects, it is likely that the number of the species of insects on the territory of *Dashtidjum Zakaznik* would decrease due to the loss of endangered and rare species, as well as the species of nival zone, and other species with narrow food and habitat requirements. The composition of species will be also altered by a prevalence of xerophilous species and pest insects.

4.4 Flora vulnerability to climate change

The territory of *Dashtidjum Zakaznik* is characterized not only by richness in fauna, but in flora too. Favorable and various climatic and soils conditions have promoted formation of abundant and diverse flora, as well as forest vegetation (Safarov *et al.* 2008). A combination of different elements, and some times the whole complexes, of subtropical and temperate botanical-geographical zones can be observed at the relatively small area of the *zakaznik*. The flora species of *Dashtidjum Zakaznik* are represented by species from such mountainous regions as Tien-Shan, Himalaya, Pamir-Alai and Hindu Kush, and from desert regions of Kara Kum and Kyzyl Kum. The flora of the *zakaznik* consists of considerable amount of endemic and rare species, as well as wild relatives of cultural plants that represent valuable genetic resources (Safarov *et al.* 2008).

The vascular plants of *Dashtidjum Zakaznik* comprise 958 species related to 490 genera and 98 families, which is more than 21% of all vascular plants occurring in Tajikistan (Safarov *et al.* 2008). The biggest families of the *zakaznik* flora are aster (*Asteraceae*) – 127 species, legume (*Fabaceae*) – 114, true grasses (*Poaceae*) – 84, and rose family (*Rosaceae)* – 45 species. The polymorphous genera include milk-vetch (*Astragalus*) – 51 species, onion (*Allium*) – 15, cousinia (*Cousinia*) – 16, knotweed (*Polygonum*) – 18, buttercup (*Ranunculus*) – 8, and meadow-grass (*Poa*) – 13 species. Among vascular plants of the *zakaznik* the dominant forms are perennial herbaceous plants (536 species), annual plants (278 species) and biennial plants (32 species) (Figure 4-10). The least prevalent form of plants is the liana, represented only by 6 species, including common grape vine (*Vitis vinifera*), bluestem joint fir (*Ephedra equisetina*), and Chinese clematis (*Clematis orientalis*) (Safarov *et al.* 2008).

Diversity of vascular plants of Dashtidjum Zakaznik

Vascular plants (*Tracheophyta*) – 958 species

Diversity of forms	**Diversity of values**
Perennial herbaceous plants – 536	Medicinal plants – 48
Biennial plants – 32	Food vitamin-containing plants – 30
Annual plants with long vegetation period – 157	Oil-bearing plants – 10
Annual plants with short vegetation period – 121	Essential oil plants – 22
Trees – 39	Tanniferous plants – 40
Shrubs – 67	Dye plants – 60
Liana – 6	Wild relatives of fruit plants – 40

Figure 4-10. Diversity of vascular plants of Dashtidjum Zakaznik Data source: Safarov *et al.* 2008

The flora of *Dashtidjum Zakaznik* comprises various endemic, rare and endangered species of regional and global significance (see Annex 10)(Safarov *et al.* 2008). Endemic species are represented by 115 species, including rare and relic magnificent ostrowskia (*Ostrowskia magnifica*) (Safarov *et al.* 2008). Seven species of flora are listed in the IUCN Red List (IUCN 2010c). Three of them, including Darvaz hawthorn (*Crataegus darvasica*), Korjinskyi's pear (*Pyrus korshinskyi*), and Darvaz swida (*Swida darvasica*) have 'critically endangered' status, another three are 'vulnerable', and one species is listed as 'endangered' (see Annex 8) (IUCN 2010c). Forty three species of plants of the *zakaznik* are included in the Red Data Book of Tajikistan; eight of them are listed as 'endangered' species (see Annex 9)(Abdusaljamov *et al.* 1988; Safarov *et al.* 2008).

Another important group of flora species of *Dashtidjum Zakaznik* are wild relatives of cultural crops, which represent unique genetic resources (Safarov *et al.* 2008). They comprise more than 200 species including 40 species of wild-growing ligneous species (Annexes 10 and 11). The latter consist of considerable amount of fruit and nut trees, such as apples, pears, cherry-plums, plums, walnuts, pistachio, and almonds. Species that form forests on the territory of the *zakaznik* are represented by 19 ligneous species, including walnut (*Juglans regia*), maples (*Acer sp.*), pistachio

(*Pistacia vera*), and almonds (*Amygdalus sp.*), as well as eight herbaceous species that form communities of light forests. Furthermore the flora of *Dashtidjum Zakaznik* comprise more than 200 species of useful plants that have value as medicinal, food, oil-bearing, tanniferous and dye plants (Figure 4-10) (Safarov *et al.* 2008).

Similar to the species of fauna, the plant species of *Dashtidjum Zakaznik* are significantly affected by a number of anthropogenic stressors, in particular cattle grazing and tree cutting for fuel wood (Safarov *et al.* 2008). The most threatened are species located in low- and mid-mountain zones. Tree cutting leads to the shrinking of forest area and associated disturbances in ecosystems' composition and services, while a cattle grazing is a main reason of degradation of vegetation cover and distribution of alien species. Altogether it leads to the replacement of valuable communities by weed and invasive species and general loss of biodiversity species (Safarov *et al.* 2008). Climate change is another threat for the flora species of *Dashtidjum Zakaznik* that leads to the loss of species diversity and significant changes in the structure and function of the ecosystems of the *zakaznik*. A brief overview of the climate change impacts on different types of flora of *Dashtidjum Zakaznik*, as well as endemic and endangered species and wild relative of cultural crops, is provided below.

4.4.1 Vulnerability of different flora types

Unlike fauna species when a main part of the climate change impacts is represented by indirect factors, climate change impact on flora species is represented by a direct pressure of temperature and precipitation anomalies. Anomalies in air temperature affect the beginning of the vegetation period of plants, as well as its duration (Safarov pers.comm.; Karimov pers.comm.). Anomalies in precipitations, especially their decrease in the springs, affect the development of vegetation cover and lead to the loss of species diversity due to the falling out of hydrophilous species (Safarov pers.comm.; Karimov pers.comm.). Climate change also contributes to the distribution of invasive species, including pest insects (section 4.3.5), which leads to the replacement of valuable species by weed communities, as well as the loss of trees affected by pests (Safarov pers.comm.; Ustjan pers.comm.).

Adaptive responses of the species of flora to climate change are mainly represented by changes in their life-cycle events, including beginning of the vegetation, leaf unfolding and fall, and flowering, as well as by shifts of distribution ranges. A lack of monitoring programs does not allow identifying phenological changes for the flora species of *Dashtidjum Zakaznik*, but there are number of observations, mainly for ligneous species, which confirm shifts of their distribution ranges to higher elevations. At the same time, it should be noted that a majority of the flora species, except of weed invasive species, has very limited natural migration capacity, which makes them at some point more vulnerable to direct impacts of climate change than fauna species of *Dashtidjum Zakaznik*. Thus, it is likely that considerable group of plants would not be able to occupy other areas and shift their distribution ranges (Safarov pers.comm.).

The most vulnerable group of plants is hydrophilous and mesophilous species that require moisturized soil and can be affected by the lack of rainfall during the vegetation and dormancy periods, as well as by higher air temperatures. Mesophytes are represented by various species occurring within different ecosystems of *Dashtidjum Zakaznik*, including plants of high-mountain meadows, ligneous and herbaceous species of mid-mountain forests, and ephemers and ephemeroids of savannoid, xerophytic, and other ecosystems. They have already responded to climate change impacts by shifting their distribution ranges. In particular, the expansion of the upper boundary of some mesophilous species has been observed along with the shift of their lower boundary to higher elevations (section 4.5). At the same time, population sizes of valuable mesophylic species have significantly declined due to their replacement by weed species with high dispersal and adaptive capacity, as well as by more xeric species (Safarov pers.comm.; Sattorov pers.comm.; Zagrebelnyi pers.comm.). It is therefore likely that further climate warming, combined with projected decrease of precipitation, will significantly reduce the share of mesophilous species in biotic communities and lead to the loss of some species, especially endemics with rare distribution and endangered species (section 4.4.2) (Safarov pers.comm.; Sattorov pers.comm.).

Besides rare and endangered species, the most vulnerable mesophytes also include ligneous species that unlike herbaceous species have lower drought-resistance and can not easily shift their distribution ranges (Safarov pers.comm.; Ustjan pers.comm.). Among them are Tien-Shan birch (*Betula tianschanica*), Turkestan maple (*Acer turkestanicum*), walnut, as well as some wild-growing fruit trees of global importance, such as Siver's apple (*Malus sieversii*), Cayon pear (*Pyrus cayon*), and Vavilov's almond (*Amygdalus vavilovii*) (see section 4.4.3). It is likely that the birch would disappear from the territory of *Dashtidjum Zakaznik* due to its high sensitivity to the lack of soil moisture and intolerance to high summer temperatures, as well as low migration capacity (Safarov pers.comm.; Ustjan pers.comm.). Turkestan maple and walnut may significantly reduce their distribution range (section 4.5.4). Mesophilous tree species of *Dashtidjum Zakaznik* may be affected not only by lack of soil moisture and anomalies in temperature, including cold temperatures of harsh winters that affect growth of wood pulp and development of young trees, but also by spread of pest insects and increased susceptibility of trees to pathogens (Safarov pers.comm.; Ustjan pers.comm.).

Reduction of forest cover will have a negative impact on herbaceous species that grow under the forest canopy, including such species as small-flowered touch-me-not (*Impatiens parviflora*), hybrid senna (*Colutea hybrida*), and Goncharov's skullcap (*Scutelaria gontscharovii*), as well as some endangered species (section 4.4.2). Mesophytes and hydrophytes that may benefit from the predicted climate include species of high-mountain meadows that can expand their distribution range due to the melting of snowfields and appearance of new territories vacant for the plants growing in the lower zone (Safarov pers.comm.; Sattorov pers.comm.). Such expansion has already been observed in the nival zone of *Dashtidjum Zakaznik* (section 4.5.1). At the same time, melting of snowfields represents a threat for the high-mountain meadows, as snowfields are an important source of water for the lower-lying areas. As a result, it can reduce species diversity of the meadows and increase prevalence of xeric and weed species (Safarov pers.comm.; Zagrebelnyi pers.comm.).

The least vulnerable to climate change mesophilous species are probably the ephemers of savannoid and xerophytic ecosystems. They are characterized by short vegetation period during the rainfall season and following dormancy period in a form of seeds that helps them to avoid the drought (Safarov pers.comm.; Karimov pers.comm.). Climate change impact on ephemers includes temporal shifts in vegetation period, and its shortening due to the higher air temperature and anomalies in precipitations (Safarov pers.comm.; Karimov pers.comm.). Despite the relatively low vulnerability of ephemers to climate change, higher air temperatures and lack of rainfall during the vegetation period may disrupt the processes of photosynthesis and seed formation, leading to the decreased richness of ephemers in a consequent year (Karimov pers.comm.) But in general, it is unlikely that climate change will considerably affect the abundance of ephemers, though it may cause changes in their composition with a dominance of well adapted species with high dispersal capacity (Safarov pers.comm.). The latter will also contribute to the expansion of area occupied by ephemers.

Similar to ephemers, the perennial herbaceous species with a short vegetation period (ephemeroids) are less vulnerable to climate change than those with a long vegetation period, as well as trees and shrubs. At the same time lack of precipitation during the vegetation period can affect the process of nutrients accumulation in tubers and bulbs, required for the vegetation in a consequent year (Karimov pers.comm.). Ephemeroids are also sensitive to the high air temperature that can cause foliage burns and affect the process of nutrients accumulation. This process can also be disrupted by decreased amount of autumn precipitation. Altogether it may result in the falling out of ephemeroids from the grass stand during some years (Karimov pers.comm.). In addition to temporal variations in species abundance, as well as shift of distribution ranges upwards, it is likely that climate change will promote changes in the composition of ephemeroids with a prevalence of weed species, at the expenses of such rare species as Korolkov's crocus (*Crocus korolkovii*), Baldjuan primrose (*Primula baldshuanica*), and Kaufman's primrose (*Primula kaufmanniana*) (Safarov *et al.* 2008; Karimov pers.comm.)

Xerophytic plants are among the least vulnerable species of *Dashtidjum Zakaznik* to climate change, as they are well adapted to dry and hot weather conditions. They are mainly occur within mid-mountain xerophytic ecosystems (section 4.5.5) and are represented by different forms of plants, including trees such as pistachio, Griffit's redbud (*Certic griffithii*), Regel's maple (*Acer regelii*), and almonds (Safarov *et al.* 2008). They may benefit from the climate warming and expand their distribution ranges (Ustjan pers.comm.; Safarov pers.comm.). At the same time, despite the resistance of these trees to droughts and high air temperatures, they are sensitive to the sharp changes in temperatures that may lead to the death of seed-buds and affect the tree growth (Ustjan pers.comm.). Xerophytic trees and shrubs are also very prone to forest fires (Safarov *et al.* 2008). At present, the frequency of forest fires on the territory of *Dashtidjum Zakaznik* is not high and is mainly triggered by anthropogenic factor (Safarov *et al.* 2008), but in a view of projections for warmer climate and decrease of precipitation, it is likely that the frequency of forest fires and area affected may considerably increase. Another negative impact of climate change on xerophytic vegetation includes increased spread of the pest insets and associated increase of trees mortality (Ustjan pers.comm.; Safarov pers.comm.).

Xerophyte herbaceous species are among the least vulnerable species to climate change. They may benefit from the warmer climate and droughts and expand there distributions ranges, replacing the mesophilous species. Species that may increase their population size under an altered climate include species with high adaptive capacities, represented mainly by weed species, such as couch grass (*Elytrigia trichophora*), bulbous bluegrass (*Poa bulbosa*), and small-flowered origanum (*Origanum tyttanthum*) (Zagrebelnyi pers.comm.). Their expansion has already been observed on the territory of *Dashtidjum Zakaznik*, and is aggravated by the intense cattle grazing (section 4.5.5). Unlike wide-spread and weed species, xerophyte species with a small and isolated ranges and endangered status may disappear from the composition of Dashtidjum's flora despite the favorable impact of climate change (section 4.4.2).

4.4.2 Endemic and endangered species

As mentioned in previous section, the flora of *Dashtidjum Zakaznik* consists of significant amount of rare and endemic species, as well as endangered species. The total amount of endemics constitutes 115 species, some of them, including keyserlingia (*Keyserlingia mollis*) and magnificent ostrovskia, have very narrow distribution ranges and can be met only on the territory of the *zakaznik* and surroundings areas (Safarov *et al.* 2008). A majority of endemic species is represented by legume family – 39 species, including 26 sub-species of the milk-vetch. A considerable part of endemic species is listed in the Red Data Book of Tajikistan as 'declining' and 'endangered' species, including keyserlingia, superior tulip (*Tulipa praestans*) (Figure 4-11), Eduard's fritillary (*Petilium eduardii*) (Figure 4-12), and Darvaz iris (*Iris darvasica*) (Annex 9). Relic species of *Dashtidjum Zakaznik* include magnificent ostrovskia, common fig (*Ficus carica*), and walnut (Safarov *et al.* 2008).

Endemic and endangered species of *Dashtidjum Zakaznik* may be significantly affected by climate change impacts as a majority of them are already characterized by fragmented narrow distribution ranges due to natural reasons or human activities. It is unlikely that they will be able to shift their distribution for a suitable climate conditions (Safarov pers.comm.; Sattorov pers.comm.). Even if some species are able to do that, areas at higher elevations most probably will be already occupied by other species with higher dispersal and adaptive capacities (Safarov pers.comm.). In long-term perspective it is likely that *Dashtidjum Zakaznik* will lose significant amount of endangered and endemic species; and those that will persist, may experience considerable reduction of their population size and distribution ranges. A brief overview of the vulnerability of some endemic and endangered species is presented below.

Eduard's fritillary is a rare species with declining populations, listed in the Red Data Book of Tajikistan (Annex 9) (Abdusaljamov *et al.* 1988). It is a perennial plant that mainly grows within mid-mountain mesophylic forests (Abdusaljamov *et al.* 1988; Safarov *et al.* 2008). The species is highly vulnerable to climate change as it mainly occurs under the broad-leaved trees and requires well-drained soils (Safarov pers.comm.; Sattorov pers.comm.). Anomalies in air temperature and lack of precipitation during the spring and summer period may affect the vegetation of this species and lead to the population decline. It is unlikely that Eduard's fritillary will shift its distribution range due to the low migration capacities. Thus, direct impact of climate change stressors, along with the reduction of forest cover, as well as anthropogenic pressure, will most probably drive this species to the extinction (Safarov pers.comm.; Sattorov pers.comm; Zagrebelnyi pers.comm.).

Figure 4-11. Superior tulip

Figure 4-12. Eduard's fritillary Photo credit: Safarov 2008

The magnificent ostrovskia (*Ostrowskia magnifica*) is a rare, endemic and relic species with declining population, included into the Red Data Book of Tajikistan (Annex 9) (Abdusaljamov *et al.* 1988). It grows on fine-grained and gravelly slopes in a shadow of trees and rocks within broad-leaved and juniper forests (Abdusaljamov *et al.* 1988). It is one of the most hydrophilous species of the *zakaznik*, and therefore is highly vulnerable to climate change (Safarov pers.comm.; Zagrebelnyi pers.comm.). Similar to Eduard's fritillary, it can be directly affected by temperature increase and lack of precipitation. An absence of flowering of this species has already been observed in recent dry years in several places of *Dashtidjum Zakaznik* (Sattorov pers.comm.). Being a shade-requiring species, the magnificent ostrovskia may suffer a significant reduction also due to the decrease of areas covered by forests and their shifts upwards. The species also has limited migration capacities, which will constrain shifts of its ranges (Safarov pers.comm.).

In addition to species mentioned above, climate change will adversely affect other endemic and rare species that inhabit mid-mountain forests of *Dashtidjum Zakaznik,* such as Goncharov's skullcap, hybrid senna, Tajik chesneya (*Chesneya tadzhikistana*), and rose-tinted desert-candle (*Eremurus roseolus*). Climate-driven shifts of forest vegetation and its xerophytization (see 4.5.5), along with the direct impact of higher air temperature and anomalies in rainfall may cause significant reduction of their population size. Another group of rare and endangered species are prevernal species, as well as ephemeroids that may be affected by warmer climate and lack of precipitation during the vegetation period (Karimov pers.comm.). Thus, it is likely that climate change, in combination with anthropogenic pressure, will drive to extinction such declining species as Korolkov's crocus, Darvaz iris, and Nikolai juno, as well as endangered Maximovich's tulip (*Tulipa maximowiczii*) and other species (Safarov *et al.* 2008).

The keyserlingia is an endangered and endemic species listed in the Red Data Book of Tajikistan (Annex 9) (Abdusaljamov *et al.* 1988). It forms shrubs up to six meters height, which grow on variegated soils mainly within xerophytic ecosystems (Abdusaljamov *et al.* 1988). The species is well adapted to hot and dry climate, and thus can be relatively resistant to climate change impacts (Safarov pers.comm.). At the same time, as it forms a community with such mesophilous plants as meadow grass and sedge, their reduction and replacement by other species may lead to the decrease of the population size of the keyserlingia (Safarov pers.comm.; Sattorov pers.comm.). It is also unlikely that this species will shift its distribution range for a better climate conditions (Safarov pers.comm.).

From the three onion species listed in the Red Data Book of Tajikistan (Annex 9), the most vulnerable species is the stalked onion (*Allium stipitatum*) that grows within forest mesophylic vegetation and is sensitive to high air temperature and lack of moisture (Abdusaljamov *et al.* 1988). At the same time, it is unlikely that this species will disappear from the flora composition of *Dashtidjum Zakaznik* as it is quite widely spread, but it may suffer reduction of its population within mesophylic communities (Safarov pers.comm.). Another species of onion – endemic Rozenbah's onion (*Allium Rosenbachianum*) also prefers to inhabit shadow areas under the trees (Abdusaljamov *et al.* 1988), but is relatively better adapted for various climatic conditions, and thus can be less affected by climate change impacts (Safarov pers.comm.). Nevertheless, it may experience delays in flowering and bearing, as well as disruption of generation processes, which may lead to the decline of population size (Safarov pers.comm.; Sattorov pers.comm.).

Such species as black cumin (*Bunium persicum*), which is listed in the Red Data Book of Tajikistan (Annex 9), and tanner's sumac (*Rhus coriaria*) and Darvaz swida (*Swida darvasica*), which are listed in the IUCN Red List (Annex 8) are probably the least vulnerable species to climate change among endangered species (Safarov pers.comm.; Sattorov pers.comm.; Zagrebelnyi pers.comm.). They are relatively wide-spread across *Dashtidjum Zakaznik*, except of very rare Darvaz swida, and are well adapted for hot and dry conditions. The black cumin occurs mainly within xerophytic communities, but can be met at elevations up to 2,500 masl (Abdusaljamov *et al.* 1988). The tanner's sumac is characterized by high resistance to various climatic conditions as well as high plasticity. It is likely that under the changing climatic conditions it will occupy new territories, outcompeting native species, and will considerably expand its distribution range (Safarov pers.comm.; Sattorov pers.comm.; Zagrebelnyi pers.comm.).

4.4.3 Wild relatives of cultural plants

The flora of *Dashtidjum Zakaznik* has significant value not only because its diversity, but also because it comprises many species, which are wild relatives of cultural crops and have global importance as valuable genetic resources. There are more than 200 plant species of wild relatives, including 40 species of wild-growing trees and shrubs (Annex 12) (Safarov *et al.* 2008). Among them are such sub-tropical species as pomegranate, fig and cherry-plum trees. The most valuable nut trees are walnut, pistachio, and almond (Figure 4-13). Endemic and endangered species of wild relatives include several species of pear, apple and almond trees, as well as hawthorn and pomegranate (Abdusaljamov *et al.* 1988; Safarov *et al.* 2008; IUCN 2010c). A brief overview of these species and their vulnerability to climate change is presented below.

Dashtidjum Zakaznik is one of the main places for the conservation of valuable wild-growing common pomegranate (*Punica granatum*) (Figure 4-14) (Safarov *et al.* 2008). This species is included into the Red Data Book of Tajikistan as rare and declining (Abdusaljamov *et al.* 1988). In the *zakaznik* it occurs mainly on the southern slopes within xerophytic ecosystems, at the elevations of 800 to 1,350 masl (Safarov *et al.* 2008). It is subtropical species that is well adapted for hot and dry conditions, and thus has relatively low vulnerability to climate change impacts (Sattorov pers.comm.; Sattorov pers.comm.). At the same time it is sensitive to the soil overheat that reduces moisture capacity and access to water, as well as to cold temperatures (Safarov pers.comm.; Sattorov pers.comm.). It can cause death of some trees, mainly along the lower boundary of their distribution range (Safarov pers.comm.). But in general, common pomegranate may expand its distribution range under the altered climate, if not affected by human activities (Safarov pers.comm.; Sattorov pers.comm.; Zagrebelnyi pers.comm.)

The wild-growing species of almond in *Dashtidjum Zakaznik* are represented by Bukharian almond (*Amygdalus bucharica*) and Vavilov's almond (*Amygdalus vavilovii*) (Safarov *et al.* 2008). The Bukharian almond (Figure 4-13) is listed in the IUCN Red List as 'vulnerable' species (IUCN 2010c), but is relatively wide-spread on the territory of *zakaznik*. Vavilov's almond, on the contrary is a very rare species, listed in the Red Data Book of Tajikistan (Abdusaljamov *et al.* 1988). Both of them grow at rocky slopes at the elevation of 800 to 1,700 masl within xerophytic ecosystems (Safarov *et al.* 2008). Similar to pomegranate, they are quite well adapted for hot and arid climate. Therefore, they can even benefit from the climate warming and expand their distribution ranges, which has already been observed for Bukharian almond (Safarov pers.comm.). At the same time, Vavilov's almond is sensitive to extremely cold temperatures, and may suffer the reduction of its population size after the harsh winters (Safarov pers.comm.).

Another species listed in the IUCN Red List is the Darvaz hawthorn (*Crataegus darvasica*), which has 'critically endangered' status (IUCN 2010c) (Annex 8). It is also listed in the Red Data Book of Tajikistan as 'endangered' species (Abdusaljamov *et al.* 1988). It is very rare species, with the only known location at Zarbuz river outlet, where its grows along the river banks among bushes of willow and poplar (Abdusaljamov *et al.* 1988). Despite a quite low vulnerability to climate change impact, this species may be affected by spread of pest insects during hot and dry years (Safarov pers.comm.). The same can be noted for the majority of species listed in this section, which may suffer reduction in population size due to increased infestation by pest insects and associated increased mortality of trees.

Figure 4-13. Bukharian almond

Figure 4-14. Wild-growing common pomegranate

Among xeric wild-growing fruit species are also fig trees, represented by two 'declining' species – common fig (*Ficus carica*) and Afghan fig (*Ficus afghanistanica*). Both of them are included into the Red Data Book of Tajikistan along with the rare and endemic species - Darvaz cherry-plum (*Prunus darvasica*). These species belong to subtropical species and are well adapted to hot and arid conditions. At the same time, fig trees are sensitive to cold temperatures, which can cause the death of this tree (Zagrebelnyi pers.comm.) and susceptible to different pathogens. The cherry-plum, on the contrary, is relatively resistant to pest insects and diseases (Safarov *et al.* 2008), and would be less affected by climate-driven manifestations of pest insects. Another xerophytic wild relatives of cultural crops are widely spread pistachio that constitutes the main part of xerophytic ecosystems, as well as less spread jujube (*Zizyphus jujuba*) (Safarov *et al.* 2008). They also belong to the group of species that may benefit from the climate change impacts and expand their distribution range on the territory of the *zakaznik*, but if anthropogenic pressure is minimized (see also section 4.5.5) (Safarov pers.comm.; Sattorov pers. comm.; Zagrebelnyi pers.comm.).

The most vulnerable species of wild relatives of cultural crops to climate change are probably apple and pear trees, as well as walnuts. The wild-growing apple tree is represented by rare and endemic species Siver's apple (*Malus sieversii*) (Safarov *et al.* 2008). It is listed in the IUCN Red List as 'vulnerable' species, and in Red Data Book of Tajikistan as 'declining' species (Abdusaljamov *et al.* 1988; IUCN 2010c). It occurs in a form of singular trees or small groups within mesophylic forests of *Dashtidjum Zakaznik* (Safarov *et al.* 2008). It is cold-resistant and relatively xerophyte species, but it may still suffer from the lack of soil moisture and spread of the pest insects (Safarov pers.comm.). It is therefore likely that it will disappear from the lower zone of its distribution range. It may also experience difficulties in shifting the distribution range due to the absence of seed reproduction (Safarov pers. comm.).

Wild-growing pear species are represented by several species, including rare and endemic Cayon pear (*Pyrus kayon*) and Korjinsky's pear (*Pyrus korchynskyii*). Both of them constitute valuable genetic resources and are listed in the IUCN Red List, as well as Red Data Book of Tajikistan (Annexes 8 and 9) (Abdusaljamov *et al.* 1988; IUCN 2010c). Though both species grow within mid-mountain mesophylic forests they have quite high adaptive capacity and resistance to high temperature (Safarov pers.comm.). At the same time, the combination of high temperature and lack of rainfall may adversely affect this species due to decrease of soils moisture. It may cause death of single trees and reduce the population size of this rare species (Safarov pers.comm.). The pears are also very susceptible to different pathogens and may suffer reduction of population size and decrease of yields due to the climate-driven spread of pest insects (Sattorov pers.comm.)

4.5 Ecosystems vulnerability to climate change

Climatic and landscape variability of *Dashtidjum Zakaznik* have promoted formation of numerous ecosystems on a relatively small area and their diversity both in horizontal and vertical dimension (Safarov *et al.* 2008). Ecosystems of the *zakaznik* comprise of 7 out of 12 ecosystems' types occurring in Tajikistan (Figure 4-15). They are represented by six natural ecosystems, including valuable mid-mountain mesophylic forests that provide habitats for rare, endemic and endangered species, and an anthropogenic ecosystem represented by agricultural ecosystems occurring around human settlements. The most wide-spread ecosystems are mid-mountain xerophytic ecosystems that cover nearly 50% of the territory of *Dashtidjum Zakaznik* and comprise of wild relatives of cultural crops of global significance (Safarov *et al.* 2008).

Figure 4-15. Ecosystems of Dashtidjum Zakaznik Source: Adapted from Noosfera 2008

Despite the nature protection regime established on the territory of *Dashtidjum Zakaznik*, it should be noted that the majority of its natural ecosystems are affected by various anthropogenic factors, including illegal wood cutting, poaching, and cattle grazing (Safarov *et al.* 2008). It results in the degradation of ecosystems especially those located at elevations up to 1,500 masl and represents a significant threat to the ecological balance in the region (Safarov *et al.* 2008). It also decreases the ability of ecosystems to adapt to climate change, worsening its impacts. It is evident that climate change already affects the ecosystems of *Dashtidjum Zakaznik* leading to various changes in their structure and distribution ranges. A brief overview of the ecosystems and their adaptive responses to climate change is presented below.

4.5.1 Nival ecosystems

Nival ecosystems of *Dashtidjum Zakaznik* are mostly represented by rocks and taluses with rare vegetation (Safarov *et al.* 2008). They cover the highest parts of the mountains belonging to the Khazratisho and Darvaz ranges at the elevations from 2,800 to 3,000 masl. Despite the small area occupied by these ecosystems (less than 5%), they play an important role in climate formation and ecological balance both at regional and local level (Safarov *et al.* 2008). Snowfields that cover the peaks of the mountain ranges are the valuable source of water for lower alpine and sub-alpine meadows and other ecosystems (Safarov pers.comm.).

Nival ecosystems of the *zakaznik* provide habitats for rare and endemic species of mammals, birds, insects and valuable plant communities (Safarov *et al.* 2008). At the cold and rocky territories of nival ecosystems around 15-30 of plant species, including such flowering species as purple bladder campion *(Melandrium apetalum)*, whitlow-grass *(Draba altaica)*, nival milk-vetch (*Astragalus nivalis)*, and snow lotus (*Saussurea glacialis*), can be met. Animal inhabitants include among others Siberian ibex and red marmot. At the lower boundaries of the nival ecosystems the endangered species markhor can be observed (Safarov *et al.* 2008).

Nival ecosystems are one of the few ecosystems of the *zakaznik* where climate change impacts can be clearly differentiated as the impacts of anthropogenic activities are very limited. During the last decades consequences of climate warming have been observed here, first of all, in the changes of snow line and melting of snowfields (Safarov pers.comm.; Zagrebelnyi pers.comm.). In particular, an area covered by the snowfields for the last 15-20 years has reduced almost in half. The territories that became vacant from snow are being occupied by the vegetation, leading to the changes in the biodiversity composition (Safarov pers.comm.; Zagrebelnyi pers.comm.).

At the lower boundaries of the ecosystem, the introduction of alien species has already been observed (Safarov pers. comm.). In particular, such species as Paulsen's dock (*Rumex paulsenianus*), Thomson's leopard plant (*Ligularia thomsonii*) (Safarov pers. comm.; Sattorov pers. comm.), as well as knotweed (*Polygonum aviculare*), common plantain (*Plantago major*), and Turkestan adonis (*Adonis turkestanicus)* (Zagrebelnyi pers.comm.), have expanded their upper boundaries, and embedded nival zone, which was previously unusual for them. A total number of the higher flowering plants that compose the ecosystem has increased from 7-10 to 15-20 species (Safarov pers. comm.). It is likely that their number would further increase due to the introduction of new species from the lower elevations. An increase of the mean temperatures and melting of snowfields could also cause an appearance of the moss cover on the rocks (Safarov pers. comm.).

Despite the increase in species number, their composition, most probably, will be represented by the easily spread weed plants that can outcompete rare aboriginal species and in long-term perspective can lead to the monotony of species composition. Reduction in a snow cover also has negative consequences for the ecosystems as it affects water provision of the lower zone of sub-alpine meadows (Safarov pers. comm.). Climate change can also cause the loss of a significant number of species of insects confined to the cold conditions of the nival zone; and the majority of them are not studied yet (Muminov pers.comm.). It is also likely that Siberian ibex will disappear from the territory of the *zakaznik* and migrate to the northern areas with colder climate (section 4.3.1) (Saidov pers. comm.).

4.5.2 High mountain meadows and steppes

High mountain meadows and steppes occupy nearly 1% of the *zakaznik*'s territory and occur in fragments at the altitudes from 2,800 to 3,000 masl (Safarov *et al.* 2008). They play an important ecological role providing habitats for numerous rare and endemic plant and animal species. The animal world of the ecosystem includes endangered markhor, as well as Siberian ibex, Tien-Shan brown bear, and red marmot. A snow leopard, an endangered species included into the IUCN Red List, can be sometimes observed here when it migrates from the high mountain areas located outside the *zakaznik* in a search of food (Safarov *et al.* 2008).

Endemic plant species of high mountain meadows include stalked onion, Goncharov's skullcap, and Pamir-Alai rice grass (*Pipthaterum pamiroalaicum*)(Safarov *et al.* 2008). Plant communities of the ecosystems are mainly formed by fescue (*Festuca alaica*), alpine meadow grass (*Poa alpina*), sedges (*Carex melanantha*, *C.stenocarpa*), cobresia (*Cobresia stenocarpa*), oxytrope (*Oxytropis savellanica*), and Zeravshan thyme (*Thymus seravshanicus*). Grass productivity of the high mountain meadow and steppe ecosystems is 5-6 times higher than of other ecosystems leading to their use as a summer pastures. As a result, nearly 30% of these ecosystems are already degraded, with a grass productivity reduced in half. Overgrazing leads to the loss of species and replacement of original valuable communities by secondary weed communities (Safarov *et al.* 2008).

High mountain meadows are among the most vulnerable ecosystems of the *Dashtidjum Zakaznik*. Decrease of precipitation and reduction of snow cover are the main climatic factors that affect this ecosystem. Decrease of the snow cover has been confirmed by the observations of several specialists who noticed absence of the snow cover in the summers (even in deep canyons) during the last decade (Safarov pers.comm.). Climate aridization is also confirmed by the changes in biodiversity composition and species' distribution ranges, as well as in ecosystem boundaries. A partial desiccation of the high mountain meadows has already been observed along the lower boundary of their distribution (Zagrebelnyi pers.comm.).

Due to the climate change the distribution ranges of hydrophilous plants that constitute the ecosystem have been shrunk (Safarov pers.comm.). This mainly refer to wild onion species, silverweed (*Potentilla sp.*), and meadow grass (Safarov pers.comm.; Sattorov pers.comm.), as well as sedge and milk-vetch species (Zagrebelnyi pers.comm.). There are cases of total disappearance of hydrophilous plants from the meadows phytocenosis (Safarov pers.comm.). In some areas of meadows the introduction of invasive species, including the Paulsen's dock, has been observed (Sattorov pers.comm.). There is an expansion of the distribution ranges of the weed and alien to the zone plants (Safarov pers.comm.; Sattorov pers.comm.; Zagrebelnyi pers.comm.). Though one of the main factors of distribution of alien species is cattle grazing, climate change aggravates the situation providing conditions favorable for the seeds growing (Sattorov pers.comm.).

Climate change impacts will promote further introduction of xeric species into the composition of meadow communities and reduction of the distribution ranges of valuable hydrophilous plants (Safarov pers.comm.). It is likely that rare endemic species will be outcompeted by alien species and disappear from the ecosystem (Safarov pers.comm.). The expansion of distribution ranges of weed plants will continue due to the expansion of such species as *Polygonum coriarum*, Paulsen's dock, and small-flowered origanum (Sattorov pers.comm.). All these changes may lead to the complete restructuring of the meadow ecosystems and their transformation into the less valuable steppe ecosystems (Safarov pers.comm.). The latter will cause a reduction of ecosystem's productivity and negatively affect populations of its inhabitants, including the ungulates - urial and markhor (Saidov pers.comm.).

4.5.3 Mid-mountain conifer forest

Mid-mountain conifer forest ecosystems occur at altitudes of 2,000-2,600 masl and cover 10-15% of the territory of *Dashtidjum Zakaznik* (Safarov *et al.* 2008). They are more common in the southern part of the *zakaznik*, and are mainly represented by juniper light forests (Figure 4-16). The latter have an important role in a water regulation and slope protection, preventing mudflows and landslides, and preserving water resources. Similar to other ecosystems, they also provide habitats for rare and endemic plant and animal species (Safarov *et al.* 2008). Juniper light forests of *Dashtidjum Zakaznik* are formed by the only juniper species – Zeravshan juniper (*Juniperus seravschanica*) (Safarov *et al.* 2008).

The most valuable plant communities of these ecosystems include motley- shrub-steppe and forbs-meadow juniper light forests. Plant communities comprise of hay plant (*Prangos pabularia*) and ferula species: *Ferula gigantea*, *F. violaceae*, and *F. clematidifolia.* Rare plant species are represented by magnificent ostrovskia, Darvaz iris, Rozenbakh's onion, anzur onion (*Alllium suworowii*), Echison's desert-candle (*Eremurus aitchisonii*), Eduard's fritillary, and tulip superior. Animal inhabitants of the juniper light forests include: markhor, urial, Tien-Shan brown bear, lebetina viper, and ring dove. Despite the nature protection regime, conifer ecosystems are highly affected by anthropogenic activities, mainly by illegal cutting of trees for fuel wood and cattle grazing (Safarov *et al.* 2008).

In comparison with the high mountain meadows, mid-mountain ecosystems are less vulnerable to climate change. It can be explained by the fact that the Zeravshan juniper that forms light forests has a certain adaptive capacity to dry and hot climate (Safarov pers.comm., Ustjan pers.comm.). At some point, climate change can even promote the expansion of the upper range of the juniper distribution, but it could happen only if the anthropogenic pressure is minimized, as it affects the

Figure 4-16. Fragments of mid-mountain conifer forest Photo credit: Safarov 2008

juniper young sprouts (Safarov pers.comm.). At the same time, climate change has a negative effect on hydrophilous plants that compose the conifer ecosystems, in particular on rare and endangered species such as magnificent ostrovskia and Eduard's fritillary (section 4.4.2). Due to the combination of climate change and anthropogenic pressure they may disappear from the ecosystem and *Dashtidjum Zakaznik* in general (Safarov pers.comm.). At present, replacement of hydrophilous plants by xeric species are being observed along with the distribution of new high-grass species, including Thomson's leopard plant, from the lower vegetation zones (Sattorov pers.comm.).

Despite a plasticity of the juniper to climatic conditions, a fall out of this species from the composition of the ecosystem can already be observed at the lower boundary of its distribution (Zagrebelnyi pers.comm.). Besides anthropogenic factors, it is caused by the moisture shortage and loss of mesophilous trees that provide a shadowed shelter for the young sprouts of juniper trees (Safarov pers.comm.). An introduction of xerophytic shrubs and steppe vegetation is occurring along the lower boundary of the ecosystem, causing its restructuring and replacement of juniper light forests by shrubs (Safarov pers.comm.; Zagrebelnyi pers.comm.; Sattorov pers.comm.). It is likely that the situation would aggravate further, with a possible modification of the Zeravshan juniper into more steppe species (Safarov pers.comm.).

4.5.4 Mid-mountain mesophylic forest

Mid-mountain mesophylic forest ecosystems cover about 20-25% of the territory of *Dashtidjum Zakaznik* and occur between 1,200 – 2,600 masl (Safarov *et al.* 2008). They are widely spread in the northern part of the *zakaznik* and are mainly represented by maple-walnut and willow-poplar forests with mesophylic light shrubs. Most of the trees are drawn towards the natural water reservoirs, such as tectonic cracks, sandstone layers, and conglomerates. Mesophylic ecosystems have a high importance for biodiversity conservation as they comprise numerous valuable communities, as well as considerable number of rare, endemic and endangered species, and wild relatives of fruit trees (Safarov *et al.* 2008).

The most valuable communities of the ecosystems include broad-leaved mesophylic relict forests represented by walnut and Turkestan maple (Figure 4-17) (Safarov *et al.* 2008). The small-leaved forests comprising of Tien-Shan birch and willow trees (*Salix sp.*) are less spread. They occur in small fragments mainly along the basin of Obiniou and Pyanj rivers. Plant species of mesophylic ecosystem include: endangered magnificent ostrovskia, endemic anzur onion, and Albert's exochorda (*Exochorda albertii*), as well as Nevski's touch-me-not (*Impatiens nevskii*), Tajik goutweed (*Aegopodium tadshicorum*), and other species (Safarov *et al.* 2008).

As mentioned above, forest communities comprise considerable number of wild relatives of fruit trees, including Siver's apple, Cayon pear, Korjinskyi's pear, Darvaz hawthorn, Darvaz cherry-plum, barberry (*Berberis heterobotrus*) and other species (Safarov *et al.* 2008). They provide favorable habitats of large mammals, including endangered species such as snow leopard, urial, Tien-Shan brown bear, Indian porcupine, and birds: ring dove, golden eagle, Egyptian vulture, etc. Due to anthropogenic pressure, such as illegal tree cutting, poaching, and cattle grazing, the mesophylic ecosystems are degrading and losing their species diversity. The valuable tree communities are replacing by the communities of exochorda and rose species (Safarov *et al.* 2008).

Mid-mountain mesophylic forest ecosystems are among the most vulnerable ecosystems of *Dashtidjum Zakaznik* to climate change. Similar to other ecosystems, the key climatic factors that affect the ecosystem and its mesophilous species are the decrease of precipitation and a general increase of mean air temperatures that lead to desiccation of water bodies and soils. Specialists have already noticed a significant reduction in the amount of springs that are highly important for the ecosystem's species (Safarov pers.comm.; Zagrebelnyi pers. comm.). Climate change impacts are aggravated by the anthropogenic pressure in a form of cattle grazing and trees cutting. The latter, in turn, aggravates the climate warming due to the increased heat flux from the rocks that have lost the vegetation cover, and decreased absorption of carbon dioxide by disrupted ecosystems (Safarov pers.comm.).

Figure 4-17. Fragments of mesophylic maple forests Photo credit: Safarov 2008

The most vulnerable species of mesophylic ecosystems to climate change are Tien-Shan birch, walnut, and Turkestan maple (section 4.4.1) (Safarov pers.comm.; Ustjan pers.comm.). The Tien-Shan birch is very sensitive to the changes in soil moisture, and it is likely that under the further warming and aridization conditions it would disappear from the territory of the *zakaznik*, giving up the space for xerophytic species (Safarov pers.comm.; Ustjan pers.comm.). A significant reduction of the areas covered by walnuts and maples has already been observed on the territory of the *zakaznik* (Safarov *et al.* 2008). At the same time, it is caused not only by illegal tree cutting, but also by the lack of soil moisture, as well as by spread of pest insects (Safarov pers.comm.; Ustjan pers.comm.). A considerable part of the maple trees is affected by leaf-cutting beetles (Safarov pers.comm). According to the Department of Forest Protection, expansion of the area affected by pests is mainly caused by the spread of a xerophilous lackey (*Malacosoma neustria*), which became dominant for the area (Sangov pers.comm.).

Maple and walnut forests of the *zakaznik* are changing their composition due to the introduction of xerophytic formations represented mainly by weed species such as barberry, rose, and exochorda (Safarov pers.comm.). In addition to tree species, there is an obvious decrease of distribution ranges and in richness of mesophylic herbaceous plants. In particular, in the lower zone of the ecosystem the shrinking of the distribution range of Thomson's leopard plant is taking place; at the same time the upper zone of its range is expanding (Sattorov pers.comm.). The vacant places are being occupied by the hay plant, and small-flowered origanum. Such uncommon species as John's-wort (*Hypericum scabrum*), knotweed, and cocksfoot (*Dactylis glomerata*) have already been observed in the composition of the ecosystem (Sattorov pers.comm.).

A further climate warming and its combination with anthropogenic pressures can lead to the extinction from the ecosystem, and the *zakaznik* in general, such rare, endemic and endangered species as Darvaz cousinia (*Cousinia darwasica*) and magnificent ostrovskia (Safarov pers.comm.; Zagrebelnyi pers.comm.). Other potential consequences of climate change include loss of valuable genetic resources due to the decline of populations of some wild relatives of fruit trees, including Siver's apple, and pears, that can be caused by soil overheat and desiccation, as well as by spread of pest insects (see also section 4.4.3)(Safarov pers.comm.).

Climate change has an adverse effect on the animal world of mesophylic forests. It promotes population decrease of a number of mammal species, including urial, through the reduction of forage resources represented by mesophylic plants and fruits, and their replacement by shrubs and inedible thorn grass (section 4.3.1)(Saidov pers.comm.; Zagrebelnyi pers.comm.). Reduction of areas that provide optimal habitats is yet another factor that affects animals and can lead to the decline of their populations, as well as to migration of animals to other territories outside the *zakaznik* (Saidov pers.comm., Murodov pers.comm.). The latter can be the case for Tien-Shan brown bear and urial (Saidov pers.comm.; Zagrebelnyi pers.comm.), and some bird species, including ring dove and paradise flycatcher (section 4.3.2) (Murodov pers.comm.).

4.5.5 Mid-mountain xerophytic forest

Mid-mountain xerophytic forest ecosystems cover vast areas of *Dashtidjum Zakaznik* at the elevations of 700 to 1,200 masl (Safarov *et al.* 2008). They occupy about 45-50% of the area and are mainly represented by the formations of pistachio, Regel's maple, Griffit's redbud (Figure 4-18), and Bukharian almond. The herbal-shrub pistachio formation is the dominant of the area (Figure 4-19). It plays an important role in water regulation and provides optimal habitat for the animals of arid zone. The animal world of the ecosystem is richer than that of the others. Large mammals include: markhor, urial, wild boar, wolf, and fox. Among reptiles species are endangered Central Asian cobra, Central Asian tortoise, and other species (Safarov *et al.* 2008).

The major part of the xerophytic light forest communities represents valuable genetic resources (Safarov *et al.* 2008). They contain wild relatives of wild barley (*Hordeum spontaneum*), vetch (*Vicia tenuifolia*), persimmon (*Diospyros lotus*), Bukharian pear (*Pyrus bucharica*), Bukharian almond, jujube, common pomegranate, grape, and many other species (Annex 12). Plant communities comprise numerous species that are listed in the Red Data Book of Tajikistan and the IUCN Red List, including Darvaz iris, Nikolai's juno, milk-vetch (*Astragalus insignis*), Tajik chesneya, keyserlingia, Rozenbakh's onion, and tanner's sumac (Annexes 8 and 9) (Abdusaljamov *et al.* 1988; Safarov *et al.* 2008; IUCN 2010c).

Figure 4-18. Flowering Griffit's redbud

Figure 4-19. Pistachio trees

Mid-mountain xerophytic forest ecosystems are among the most affected ecosystems by anthropogenic activities due to their location at low elevations near the settlements (Safarov *et al.* 2008). Due to illegal cuttings for fuel wood, around 15% of pistachio light forests are replaced by the secondary shrubs and semi-savanna communities of bulbous barley (*Hordeum bulbosum*), bulbous bluegrass, sedge (*Carex pachystylis*), Baldjuan sagebrush (*Artemisia baldshuanica*), and hay plant (*Prangos pabularia*). Use of the ecosystems as winter pastures and hay lands caused significant degradation of the lower zone of xerophytic light forests and affects natural restoration of pistachio forests. Yet another threat for the fire-prone xerophytic forest are forest fires resulting from the careless behaviour of the local people (Ustjan 2006; Safarov *et al.* 2008) and destroying several hectares of forested area almost every year (Begov pers.comm.; Ustjan pers.comm.).

Mid-mountain xerophytic ecosystems belong to the ecosystems with a high resistance to climate change impacts. At the same time, they also tend to change their structure, which can be observed in their further xerophytization, distribution of the invasive weed species, reduction in species diversity and increasing monotony of phytocenosis (Safarov pers.comm.; Sattorov pers.comm.). Aridization of climate also leads to the expansion of areas affected by pests with a consequent loss of trees and shrubs plantations. At present, about 40% of the hawthorn and cherry-plum trees are affected by pests; areas of the Regel's maple affected by leaf beetles have also expanded (Safarov pers.comm.).

Climate change promotes the expansion of xerophytic light forests, in particular in the upper zone of their distribution, mainly at the expense of mesophylic ecosystems. At the same time, in the lower zone of the ecosystem, there is a tendency for the replacement of wood species of Regel's maple and pistachio by shrub vegetation (Safarov pers.comm.). This process is aggravated by tree cuttings and cattle grazing that disrupt natural restoration of the forest cover (Ustjan pers.comm.; Zagrebelnyi pers.comm.). In the lower zone of the ecosystems, the distribution of ruderal communities and species typical for savannoid ecosystems is taking place (Safarov pers.comm.). In particular the distribution of comose desert-candle (*Eremurus comosus*), small-flowered origanum, bush pea (*Thermopsis dolichocarpa*), and chicory (*Cichorium intybus*) has been observed (Sattorov pers.comm.). In 2005-2007 years that have been characterized by unusual aridity (Asanova pers.comm.), some specialists observed the declined richness of annual herbaceous species (Sattorov pers.comm.).

Climate change also affects populations of rare and endangered plant species occurring within xerophytic ecosystems. It is likely that climate change would cause the decline of distribution ranges of such species as magnificent ostrovskia, Eduard's fritillary, and keyserlingia, and can lead to the loss of these species from the ecosystem composition (Safarov pers.comm.; Sattorov pers.comm; Zagrebelnyi pers.comm). Shrinking of distribution ranges is also a threat to the wild relatives of fruit trees that have high importance as genetic resources. In particular, the common pomegranate, despite its resistance to high air temperature and low amount of precipitation, is quite sensitive to the potential soil overheat and decrease of soils' moisture capacity; thus it could disappear from the lower zone of its current distribution along with the Siver's apple tree (section 4.4.3)(Safarov pers.comm.).

Climate change consequences to the animal world of the ecosystem are ambiguous. It is likely that the population size of some species would decline due to the changes in plants' vegetation and associated reduction of the activity period of the animals, for instance Central Asian steppe tortoise (Saidov pers.comm.). From the other side, climate change can promote increase of the population size and expansion of distribution ranges of such species as Central Asian cobra, and lebetina viper, which may benefit from warmer climate (section 4.3.3) (Nadjmidinov pers.comm). Meanwhile, this can be the case only in the absent of anthropogenic pressure that affects populations of snakes. Other species that can expand their distribution range are insects, but mainly pests (section 4.3.5)(Muminov pers.comm.).

4.5.6 Savannoid ecosystems

Mid and low semi-savanna (savannoid) ecosystems are wide-spread on the territory of *Dashtidjum Zakaznik* (Safarov *et al.* 2008). They cover around 30% of the territory and occur at altitudes 700-800 masl. These ecosystems have developed under the dry and hot climatic conditions, thus the considerable part of plants and animals belongs to the species with summer aestivation period. Animals, except for insects, are represented by a small number of species. The background reptiles are Central Asian steppe tortoise and grass lizard. Some rare and endangered species can also be found here including Turkestan saker falcon and golden eagle (Safarov *et al.* 2008).

Valuable communities of this ecosystem are high-grass and forbs-shrub communities, represented mainly by bulbous barley, bulbous bluegrass, sedge, Kuhistan ferula (*Ferula kuhistanica*), Jerusalem sage (*Phlomis bucharica*) and hay plant. A mass vegetation of plants starts in March with the flowering of early geophytes Ephemers and ephemeroids are flowering in early April (Figure 4-20). A grass cover is maximally high in April and completely disappears by the end of May. Vast areas of these ecosystems are used as pastures (Figure 4-21) leading to their degradation and replacement of vegetation by low-productive weed species (Safarov *et al.* 2008).

Similar to xerophytic ecosystems, savannoid ecosystems are among the least vulnerable ecosystems to climate change. A majority of the plant species that compose the ecosystem can be characterized by the high adaptive capacity to climate change due to their unpretentiousness and short vegetation period (Safarov pers.comm.). At the same time, some of them may suffer reduction of their population size due to shorter vegetation period and disrupted process of nutrients accumulations (section 4.4.1) (Karimov pers.comm.). The native communities of the savannoid ecosystems are also considerably threatened by the distribution of invasive weed species, due to both climate change and use of savannoids as pastures (Safarov pers.comm.; Zagrebelnyi pers.comm.).

Despite the extension of the upper zone of the ecosystem and its introduction into the lower distribution range of xerophytic ecosystems (Safarov pers.comm.; Sattorov pers.comm.), there is a general tendency of the shrinking of areas occupied by native savannoids and their replacement by weed-ruderal communities and desertificated species (Safarov *et al.* 2008). Productive savannoid species are being replaced by thorn-grass species, including cousinia and milk-vetch, some ephemeroids, including desert-candle (*Eremurus sp.*), and scutch grass (*Cynodon dactylon*) (Safarov pers.comm.). Weed species like Paulsen's dock, small-flowered origanum and Jerusalem sage are also expanding their distribution range, outcompeting native species (Sattorov pers.comm.). The future changes in the ecosystem will be characterized by a further loss of plant and animal species and prevalence of weed and desertificated species (Safarov pers.comm.).

Figure 4-20. Flowering Juno bucharica

Figure 4-21. Savannoid ecosystem used as a pasture

4.5.7 Agricultural ecosystems

Agricultural ecosystems of *Dashtidjum Zakaznik* are mainly located around settlements and occur at the altitudes from 700 to 1, 200 masl (Safarov *et al.* 2008). They cover about 10% of the area and are mainly represented by vegetables and fruit trees plantations (Figure 4-22), including pomegranate, pear, apple, as well as grain and leguminous crops. The cultivated crops are very often represented by endemic wild relatives of cultural crops, thus contributing to the conservation of valuable genetic resources (Figure 4-23). There is a tendency for the considerable extension of this anthropogenic ecosystem due to the development of rain-fed and irrigable lands. It leads to the degradation of natural ecosystems, soil erosion and other problems (Safarov *et al.* 2008).

Changes of agricultural ecosystems promoted by climate change mainly include changes in the composition of cultivated crops, their productivity, as well as altitude characteristics of the rain-fed crops (Safarov pers.comm; Irgashev pers.comm.). Local people emphasize significant decrease of fruit trees yields, including apple, pomegranate and pistachio, during the last years (Faizov pers.comm.; Boboev pers.comm.). One of the reasons for that are pest outbreaks usual for dry years. In general, crop yields in last decade have decreased by 20-30% (Safarov pers.comm.). Occasional years with a high amount of precipitation are characterized by the expansion of invasive weed species (Safarov pers.comm.). The latter is also common for the southern part of the agricultural ecosystems' distribution range, with the weed species represented by dature (*Datura stramonium*), dandelion (*Taraxacum sp.*), chicory (*Cichorium intybus*) and other invasive species (Sattorov pers.comm.).

Figure 4-22. Fruit garden near the village

Figure 4-23. Wild almond nursery near the village

During the last decades, there is a tendency of shifting rain-fed crops to higher elevations caused by the lack of precipitation at lower altitudes (Safarov pers.comm.; Irgashev pers.comm.). If in the past areas under the rain-fed crops mainly occurred at the altitudes from 700 to 1,000 masl, nowadays they are mainly cultivated at the altitudes from 1,100 to 1,200 masl (Safarov pers.comm.). A composition of cultivated crops has changed several times for the last 20-30 years, mainly due to climate warming and decrease of precipitation in comparison with previous decades (Irgashev pers.comm.). Crops' productivity is decreasing, which forces farmers to replace cultivated local crops by other crops, mainly alien, in a search of higher productivity. In particular, the local varieties of wheat that were common in the past decades – *surkhak* and *safedalak* – were replaced by alien crops (Irgashev pers.comm.). The later is an example of the indirect consequences of the climate change that lead to the loss of valuable genetic resources of global significance.

4.6 Summary

4.6.1 Climate change

The analysis of meteorological observations for the period 1961 to 2008 has shown that the climate change on the territory of *Dashtidjum Zakaznik* is characterized by a steady warming trend. In particular, annual mean temperatures in the last twenty years have increased at almost a four-fold pace (0.07°C per year) compared with the baseline period (0.02°C per year). The overall increase of mean annual temperatures for the period 1961-2008 is 0.8°C, which is higher than the 0.5°C warming trend observed in the majority of country regions. The analysis of monthly trends has revealed a significant increase of mean spring temperatures, which constitutes 3.2°C for the period 1991 to 2008, as well as a change of - 0.9°C in summer temperatures.

In addition to temperature increase, the climate change is characterized by changes in the amount of precipitations. And if during the baseline period there was an increase of 12%, the analysis of the following years has shown a marked decrease of precipitation for the period 1991-2008. The monthly analysis has identified a decrease of precipitations for all months, except February, October and November. The most important climate change impact on biodiversity of *Dashtidjum Zakaznik* is the decrease of spring precipitation, which is important for plant vegetation, as well as increases in spring air temperatures, which may lead to considerable changes in species phenology. A further climate warming, with a projected temperature increase of 1.8 – 2.9°C by the end of 2050 and precipitation decrease by 20% may considerably aggravate the consequences for Dashtidjum's biodiversity.

4.6.2 Fauna vulnerability

Climate change impact on the species of animals of *Dashtidjum Zakaznik* varies from positive to negative. Some species may benefit from climate warming and increase their populations. This mainly refers to pest insects that have already significantly expanded their distribution and increased population. One factor that provides favorable conditions for pest distribution is increases in air temperature. Lack of precipitation affects the composition of pest insects causing a prevalence of xeric species. Other species that benefit from climate change are birds inhabiting high-mountain areas. The decrease of snow cover and melting of snowfields increases area of suitable habitats, making them available for species of birds from lower elevations. The increase of populations of some high-mountains species of birds has already been observed in the last decade. Another group of animals that may experience positive effects from climate change is reptiles, mainly snakes. They may benefit from the warmer climate, as well as increased populations of pest insects and some rodents. One of the positive effects of climate change that may be beneficial for the majority of non-hibernating species is the warmer air temperature during some winters that may increase survival rates of the animals and their offspring.

At the same time, a majority of the animals of *Dashtidjum Zakaznik* experiences negative effects of climate change that may result in the decline of their populations. Factors that affect populations of animals are mainly represented by indirect impacts. One is the decrease of suitable habitats due to changes in ecosystem composition and distribution. In this situation, species that occur in various habitats and are able to migrate upwards or to higher latitudes are less vulnerable than species with specific habitat requirements and limited migration capacity. The former mainly refers to species of birds and large mammals, including carnivores and ungulates. Climate warming has already forced them to shift their distribution ranges. Further warming would most likely result in the decline of the populations of these species on the territory of the *zakaznik*. Some species, including Siberian ibex, snow leopard, ring dove, and paradise flycatcher would most probably disappear from the territory of the *zakaznik* due to the lack of suitable habitats, and move northwards. One of the representatives of birds – black kite – has already left the territory of the *Dashtidjum Zakaznik*.

Another indirect impact that adversely affects populations of the majority species is the decrease of forage resources due to the changes in ecosystems productivity and prey abundance. The least vulnerable to this impact are polytrophic species that feed on diverse group of plants and/or animals, and are possible to switch their nutritive base. The most vulnerable species are specialist species that feed on specific type of plants or prey and can experience difficulties in shifting to another type of fodder. These species include markhor, urial, Turkestan rat, juniper vole, lammergeyer, several species of endangered insects *Dalpada pavlovskii*, *Mustha baranovi, Porphyrophora odorata,* ashen hawk moth, large-headed mantis, and many other species. In general, considerable number of species are affected by the combination of both factors – decrease of suitable habitats and forage abundance, which aggravates the impact of climate change and may lead to significant decline of the populations of these species.

In addition to indirect factors, some species may be directly affected by anomalies in temperature and precipitation. Increase of ambient temperature affects the hibernation process of several species, including long-eared hedgehog, Central Asian steppe tortoise, red marmot, and others, and may disrupt their life activity, including the reproduction. Higher air temperatures also provide negative effect on psychrophilic species of high mountain nival zone, including Siberian ibex and insect species. Harsh winters with heavy snow cover have negative affect on species with limited capacity to walk on a snow cover, including urial, snow leopard and chukar, and may lead to their death from starvation. It also affects tolai hare, constraining the access to fodder. Increased number of days with heavy rains has a negative effect on eggs and tadpoles of the green toad, and may affect density of its population. Indirect effect of the temperature increase may be experienced by the species of fish, as well as amphibians. It leads to increase of water temperature in small watercourses and associated decrease of dissolved oxygen. The latter affects reproduction and survival rates of river inhabitants. Indirect affect of the heavy rains can be also a threat for the blind snake by making it an easy prey for predators.

Despite the positive impact of climate change on some species of animals, mainly insects and reptiles, it is evident that the majority of the species of *Dashtidjum Zakaznik* may be affected in a negative way. A variety of climate change impacts (Annex 13) and species vulnerability to them may result in considerable declines of species populations inhabiting the *zakaznik*. While few species with high migration capacities may migrate northwards and disappear from the territory of *zakaznik*, other species would be threatened by the risk of extinction. A combination of climate change impacts with anthropogenic pressures would most likely have devastating synergetic effects on the animals of *Dashtidjum Zakaznik* and may cause significant decline of its species diversity.

4.6.3 Flora vulnerability

Climate change impact on the flora of *Dashtidjum Zakaznik* also varies from negative to positive. The main factors that directly affect plant species include anomalies in air temperature and precipitation; the indirect factors include spread of invasive species under an altered climate, as well as the disturbance of the fire regime. Adaptive responses of species are mainly represented by temporal shifts of phenological events, including the advancement of the vegetation period and its shortening, and shifts of distribution ranges. The latter has already been observed for some flora species of *Dashtidjum Zakaznik*, while the observation of phenological shifts is complicated due to the lack of long-term monitoring programs.

The most vulnerable to climate change is a group of hydrophilous and mesophilous species, which are sensitive to high air temperature and lack of precipitation. Among them are mesophilous trees, such as Tien-Shan birch, Turkestan maple and walnut, which may significantly decline the size of their populations, and even become extinct, which is most probable for the birch. The herbaceous species, especially annual grasses, though are less vulnerable than ligneous species, may also experience shrinking of distribution ranges and decline of population sizes. It is likely that mesophilous communities would lose majority of valuable species, including meadow-grass and Tajik goutweed, which will be replaced by weed species with higher adaptive and migration capacities. Perennial grasses with short vegetation period can also suffer from the climatic anomalies and reduce their diversity due to the loss of rare and endangered species.

Species that may benefit from climate change mainly include xerophilous and xerophyte species, as well as weed and invasive species. The latter have very high adaptive and migration capacities and include such species as couch grass (*Elytrigia trichophora*), sadgebrush, sedge, small-flowered origanum and others. Under an altered climate, and in combination with anthropogenic pressure, they may outcompete valuable native species and become dominant in the majority of herbaceous and shrub communities. Other species that may benefit from warmer climate include species of alpine and sub-alpine zone, in particular those with high migration and adaptive capacities, which may expand their distribution ranges and occupy nival zone of the *zakaznik*.

It is likely that climate change will contribute to the extinction of a considerable part of rare, endemic and endangered species. Among them the most vulnerable are those that grow within communities of mid-mountain mesophylic and juniper forests, including Eduard's fritillary, magnificent ostrovskia, and Goncharov's skullcap; as well as prevernal species and ephemeroids such as Korolkov's crocus, Darvas iris, Nickolai juno, superior tulip, and Maximovich's tulip.

Many endangered species may experience significant decline of their populations, including the xerophyte shrub – keyserlingia, and mesophylic species of onion, including endemic Rozenbah's onion and stalked onion. The least vulnerable species of rare and endangered plants to climate change include black cumin and tanner's sumac. They may benefit from warmer climate and expand their current distribution range.

A majority of wild relatives of cultural crops, including rare and endangered species, has relatively low vulnerability to climate change. They are mainly represented by xerophyte species, including common pomegranate, almond species, pistachio and fig species. It is likely that they may expand their distribution ranges and occupy higher elevations of *Dashtidjum Zakaznik*. The negative impact of climate change on these xerophyte species, except the cherry-plums, can be caused by the spread of invasive species, which may lead to the loss of single trees, in particular in a lower zone of their distribution ranges. Another threat is the potential disturbance of the fire regime, as a majority of these species belongs to the fire-prone species. Among the most vulnerable species of this group are those that occur within mid-mountain mesophylic forests, including Cayon pear and Korjinskyi's pear, Siver's apple and walnuts. They may suffer the population decline due to higher air temperature and anomalies in precipitation, which lead to soil desiccation and death of single trees.

4.6.4 Ecosystems vulnerability

A major part of the ecosystems of *Dashtidjum Zakaznik* is vulnerable to climate change impacts and is already affected to a various degree. The most vulnerable are high mountain meadows and mid-mountain mesophylic ecosystems that possess considerable number of hydrophilous species with limited adaptive capacities to climate change impacts. The main climatic factors that affect these and other ecosystems are the increase of mean temperature, anomalies in precipitation, melting of snowfields and reduction of snow cover. The least vulnerable ecosystems are mid-low-mountain savannoid ecosystems as well as mid-mountain xerophytic light forests that consist of significant amount of xeric species, including sub-tropical.

Climate change impacts on the ecosystems of the *zakaznik* can be mainly observed in the changes of their compositions, shifting of distribution ranges, as well as in the changes of population size of the composite plant and animal species. In particular, in all zones, except of nival, there is a general decrease in species diversity due to the loss of hydrophilous plants, as well as rare, endemic and endangered species. A structure of the ecosystems is changing, with the replacement of mesophylic species by more xeric species as well as by weed plants with a high adaptive and migration capacity. Distribution of invasive species decreases the productivity of the ecosystems leading to the decrease of animal species diversity and population size, and their migration to other territories. In general, changes in ecosystems of *Dashtidjum Zakaznik* can be characterized by the loss of species diversity, xerophytization, and homogenization due to the replacement of valuable native communities by weed and invasive species. Climate change impacts also promoted expansion of upper zones of the ecosystems, which indicates vertical migration of species in a search of suitable climates.

One of the positive consequences of the climate change impacts is the increased number of plant species in the nival zone caused by the shrinking of areas covered by snow and migration of species from lower alpine zone. At the same time, in a long-term perspective, it is likely that this ecosystem will lose its "short-term" diversity due to the replacement of native species by the new-coming weed and invasive species. A loss of the poor-studied psychrophilic insects is yet another threat for the nival ecosystems. The positive effects of the climate change can be experienced by some insects, but the later mainly refers to the pest insects, which already affected considerable part of forest resources and fruit trees. An increase of population size of some reptiles, such as cobra and lebetina viper, though is possible theoretically, is unlikely due to anthropogenic pressures and extermination of these species by local population.

As it can be seen from above, climate change impacts on the ecosystems of *Dashtidjum Zakaznik* can already be observed on its territory, and mainly in a form of negative consequences for the ecosystems. At the same time, it should be noted, that it is difficult to refer the ongoing changes only to the consequences of climate change due to the high anthropogenic pressure. Meanwhile, the tendency of the replacement of mesophylic species by xerophytic species, vertical shifts in distribution ranges as well as the increase of species in the nival zone are one of the obvious consequences of climate change impacts. Thus, we can say about cumulative action of the anthropogenic factors and climate change that aggravates the consequences for already vulnerable mountain ecosystems. Further interaction of these factors will cause significant disruption of the ecosystems' self-recovery capacity and irreversible changes in their current structure with catastrophic consequences for biodiversity conservation.

5. Needs and Capacities for Adaptation Measures

The vulnerability assessment of the biodiversity of *Dashtidjum Zakaznik* to climate change impacts has shown that a considerable number of species may suffer population decline, in particular rare and endangered species. It therefore questions the achievement of the main conservation goals and undermines the established protection regime. The implementation of adaptation measures is required to minimize the negative impacts of climate change on the biodiversity of the *zakaznik* and ensure biodiversity conservation. This chapter provides a brief overview of the implications for *Dashtidjum Zakaznik* management from climate change impacts, based on the results of the vulnerability assessment presented in the previous chapter. It also provides an assessment of the capacities for adaptation measures, starting with the assessment of the natural adaptation capacity of the *zakaznik* itself, and then focusing on the assessment of national policies and programs in terms of their potential contribution to implementation of climate change adaptation measures.

5.1 Implications for Dashtidjum Zakaznik management

As mentioned in section 4.1, *Dashtidjum Zakaznik* was established as a zoological reserve, with a primary conservation goal to protect populations of the endangered markhor, as well as other endangered species, including urial, snow leopard and Tien-Shan brown bear (Safarov *et al.* 2008). According to the results of the vulnerability assessment, it is likely that these species would be affected by climate change impacts. The most vulnerable among them are urial and markhor, and relatively less vulnerable are Tien-Shan brown bear and snow leopard (section 4.3.1). Under an altered climate these species may be affected by a lack of forage resources, as well as suitable habitats. As a result they may suffer population decline, and migrate northwards, leaving the territory of *Dashtidjum Zakaznik*. Other endangered animal species that may leave the territory of *the zakaznik* include Siberian ibex and Turkestan lynx and such bird species as ring dove, paradise flycatcher, and peregrine and saker falcons.

A considerable number of rare and endangered species of animals and plants of the *zakaznik* may suffer population decline and become extinct. They include a majority of the insect species listed in the Red Data Book of Tajikistan (section 4.3.5), as well such rare and endemic plant species as magnificent ostrovskia, Eduard's fritillary, keyserlingia, Goncharov's skullcap, Darvaz iris, and others. Climate change may also affect such rare species as Cayon pear, Siver's apple, and Vavilov's almond (section 4.4.3), which have global importance as valuable genetic resources, despite their relatively low vulnerability to hot and dry climatic conditions.

Mid-mountain forests are another conservation target of *Dashtidjum Zakaznik*. The vulnerability assessment has shown that a considerable part of these forests experiences negative impacts of climate change. These impacts are represented by forest xerophytization and decrease of areas occupied by mesophylic species, loss of hydrophilous species, and restructuring of forests with a prevalence of shrub communities as well as invasive and weed species. The most vulnerable to climate change impacts are mesophylic forests represented by species that are sensitive to high air temperature and lack of precipitation, including Tien-Shan birch, Turkestan maple, and walnut. It is likely that area occupied by this species would be significantly decreased (section 4.5.4).

It is therefore evident that climate change impacts on biodiversity of *Dashtidjum Zakaznik* have direct implications for its management. In particular, a number of species, including key species for biodiversity conservation, may leave the territory of the *zakaznik* and migrate northwards. Many species under protection may suffer population decline and become extinct. Composition of ecosystems is changing with a prevalence of xerophytic shrubs communities and loss of valuable mesophylic and hydrophilous species. Climate change therefore affects achievement of the *zakaznik's* conservation goals and requires development and implementation of adaptation measures, as well as a revising of its conservation goals. An assessment of the natural adaptation capacities of the *zakaznik*, as well as prerequisites for adaptation measures is presented below.

5.2 Natural adaptation capacities of Dashtidjum Zakaznik

Dashtidjum Zakaznik possesses several positive characteristics that contribute to the adaptation of its biodiversity to climate change. One such characteristic is an altitudinal diversity of its habitats. As mentioned in section 4.1, *Dashtidjum Zakaznik* is located at elevations ranging from 700 to 2,911 masl (Safarov *et al.* 2008). It creates a wide spectrum of habitats with different climatic and landscape conditions and allows a number of species to shift their distribution range upwards. In comparison with latitudinal shifts, the altitudinal shift allows adjustment to climate change by minor shifts due to significant temperature gradient in montane areas (Mackinnon 2008). The main species that are constrained in adaptations by the vertical shifts are immobile species of the nival zone that may suffer extinction. In case of *Dashtidjum Zakaznik*, the vertical shifts may bring additional benefits, as territories located upwards, to some extent, experience lesser anthropogenic pressure due to their remoteness from human settlements. At the same time, it should be noted that despite the climatic and landscape conditions many species would still suffer a reduction in population size due to their limited migration capacities, as well as specific habitat requirements.

Another positive characteristic of *Dashtidjum Zakaznik* is its long north-south axis (Figure 4-1) that allows latitudinal shifts within the area of the *zakaznik*. Similar to the wide range of altitudes, the south-north elongation creates a variety of climatic conditions (Mackinnon 2008), providing the possibility for northwards migration of species. The south-north orientation of the main mountain ranges - Khazratisho and Darvaz ranges (Figure 4-1) also creates favorable conditions for the latitudinal shifts in distribution ranges, therefore contributing to species adaptation to climate change. The physical complexity of the landscape of *Dashtidjum Zakaznik*, including the combination of valleys, gorges and mountain peaks, at some point contributes to the variety of habitats with different climatic conditions, increasing chances for species adaptation, but at the same time may create barriers for species migration. Mountain ranges also serve as a moisture trap preventing the site, and in particular high-mountain areas, from desiccation.

Though the area of *Dashtidjum Zakaznik* is not large, it can be characterized by good connectivity with surrounding natural landscapes that may provide suitable habitats for migrating animals. In particular, it is connected with the reserve of the same name and serves as the migration corridor for many mammal species that can be observed on the territory of both reserves, including urial, markhor, and Tien-Shan brown bear (Safarov *et al.* 2008). Areas located in the north of the *zakaznik*, along the Khazratisho and Darvaz ranges, also possess natural ecosystems similar to those of *Dashtidjum Zakaznik* and can serve as suitable habitats for animals shifting their ranges northwards. Many bird species, as well as such large mammals as Siberian ibex, snow leopard, and markhor, already inhabit the surrounding areas of the *zakaznik* (Safarov *et al.* 2008). The latter constituted the basis for the recommendation on extension of the area of the *zakaznik* within the Econet strategy (section 5.3.1). It should be highlighted that despite relatively good connectivity with the surrounding areas, many migration routes of the animals, as well as natural landscapes have been disrupted by the construction of the Kulyab-Kalaikhumb road, as well as by expansion of human settlements (Safarov *et al.* 2008).

Despite the natural features of *Dashtidjum Zakaznik*, which create favorable conditions for species adaptation to climate change, there are a number of negative factors that constrain this adaptation and undermine species' attempts to survive. They are represented by anthropogenic activities, in particular poaching, tree cutting and cattle grazing (Safarov *et al.* 2008). While the first two activities lead to the direct destruction of animal and plant species, cattle grazing is the main cause of habitat degradation, as well as distribution of invasive and weed species. Livestock disrupts the reproduction of valuable plant species by trampling down and grazing young sprouts, as well as reduces the forage abundance for wild ungulates, which affects their population size. Tree cutting results not only in a loss of valuable tree species, which have global importance as genetic recourses, but also reduces the population size of animals and plants associated with mid-mountain forests. Poaching reduces the conservation efforts as well as species natural adaptation to climate change. Anthropogenic activities not only prevent species adaptation, but also contribute to global warming. Reduction of forest cover and degradation of pastures affect the ecosystems' capacity for carbon sequestration, as well as contribute to the increase of local air temperature due to the higher heat flux from the rocks that have lost their vegetation cover. It is therefore important to minimize the anthropogenic pressure on the territory of the *zakaznik* to ensure the implementation of conservation measures as well as adaptation strategies aimed to minimize climate change impacts.

5.3 Prerequisites for adaptation measures

Responses of species to climate change impact are mainly observed in phenological changes, as well as in shifts in species distribution ranges poleward or to higher elevations (section 2.1.2). The latter has constituted the basis for a number of recommendations on adaptation measures that are aimed to ensure the availability of suitable habitats for species shifting their distribution ranges in search for suitable climates. These measures, among others, include the expanding of existing protected areas networks, increasing connectivity among natural habitats, as well as development of matrix or buffer zones around protected areas to minimize anthropogenic pressure on wildlife (section 2.2.2). A brief analysis of available national strategic documents and programs that can contribute to the implementation of adaptation measures on the territory of *Dashtidjum Zakaznik* is presented below.

5.3.1 Possibilities for expansion

As mentioned in section 2.3.3, different protected areas have been established on the territory of Tajikistan to ensure conservation of rare and endangered species, as well as valuable ecosystems. According to national legislation, protected areas are owned only by the state and are managed by competent national authorities designated for this purpose (*Law on Protected Areas* 1996). The Law on Protected Areas (1996) envisages the establishment of new protected areas, which can be created based on the decision of the Government of the Republic of Tajikistan (Article 4)(*Law on Protected Areas* 1996). Article 24 of the Law stipulates the procedures for the establishment of state reserves (*zakazniks*) - the group of protected areas to which *Dashtidjum Zakaznik* belongs. According to this article, state *zakazniks* can be established by the Government of the Republic of Tajikistan following the request from designated national authorities. It is permitted to declare the territory as a state *zakaznik*, without withdrawal of land from the current land owners (leased by the state) (*Law on Protected Areas* 1996). Unlike the provisions regarding reserves, which stipulate procedures not only for the establishment of new reserves, but also for the expansion of existing ones (Article 16)(*Law on Protected Areas* 1996), there are no provisions for the expansion of state *zakazniks*. At the same time, it is evident that the extension of the *zakazniks* does not contradict the Law, which is confirmed by a number of recent documents approved by the Government (see below).

One of the main national documents aimed at the development of protected areas in Tajikistan is the State Program on Protected Areas Development in 2005-2015, adopted by the Government in 2005 (section 2.3.3). Though the program does not directly stipulate any adaptation measures to climate change, a majority of the envisaged measures has a direct relation to climate change adaptation strategies suggested worldwide (section 2.2.2). In particular, the program provides measures on the establishment of new *zakazniks,* as well as expanding the territory of existing *zakazniks* (SCEPF 2005). Although the Action Plan, which constitutes an integral part of the program, does not stipulate any measures related to the extension of *Dashtidjum Zakaznik*, one of the main goals of the program itself is "the extension of the area of protected areas" (Article 2) (SCEPF 2005). Other national documents that envisage an extension of existing protected areas are the State Ecological Program of the Republic of Tajikistan for 2009-2019 adopted in 2009 (CEP 2009), NEAP adopted in 2006, and NBSAP adopted in 2003 (section 2.3.3). Similar to the State Program on Protected Areas Development, these documents do not stipulate concrete actions for the extension of *Dashtidjum Zakaznik*, but provide a general basis for such actions.

One of the strategic documents that provide specific measures on the extension of *Dashtidjum Zakaznik* is the Strategy and Action Plan on Econet Implementation, adopted by the governments of five Central Asian republics (WWF 2008). While the Strategy provides the necessary legal, structural, technical and financial mechanisms for Econet implementation (see section 2.3.3) (NBBC 2006), the Econet document comprises several activities for the development of *Dashtidjum Zakaznik*. In particular, it envisages the extension of the *zakaznik* and its reorganization into *Obiniou National Nature Park* (activities 56, 57, 59) (GRT 2006). The extension is supposed to be done by incorporating areas located mainly north of the *zakaznik*. The total area of planned extension constitutes 15,000 ha, which is almost 30% of the current area of the *zakaznik* (Safarov *et al.* 2008). According to the document, the main reason for the extension is the protection of xerophytic and mesophylic forests, as well as endemic and endangered species listed in the Red Data Book of Tajikistan, including markhor, urial, snow leopard, Tien-Shan brow bear and other species (GRT 2006). It is evident that the suggested extension of *Dashtidjum Zakaznik* and incorporation of areas located at higher latitudes provide a significant contribution to mitigation of climate change impacts on the territory of the *zakaznik*.

Following the Econet provisions, the necessity to expand the territory of *Dashtidjum Zakaznik*, as well as to raise its protection status, has been emphasized in the Management Plan of *Dashtidjum Zakaznik*. This document has been agreed by various stakeholders and represents an official document that defines the strategy and action plan on the conservation and sustainable use of biodiversity of the *zakaznik* for the near future (Safarov *et al.* 2008). In addition to the recommendations on the expansion of the territory of *Dashtidjum Zakaznik* and raising its status to "National Park", the Management Plan provides the detailed nature conservation zoning of the current territory of the *zakaznik*, as well as the area suggested for its extension (see Figure 5-1). Similar to the approach employed for the development of Econet (section 2.3.3), the elements of nature conservation zoning have been identified based on the comprehensive analysis of the current distribution of rare and endangered species, as well as socio-economic activities in the region. As can be seen from Figure 5-1, in addition to buffer zones and ecological corridors (sections 5.3.2 and 5.3.3), the nature conservation zones are represented by a number of core areas of the first and second order. They encompass relatively intact areas and ecosystems with habitats of such rare and endangered species as markhor, urial, Siberian ibex, snow leopard, brown bear, see-see partridge and others (core areas of the first order), as well as valuable ecosystems and wild relatives of cultural crops (core areas of the second order), and suppose to be excluded from any economic activity (Safarov *et al.* 2008; Shermatov pers.comm.).

In should be noted that despite the documents mentioned above, including the Strategy and Action Plan on Econet implementation adopted by the Government of the Republic of Tajikistan and Management Plan of *Dashtidjum Zakaznik* adopted by the relevant stakeholders, including national competent authorities on protected areas, no official decision on the extension of *Dashtidjum Zakaznik* has yet been made by the Government. At the same time, it is probable that such decision will be taken, as territories of some protected areas, for instance *Tigrovaya Balka Reserve*, have been recently expanded in accordance with the Econet document (GRT 2006; WWF 2008). Results and recommendations of the current research can provide additional justification for the extension of the area of the *zakaznik* in the light of its biodiversity adaptation to climate change impacts.

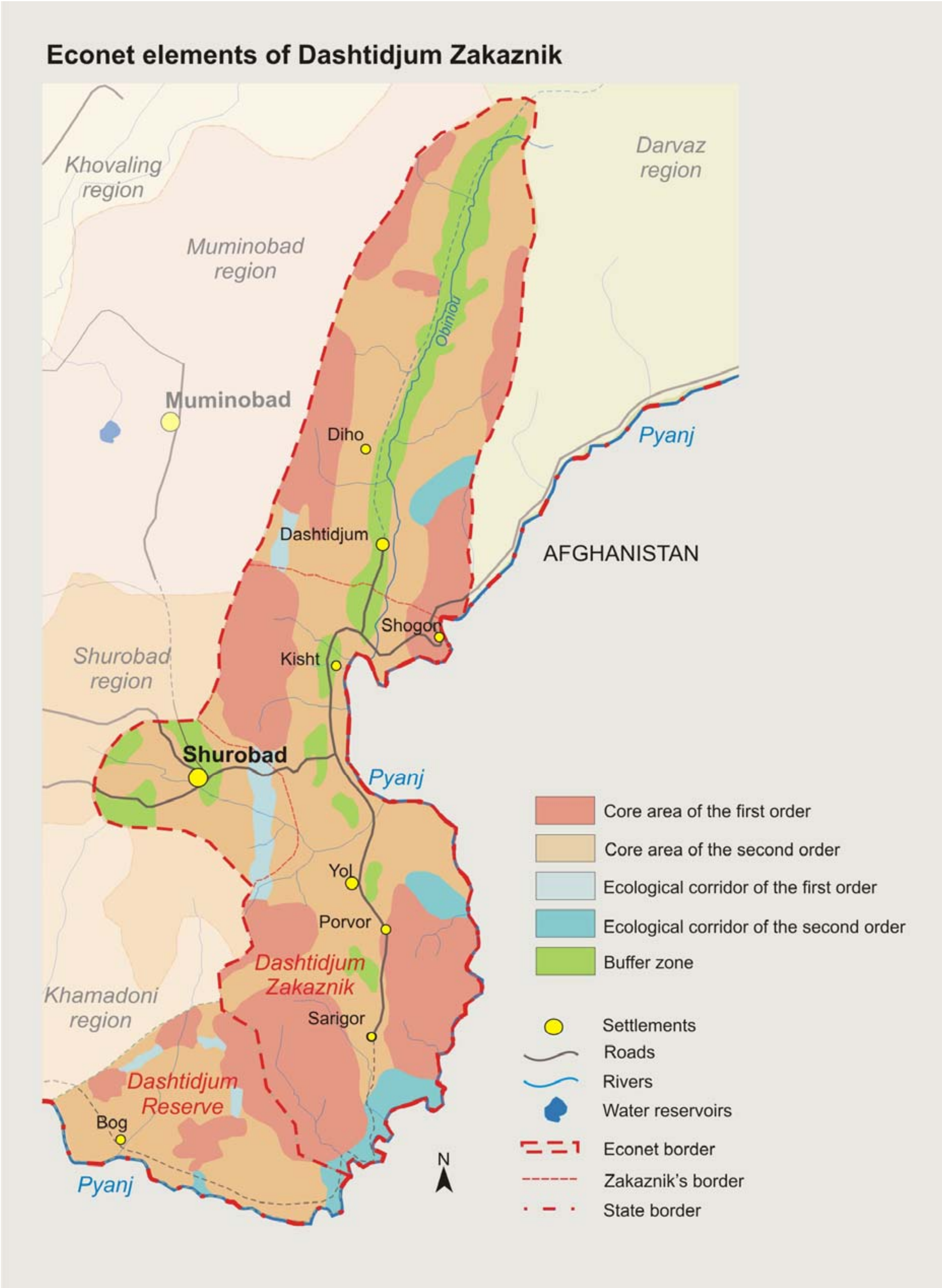

Figure 5-1. Econet elements of Dashtidjum Zakaznik Source: Adapted from Noosfera 2008

5.3.2 Increasing connectivity

Unlike the extension measures, the national documents that emphasize the need to increase connectivity among protected areas are quite limited. There are no such provisions in NBSAP and NEAP documents, or in the State program on the development of protected areas. At the same time, migration or ecological corridors constitute one of the key elements of the developed Econet of Tajikistan (Pereladova *et al.* 2006). They have been identified along with the core areas and buffer zones, and aimed to link core areas to ensure sustainable links between species populations and habitats of sufficient size (Pereladova *et al.* 2006). The same approach has been employed for the development of the Management Plan of *Dashtidjum Zakaznik*, in particular its nature conservation zoning (see section above). As can be seen from Figure 5-1, several migration corridors are suggested to connect core areas located within the current area of *Dashtidjum Zakaznik*, as well as in the territory of *Dashtidjum Reserve*, and the area proposed for *zakaznik* extension. The corridors of the first order are aimed to ensure connection between core areas of the first order. The corridors of the second order connect core areas of the first order with the core areas of the second order (Figure 5-1). Establishment and management of migration corridors implies the limitation of economic activities on their territory (Safarov *et al.* 2008). If implemented, it would considerably contribute to biodiversity conservation on the territory of *Dashtidjum Zakaznik*, as well as species' adaptation to climate change.

5.3.3 Management of matrix area

Management of a matrix area, or in other words a buffer zone, is envisaged by a number of documents, including the Law on Protected Areas (1996). At the same time, the Law stipulates the establishment of buffer zones only for reserves, and not for *zakazniks (Law on Protected Areas 1996).* According to Article 18 of the Law, the main purpose of the buffer zone is to minimize the negative effect of the economic activities on natural objects and complexes of reserves *(Law on Protected Areas 1996).* Thus the economic activity on the territory of buffer zones is restricted, and in some cases prohibited (*Law on Protected Areas* 1996). The same is stipulated in Article 60 of the Law on Nature Protection (1993). There are no provisions on buffer zones for *zakazniks.*

One of the main objectives of the State Program on Protected Areas Development is the designation of buffer zones for state reserves (SCEPF 2005). The same is stipulated in the Action Plan of the Program (Activity 7); there is no mentioning of buffer zones in respect of *zakazniks.* Similar to the State Program on Protected Areas Development, the NEAP, as well as NBSAP, lists as one of the priority measures on biodiversity conservation only the rehabilitation of buffer zones of some reserves (Safarov *et al.* 2003; Safarov *et al.* 2006). At the same time, NBSAP also emphasizes the need to develop the regulations on buffer zones for the whole network of protected areas in Tajikistan (Safarov *et al.* 2003).

The document on Econet development is probably the first to envisage the creation of buffer zones not only for reserves. The proposed ecological network comprises a number of buffer zones that are aimed to protect both core areas and migration corridors from negative outside interference (GRT 2006; Pereladova *et al.* 2006). As core areas are located not only on the territory of reserves, but also *zakazniks* and other categories of protected areas, the proposed network has a direct relation to the establishment of buffer zones for *zakazniks*. According to the Econet document, the specific land use regulations with the limited socio-economic activity should be established for all buffer zones (GRT 2006).

The same approach has been employed for the nature conservation zoning of *Dashtidjum Zakaznik* and surrounding areas. As can be seen from Figure 5-1, a number of buffer zones have been allocated in addition to core areas and migration corridors. They are aimed to prevent the direct contact of areas used for socio-economic activities with the habitats of protected species (Safarov *et al.* 2008). Buffer zones are characterized by the protection regime that allows use of nature resources, but at the same time restricts it to prevent negative impact on biodiversity. The main part of the areas suggested as buffer zones comprises fragments of wild-growing fruit trees, and is being currently used as outruns (Safarov *et al.* 2008). In addition to internal buffer zones, the Management Plan highlights the need for designated buffer zones along the boundary of the *zakaznik* with the adjacent areas. The latter is though difficult due to the complex administration division of the area, which belongs to different regions (Figure 5-1).

5.3.4 Other measures

One the main activities that can contribute to the development and implementation of adaptation measures to climate change on the territory of *Dashtidjum Zakaznik* is monitoring of different components of its biodiversity. A systematic monitoring with a focus on indicator species will allow better understanding of the species responses to climate change and identifying changes in their distribution ranges, phenology and population size. The information obtained will constitute an essential basis for the development of adaptation measures for species inhabiting *Dashtidjum Zakaznik,* as well as their efficient management. A brief overview of the national documents that emphasize the need for monitoring is presented below.

Apart from the legislative acts that envisage monitoring and complex researches of flora and fauna on the territory of Tajikistan, and on the territory of protected areas in particular, this issue is highlighted in all national programs and strategies related to biodiversity conservation. In particular, the State Program on Protected Areas Development requires aerial census of all wild animals on the territory of protected areas (Activity 18), as well as study of the biology and ecology of the markhor and development of recommendations for its conservation within the Darvaz and Khazratisho ranges (Activity 19) (SCEPF 2005). The State Ecological Program stipulates restoration of research activities on the territory of reserves and *zakazniks*; aerial census of wild animals, habitat assessment of species included in the Red Data Book of Tajikistan, and other activities (CEP 2009).

The NBSAP emphasizes the necessity to develop long-term research and monitoring programs as one of the priorities for biodiversity conservation, and stipulates a number of monitoring-related activities for different ecosystems and other components of biodiversity, including endangered species (Safarov *et al.* 2003). In addition, the document highlights the importance of studying and assessment of climate change impact on biodiversity (Safarov *et al.* 2003). The NEAP document lists the organization of systematic monitoring for all protected areas as one of the elements of its Action Plan for biodiversity conservation (Activity 16) (Safarov *et al.* 2006). The National Action Plan for Climate Change Mitigation also stipulates systematic monitoring of the ecosystems and enhancing of scientific understanding of the climate change impact on ecosystems with a special focus on protected areas, as priority measures for adaptation to climate change (Makhmadaliev *et al.* 2003b).

At the local level, the requirements of systematic monitoring on the territory of *Dashtidjum Zakaznik* are stipulated in its Management Plan, adopted by the national authorities on protected areas management (Safarov *et al.* 2008). The document not only emphasizes the need for monitoring, but provides the detailed Monitoring Plan, which defines the main components of the monitoring, indicator species, as well as institutions responsible for its implementation. The monitoring itself is described as a system for air-inventory collection and systematization of information on biodiversity of *Dashtidjum Zakaznik*, as well as for dynamics control of different components of biodiversity and its management on species, populations and ecosystem levels (Safarov *et al.* 2008). The Monitoring Plan is supplemented with handbooks on the monitoring of different components of biodiversity, including flora, fauna and forest resources, aimed to raise the awareness of people responsible for monitoring and provide general guidance (Saidov 2006b; Sattorov 2006; Ustjan 2006).

Although there is no direct reference to the monitoring of species in respect of their responses to climate change, the Monitoring Plan is highly relevant for these types of studies. The majority of the indicator species identified for the monitoring of different components of biodiversity, including ecosystems, flora, fauna, forests, endangered species and wild relatives of cultural crops, are represented by species sensitive to environmental changes. Among them are those that are highly sensitive to changes of climatic parameters, including Tien-Shan birch, Turkestan maple, Eduard's fritillary, ring dove, paradise flycatcher, urial and other species, and may provide valuable information on species responses to climate change, including distribution shifts.

In addition to indicator species relevant to the monitoring of climate change impacts, the Monitoring Plan contains the requirements for systematic phenological observations, which were not carried out before (Safarov *et al.* 2008). If implemented, the long-term phenological observations, combined with meteorological data, would allow identifying climate-related changes in species behavior and contribute to the development of adaptation strategies. At the same time, it should be mentioned that despite the strong political and scientific support to the necessity of implementing monitoring and research activities, their implementation remains at a very low level (Safarov pers.comm.; Saidov pers.comm.). This can be explained by the poor socio-economic situation in the country, as well as by the lack of professional human resources. It is unlikely that the situation will significantly improve in the nearest future.

5.4 Summary

Vulnerability of the biodiversity of *Dashtidjum Zakaznik* to climate change affects achievement of the *zakaznik's* conservation goals and requires the implementation of a number of adaptation measures to help to mitigate its negative impacts. Apart from the measures related to protected areas management and biodiversity conservation, there are a number of natural peculiarities of *Dashtidjum Zakaznik* that contribute to species' adaptation to climate change. They include altitudinal variety of habitats, long south-north axis, diversity of landscape elements, as well as good connectivity with surrounding areas with suitable habitats. Altogether it provides a rich variety of climatic conditions and habitats, and assists in species' migration both upwards and northwards. At the same time, the high anthropogenic pressure on biodiversity of *Dashtidjum Zakaznik*, in the form of poaching, tree cutting and cattle grazing, not only affects the adaptive capacity of species and leads to the species loss, but also contributes to the climate warming on the territory of the *zakaznik*.

Analysis of national legislation and strategic documents aimed at biodiversity conservation and enhanced management of protected areas has shown that there are many prerequisites for the development and implementation of climate change adaptation strategies both at the national and local level. In particular, general expansion of protected area networks has been stipulated in such documents as the State Program on Protected Areas Development, State Ecological Program, NBSAP, NEAP and Econet document. The latter also provides concrete measures for the expansion of *Dashtidjum Zakaznik* by incorporating 15,000 ha of adjacent areas located mainly north of the *zakaznik*; although no Government decision has been yet made in this respect. The same document, as well as the Management Plan of *Dashtidjum Zakaznik*, provides measures to enhance connectivity between species' populations and habitats of sufficient size.

While the majority of the national strategies and programs, as well as environmental legislation, envisages the development of buffer zones to minimize the negative impact from the economic activities only for reserves, the Econet document stipulates the development of buffer zones for all elements of protected areas networks. Following this approach, a number of buffer zones have been identified for *Dashtidjum Zakaznik* during the development of its Management Plan. They are aimed to delimit the core areas with a high concentration of valuable biodiversity from the areas with socio-economic activities. In addition to internal buffer zones located within the borders of *Dashtidjum Zakaznik*, the document highlights the need to designate buffer zones from the surrounding areas to minimize outside pressure and support the natural migration of species.

Other activities that are highly relevant to the development of adaptation measures to climate change include the implementation of monitoring and research activities on the territory of protected areas. These activities constitute the main elements of biodiversity conservation as well as protected areas management and are stipulated in related legislative acts. The need for systematic monitoring of biodiversity components, in particular on the territory of protected areas is emphasized in the related national strategies and programs. Moreover, the NBSAP and National Action Plan for Climate Change Mitigation list the research and assessment of climate change impact on biodiversity as one of the priority activities. The Management Plan of *Dashtidjum Zakaznik* provides the detailed Monitoring Plan, which if implemented would significantly contribute to the understanding of species' responses to climate change on its territory. It should be noted that despite overall political support to the development of monitoring and research program, their implementation remains at a very low level due to the poor economic situation in the country, as well as the lack of professional human resources.

6. Conclusions and Recommendations

6.1 Conclusions

The analysis of climate change trends on the territory of *Dashtidjum Zakaznik* has confirmed the warming trend of annual mean temperature, which constitutes 0.8°C for the last fifty years and has a tendency for a further increase. Combined with the anomalies in precipitations, in particular the decrease in spring precipitation and projections of up to 20% precipitation decrease by the end of 2050, climate warming poses a real threat for the unique biodiversity of *Dashtidjum Zakaznik* represented by many rare and endemic species and wild relatives of cultural plants.

Climate change affects the biodiversity of the *zakaznik* both directly and indirectly. The latter mainly refers to animal species and is represented by the decrease of suitable habitats due to the changes in ecosystem composition and distribution, as well as the decrease of forage resources due to the changes in ecosystems' productivity and in prey abundance. An increase of air temperature also directly affects a considerable number of species leading to phenological changes and species' migration. Other factors include anomalies in snow cover, water temperature, and frequency of extreme weather events that affects populations of some species.

The plant species of *Dashtidjum Zakaznik* are affected directly by anomalies in air temperature and precipitations. The temperature factor is mainly represented by an increase of air temperature, as well as by potential decrease during the winters. The precipitation factor is represented by a decrease of precipitation, especially in the springs. The indirect climate change factors include the spread of invasive species under an altered climate and the potential disturbance of the fire regime, as well as melting of snowfields and reduction of snow cover due to higher air temperatures.

Climate change impact on the biodiversity of the *zakaznik* varies from negative to positive. A majority of the species, in particular rare and endangered species, may experience population decline and some species even extinction. A few species may leave the territory of the *zakaznik* and migrate northwards. The latter refers to several species of birds and mammals. The most vulnerable animal species on the territory of the *zakaznik* are mammals, and the hydrophilous and mesophylic plant species. Species that may benefit from climate warming include xerophilous and subtropical species of plants, weed species, pest insects and some reptiles, as well as species inhabiting high mountain meadows and steppes.

Responses of plant species to climate change are mainly represented by the temporal shifts of phenological events, including the advancement of the vegetation period and its shortening, and shifts in distribution ranges. The latter has already been observed for some flora species of *Dashtidjum Zakaznik*, while observation of phenological shifts is complicated due to the lack of long-term monitoring programs. Responses of animal species include changes in distribution ranges and population size, as well as phenological changes, including disruption of hibernation and aestivation, and others. The animal responses observed include the earlier arrival and wintering of migratory birds and shifts of distribution ranges for a number of species.

Climate change impacts on the ecosystems of *Dashtidjum Zakaznik* are represented by changes in their composition and distribution. The former includes xerophytization, loss of valuable mesophylic and hydrophilous species, as well as rare and endangered species, and community restructuring with a prevalence of weed species and shrub communities. The most vulnerable ecosystems are mid-mountain mesophylic forests, as well as high mountain meadows that may be affected by melting of snowfields and reduction of snow cover. The least vulnerable ecosystems are mid-low-mountain savannoid ecosystems and mid-mountain xerophytic light forests that consist of a significant number of xeric species, including sub-tropical. Changes in ecosystems distribution include the expansion of upper zones and shrinking of lower zones of ecosystems.

Climate change impacts on biodiversity of *Dashtidjum Zakaznik* have direct implications for its management. In particular, a number of species, including key species for biodiversity conservation: markhor, snow leopard and Turkestan lynx may leave the territory of the *zakaznik* and migrate northwards. Many species under protection may suffer a population decline and become extinct. The composition of mid-mountain forests is changing with a prevalence of xerophytic shrub communities, and loss of valuable mesophylic and hydrophilous species. Climate change therefore affects achievement of the *zakaznik's* conservation goals and requires the development and implementation of adaptation measures.

Dashtidjum Zakaznik itself contributes to the species adaptation to climate change due to a number of natural peculiarities. They include the altitudinal variety of habitats, long south-north axis, diversity of landscapes, as well as good connectivity with surrounding areas with suitable habitats. Altogether it provides a rich variety of climatic conditions and habitats, and assists in species migration both upwards and northwards. At the same time, the high anthropogenic pressure on biodiversity of the zakaznik not only affects the adaptive capacity of species and leads to the species' loss, but also contributes to the climate warming on its territory.

Analysis of relevant national legislation and strategic documents aimed at biodiversity conservation and enhanced management of protected areas has shown that there are many prerequisites for the development and implementation of climate change adaptation strategies both at the national and local level. They include provisions on the expansion of the protected areas network, and in particular expansion of *Dashtidjum Zakaznik* by incorporating 15,000 ha of adjacent areas located mainly north of the *zakaznik*, which is stipulated in the Econet document. Though the majority of the national documents do not envisage the development of buffer zones and a migration corridor, these measures are stipulated in the Econet document, as well as in the Management Plan of *Dashtidjum Zakaznik* adopted by relevant national competent authorities. Implementation of these measures will allow minimizing anthropogenic pressure on the biodiversity of the *zakaznik* and protecting species that migrate northwards.

Other activities that are highly relevant to the development of adaptation measures to climate change include the implementation of monitoring and research activities on the territory of protected areas. These activities constitute the main elements of biodiversity conservation as well as protected areas management and are stipulated in related legislative acts. The Management Plan of *Dashtidjum Zakaznik* provides the detailed Monitoring Plan, which if implemented would significantly contribute to the understanding of species' responses to climate change on its territory. It should be noted that despite the overall political support to the development of monitoring and research program, their implementation remains at a very low level due to the poor economic situation in the country, as well as the lack of professional human resources.

6.2 Recommendations

Taking into account the adverse effects of climate change on the biodiversity of *Dashtidjum Zakaznik* it is important to implement the adaptation measures as soon as possible. It is therefore recommended to expand the territory of the *zakaznik* as envisaged in the document on Econet development and Management Plan of *Dashtidjum Zakaznik*, and in accordance with the State Program on Protected Areas Development and National Action Plan on Climate Change Mitigation. The incorporation of adjacent areas will contribute to the protection of rare and endangered species and increase the abundance of suitable climates and habitats. It is also recommended not to limit the expansion by the top of the mountain range, but incorporate the northern slopes of the Khazratisho range too.

It is also important to implement provisions on the designation of buffer zones and migration corridors envisaged by the Econet document and the Management Plan of *Dashtidjum Zakaznik*, as they will minimize the negative impact on species and ecosystems from anthropogenic activities and enhance conditions for species' migrations both upwards and northwards. It is also important to raise the status of the *zakaznik* as it will help to reduce the negative impacts from human activities. In general, it is highly important to minimize the anthropogenic pressure on the ecosystems and species of *Dashtidjum Zakaznik*, in particular cattle grazing, tree cutting and poaching, as it constrains species adaptation to climate change and considerably aggravates its consequences.

Other conservation measures can include a provision of forage resources for a number of species, including urial and markhor, especially in the winter. To avoid the irreversible loss of rare and endangered species, it is recommended to ensure the collection of seed material for plant species and growing some species in nurseries, for instance wild fruit trees of global importance. Similar measures for animals may include keeping of the most vulnerable species, for instance urial, markhor, Siberian ibex, falcons and others, in animal breeding and caring centers to increase the reproduction rate with a further release into nature.

It is also recommended to implement monitoring measures, in particular those stipulated in the Management Plan of *Dashtidjum Zakaznik*, including phenological observations. The indicator species that may be used to study the climate change impacts on the territory of *the zakaznik* include urial, Siberian ibex, ring dove, steppe tortoise, as well as birch and Turkestan maple. The majority of these species are already identified in the Management Plan as indicator species. Monitoring observations will allow a better understanding of climate change impacts and identifying trends in species' populations and distribution. In general, it is also recommended to expand this study and assess the climate change impacts on biodiversity of other protected areas of the country to identify priority conservation and adaptation measures.

Last, but not least, it is important to incorporate the issue of climate change impact on biodiversity and its implications for protected areas management into all relevant national policies and programs, in particular those on protected areas management and biodiversity conservation. It is necessary to emphasize the importance to implement adaptation measures to mitigate climate change impacts and to envisage concrete action plans for such measures. It is also recommended to update the country's management plans for protected areas to ensure climate change impacts on biodiversity are considered.

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Appendices

Annex 1. List of endangered species in Tajikistan

	Name	IUCN status*	Population trend
	ANIMALS		
1	*Pseudoscaphirhynchus fedtschenkoi* ** (Syr Darya shovelnose sturgeon)	CR	unknown
2	*Vanellus gregarius* (Sociable lapwing)	CR	decreasing
3	*Capra falconeri* (Markhor)	EN	decreasing
4	*Cuon alpinus* (Dhole)	EN	decreasing
5	*Equus hemionus* (Asiatic wild ass)	EN	decreasing
6	*Falco cherrug* (Saker falcon)	EN	decreasing
7	*Neophron percnopterus* (Egyptian vulture)	EN	decreasing
8	*Oxyura leucocephala* (White-headed duck)	EN	decreasing
9	*Panthera tigris* (Tiger)**	EN	decreasing
10	*Panthera uncia* (Snow leopard)	EN	decreasing
	PLANTS		
1	*Betula schugnanica* (Shugnan birch)	CR	decreasing
2	*Crataegus darvasica* (Darvaz hawtorn)	CR	decreasing
3	*Crataegus necopinata*	CR	decreasing
4	*Pyrus korshinskyi* (Korjynskyi's pear)	CR	decreasing
5	*Pyrus tadshikistanica* (Tajikistan's pear)	CR	decreasing
6	*Swida darvasica* (Darvaz swida)	CR	decreasing
7	*Zygophyllum darvasicum* (Darvaz bean caper)	CR	stable
8	*Lonicera paradoxa* (Paradoxic honeysuckle)	EN	decreasing
9	*Prunus tadzhikistanica* (Tajikistan's cherry-plum)	EN	decreasing
10	*Pyrus cajon* (Cayon pear)	EN	decreasing

Adapted from IUCN 2010a

* EN – Endangered: a taxon is considered to be facing a very high risk of extinction in the wild.

CR – Critically endangered: a taxon is considered to be facing an extremely high risk of extinction in the wild (IUCN 2001).

** These species have 'extinct' status in the Red Data Book of Tajikistan (Abdusaljamov *et al.* 1988)

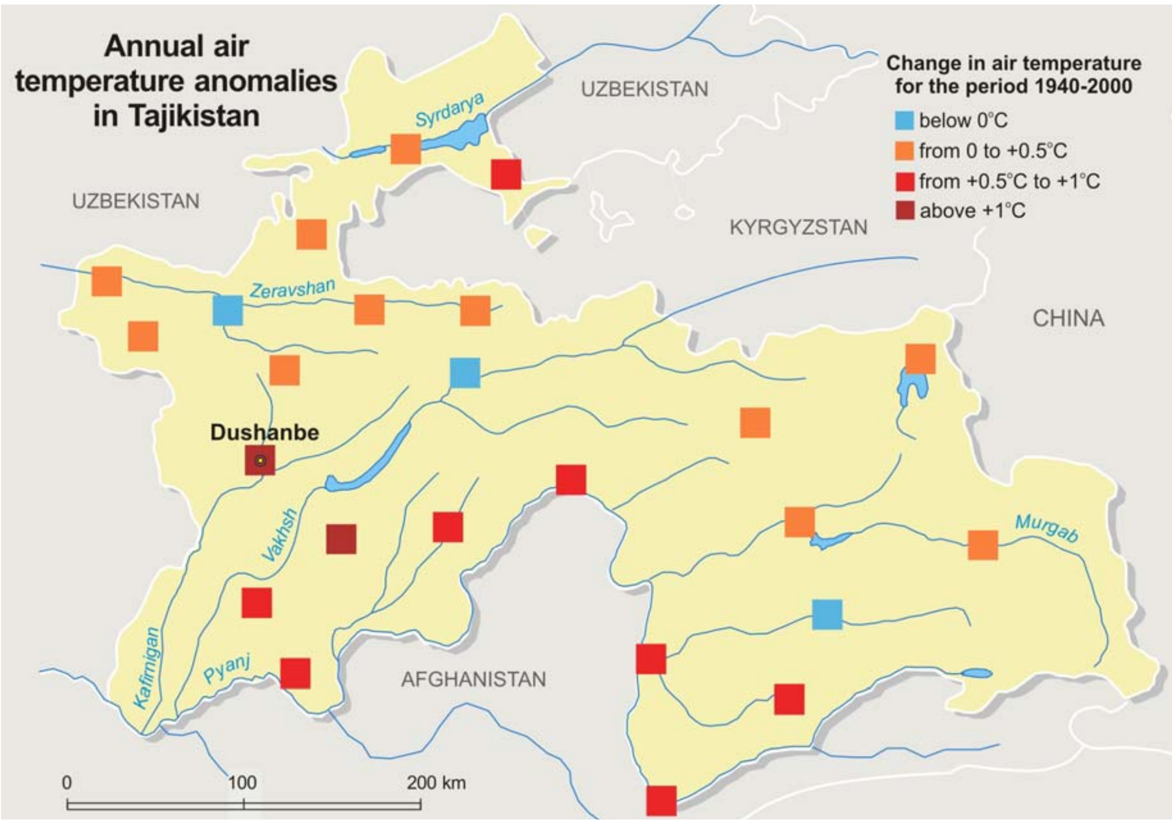
Annex 2. Protected areas of Tajikistan

#	Name	Creation	Area (ha)	Protection objectives	Protected species
	Natural reserves				
1.	Tigrovaya Balka	1938	49,786	Tugai forests	Bukhara red deer (*Cervus elaphus*), pheasant (*Phasianus colchicus*), hyena (*Hyaena hyaena*), Persian gazelle (*Gazella subgutturosa*), gray monitor lizard (*Varanus griseus*) and waterfowls
2.	Romit	1959	16,100	Complex	Brown bear (*Ursus arctos*), snow leopard (*Uncia uncia*), Siberian ibex (*Capra sibirica),* Golden eagle (*Aguila chrysaetus laphanea*)
3.	Dashtidjum	1983	19,700	Complex, mountain-forest	Brown bear (*Ursus arctos*), Bukhara wild sheep (*Ovis vignei bochariensis*), Tajik markhur (*Capra falconeri*), partridge (*Alectorius kakelik*), snow leopard (*Uncia uncia*)
4.	Zorkul	2000	87,700	Zoological	Bar-headed goose (*Anser indicus*), Pamir wild ram (*Ovis ammon polii*), Siberian ibex (*Capra sibirica*), snow leopard (*Uncia uncia*), red wolf (*Canis lupus*)
	Zakazniks				
1	Kusavlisai	1959	19,844	Mountain forests	Juniper forests (*Juniperus*)
2.	Iskanderkul	1969	30,000	Landscape, mountain forests	Snow leopard (*Uncia uncia*), Bukhara wild sheep (*Ovis vignei bochariensis*), birch (*Betula*)
3.	Saivota	1970	4,200	Mountain forests	Juniper forest (*Juniperus*)
4.	Childukhtaron	1970	14,500	Landscape, mountain forests	Juniper forest (*Juniperus*), brown bear (*Ursus arctos*), Bukhara wild ram (*Ovis vignei bochariensis*), partridge (*Ammoperdix griseogularis*), wild boar (*Sus scrofa*)
5.	Kamarov	1972	9,000	Mountain forests	Brown bear (*Ursus arctos*), Siberian ibex (*Capra sibirica*), trout (*Salmo trutta morfa fario*)
6.	Dashtidjum	1972	50,100	Zoological, and mountain forests	Juniper forest (*Juniperus*), brown bear (*Ursus arctos*), Bukhara wild ram (*Ovis vignei bochariensis*), partridge (*Ammoperdix griseogularis*), wild boar (*Sus scrofa*)
7.	Karatav	1972	14,400	Zoological	Bukhara wild ram (*Ovis vignei bochariensis*), partridge (*Alectoris graeca*), Bukhara Red deer (*Cervus elaphus*)

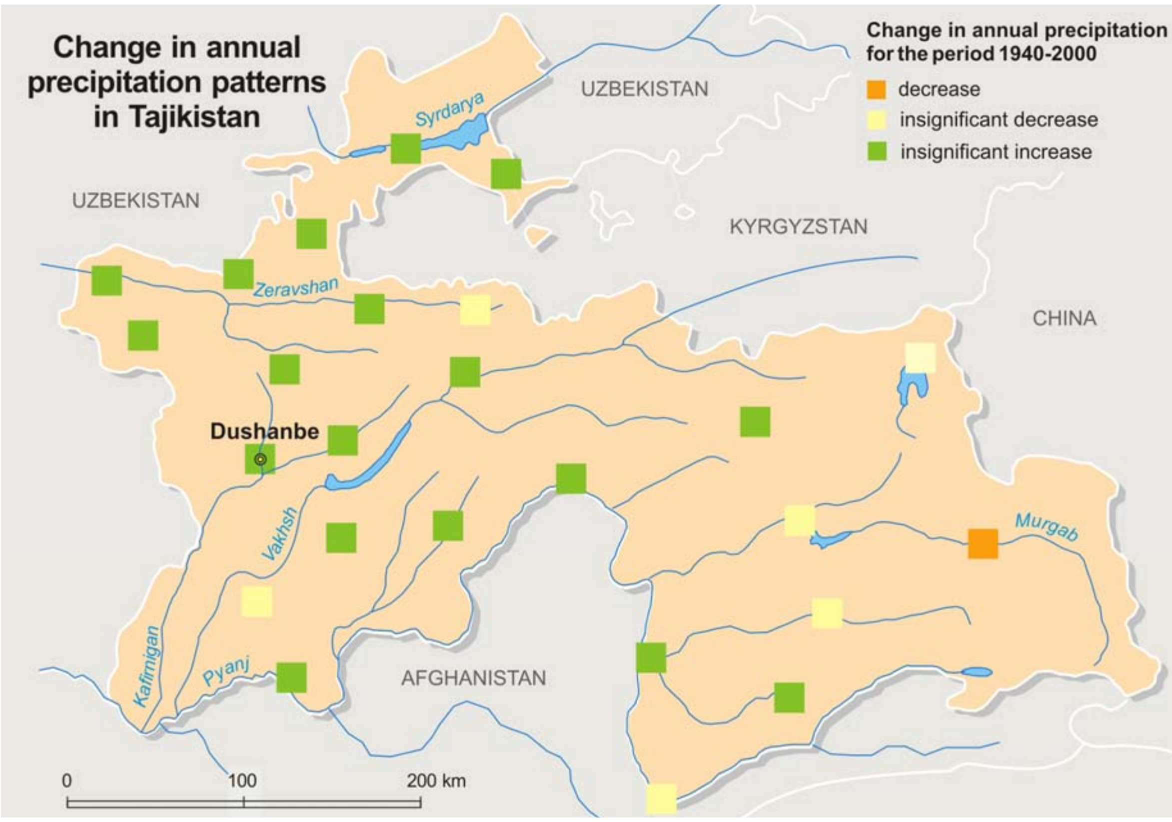
8.	Sangvor	1972	50,900	High-mountain ecosystems	Pamir wild ram (*Ovis ammon polii*), Tibetian snow partridge (*Tetraogallus tibetanus tibetanus*)
9.	Muzkul	1972	66,916	Zoological	Bar-headed goose (*Anser indicus*), Pamir wild ram (*Ovis ammon polii*), Siberian ibex (*Capra sibirica*), snow leopard (*Uncia uncia*)
10.	Oktash	1977	15,000	Zoological	Bukhara wild ram (*Ovis vignei bochariensis*), *Vipera lebetina*, peregrine falcon (*Falco peregrinus*), saker falcon (*Falco cherrug*)
11.	Zeravshan	1976	2,300	Complex, tugai forests	Pheasant (*Phasianus colchicus*), Bukhara red deer (*Cervus elaphus bactrianus*)
12.	Almasi	1983	6,000	Botanical	*Ungernia victoris*
13.	Nurek	1984	30,000	Complex, mountain forests	Bukhara wild ram (*Ovis vignei*), brown bear (*Ursus arctos*), partridge (*Ammoperdix griseogularis*), snow leopard (*Uncia uncia*)
14.	Sajoda microzakaznik	2008	240	Mountain forests	Valuable mid-mountain forests
National Parks					
1.	Historical Natural Park "Shirkent"	1993	3,000	Mountain forests, landscape	Bukhara wild ram (urial) (*Ovis vignei bochariensis*), juniper forest (*Juniperus*), Ungernia (*Ungernia*)
2.	Tajik National Park	2002	2,611,674	Complex, landscape, botanical, zoological	High-mountain, meadow-steppe, desert ecosystems, tugai, Pamir wild ram (*Ovis ammon polii*), Siberian ibex (*Capra sibirica*), Snow leopard (*Uncia uncia*), red wolf (*Canis lupus*)
3.	Natural Park "Sari-khosor"	2005	3,805	Mountain forests, zoological	Juniper forest (*Juniperus*), brown bear (*Ursus arctos),* snow leopard (*Uncia uncia*), Siberian ibex (*Capra sibirica*), golden eagle (*Aquila chrysaetus*), saker falcon (*Falco cherrug*), etc.

Adapted from Safarov *et al.* 2003, NBBC 2009

Annex 3. Climate change patterns in Tajikistan



Annual temperature anomalies in Tajikistan Source: Makhmadaliev *et al.* 2008



Change in annual precipitation patterns in Tajikistan Source: Makhmadaliev *et al.* 2008

Annex 4. List of interviewees

	Name	Institution, Position	Relevant area of expertise
1	Prof. Khurshed KARIMOV	Academy of Science, Vice-President	Plant physiology; climate change impacts
2	Dr. Neimatullo SAFAROV	CBD National Focal Point, Research Laboratory for Nature Protection, Head	Flora and ecosystems; protected areas management; *Dashtidjum Zakaznik*
3	Dr. Abdusattor SAIDOV	Institute of Zoology and Parasitology, Head	Fauna; climate change impacts; *Dashtidjum Zakaznik*
4	Dr. Saidakhmad DUSTOV	State Administration for Hydrometeorology, Deputy Head	Animal physiology, climate change
5	Dr. Rakhmatullo SATTOROV	Tajik State National University, Associate Professor	Flora and ecosystems; *Dashtidjum Zakaznik*
6	Mr. Ivan USTJAN	State Administration on Protected Areas, Head of Department	Forestry; climate change impacts; *Dashtidjum Zakaznik*
7	Ms. Valentina ASANOVA	State Administration for Hydrometeorology, Head of Department	Meteorological observations and analysis; climate change; Dashtidjum area
8	Dr. Rustam MURODOV	Institute of Zoology and Parasitology, Senior Research Officer	Birds, climate change impacts
9	Dr. Nuriddin MUMINOV	Institute of Zoology and Parasitology, Senior Research Officer	Insects, climate change impacts
10	Dr. Tolib IRGASHEV	Tajik Academy of Agricultural Sciences, Scientific Secretary	Agriculture; climate change impacts; *Dashtidjum Zakaznik*
11	Dr. Todjidin NADJMIDINOV	Institute of Zoology and Parasitology, Deputy Head	Reptiles, climate change impacts
12	Mr. Ivan ZAGREBELNYI	Research Pharmaceutical Center, Deputy Director	Flora and ecosystems; *Dashtidjum Zakaznik*
13	Dr. Radjabali SANGOV	State Administration for Forestry and Wildlife Service, Head of Department	Forestry, invasive species, climate change
14	Mr. Khisrav SHERMATOV	National Biodiversity and Biosafety Center, Head of Department	Econet, protected areas *Dashtidjum Zakaznik*
15	Mr. Safarali BEGOV	Dashtidjum Forestry, Forester	Protected areas management *Dashtidjum Zakaznik*
16	Mr. Ismoil FAIZOV	Aga Khan Foundation, Community Development Specialist	Protected areas, *Dashtidjum Zakaznik*
17	Mr. Zikriyo BOBOEV	Hydrological Station “Khirmandjou, Head	Meteorological observations, Dashtidjum area
18	Mr. Faizali SHARIPOV	“Murodi Sharif” Farm Association, Farmer	Protected areas management *Dashtidjum Zakaznik*

Annex 5. List of sample questions

Please tell me about your experience of work in *Dashtidjum Zakaznik*/climate change vulnerability assessment.

In your opinion:

What are the main impacts from climate change on biodiversity of *Dashtidjum Zakaznik*?

What are the main impacts from climate change on management of *Dashtidjum Zakaznik*?

What species of *Dashtidjum Zakaznik* are the most threatened by climate change impacts? Why?

What species of *Dashtidjum Zakaznik* are the least threatened by climate change? Why?

What ecosystems of *Dashtidjum Zakaznik* are the most sensitive to climate change? Why?

What measures should be undertaken to minimize climate change impact on protected areas?

Which measures have the highest priority?

What obstacles do you see for implementation of adaptation measures on the territory of the *zakaznik* and at country level?

What can you say about temperature and precipitation anomalies on the territory of *Dashtidjum Zakaznik* during last years?

What can you say about frequency of extreme weather events on the territory of *Dashtidjum Zakaznik* during last years?

What can you say about spread of invasive species on the territory of *Dashtidjum Zakaznik* for the last years?

What kind of phenological changes have been observed on the territory of *Dashtidjum Zakaznik*?

What kind of changes in species distribution ranges have been observed on the territory of *Dashtidjum Zakaznik*?

Annex 6. Sample table for interviews

ОЦЕНКА УЯЗВИМОСТИ ВИДОВ И ЭКОСИСТЕМ ДАШТИДЖУМА К ИЗМЕНЕНИЮ КЛИМАТА

НАЗВАНИЕ ВИДА ИЛИ ЭКОСИСТЕМЫ: ______________________________________ **ФИО ЭКСПЕРТА:** __________________________

Краткое описание вида или экосистемы:

Диапазон высот: % от общей территории (для экосистем):

Общая уязвимость вида или экосистемы к изменению климата:

Подчеркнуть необходимое: 1 2 3 4 5 (1 низкая→ 5 высокая)

Пояснение оценки:

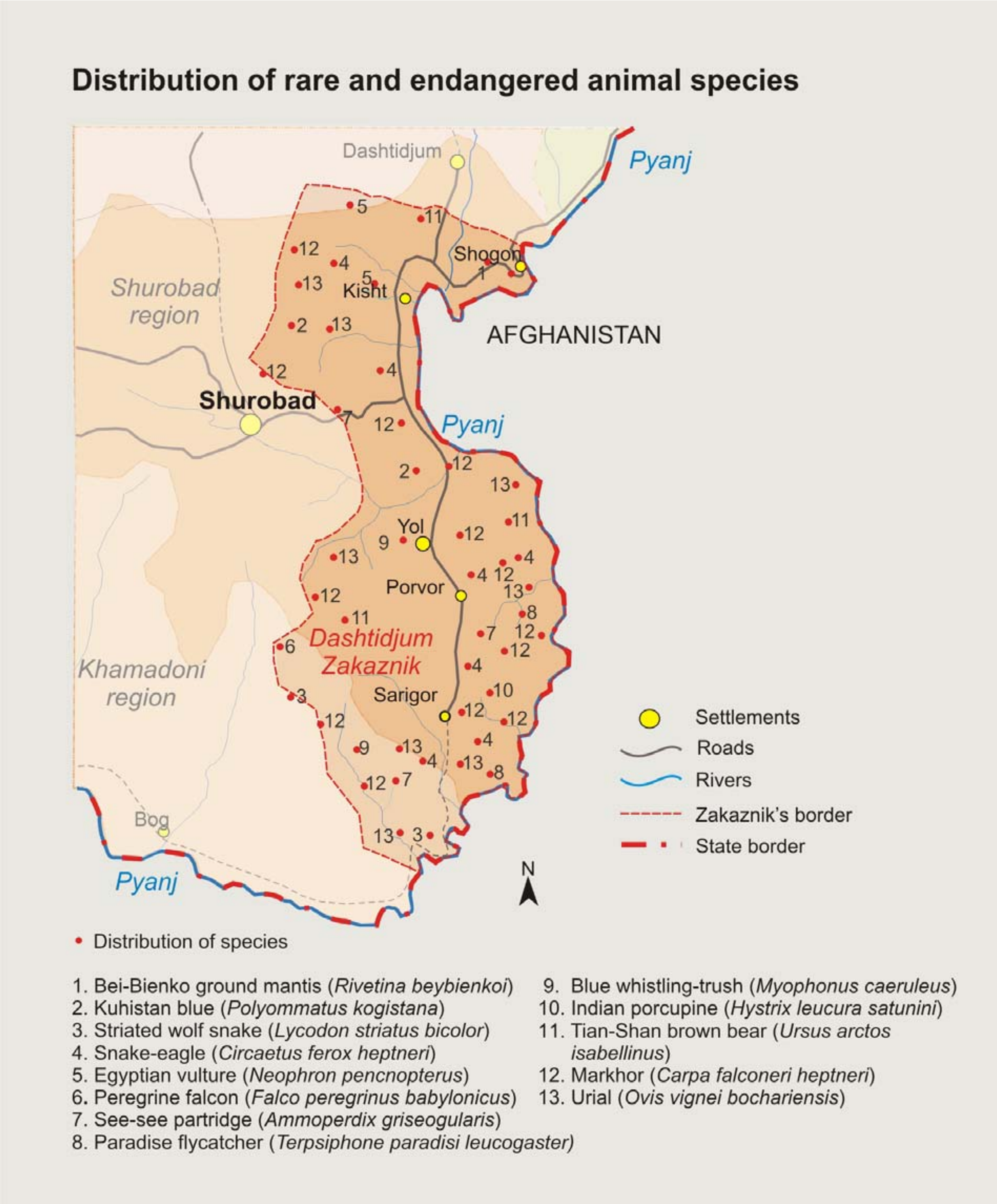
Наблюдаемые изменения состояния экосистемы/вида в результате изменения климата

Любые примеры по следующим факторам: изменение состава, распространение чужеродных видов, изменение ареала видов, изменение видового разнообразия / изменение ареала распространения, изменения численности, фенологические изменения.

Потенциальные изменения состояния экосистемы или вида в результате изменения климата

Конкретные примеры по следующим факторам: изменение состава, распространение чужеродных видов, изменение ареала видов, изменение видового разнообразия / изменение ареала распространения, изменения численности, фенологические изменения.

Annex 7. Distribution of key endangered animal species



Source: Adapted from Noosfera 2008

Annex 8. Dashtidjum Zakaznik: Species listed in the IUCN Red List

Scientific Name	Common name	Class	IUCN category	Trend
Animals				
Columba eversmanni	Pale-backed pigeon	*Aves*	Vulnerable	Decreasing
Falco cherrug	Saker falcon	*Aves*	Endangered	Decreasing
Neophron percnopterus	Egyptian vulture	*Aves*	Endangered	Decreasing
Capra falconeri	Markhor	*Mammalia*	Endangered	Decreasing
Ovis orientalis	Urial	*Mammalia*	Vulnerable	Decreasing
Panthera uncia	Snow leopard	*Mammalia*	Endangered	Decreasing
Testudo horsfieldii	Central Asian tortoise	*Reptilia*	Vulnerable	n/a
Plants				
Amygdalus bucharica	Bucharian almond	*Angiospermae*	Vulnerable	Decreasing
Crataegus darvasica	Darvaz's hawthorn	*Angiospermae*	Critically Endangered	Decreasing
Malus sieversii	Siver's apple	*Angiospermae*	Vulnerable	Decreasing
Pyrus cajon	Cayon pear	*Angiospermae*	Endangered	Decreasing
Pyrus korshinskyi	Korshinskyi's pear	*Angiospermae*	Critically Endangered	Decreasing
Rhus coriaria	Tanner's sumac	*Angiospermae*	Vulnerable	Decreasing
Swida darvasica	Darvaz's swida	*Angiospermae*	Critically Endangered	Decreasing

Source: Adapted from IUCN 2010c

Annex 9. Dashtidjum Zakaznik: Species listed in Tajik Red Data Book

No.	Scientific Name	Class	Status
	Animal species		
1	*Hierodula tenuidentata Saussure*	*Insecta*	Endangered
2	*Rivetina beybienkoi Lindt*	*Insecta*	Critically endangered
3	*Mantis macrocephala Lindt*	*Insecta*	Endangered
4	*Porphyrophora odorata Arch.*	*Insecta*	Declining
5	*Dalpada pavlovskii Kir.*	*Insecta*	Relict, declining
6	*Mustha baranovi Kir.*	*Insecta*	Rare, endangered
7	*Polyommatus kogistana Gr.-Gr.*	*Insecta*	Rare
8	*Dolbinopsis grisea Hamps.*	*Insecta*	Relict, rare
9	*Netelia fuscicornis Holmg.*	*Insecta*	Rare
10	*Typhlops vermicularis Merrem*	*Reptilia*	Rare, declining
11	*Eryx tataricus Lichtenstein*	*Reptilia*	Rare, declining
12	*Lycodon striatus bicolor Nicolsky*	*Reptilia*	Rare
13	*Naja oxiana Eichward*	*Reptilia*	Rare, declining
14	*Vipera lebetina turanica Cernow*	*Reptilia*	Declining
15	*Eumeces schneideri Daudin*	*Reptilia*	Rare
16	*Gypaetus barbatus hemachalanus Hutt*	*Aves*	Rare, declining
17	*Circaetus ferox heptneri Dementijev*	*Aves*	Rare, declining
18	*Neophron percnopterus L.*	*Aves*	Rare
19	*Aquila chrysaetus daphanea Menzbier*	*Aves*	Rare, declining
20	*Falco cherrug coatsi Dementijev*	*Aves*	Rare, endangered
21	*Falco peregrinus babylonicus Sclat.*	*Aves*	Rare, declining
22	*Ammoperdix griseogularis Brandt*	*Aves*	Rare
23	*Columba palumbus casiotis Bp.*	*Aves*	Rare
24	*Apus affinis galilejensis Antorini*	*Aves*	Rare
25	*Garrulax lineatus bilkevitchi Zarudny*	*Aves*	Rare
26	*Terpsiphone paradisi leucogaster Swain.*	*Aves*	Rare, declining

27	*Myophonus caeruleus turkestanicus Zarudny*	*Aves*	Rare
28	*Tadarida teniotis Rafinesque*	*Mammalia*	Rare
29	*Rhinolophus hipposideros Bechstein*	*Mammalia*	Rare
30	*Rhinolophus ferrumequinum Schreber*	*Mammalia*	Rare
31	*Myotis mystacinus Kuhl*	*Mammalia*	Rare
32	*Hystrix leucura satunini Muller*	*Mammalia*	Rare, endangered
33	*Mustela nivalis pallida Barrett-Hamilton*	*Mammalia*	Rare
34	*Vormela peregusna koshevnikovi Satunin*	*Mammalia*	Rare, declining
35	*Ursus arctos isabellinus Horsfield*	*Mammalia*	Declining
36	*Lutra lutra seistanica Birula*	*Mammalia*	Endangered
37	*Felis lynx isabellina Blyth*	*Mammalia*	Endangered
38	*Uncia uncia Schreber*	*Mammalia*	Rare, declining
39	*Capra falconeri heptneri Zalkin*	*Mammalia*	Endangered
40	*Ovis vignei bochariensis Nasonov*	*Mammalia*	Endangered
	Plant species		
1	*Fissidens karataviensis Sams.*	*Bryophyta*	Rare
2	*Tortula ferganensis Lasar.*	*Bryophyta*	Rare
3	*Weisia papillosissima Lasar.*	*Bryophyta*	Declining
4	*Ostrowskia magnifica Regel*	*Angiospermae*	Declining
5	*Jurinea impressinervis Iljin*	*Angiospermae*	Endangered
6	*Crocus korolkovii Regel et Maw.*	*Angiospermae*	Declining
7	*Iris darvasica Regel*	*Angiospermae*	Declining
8	*Juno nicolai Vved.*	*Angiospermae*	Declining
9	*Astragalus insignis Gontsch.*	*Angiospermae*	Rare
10	*Chesneya tadzhikistana Boriss.*	*Angiospermae*	Rare
11	*Keyserlingia mollis (Royle) Boiss.*	*Angiospermae*	Endangered
12	*Allium rosenbachianum Regel*	*Angiospermae*	Rare
13	*Allium stipitatum Regel*	*Angiospermae*	Rare
14	*Allium suworowii Regel*	*Angiospermae*	Declining
15	*Eremurus aitchisonii Baker*	*Angiospermae*	Declining
16	*Eremurus roseolus Vved.*	*Angiospermae*	Rare

17	*Petilium eduardii (Regel) Vved.*	*Angiospermae*	Declining
18	*Cousinia darwasica C.Winkl.*	*Angiospermae*	Rare
19	*Scilla raevskiana Regel*	*Angiospermae*	Rare
20	*Tulipa maximowiczii Regel*	*Angiospermae*	Rare
21	*Tulipa praestans Hoog*	*Angiospermae*	Declining
22	*Tulipa subquinquefolia Vved.*	*Angiospermae*	Rare
23	*Tulipa tubergeniana Hoog*	*Angiospermae*	Rare
24	*Vassilczenkoa sogdiana (Lincz.) Lincz.*	*Angiospermae*	Declining
25	*Ficus afghanistanica Warb.*	*Angiospermae*	Declining
26	*Ficus carica L.*	*Angiospermae*	Declining
27	*Eulophia turkestanica (Litv.) Schlechter*	*Angiospermae*	Endangered
28	*Paeonia intermedia C. A. Mey.*	*Angiospermae*	Declining
29	*Atraphaxis avenia Botsch.*	*Angiospermae*	Endangered
30	*Polygonum ovczinnikovii Czuk.*	*Angiospermae*	Rare
31	*Punica granatum L.*	*Angiospermae*	Rare
32	*Anemone bucharica Regel Fin. et Gagnep.*	*Angiospermae*	Endangered
33	*Delphinium decoloratum Ovcz. et Koczk.*	*Angiospermae*	Rare
34	*Amygdalus vavilovii M. Pop.*	*Angiospermae*	Declining
35	*Crataegus darvasica Pojark.*	*Angiospermae*	Endangered
36	*Prunus darvasica Temberg*	*Angiospermae*	Rare
37	*Rosa longisepala Koczk.*	*Angiospermae*	Rare
38	*Bunium persicum (Boriss.) B. Fedtsch.*	*Angiospermae*	Declining
39	*Parasilaus asiaticus (Korov.) M. Pimen.*	*Angiospermae*	Endangered
40	*Valerianella kulabensis Lipsky. ex Lincz.*	*Angiospermae*	Rare
41	*Swida darvasica (Pojark.) Sojak*	*Angiospermae*	Endangered
42	*Pyrus cajon Zapr.*	*Angiospermae*	Rare
43	*Malus sieversii (Ledeb.) Roem.*	*Angiospermae*	Declining

Adapted from Abdusaljamov *et al.* 1988; Safarov *et al.* 2008

Annex 10. Distribution of key endangered plant species

Source: Adapted from Noosfera 2008

Annex 11. Distribution of key wild relatives of cultural plants

Source: Adapted from Noosfera 2008

Annex 12. Dashtidjum Zakaznik: Wild relatives of cultural plants

No.	Scientific Name
1	*Crataegus pontica C. Koch.*
2	*Crataegus turkestanica*
3	*Crataegus darvasica Pojark.*
4	*Vitis vinifera L.*
5	*Punica granatum L.*
6	*Pistacia vera L.*
7	*Elaeagnus angustifolia L.*
8	*Elaeagnus orientalis L.*
9	*Amygdalus bucharica Korsh.*
10	*Amygdalus vavilivii M. Pop.*
11	*Malus sieversii (Ledeb.) Roem.*
12	*Celtys caucasica Willd.*
13	*Keyserlingia mollis (Royle) Boiss.*
14	*Ficus carica L.*
15	*Berberis heterobotrys E. Wolf*
16	*Berberis multispinosa Zapr.*
17	*Ribes meyerii Maxim.*
18	*Ribes malvifolium Pojark.*
19	*Pyrus bucharica Litv.*
20	*Pyrus cajon Zapr.*
21	*Pyrus korshinskyi Litv.*
22	*Prunus sogdiana Vass.*
23	*Prunus darvasica Tember*
24	*Vitex agnus-castus L.*
25	*Rhus coriaria L.*
26	*Cerasus verrucosa (Franch.) Nevski.*
27	*Cerasus erythrocarpa Nevski.*
28	*Rosa beggeriana Scherenk*
29	*Rosa canina L.*
30	*Rosa maracandica Bunge*
31	*Rosa divina Sumn.*
32	*Juglans regia L.*
33	*Sorbus persica Hedl.*
34	*Sorbus turkestanica (Franch.) Hedl*
35	*Rubus caesius L.*
36	*Rubus turkestanicus Regel*
37	*Ampelopsis vitifolia (Boiss.) Planch.*
38	*Zizyphus jujuba Mill.*
39	*Hippophae rhamnoides L.*
40	*Calophaca grandiflora Regel*

Source: Adapted from Safarov *et al.* 2008

Annex 13. Summary of climate change impacts on animal species

	Main impact	Main species concerned
Mammals		
Insectivores	Anomalies in air temperature affect hibernation process Decrease of suitable habitats combined with low migration capacities	Long-eared hedgehog
Bats	Anomalies in air temperature affect hibernation process	Rare and endangered species
	Increased abundance of pest insects	All
Rodents	Decrease of suitable habitats and forage resources	Indian porcupine, Turkestan rat, juniper vole, red marmot
Hares	Decrease of forage resources; cold winters with heavy snow cover	Tolai hare
Ungulates	Decrease of suitable habitats	Urial, Siberian ibex
	Cold winters with heavy snow cover	Urial
	Decrease of forage resources	Urial, markhor, wild boar
Carnivores	Decrease of suitable habitats; decrease of prey and/or forage abundance.	Turkestan lynx, snow leopard, Tian-Shan brown bear
Birds	Decrease of suitable habitats and forage resources	Ring dove, paradise flycatcher, lammergeyer, falcons
	Increase of suitable habitats due to the melting of snowfields	High-mountain species
	Increase of prey abundance	Snake-eagle
	Cold winters with heavy snow cover	Chukar
Reptiles	Anomalies in temperature and decrease of forage resources affect hibernation and period of activity	Central Asian steppe tortoise
	Increase of forage resources (insects)	All
	Indirect negative effect of heavy rains	Blind snake
	Increase of predators (snakes)	Lizards

Amphibians	Decrease of breeding sites due to the desiccation of small water bodies	Green toad, marsh frog
	Negative affect of heavy rains on eggs and tadpole	Green toad
Fishes	Increase of water temperature and associated decrease of dissolved oxygen	All species in small rivers and water bodies
Insects	Warmer climate creates favorable conditions for species distribution	Pest insects
	Warmer climate creates unfavorable conditions for species	Inhabitants of nival ecosystems
	Decrease of suitable habitats and forage resources	*Dalpada pavlovskii*, *Mustha baranovi, Porphyrophora odorata,* ashen hawk moth, large-headed mantis

Annex 14. Taxonomic nomenclature of main Dashtidjum species

Scientific Name	English Common Name	Russian Common Name
Animal species		
Mammals		
Apodemus sylvatycus	Forest mouse	Лесная мышь
Capra sibirica	Siberian ibex	Сибирский козерог
Carpa falconeri heptneri	Markhor	Винторогий козел
Dryomus nitedula	Tree dormouse	Лесная соня
Ellobius tancrei	Zaisan mole vole	Восточная слепушонка
Hemiechinus auritus	Long-eared hedgehog	Ушастый ёж
Hystrix leucura satunini	Indian porcupine	Индийский дикобраз
Lepus tolai	Hare-tolai	Заяц-толай
Lutra lutra	Central Asian otter	Среднеазиатская выдра
Lynx lynx	Turkestan lynx	Туркестанская рысь
Marmota caudata	Red marmot	Красный сурок
Martes foina	Stone marten	Каменная куница
Meles meles	Badger	Барсук
Microtus carruthersi	Juniper vole	Арчовая полевка
Mustela nivalis	Least weasel	Ласка
Myotis mystacinus	Whiskered Bat	Усатая ночница
Myotis oxygnathus	Lesser mouse-eared Bat	Остроухая ночница
Ovis vignei bochariensis	Urial	Уриал
Pipistrellus pipistrellus	Common pipistrelle	Нетопырь-карлик
Rattus turkestanicus	Turkestan rat	Туркестанская крыса
Rhinolophus ferrumequinum	Lesser horseshoe	Большой подковонос
Rhinolophus hipposideros	Greater horseshoe	Малый подковонос
Sus scrofa	Wild boar	Кабан
Tadarida teniotis	Free-tailed bat	Широкоухий складчатогуб
Uncia uncia Schreber	Snow leopard	Снежный барс
Ursus arctos tiancshanicus	Tien-Shan brown bear	Тяньшанский бурый медведь

Vormela peregusna	Marbled polecat	Перевязка
Vulpes vulpes	Fox	Лиса
Canis lupus	Wolf	Волк
Crocidura suaveolens	Lesser white-toothed shrew	Малая белозубка
Birds		
Acridotheres tristis	Common myna	Майна
Alectoris kakelik kakelik	Chukar	Кеклик
Ammoperdix griseogularis	See-see partridge	Пустынная куропатка
Anthus camprestris griseus	Tawny pipit	Полевой конек
Apus affinis galilejensis	Little swift	Черный стриж
Aquila chrysaetus daphanea	Golden eagle	Беркут
Buteo rufinus	Long-legged buzzard	Курганник
Cannabia cannabia bella	Turkestan linnet	Туркестанская коноплянка
Caprimulgus europaeus	Nightjar	Козодой
Chloris chloris turkestanicus	Turkestan greenfinch	Туркестанская зеленушка
Circaetus ferox heptneri	Snake-eagle	Орел-змееяд
Coccothraustes coccothraustes humi	Indian grosbeak	Индийский дубонос
Columba eversmanni	Pale-backed pigeon	Сизый голубь
Columba palumbus casiotis	Ring dove	Вяхирь
Emberiza bruniceps	Red-headed bunting	Желчная овсянка
Emberiza calandra	Common bunting	Просянка
Emberiza cia par	Rock bunting	Горная овсянка
Falco cherrug coatsi	Saker falcon	Туркестанский балобан
Falco peregrinus babylonicus	Peregrine falcon	Рыжеголовый сапсан
Garrulax lineatus bilkevitchi	Streaked laughing-thrush	Кустарница
Gypaetus barbatus hemachalanus	Lammergeier	Бородач
Hirundo rustica	Barn swallow	Деревенская ласточка
Ibidorhyncha struthersii	Ibis bill	Серпоклюв
Lanius schach	Long-tailed shrike	Сорокопут
Motocilla alba dukhunensis	White wagtail	Белая трясогузка
Motocilla cinerea caspica	Rock wagtail	Горная трясогузка

Mycerobas carnipes	White-winged grosbeak	Арчовый дубонос
Myophonus caeruleus	Blue whistling-thrush	Синяя птица
Milvus korschun	Black kite	Коршун
Neophron percnopterus	Egyptian vulture	Стервятник
Oriolus oriolus kundoo	Indian golden oriole	Индийская иволга
Pyrrhocorax graculus forsythia	Alpine chough	Альпийская галка
Riparia rupestris	Sand martin	Скалистая ласточка
Streptopelia senegalensis	Laughing dove	Малая горлица
Strix aluco	Tawny owl	Серая неясыть
Terpsiphone paradise leucogaster	Paradise flycatcher	Райская мухоловка
Tetraogallus himalayensis	Himalayan snowcock	Гималайский улар
Tringa hypolevcos	Common sand-piper	Перевозчик
Turdus merula	Blackbird	Черный дрозд
Reptiles		
Ablepharus brandti	Asian snake-eyed skink	Азиатский гологлаз
Agama caucasica	Caucasian agama	Кавказская агама
Agama lehmanni	Turkestan agama	Туркестанская агама
Agreonomys horsfieldi	Central Asian steppe tortoise	Среднеазиатская степная черепаха
Coluber ravergieri	Mountain racer	Разноцветный полоз
Elaphe dione	Pallas' coluber	Узорчатый полоз
Eryx tataricus	Oriental boa	Восточный удавчик
Eumesces schneideri	Long-legged skink	Длинноногий сцинк
Gymnodactylus fedtschenkoi	Naked-toed gecko	Голопалый геккон
Lycodon striatus bicolor	Striated wolf snake	Поперечнополосатый волкозуб
Naja oxiana	Central Asian cobra	Среднеазиатская кобра
Natrix tesselata	Water snake	Уж водяной
Ophisaurus apodus	Grass lizard	Желтопузик
Typhlops vermicularis	Blind snake	Червеобразная слепозмейка
Vipera lebetina turanica	Central Asian lebetina viper	Среднеазиатская гюрза

Amphibians		
Bufo viridis	Green toad	Зеленая жаба
Rana ridibunda	Marsh frog	Озерная лягушка
Fishes		
Glyptosternon reticulatum	Turkestan somik	Туркестанский сомик
Nemachilus pardali	Tajik beardie	Таджикский голец
Nemachilus stoliczkai	Tibetan beardie	Тибетский голец
Schizothorax intermedius	Common marinka	Обыкновенная маринка
Varicarhinus heratensis	Samarkand khramulya	Самаркандская храмуля
Insects		
Dolbinopsis grisea	Ashen hawk moth	Ясеневый бражник
Hierodula tenuidentata	Wood mantis	Древесный богомол
Mantis macrocephala	Large-headed mantis	Мантис большеголовый
Polyommatus kogistana	Kuhistan blue	Кухистанская голубянка
Rivetina beybienkoi	Bei-Bienko ground mantis	Риветина Бей-Биенко
Dalpada pavlovskii,	n/a	Дальпада Павловского
Mustha baranovi	n/a	Муста Баранова
Netelia fuscicornis	n/a	Нетелия буроусая
Porphyrophora odorata	n/a	Душистый карминоносный червец
Plant species		
Acer regelii	Regel's maple	Клен Регеля
Acer turkestanicum	Turkestan maple	Клен туркестанский
Adonis turkestanicus	Turkestan adonis	Адонис туркестанский
Aegopodium tadshicorum	Tajik goutweed	Сныть таджиков
Allium Rosenbachianum	Rozenbah's onion	Лух Розенбаха
Allium stipitatum	Stalked onion	Лук стебельчатый
Alllium suworowii	Anzur onion	Лук Суворова, анзур
Amygdalus bucharica	Bukharian almond	Миндаль бухарский
Amygdalus vavilovi	Vavilov's almond	Миндаль Вавилова
Artemisia baldshuanica	Baldjuan sagebrush	Полынь бальджуанская
Asteraceae	Aster	Сложноцветные

Astragalus sp.	Milk-vetch	Астрагал
Berberis sp.	Barberry	Барбарис
Betula tianschanica	Tien-Shan birch	Береза тяньшанская
Bunium persicum	Black cumin	Буниум персидский
Carex sp.	Sedge	Осока
Cercis griffithii	Griffit's redbud	Багрянник Гриффита
Chesneya tadzhikistana	Tajik chesneya	Чезнея таджикская
Cichorium intybus	Chicory	Цикорий обыкновенный
Clematis orientalis	Chinese clematis	Ломонос восточный
Colutea hybrida	Hybrid senna	Пузырник гибридный
Cousinia sp.	Cousinia	Кузинья
Crataegus darvasica	Darvaz hawthorn	Боярышник дарвазский
Crocus korolkovii	Korolkov's crocus	Шафран Королькова
Cynodon dactylon	Scutch grass	Пальчатка
Dactylis glomerata	Cocksfoot	Ежа сборная
Datura stramonium	Dature	Дурман обыкновенный
Diospyros lotus	Caucasian persimmon	Хурма кавказская
Draba altaica	Whitlow-grass	Крупка
Elytrigia trichophora	Couch grass	Пырей волосоносный
Ephedra equisetina	Bluestem joint fir	Эфедра хвощевая
Eremurus aitchisonii	Echison's desert-candle	Ширяш Эчисона
Eremurus comosus	Comose desert-candle	Ширяш хохлатый
Eremurus roseolus	Rose-tinted desert-candle	Ширяш розоватый
Exochorda albertii	Albert's exochorda	Экзохорда Альберта
Fabaceae	Legume	Бобовые
Ferula sp.	Ferula	Ферула
Festuca alaica	Fescue	Типчак
Ficus afghanistanica	Afghan fig	Инжир афганистанский
Ficus carica	Common fig	Инжир обыкновенный
Hordeum bulbosum	Bulbous barley	Ячмень луковичный
Hordeum spontaneum	Wild barley	Ячмень дикий

Hypericum scabrum	John's-wort	Зверобой шершавый
Impatiens nevskii	Nevski's touch-me-not	Недотрога Невского
Impatiens parviflora	Small-flowered touch-me-not	Недотрога мелкоцветная
Iris darvasica	Darvaz iris	Ирис дарвазский
Iris sogdiana	Sogdian iris	Ирис согдийский
Juglans regia	Walnut	Орех грецкий
Juniperus seravschanica	Zeravshan juniper	Арча зеравшанская
Juno nicolai	Nikolai's junos	Юнона Николая
Keyserlingia mollis	Keyserlingia	Кейзерлингия мягкая
Ligularia thomsonii	Thomson's leopard plant	Бузульник Томсона
Malus sieversii	Siver's apple	Яблоня Сиверса
Melandrium apetalum	Purple bladder campion	Дрема
Origanum tytthanthum	Small-flowered origanum	Душица мелкоцветковая
Ostrowskia magnifica	Magnificent ostrowskia	Островския величественная
Oxytropis sp.	Oxytrope	Остролодочник
Petilium eduardii	Eduard's fritillary	Петилиум Эдуарда
Phlomis bucharica	Jerusalem sage	Фломис бухарский
Pipthaterum pamiroalaicum	Pamir-Alai rice grass	Рисовидка Памироалайская
Pistacia vera	Pistachio	Фисташка настоящая
Plantago major	Common plantain	Подорожник большой
Poa alpina	Alpine meadow grass	Мятлик альпийский
Poa bulbosa	Bulbous bluegrass	Мятлик луковичный
Poa sp.	Meadow-grass	Мятлик
Poaceae	True grasses	Злаковые
Polygonum sp.	Knotweed	Горец
Potentilla sp.	Silverweed	Лапчатка
Prangos pabularia	Hay plant, yugan	Юган
Primula baldshuanica	Baljuan primrose	Первоцвет бальджуанский
Primula kaufmanniana	Kaufman's primrose	Первоцвет Кауфмана
Prunus darvasica	Darvaz cherry-plum	Алыча дарвазская
Punica granatum	Common pomegranate	Гранат обыкновенный

Pyrus bucharica	Bukharian pear	Груша бухарская
Pyrus cayon	Cayon pear	Груша кайон
Pyrus korshinskyi	Korzhinskyi pear	Груша Коржинского
Ranunculus sp.	Buttercup	Лютик
Rheum maximoviczii	Pieplant	Ревень Максимовича
Rhus coriaria	Tanner's sumac	Сумах дубильный
Rosaceae	Rose family	Розоцветные
Rumex paulsenianus	Paulsen's dock	Щавель Паульсена
Salix sp.	Willow tree	Ива
Saussurea glacialis	Snow lotus	Горькуша
Scutelaria gontscharovii	Goncharov's skullcap	Шлемник Гончарова
Swida darvasica	Darvaz swida	Свидина дарвазская
Taraxacum sp.	Dandelion	Одуванчик
Thermopsis dolichocarpa	Bush pea	Термопсис длинноплодный
Thymus seravshanicus	Zeravshan thyme	Тимьян зеравшанский
Tulipa maximowiczii	Maximovich's tulip	Тюльпан Максимовича
Tulipa praestans	Superior tulip	Тюльпан превосходящий
Vicia tenuifolia	Vetch	Вика тонколистная
Vitis vinifera	Common grape vine	Виноград
Zizyphus jujuba	Jujube	Челон