3.2. Impacts of climate change on biodiversity and its implications for protected areas management

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This chapter focuses on Tajikistan, 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 current knowledge, experts' assumptions and observations.

3.2.1. Case study context

Climate change is an unequivocal global issue 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 (last 50 years), which is twice that recorded for the last 100 years (IPCC, 2007). Scenarios developed by the IPCC predict that increase of global mean temperature by 2099 may reach 6.4 °C if greenhouse gases 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 temperature increase has many negative consequences and can become the dominant direct driver for the loss of valuable ecosystems and their services at a 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). 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 the cloud forests of Costa Rica (IUCN, 2010a).

Species responses to climate change impacts include physiological adaptations as a result of their capacity to tolerate some degree of change and migration (behavioral) to a more suitable location in response to the changes, both of which are expressions of phenotypic plasticity (Auld & Keith, 2009; Omann et al., 2009). Adaptation mechanisms are mainly 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; Vitt et al., 2010). In spite of the adaptative nature of these changes, climate change poses a number of threats to species and could lead to population declines due to changes in species interactions, particular predator-prey interactions and mutualisms (Leech & Crick, 2007; Rosenzweig et al., 2007; SCBD, 2009). Another notable point is that the capacity of organisms for adaptation is limited and could be slower than the pace of climate change, which may lead to decreasing populations and eventually species extinctions (Parmesan & Yohe, 2003; Thomas et al., 2004; Brook et al., 2008).

Posing 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). The main challenges are related to species' tendency to move poleward and to higher altitudes for suitable climatic conditions and thus landscape-level shifts in ecosystem structure and distribution (Lemieux & Scott, 2005; Willis et al., 2009). Existing protected area networks have largely been developed to protect static patterns of biodiversity, and thereby may not adequately respond to the dynamic changes in ecosystem composition and distribution triggered by climate change impacts (Burns et al., 2003; Heller & Zavaleta, 2009; Mawdsley et al., 2009). New management approaches and climate change adaptation measures must be developed and integrated into protected areas planning and management to ensure biodiversity conservation, as well as mitigation of climate change impacts.

This chapter focuses on climate change impacts on biodiversity of Tajikistan — a country that despite its small land area is characterised 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 1000 species of wild relatives of cultivated plants, 1132 endemic plants, and 20 vegetation types represented by plant communities that range from broadleaf forests and boreal meadows to subtropical and tropical deserts (NBBC, 2003, 2009). 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 (NBBC, 2003; Safarov et al., 2003).

Similar to other countries, the 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 faunal and 16 floral species have already been extirpated from Tajikistan (Safarov et al., 2003). Species negatively affected by anthropogenic activities may also become even more vulnerable to climate change due to synergistic effects, and will have diminished capacity for successful adaptation to its impacts (Millsap et al., 1990; Mkanda, 1996).

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 a 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 associated natural disasters (Makhmadaliev et al., 2003; 2008). A further increase of temperature could be 3.7 °C on average by the end of 2099 (0.3–0.4 °C per decade) according to IPCC models (Christensen et al., 2007), or by 0.2–0.4 °C by 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., 2003).

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

The Government of Tajikistan has undertaken a number of measures towards biodiversity conservation, including the development of a 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 considers climate change impacts on biodiversity, though they have unquestionable implications for protected areas. 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 specific species within particular areas.

Meanwhile, the importance of assessing climate change impacts on biodiversity is highlighted in the National Action Plan for the Mitigation of Climate Change (Makhmadaliev et al., 2003). 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. Here, we report on research, which analyzes climate change impacts on protected areas in Tajikistan. This chapter seeks to inform policy development geared towards the mitigation of negative consequences of climate change on Tajikistan's biodiversity, and fills an important research gap by investigating climate change impacts on one of the most vulnerable reserves rich in biodiversity — Dashtidjum Zakaznik.

The following objectives were developed for the research: (i) analyze meteorological data and identify climate change trends on the territory of Dashtidjum Zakaznik; (ii) 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; (iii) analyze relevant national policies and programs and identify prerequisites for implementation of adaptation measures, and (iv) identify implications for protected areas management and develop recommendations for adaptation measures to climate change.

The results of the research contributed to the implementation of national strategies on biodiversity conservation and climate change mitigation in Tajikistan. Therefore, they may be of interest not only to scientists and protected areas managers, but also to policy and decision makers. Though the research was 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, and other areas with similar conditions.

3.2.2. Research methodology

In the absence of long-term ecological monitoring in the *zakaznik*, we employed a combination of complementary methods, including archival reviews and expert interviews, quantitative methods for analyses of meteorological data and qualitative vulnerability assessment. A case study approach was chosen to address 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 number of criteria, including sensitivity to climate change, data availability and site significance for biodiversity conservation. Archival reviews involved review of publications and materials from various sources, such as academic, government, intergovernmental, international and non-governmental organisations.

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. In total, 18 experts with various backgrounds and from different institutions, including academic and governmental, were interviewed. A majority of interviews was conducted face-to-face; three interviews were conducted by phone. The interviews were held in a semi-structured form, with most of the questions prepared in advance. 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.

The current and potential impacts of climate change on biodiversity have been analyzed following the simplified Driver-Pressure-State-Impact-Response (DPSIR) assessment framework that allowed focusing on several aspects of biodiversity vulnerability to climate change and addressing the research problem from various angles. The framework was developed by European Environment Agency (EEA) in 1995, adopted by many organisations worldwide as a tool for environmental assessments (EEA, 1998; Maxim et al., 2009), and 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). Here, we utilise the DPSIR approach to (i) assess the vulnerability of the biodiversity of *Dashtidjum Zakaznik* to climate change impacts, (ii) identify implications for its management, and (iii) develop recommendations on adaptation measures to mitigate climate change impacts on the biodiversity of the *zakaznik*.

Quantitative methods have been employed to analyze and characterise climate change on the territory of *Dashtidjum Zakaznik.* The modern climate has been identified using meteorological data from the Yol meteorological station, which is located on the territory of *Dashtidjum Zakaznik* at 1283 masl and represents the climate of most territory of the *zakaznik* (Asanova, 2010b), for the baseline period 1961–1990 as recommended by the World Meteorological Organisation (WMO) (McCarthy et al., 2001). The analysis of climate change on the territory of *Dashtidjum Zakaznik* for the period from 1991 to 2008 has been conducted employing data from mid-mountain meteorological stations that are representative for the study area through a comparative analysis of temperature and precipitation trends, as well as Pearson's R correlation analysis. A need to use the representative dataset was implied by nascent meteorological data from the study area.

3.2.3. Case study area

Dashtidjum Zakaznik[3] was established in 1972 with the objective of the conservation of the rare population of endangered 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 (NBBC, 2003; Safarov et al., 2003). The total area of the *zakaznik* is 51,300 ha (Safarov et al., 2008), and is located on the southeast slopes of the Khazratisho mountain range in southern Tajikistan (Fig. 3.2). 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 (*zapovednik*) 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 (see Fig. 3.2) (Safarov et al., 2008).

The territory of the *zakaznik* comprises diverse elevations ranging from 700 to 2911 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: 2911 and 2843 masl, respectively. The territory of *Dashtidjum*

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[3] National legislation classifies protected areas in four categories depending on the protection regime and land management: 1) state strict nature reserves or *zapovedniks* (IUCN category I), 2) state natural parks or national parks (IUCN category II), 3) state natural monuments (IUCN category III), and 4) state nature reserves, species management sites or *zakazniks* (IUCN category IV) (IUCN, 1994; *Law on Protected Areas*, 1996). For the purposes of this chapter, we use 'reserve' or '*zapovednik*' for category 1 and '*zakaznik*' for category 4.

Zakaznik is characterised 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 to high mountains. They have diverse shapes and constitute one of the main elements that form the landscape of the *zakaznik* (Fig. 3.3). These formations represent the main attractions for tourists, as well as provide shelter for many rare and endemic animal species (Safarov et al., 2008).

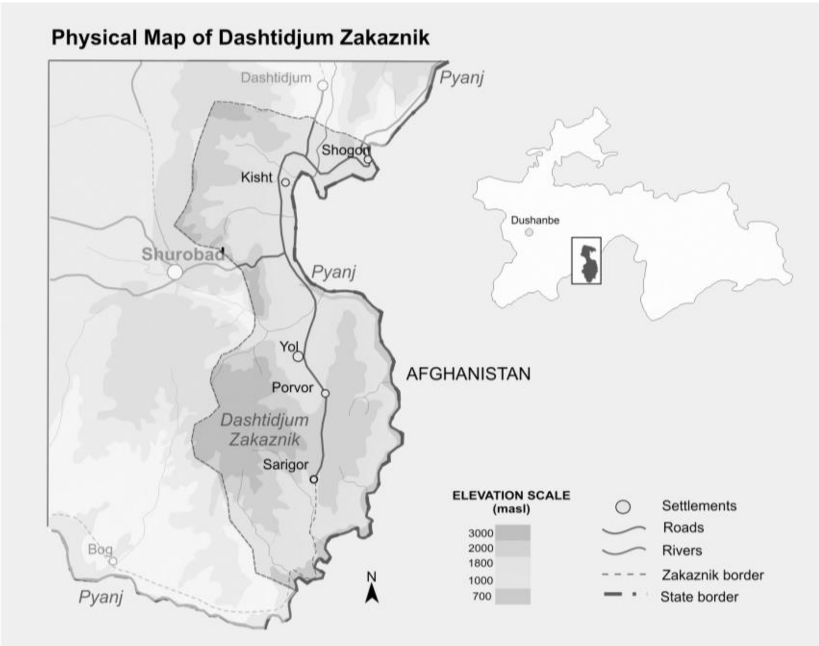

Fig. 3.2. Location and physical map of Dashtidjum Zakaznik
Source: Adapted from Noosfera, 2008

Fig. 3.3. Diverse landscapes of Dashtidjum Zakaznik

3.2.4. Outcomes of the vulnerability assessment

Driver: Climate change in Dashtidjum area

Climate change on the territory of *Dashtidjum Zakaznik* is confirmed by the analysis of data from meteorological stations located at altitudes of 1000 to 2500 masl. According to data processed, there are significant changes in air temperatures during the period analyzed, which resulted in expected fluctuations in mean temperatures (Fig. 3.4). At the same time, there is a clear trend of increase in annual mean temperatures, which can already be observed during the baseline period of 1961–1990, i. e. an increase of 0.5 °C or by 0.02 °C per year. This increase is caused by observed increases in mean 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 characterised by a slight decrease, which constitutes –0.1 °C.

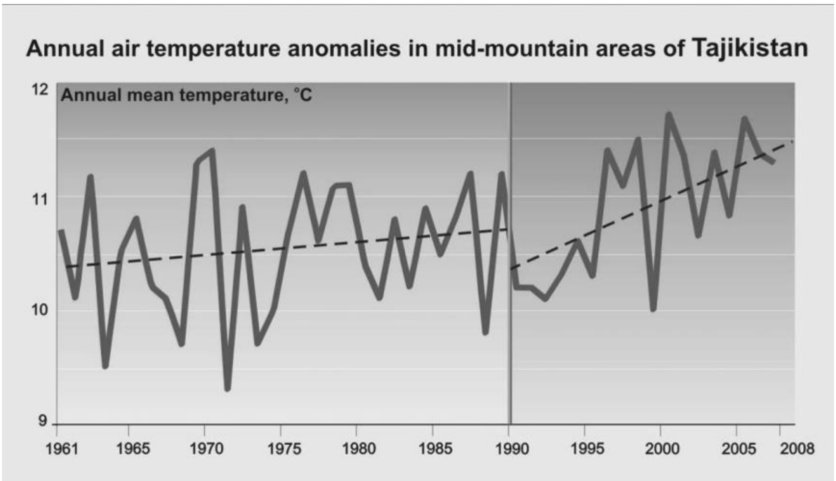

Fig. 3.4. Annual air temperature anomalies in mid-mountain areas. Data source: SAH, 2010

Climate change from 1991–2008 is characterised by a further increase of 1.3 °C (Fig. 3.4). This increase is 0.07 °C per year, which is over three times higher than for the baseline period. Similar to the baseline period, increase of annual mean temperatures is caused by increases in mean 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 significantly higher than the 0.5 °C trend observed in the majority of the country's regions for the same period.

Climate change on the territory of *Dashtidjum Zakaznik* is also confirmed by changes in precipitation. Analysis of annual and monthly variation has revealed significant differences between the baseline period and the following 18 years. As illustrated in Fig. 3.5, the baseline period is characterised by an insignificant increase of annual precipitation, which is 12 % of the average precipitation rate for 1961–1990. In a monthly analysis, the increase in precipitation has been observed in eight of twelve months. From 1991–2008, anomalies in precipitation patterns are characterised by a significant decrease of 32 % (Fig. 3.5), evident in all months except February, October and November. The most significant decreases in precipitation were observed in September, May and December.

Climate change on the territory of *Dashtidjum Zakaznik* has also been observed by its inhabitants who cite hotter and drier summers in the last decade, as well as a decrease in winter snow cover in valleys and mid-mountain areas, and its increase in high mountain areas (Boboev pers. comm.; Faizov pers. comm.). Inhabitants also noticed more frequent extreme weather events, in particular heavy rains, which very often lead to mudflows and unusual extremely cold temperatures during recent 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.).

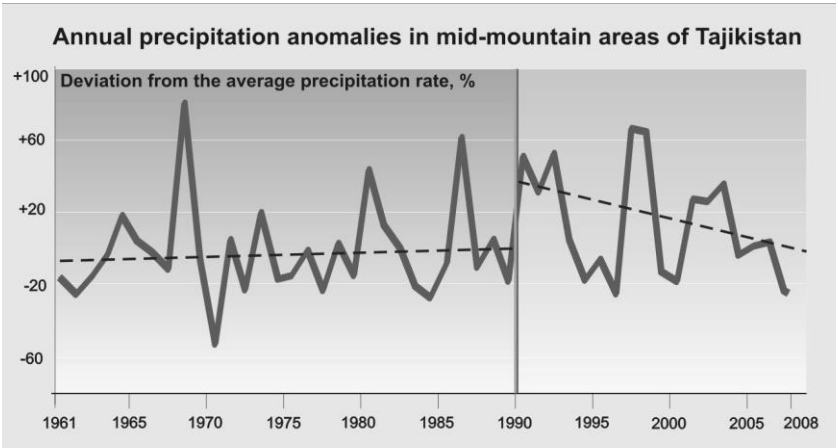

Fig. 3.5. Annual precipitation anomalies in mid-mountain areas. The trends for both periods (1961–1990, 1990–2008) are compared to the average mean precipitation for 1961–1990.
Data source: SAH, 2010

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 in spring precipitation important for vegetation, as well as a significant increase in spring air temperatures, which may lead to considerable changes in species phenology. A further climate warming, which is projected to continue at the currently observed rate (Makhmadaliev et al., 2008; Asanova, 2010a), may aggravate the consequences for 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 a decrease of annual precipitation may reach 20 % for the next 100 years (Asanova, 2010a).

Pressure and State: vulnerability of biodiversity — fauna

The unique geographical location of *Dashtidjum Zakaznik* between the large mountain systems of Pamir-Alai and Hindu Kush, and their proximity to the Himalayas and Tibet, has promoted the development of diverse fauna, which possesses characteristics of various mountainous regions (Safarov et al., 2008). A second factor, which contributes to 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, with a considerable amount of endemic and rare species, as well as relics of the Tertiary period (Safarov et al., 2008).

Dashtidjum Zakaznik provides habitat for many rare, vulnerable and endangered species of fauna. Seven vertebrate species are classified as threatened in the IUCN Red List; four are 'endangered' and three are 'vulnerable' (IUCN, 2010b). Forty species of the *zakaznik* are included in the Red Data Book of Tajikistan (Safarov et al., 2008), with nine listed as 'endangered' and one as 'critically endangered' (Abdusaljamov et al., 1988). *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, its biodiversity experiences 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 livestock 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 exacerbates habitat degradation, but also directly affects animals leading to changes in their phenology, population size and distribution range. The main factors of climate change impact include changes in food abundance and availability of suitable habitats, desynchronisation of species interaction, as well as spread of invasive species. 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 faunal taxa of the *zakaznik*. They are mainly represented by shifts in species' distribution ranges, as the paucity of regular monitoring does not allow identifying other changes, including phenological.

Climate change impact on animal species 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 populations (Safarov et al., 2008; Muminov pers. comm.; Saidov pers. comm.). One factor that provides favorable conditions for pest distribution is increases in air temperature. Reduced precipitation affects the composition of pest insects causing a prevalence of xeric species (Sangov pers. comm.). 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 (Murodov pers. comm.). The increase of populations of some high-mountains species of birds has already been observed in the last decade (Murodov pers. comm.). 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 prey populations of pest insects and some rodents (Nadjmidinov pers. comm.). 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 animals and their offspring (Zaumyslova, 2006).

At the same time, a majority of the fauna of *Dashtidjum Zakaznik* experience negative (mainly indirect) effects of climate change that may result in the decline of their populations. These effects include reductions 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 birds and large mammals, including carnivores and ungulates. Climate warming has already forced them to shift their distribution ranges (Saidov pers. comm.; Zagrebelnyi pers. comm.). Some species, including Siberian ibex (*Capra sibirica*), snow leopard, ring dove (*Columba palumbus casiotis*), and paradise flycatcher (*Terpsiphone paradise leucogaster*) will most probably move northwards and disappear from the territory of the *zakaznik* due to the lack of suitable habitats (Saidov pers. comm.; Zagrebelnyi pers. comm.; Murodov pers. comm.). One representative bird, the black kite (*Milvus korschun*), has already left the territory (Murodov pers. comm.).

Another indirect impact that adversely affects populations is any decrease of forage resources due to changes in ecosystem productivity and prey abundance. The least vulnerable to this impact are polytrophic species that feed on diverse groups of plants and/or animals, and are able to switch their nutritive base. In contrast, the most vulnerable species are specialist species that feed on specific type of plants or prey and can experience difficulties in shifting to alternative prey. These include markhor, urial, Turkestan rat (*Rattus turkestanicus*), juniper vole (*Microtus carruthersi*), lammergeyer (*Gypaetus barbatus hemachalanus*), ashen hawk moth (*Dolbinopsis grisea*), large-headed mantis (*Mantis macrocephala*), and several species of endangered insects (*Dalpada pavlovskii*, *Mustha baranovi, Porphyrophora odorata*) (Saidov, 2006; Safarov et al., 2008; Valdez, 2008a; Muminov pers. comm.; Murodov pers. comm.; Saidov pers. comm.). In general, a considerable number of species are affected by the combination of both factors — decreasing suitable habitats and forage abundance, which exacerbates the impact of climate change and may lead to significant population declines.

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 *inter alia* long-eared hedgehog (*Hemiechinus auritus*), Central Asian steppe tortoise (*Agreonomys horsfieldi*), red marmot (*Marmota caudata*), and may disrupt their life activity, including reproduction (Dustov pers. comm.; Saidov pers.comm.). Higher air temperatures also negatively affect psychrophilic species of high mountain nival zones, including Siberian ibex and some insect species (Muminov pers. comm.; Saidov pers. comm.).

Harsh winters with heavy snow cover have negative consequences on species with limited capacity to walk on snow cover, including urial, snow leopard and chukar (*Alectoris kakelik kakelik)*, and may lead to their death from starvation (Kokorin et al., 2001;

Valdez, 2008b; Saidov pers. comm.; Murodov pers. comm.). They also affect tolai hare (*Lepus tolai*), constraining its access to fodder (Saidov pers. comm.). Increased number of days with heavy rains has a negative effect on eggs and tadpoles of the green toad (*Bufo viridis*), and may affect population and abundance (Bickford et al., 2010). Indirect effects of increasing temperature increase may also be experienced by fish species, resulting from increased water temperatures in small watercourses and associated declines in dissolved oxygen, complicating reproduction and survival rates (Saidov, 2006; Saidov pers. comm.). Indirect effects of heavy rains can also threaten the blind snake (*Typhlops vermicularis*), by reducing its avoidance capabilities against predators (Nadjmidinov pers. comm.).

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 adversely affected. 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 extirpation. A combination of climate change impacts with anthropogenic pressures would most likely have devastating synergetic effects on the animals of *Dashtidjum Zakaznik*, culminating in significant biodiversity loss.

Pressure and State: vulnerability of biodiversity — flora

Favorable and various climatic and soils conditions have promoted the formation of abundant and diverse flora, including forest vegetation (Safarov et al., 2008). A combination of elements, and sometimes entire 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 those from such mountainous regions as Tien-Shan, Himalaya, Pamir-Alai and Hindu Kush, and from desert regions of Kara Kum and Kyzyl Kum. It consists of many endemic and rare species, as well as wild relatives of cultural plants that represent valuable genetic resources (Safarov et al., 2008).

The flora of *Dashtidjum Zakaznik* comprises various endemic, rare and endangered species of regional and global significance. Endemic species are represented by 115 species, including rare and relic magnificent ostrowskia (*Ostrowskia magnifica*) (Safarov et al., 2008). Seven floral species are listed in the IUCN Red List (IUCN, 2010b), including the 'critically endangered' Darvaz hawthorn (*Crataegus darvasica*), Korjinskyi's pear (*Pyrus korshinskyi*), and Darvaz swida (*Swida darvasica*). Of 43 species of plants of the *zakaznik* included in the Red Data Book of Tajikistan, eight are listed as 'endangered' (Abdusaljamov et al., 1988; Safarov et al., 2008).

Another important group of floral species 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. The latter consist of fruit and nut trees, such as apples, pears, cherry-plums, plums, walnuts, pistachio, and almonds. Species that form forests on the *zakaznik* are represented by 19 ligneous species, including walnut (*Juglans regia*), maples (*Acer* spp.), pistachio (*Pistacia vera*), and almonds (*Amygdalus* spp.), as well as eight herbaceous species that form communities of light forests. Furthermore the flora of *Dashtidjum Zakaznik* comprise more than 200 species of plants that have value as medicine, food, oils, tannins and dyes (Safarov et al., 2008).

Similar to fauna, the plant species of *Dashtidjum Zakaznik* are significantly affected by a number of anthropogenic stressors, in particular livestock 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 livestock grazing can degrade vegetation cover and promote the distribution of invasive species. Combined, these processes lead to the replacement of valuable communities by weed species and a general loss of biodiversity (Safarov et al., 2008).

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 in distribution ranges. The latter has already been observed for some species, 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 (Safarov pers. comm.; Karimov pers. comm.). Among them are mesophilous trees, such as Tien-Shan birch (*Betula tianschanica*), Turkestan maple (*Acer turkestanicum*) and walnut, which may significantly reduce their distribution, even to the point of extinction, which is most probable for birch (Safarov pers. comm.; Ustjan pers. comm.). Herbaceous species, especially annual grasses, though less vulnerable than ligneous species, may also experience shrinking of distribution ranges and a decline in population sizes (Karimov pers. comm.). It is likely that mesophilous communities would lose a majority of valuable species, including meadow-grass (*Poa* spp.) and Tajik goutweed (*Aegopodium tadshicorum*), which will be replaced by weed species with higher adaptive and migration capacities (Safarov pers. comm.; Sattorov pers. comm.; Ustjan pers. comm.; Zagrebelnyi pers. comm.). Perennial grasses with short vegetation periods can also suffer from the climatic anomalies and suffer diversity loss (Karimov pers. comm.).

Species that may benefit from climate change mainly include xerophilous and xerophyte species, as well as invasive species (Ustjan pers. comm.; Safarov pers. comm.). The latter include such species as couch grass (*Elytrigia trichophora*), sagebrush (*Artemisia* spp.), sedge (*Carex* spp.), small-flowered origanum (*Origanum tyttanthum*) (Zagrebelnyi pers. comm.). 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 (Safarov pers. comm.; Karimov pers. comm.; Zagrebelnyi pers. comm.). Other species that may benefit from a warmer climate include species of alpine and sub-alpine zones, in particular those with high migration and adaptive capacities, which may expand their distribution ranges and occupy the nival zone of the *zakaznik* (Safarov pers. comm.; Sattorov pers. comm.).

It is likely that climate change will contribute to the extinction of a considerable proportion of rare, endemic and endangered species. Among the most vulnerable are those that grow within communities of mid-mountain mesophylic and juniper forests, including Eduard's fritillary (*Petilium eduardii*), magnificent ostrovskia (*Ostrowskia magnifica*), and Goncharov's skullcap (*Scutelaria gontscharovii*); as well as prevernal species and ephemeroids such as Korolkov's crocus (*Crocus korolkovii*), Darvas iris (*Iris darvasica*), Nickolai juno (*Juno nicolai*), superior tulip (*Tulipa praestans*), and Maximovich's tulip (*Tulipa maximowiczii*) (Karimov pers. comm.; Safarov pers. comm.; Sattorov pers. comm; Zagrebelnyi pers. comm.). Many endangered species may experience significant declines in their populations, including the xerophyte shrub — keyserlingia (*Keyserlingia mollis*), and mesophylic species of onion, including endemic Rozenbah's onion (*Allium rosenbachianum*) and stalked onion (*Allium stipitatum*) (Safarov pers. comm.; Sattorov pers. comm.). The least vulnerable species of rare and endangered plants to climate change include black cumin (*Bunium persicum*) and tanner's sumac (*Rhus coriaria*) (Safarov pers. comm.; Sattorov pers. comm.; Zagrebelnyi pers. comm.), which may even benefit from a warmer climate and expand their current distribution.

A majority of wild relatives of cultural crops, including rare and endangered species, has relatively low vulnerability to climate change (Sattorov pers. comm.; Sattorov pers. comm.). They are mainly represented by xerophyte species, including common pomegranate (*Punica granatum*), almond species, pistachio and fig species (*Ficus spp*). It is likely that they may expand their distribution ranges and occupy higher elevations of *Dashtidjum Zakaznik* (Safarov pers. comm.; Sattorov pers. comm.; Zagrebelnyi pers. comm.). The negative impact of climate change on these xerophyte species, except the cherry-plums (*Prunus* spp.), can be caused by the spread of invasive species, which may lead to the loss of single trees, in particular in the lower zone of their distributions (Safarov pers. comm.; Sattorov pers. comm.). Among the most vulnerable species of this group are those that occur within mid-mountain mesophylic forests, including Cayon pear (*Pyrus cayon*) and Korjinskyi's pear, Siver's apple (*Malus sieversii*) and walnut (Safarov pers. comm.). They may suffer population declines due to higher air temperature and anomalies in precipitation, which may lead to soil desiccation and death of single trees.

Pressure and State: vulnerability of biodiversity — ecosystems

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 dimensions (Safarov et al., 2008). Ecosystems of the *zakaznik* comprise seven of twelve ecosystems types occurring in Tajikistan. 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 areas occurring around human settlements. The most wide-spread ecosystem are mid-mountain xerophytic ecosystems that cover nearly 50 % of the territory of *Dashtidjum Zakaznik* and comprise wild relatives of cultural crops of global significance (Safarov et al., 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 livestock grazing (Safarov et al., 2008). This results in the degradation of ecosystems especially those located at elevations < 1500 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. Climate change already affects the ecosystems of *Dashtidjum Zakaznik* leading to various changes in their structure and distribution ranges. 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. A brief overview of the ecosystems and their adaptive responses to climate change is presented below.

A major part of the ecosystems of *Dashtidjum Zakaznik* is vulnerable to climate change impacts and is already affected to varying degrees. The most vulnerable are high mountain meadows and mid-mountain mesophylic ecosystems that possess considerable numbers of hydrophilous species with limited adaptive capacities to climate change impacts. The main climatic factors that affect these and other ecosystems are increasing mean temperatures, precipitation anomalies, melting of snowfields and reduction of snow cover (Safarov pers. comm.; Zagrebelnyi pers. comm.). The least vulnerable 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 (Safarov pers. comm.; Sattorov pers. comm.).

Climate change impacts on the ecosystems of the *zakaznik* can mainly be observed in changing compositions, shifting of distribution ranges, as well as modified population sizes of the composite plant and animal species. In particular, in all zones except nival, there is a general decrease in species diversity due to the loss of hydrophilous plants, as well as rare, endemic and endangered species. The structures of ecosystems are changing, with the replacement of mesophylic species by more xeric species as well as by weedy plants. A higher prevalence of invasive species decreases the productivity of the ecosystems leading to cascading effects on animal species diversity and population size, and their migration to other territories (Safarov pers. comm.; Zagrebelnyi pers. comm.). In general, changes in ecosystems of *Dashtidjum Zakaznik* can be characterised by the loss of species diversity, xerophytisation, and homogenisation due to the replacement of valuable native communities by weed species (Safarov pers. comm.; Sattorov pers. comm.; Zagrebelnyi pers. comm.). Climate change impacts also promote expansion of upper zones of the ecosystems, which indicates vertical migration of species in search of suitable climates (Safarov pers. comm.; Sattorov pers. comm.).

One of the positive consequences of climate change 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 the lower alpine zone (Safarov pers. comm.; Zagrebelnyi pers. comm.). However, 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 incoming weed species. Reduction in 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.). A loss of the poor-studied psychrophilic insects is yet another threat for the nival ecosystems (Muminov pers. comm.). The positive effects of climate change can be experienced by some insects, but this mainly refers to pest insects, which already affect a considerable part of forest resources and fruit trees (Muminov pers. comm.; Safarov pers. comm.). A theoretical increase of population size of some reptiles of mid-mountain xerophytic forests, such as cobra (*Naja oxiana*) and lebetina viper (*Vipera lebetina turanica*), is unlikely due to anthropogenic pressures and extermination of these species by the local human population (Nadjmidinov pers. comm.).

Impacts and implications for management

The main goal of *Dashtidjum Zakaznik* is to protect biodiversity and specific natural features, threatened by anthropogenic activities (see Study area). Thus its effectiveness (and conservation success) is measured by persistence of species and ecosystems selected for conservation. Posing a critical threat to biodiversity of the *zakaznik*, climate change affects its management, questioning its adequacy in the conservation of representative ecosystems and endangered species. The main challenges are associated with various characteristics of this *zakaznik*, as well as other protected areas, such as fixed borders and protection of particular species assemblages and ecosystems within these borders. The majority of *zakazniks* in Tajikistan have very narrow conservation targets and focus on the protection of only a few endangered species (Safarov et al., 2006), which makes protected areas effectiveness even more vulnerable to climate change impacts.

It is evident from the vulnerability assessment that a number of species, including key species for biodiversity conservation, may vacate the territory of the *zakaznik* and migrate northwards to unprotected territories. Many species under protection may suffer population decline and, eventually, become extinct. In addition, some new species may migrate to the *zakaznik* from southern areas in a search of suitable climate. The composition of ecosystems is also 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 revision of its conservation goals.

The Government of Tajikistan has undertaken a number of measures towards biodiversity conservation, which includes development of national strategies, such as a National Strategy on Conservation and Sustainable Use of Biological Diversity (NBSAP) and

National Environmental Action Plan (NEAP), the development of an ecological network for the country (Econet) and adoption of the State Program on Protected Areas Development in 2005–2015. At the same time, none of these documents addresses climate change impacts on biodiversity. This will inevitably slow down development and implementation of measures needed to adjust current conservation practices to changing conditions. Nevertheless, these documents do provide a number of possibilities for implementation of adaptation measures, which are described in the next section.

Adaptive capacity

Dashtidjum Zakaznik possesses several positive characteristics that contribute to the adaptation of its biodiversity to climate change. One such feature is the altitudinal diversity of its habitats, with elevations ranging from 700 to 2911 masl (Safarov et al., 2008). This facilitates 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 gradients in montane areas (Mackinnon, 2008). The main species that are constrained in adaptations by vertical shifts are immobile species of the nival zone that may suffer extinction. In case of *Dashtidjum Zakaznik*, vertical shifts may bring additional benefits, as territories located upwards, to some extent, experience less 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 (Fig. 3.2) that allows latitudinal shifts within its territory. Similar to the wide range of altitudes, the north-south elongation creates a variety of climatic conditions (Mackinnon, 2008), providing the possibility for northward migration of species. The north-south orientation of the main mountain ranges — Khazratisho and Darvaz ranges (Fig. 3.2) also creates favorable conditions for 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, contributes to the variety of habitats with different climatic conditions, increasing opportunities 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 (Safarov pers. comm.).

Though the area of *Dashtidjum Zakaznik* is not large, it can be characterised by good connectivity with surrounding natural landscapes that may provide suitable habitats for migrating animals. In particular, it is connected to *Dashtidjum Zapovednik* (strict nature reserve) and serves as a migratory corridor for many mammal species that can be observed on the territory of both protected areas, including urial, markhor, and Tien-Shan brown bear (Safarov et al., 2008). Areas located to the north of the *zakaznik*, along the Khazrat-isho 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 large mammals such 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 document developed in 2006 (GRT, 2006). It should be highlighted that despite relatively good connectivity with the surrounding areas, many migration routes, 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' likelihood to persist. They are represented by anthropogenic activities, in particular poaching, tree cutting and livestock grazing (Safarov et al., 2008). While the first two activities lead to the direct destruction of animal and plant species, livestock grazing is the main cause of habitat degradation, as well as facilitating the spread of invasive species. Livestock disrupts the reproduction of valuable plant species by trampling and grazing young sprouts, as well as reducing the forage abundance for wild ungulates, which ultimately influences their population size. Tree cutting results not only in a loss of valuable tree species, which have global importance as genetic resources, 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. Many 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 surfaces that have lost their vegetation cover. It is therefore important to minimise anthropogenic pressure on the *zakaznik* to ensure the implementation of conservation measures as well as adaptation strategies aimed to minimise climate change impacts.

Adaptation measures and conditions for their implementation

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. 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. These measures, among others, include the expanding of existing protected areas networks, increasing connectivity among natural habitats, as well as development of matrix and buffer zones around protected areas to minimise anthropogenic pressure on wildlife.

Options for expansion

Expansion of protected areas networks has been proposed as a tool to address the problem of species loss 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 fulfilment of their conservation objectives and maintaining biodiversity representation targets in the face of range shifts (Hannah et al., 2002; Hannah, 2008; Hodgson et al., 2009). 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). Although expansion of the network is not a 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).

Analyses of legislation and strategic documents of the Republic of Tajikistan aimed at biodiversity conservation and enhanced management of protected areas shows that there are many prerequisites for the development and implementation of climate change adaptation strategies both at the national and local level. According to the *Law on Protected Areas* (1996), protected areas are owned only by the state and are managed by competent national authorities designated for this purpose. It 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 *zakazniks,* which can be done by the government following a 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 *zakazniks* does not contradict the Law, which is confirmed by a number of recent documents approved by the Government, including the State Program on Protected Areas Development in 2005–2015, adopted in 2005. 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. 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. 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*, as well as its reorganisation into *Obiniou National Nature Park*, is the Econet document (GRT, 2006). 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). The suggested extension and incorporation of areas located at higher latitudes (see Fig. 3.6) provide a significant contribution to mitigation of climate change impacts on the *zakaznik*.

Following the Econet provisions, the necessity to expand *Dashtidjum Zakaznik*, as well as to raise its protection status, has been emphasised within the *Dashtidjum Zakaznik* Management Plan. This official document has been agreed by various stakeholders and 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). It also provides the detailed nature conservation zoning of the current territory of the *zakaznik*, as well as the area suggested for its extension based on a comprehensive analysis of the current distribution of rare and endangered species, as well as socio-economic activities in the region (Fig. 3.6). In addition to buffer zones and ecological corridors, 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 rare and endangered species (core areas of the first order), as well as valuable ecosystems and wild relatives of cultural crops (core areas of the second order), and are excluded from any economic activity (Safarov et al., 2008; Shermatov pers. comm.).

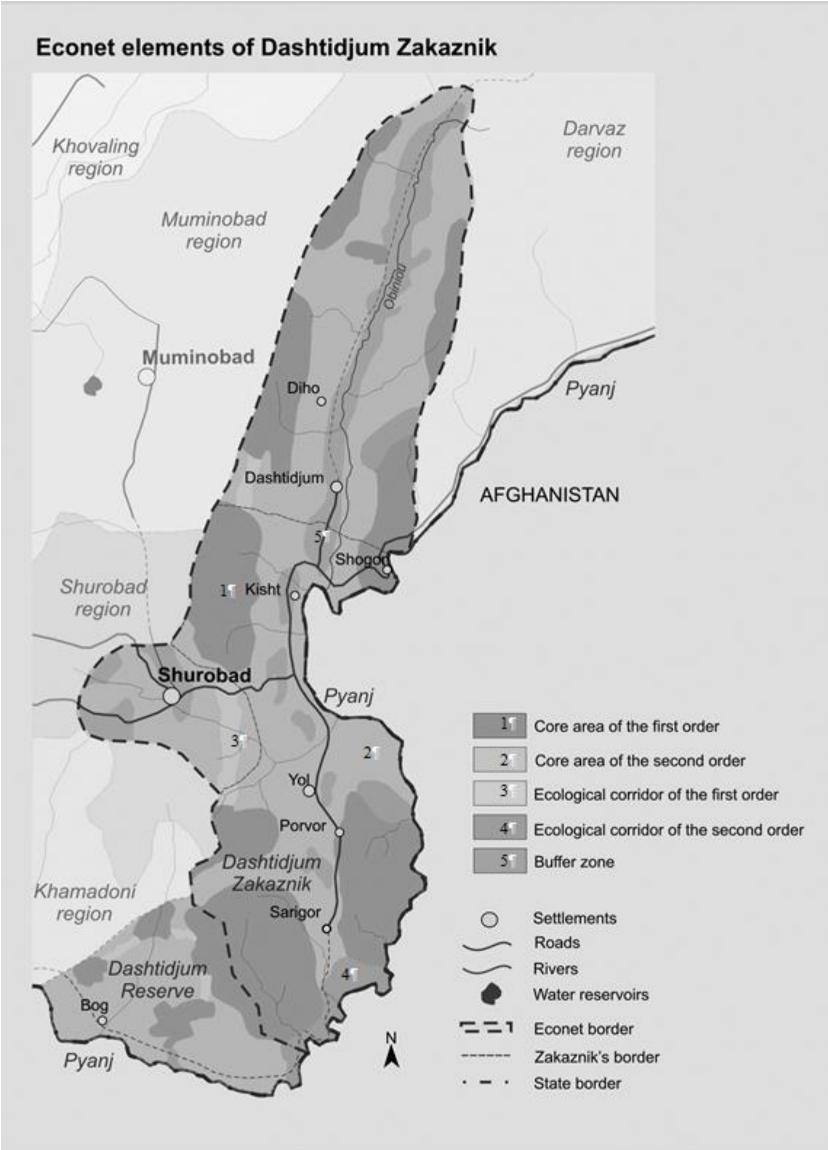

Fig. 3.6. Econet elements of Dashtidjum Zakaznik
Source: Adapted from Noosfera, 2008

Despite the documents mentioned above, 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). While the extension of the *zakaznik* may considerably contribute to adaptation of biodiversity to climate change impacts, it can also trigger tensions over land use and consequent violations of the protection regime. On one hand, national legislation allows establishment of *zakazniks* without withdrawal of land from current land users (see above) which can minimise conflicts with local communities. On the other hand, such shifts in conservation regime imply certain limitations on the use of natural resources, which can affect the livelihoods of local resource-dependent communities. Taking into account the current poor socio-economic conditions in the country and associated frequency of protection regime violations (Safarov et al., 2008), the extension of the *zakaznik* itself cannot ensure effective biodiversity conservation if implemented in isolation from other measures.

Increasing connectivity

The concept of connectivity is conceived from the assumption that organisms require 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 overemphasised, 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 solely creating corridors (Hodgson et al., 2009).

Unlike extension measures, the national documents that emphasise 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). These corridors have been identified along with core areas and buffer zones, and aim to link core areas to ensure sustainable links between species populations and habitats of sufficient size (Pereladova et al., 2006). Meanwhile, corridors are usually located within or in close proximity to existing and/or proposed protected areas, and do not connect reserves located in different parts of the country, which is rational considering its mountainous landscape. Though the idea of connectivity in this case is a bit different from the more extensive concept described above, the designated corridors can contribute to the adaptation to climate change impacts by providing pathways for migration to the northern parts of those protected areas that do not prohibit economic activities.

An approach similar to Econet has been employed for the development of the Management Plan of *Dashtidjum Zakaznik*, in particular its nature conservation zoning. Several migration corridors were suggested to connect core areas located within the current area, as well as in the territory of *Dashtidjum Zapovednik*, and the area proposed for *zakaznik* extension (Fig. 3.6). The corridors of the first order aim to ensure connection between core areas of the first order; and the corridors of the second order connect core areas of first order with core areas of second order (Safarov et al., 2008). The corridors also do not extend beyond the proposed protected area border and aim to provide reliable pathways to wild animals by limiting economic activities on their territories. If implemented, it would contribute to biodiversity conservation on the territory of *Dashtidjum Zakaznik*, as well as species' adaptation to climate change.

At the same time, the country is quite far from the actual establishment and management of migration corridors. There are no guidelines or procedures that can help responsible authorities to enforce such provisions, and thus there is a high probability that they will remain on paper only at least within the current decade. Moreover, taking into account various challenges that are being faced by nature protection authorities, including lack of funds, personnel and equipment, as well as lack of enforcement of the already established protection regime (Safarov et al., 2003), management of the migration corridors within protected areas may not receive priority. Nevertheless, considering the approach taken during the development of both documents, in particular designation of corridors based on information about current pathways for animal migrations as well as economic activities in the region, maintaining these corridors may not require significant additional efforts and funding.

Management of matrix area

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 areas combine diverse 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 various species, rather than facilitating the movement of specific species or ecosystem types (Hannah et al., 2002).

Inappropriate management of the matrix area could make the landscape also highly permeable for invasive 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 increasingly important role in supporting species shifts and may contain the only habitat available for species (Hannah, 2008; Willis & Bhagwat, 2009).

Although management of matrix areas *per se* is not reflected in any national legislation or strategic documents, there are a number of provisions concerning buffer zones. The main purpose of the buffer zone is to minimise the negative effect of economic activities on natural objects and complexes of reserves (Law on Nature Protection, 1993; Law on Protected Areas, 1996). Thus, economic activity within buffer zones is restricted, and in some cases prohibited. At the same time, the documents stipulate the establishment of buffer zones only for *zapovedniks*, and not for *zakazniks* (Law on Nature Protection, 1993; Law on Protected Areas, 1996; SCEPF, 2005). Similarly, the NEAP, as well as NBSAP, lists only the rehabilitation of buffer zones of some reserves as a priority measure for biodiversity conservation (Safarov et al., 2003, 2006). Further, the NBSAP also emphasises the need to develop regulations on buffer zones for the entire national network of protected areas (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, specific land use regulations with 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 (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 adjacent areas. The latter, however, is difficult due to the complex administration of the area that is divided between four administrative regions: Khamadoni, Shurobad, Muminobad and Darvaz (Fig. 3.6).

Other measures

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 emphasised 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 (Makhmadaliev et al., 2003; Safarov et al., 2003). The Management Plan of *Dashtidjum Zakaznik* provides a detailed Monitoring Plan which, if implemented, would significantly contribute to the understanding of species' responses to climate change on its territory (Safarov et al., 2008).

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. In such conditions, support of international organisations and donor agencies plays an important role in overcoming the challenges of, and building capacity for, biodiversity conservation and adaptation to climate change impacts. The situation has already been slowly improving as a result of several projects implemented (and being implemented) with the support of Global Environment Facility, United Nations Development Programme, United Nations Environment Programme, World Bank and other international organisations. Although a number of monitoring programs have been developed with this support, including for *Dashtidjum Zakaznik*, their long-term implementation requires not only sustained funding, but also integration into other sectoral programs and policies.

3.2.5. Conclusions on the case study

Driver: Analyses of meteorological data confirmed a warming trend of annual mean temperature, which constitutes 0.8 °C from 1961–2008 and has a tendency for further increase. Combined with anomalies in precipitation, 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.

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

State: Climate change impact on the biodiversity of the *zakaznik* varies. A majority of species, in particular rare and endangered species, may experience population declines and some even extinction. The most vulnerable are mammals, and 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 plants to climate change are mainly represented by temporal shifts of phenological events, including the advancement of the vegetation period and its shortening, and shifts in distribution ranges. Responses of animal species include changes in distribution ranges and population sizes, as well as phenological changes, including disruption of hibernation and aestivation.

Impact: Climate change impacts on biodiversity of *Dashtidjum Zakaznik* have direct implications for its management. In particular, a number of key species for biodiversity conservation, i.e. markhor, snow leopard and Turkestan lynx may vacate 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 shifting with an increasing 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.

Response: Analyses of relevant national legislation and strategic documents aimed at biodiversity conservation and enhanced management of protected areas indicates 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, development of buffer zones and migration corridors. Implementation of these measures will allow securing suitable habitats 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, which, if implemented, would significantly contribute to the understanding of species' responses to climate change on its territory.

3.2.6. Recommendations to policy-makers

Taking into account the adverse effects of climate change on the biodiversity of *Dashtidjum Zakaznik*, it is important to implement 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 to the top of the mountain range, but to also incorporate the northern slopes of the Khazratisho range.

It is also vital to implement provisions on the designation of buffer zones and migration corridors envisaged by the Econet document and the *Dashtidjum Zakaznik* Management Plan, as they will minimise the negative impact on species and ecosystems from anthropogenic activities and enhance conditions for species' migrations both altitudinally and northward. It is also essential to raise the status of the *zakaznik* as it will help to reduce the negative impacts from human activities. In general, it is highly critical to minimise the anthropogenic pressure on the ecosystems and species of *Dashtidjum Zakaznik*, in particular livestock grazing, tree cutting and poaching, as it constrains species adaptation to climate change and considerably aggravates its consequences. This can be accomplished, *inter alia*, by implementing programs to raise awareness and by involvement of local communities in biodiversity conservation activities.

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 *Dashtidjum Zakaznik* Management Plan, including phenological observations. Appropriate indicator species on the territory of the *zakaznik* include species highly sensitive to changes in climatic parameters, such as urial, Siberian ibex, ring dove, steppe tortoise, as well as birch and Turkestan maple that may provide valuable information on species response to e. g. distribution shifts. 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. This includes emphasising the importance of implementing adaptation measures to mitigate climate change impacts and to envisage concrete action plans for such measures, including within existing management plans of protected areas where climate change impacts are not considered.

References

Abdusaljamov I., Narzikulov M., Rasulova M., Danijarov M., Davydov G., Isakov S., Sokov A., Sapojnikov G., Kamelin R., Unusov S., & Vihrestjuk V. (Eds.). (1988). *Red Data Book of Tadjik SSR*. Dushanbe: Donish.

Araujo M., Thuiller W., & Pearson R. (2006). Climate warming and the decline of amphibians and reptiles in Europe. *Journal of Biogeography 33*, 1712–1728.

Asanova V. (2010a). *Izmenenie climaticheskih uslovii v tselevyh raionax proekta* [*Climate change at the project's target sites*]. Internal report. Available from the National Biodiversity and Biosafety Center, Dushanbe.

Asanova V. (2010b). *Prirodno-klimaticheskie osobennosti Tadjikistana i tselevyh rayonov proekta* [*Natural and climatic con-

ditions of Tajikistan and target project sities]. Internal report. Available from the National Biodiversity and Biosafety Center, Dushanbe.

Auld T. & Keith D. (2009). Dealing with threats: Integrating science and management. *Ecological Management and Restoration 10*, 79–87.

Bickford D., Howard S., Ng D., & Sheridan J. (2010). Impacts of climate change on the amphibians and reptiles of Southeast Asia. *Biodiversity and Conservation 19*(4), 1043–1062.

Brook B., Sodhi N., & Bradshaw C. (2008). Synergies among extinction drivers under global change. *Trends in Ecology and Evolution 23*(8), 453–460.

Burns C., Johnston K., & Schmitz O. (2003). Global climate change and mammalian species diversity in U.S. national parks. *PNAS 100*(20), 11474–11477.

Christensen J., Hewitson B., Busuioc A., Chen A., Gao X., Held I., Jones R., Kolli R., Kwon W.-T., Laprise R., Rueda V., Mearns L., Menendez C., Rasaen J., Rinke A., Sarr A., & Whetton P. (2007). Regional climate projections. In S. Solomon D. Qin M. Manning Z. Chen M. Marquis K. Averyt M. Tignor, & H. Miller (Eds.), *Climate change 2007: The physical science basis. Contribution of working group I to the fourth assessment report of the Intergovernmental Panel on Climate Change* (pp. 847–940). Cambridge: Cambridge University Press.

Committee on Environment Protection (CEP). (2009). *Gosudarstvennaja ecologicheskaya programma Respubliki Tadjikistan na 2009–2019 gody* [*State ecological program of the Republic of Tajikistan for the period 2009–2019*]. Dushanbe: Committee on Environment Protection of the Government of the Republic of Tajikistan.

Crick H. (2004). The impact of climate change on birds. *Ibis 146*(s1), 48–56.

European Environment Agency (EEA). (1998). *EU state of the environment report 1998. Guidelines for data collection and processing*. Copenhagen: European Environment Agency.

Fischlin A., Midgley G., Price J., Leemans R., Gopal B., Turley C., Rounsevell M., Dube O., Tarazona J., & Velichko A. (2007).

Ecosystems, their properties, goods, and services. In M. Parry, O. Canziani J. Palutikof P. van der Linden, & C. Hanson (Eds.), *Climate change 2007: impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the Intergovernmental Panel on Climate Change* (pp. 211–272). Cambridge: Cambridge University Press.

Government of the Republic of Tajikistan (GRT). (2006). *Ecological Network of Tajikistan.* Available from the National Biodiversity and Biosafety Center, Dushanbe.

Guariguata M. (2008). Interlinkages between biodiversity and climate change. In *Migratory species and climate change: Impacts of a changing environment on wild animals* (pp. 8–11). Bonn: United Nations Environment Programme/Secretariat of the Convention on the Conservation of Migratory Species of Wild Animals.

Hagerman S., Dowlatabadi H., Satterfield T., & McDaniels T. (2010). Expert views on biodiversity conservation in an era of climate change. *Global Environmental Change 20*, 192–207.

Hannah L. (2008). Protected areas and climate change. *Annals of the New York Academy of Sciences 1134*, 201–212.

Hannah L., Midgley G., & Millar D. (2002). Climate change-integrated conservation strategies. *Global Ecology & Biogeography 11*, 485–495.

Heino J., Virkkala R., & Toivonen H. (2009). Climate change and freshwater biodiversity: detected patterns, future trends and adaptations in northern regions. *Biological Reviews 84*, 39–54.

Heller N. & Zavaleta E. (2009). Biodiversity management in the face of climate change: A review of 22 years of recommendations. *Biodiversity Conservation 142*, 14–32.

Hodgson J., Thomas C., Wintle, B., & Moilanen, A. (2009). Climate change, connectivity and conservation decision making: back to basics. *Journal of Applied Ecology 46*, 964–969.

Intergovernmental Panel on Climate Change (IPCC). (2007). *Climate change 2007: The physical science basis. Contribution of working group I to the fourth assessment report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

International Union for Conservation of Nature (IUCN). (1994). *Guidelines for protected area management categories*. Gland: International Union for Conservation of Nature.

International Union for Conservation of Nature (IUCN). 2004. *Securing protected areas in the face of global change issues and strategies*. Gland: International Union for Conservation of Nature and Natural Resources.

International Union for Conservation of Nature (IUCN). 2010a. *The IUCN Red List of threatened species. Global extinctions due to climate change.* Retrieved from: [Electronic resource]: URL: http://www.iucnredlist.org/apps/redlist/search/link/4ba281f6-2b20a1c6 [consulted 11 September 2018].

International Union for Conservation of Nature (IUCN). 2010b. T*he IUCN Red List of threatened species. List of threatened species in Tajikistan.* Retrieved from: [Electronic resource]: URL: http://www.iucnredlist.org/apps/redlist/search/link/4bb9b22e-0b866ecb [consulted 5 April 2010].

Kokorin A., Kozharinov A., & Minin A. (Eds.). (2001). *Ecoregional climate change and biodiversity decline: Altai-Sayan ecoregion*. Moscow: World Wide Fund for Nature.

Krever V., Pereladova O., Williams M., & Jungius H. (Eds.). (1998). *Biodiversity conservation in Central Asia: An analysis of biodiversity and current threats and initial investment portfolio*. Moscow: World Wide Fund For Nature.

Law on Nature Protection. (1993). Majlisi Oli of the Republic of Tajikistan.

Law on Protected Areas. (1996). Majlisi Oli of the Republic of Tajikistan.

Leech D. & Crick H. (2007). Influence of climate change on the abundance, distribution and phenology of woodland bird species in temperate regions. *Ibis 149,* 128–145.

Lemieux C. & Scott, J. (2005). Climate change, biodiversity conservation and protected area planning in Canada. *The Canadian Geographer 49*(4), 384–399.

Lepetz V., Massot M., Schmeller D., & Clobert J. (2009). Biodiversity monitoring: some proposals to adequately study species' responses to climate change. *Biodiversity Conservation 18,* 3185–3203.

Mackinnon J. (2008). Species richness and adaptive capacity in animal communities: lessons from China. *Integrative Zoology 3,* 95–100.

Makhmadaliev B., Kayumov A., Novikov V., Mustaeva N., & Rajabov, I. (Eds.). (2008). *The Second national communication of the Republic of Tajikistan under the United Nations Framework Convention on Climate Change*. Dushanbe: State Agency for Hydrometeorology of the Committee for Environmental Protection.

Makhmadaliev B., Novikov V., Kayumov A., Karimov U., & Perdomo, M. (Eds.). (2003). *National action plan of the Republic of Tajikistan for climate change mitigation*. Dushanbe: Tajik Met Service.

Malcolm J. (1998). Biodiversity: species, communities, and ecosystems. In J. Feenstra, I. Burton, J. Smith, & R. Tol, *Handbook on methods for climate change impact assessment and adaptation strategies* (pp. 131–141). Nairobi: United Nations Envrionmental Programme.

Mawdsley, J., O'Malley, R., & Ojima, D. (2009). A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. *Conservation Biology 23*(5), 1080–1089.

Maxim L., Spangenberg J., & O'Connor M. (2009). An analysis of risks for biodiversity under the DPSIR framework. *Ecological Economics 69,* 12–23.

McCarthy J., Canziani O., Leary N., Dokken D., & White K. (Eds.). (2001). *Climate change 2001: Impacts, adaptation and vulnerability. Contribution of working group II to the third assessment report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

Millsap B., Gore J., Runde D., & Cerulean S. (1990). Setting priorities for the conservation of fish and wildlife species in Florida. *Wildlife Monographs 111,* 3–57.

Mkanda F. (1996). Potential impacts of future climate change on nyala *Tragelaphus angasi* in Lengwe National Park, Malawi. *Climate Research 6*(2), 157–164.

National Biodiversity and Biosafety Center (NBBC). (2003). *First national report on biodiversity conservation of the Republic of Tajikistan*. Dushanbe: National Biodiversity and Biosafety Center.

National Biodiversity and Biosafety Center (NBBC). (2009). *Fourth report on biodiversity conservation of the Republic of Tajikistan*. Dushanbe: National Biodiversity and Biosafety Center.

Noosfera. (2008). Maps of Dashtidjum Zakaznik. Internal database. Available from the Noosfera Association, Dushanbe.

Omann I., Stocker A., & Jager J. (2009). Climate change as a threat to biodiversity: An application of the DPSIR approach. *Ecological Economics 69*, 24–31.

Parmesan C. & Yohe G. (2003). A globally coherent fingerprint of climate change impacts across natural systems. *Nature 421*, 37–42.

Pereladova O., Krever V., & Shestakov A. (Eds.). (2006). *Econet Central Asia: web for life*. Moscow: World Wide Fund For Nature.

Root T., Price J., Hall K., Schneider S., Rosenzweig C., & Pounds J. (2003). Fingerprints of global warming on wild animals and plants. *Nature 421*, 57–60.

Rosenzweig C., Casass G., Karoly D., Imeson A., Liu C., Menzel A., Rawlins S., Root T., Seguin B., & Tryjanowski P. (2007). Assessment of observed changes and responses in natural and managed systems. In M. Parry, O. Canziani, J. Palutikof, P. van der Linden, & C. Hanson (Eds.), *Climate change 2007: impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the Intergovernmental Panel on Climate Change* (pp. 79–131). Cambridge: Cambridge University Press.

Safarov N., Asrorov I., Isufov U., Mahmadaliev B., Novikova T., & Khairullaev R. (2006). *National environmental action plan of the Republic of Tajikistan*. Dushanbe: Mir polygraphii.

Safarov N., Ismailov M., Karimov K., Novikova T., Idrisova A., Koimdodov K., Shokirov U., & Novikov V. (Eds.). (2003). *National strategy and action plan on conservation and sustainable use of biodiversity of the Republic of Tajikistan*. Dushanbe: National Biodiversity and Biosafety Center.

Safarov N., Novikova T., Sattorov R., Saidov A., Khairullaev R., Ustjan I., Zagrebelnyi I., Dustov D., & Shermatov K. (2008). *Plan upravlenja zakaznika Dashtidjum* [*Management plan of Dashtidjum Zakasnik*]. Dushanbe: National Biodiversity and Biosafety Center.

Saidov A. (2006). *Otsenka ujazvimosti fauny Tadjukistana k posledstvijam izmenenija klimata* [*Assessment of the vulnerability of the fauna of Tajikistan to the impacts of climate chage*]. Internal report. Available from the State Administration for Hydrometeorology, Dushanbe.

Scott D. (2004). Climate change and conservation: challenges at the science-management interface. In N. Munroe, T. Herman, K. Beaszley, & P. Dearden (Eds.), *Proceedings of the Fifth International Conference of Science and Management of Protected Areas* (pp. 1–7). Victoria: SAMPAA.

Secretariat of the Convention on Biological Diversity (SCBD). (2009). *Connecting biodiversity and climate change mitigation and adaptation: Report of the Second Ad Hoc Technical Expert Group on biodiversity and climate change. Technical Series № 41*. Montreal: Secretariat of the Convention on Biological Diversity.

State Administration for Hydrometeorology (SAH). (2010). *Dannye nabludenii meteorologicheskih stantsii za temperaturoi i atmosfernymi osadkami s 1940 po 2008 gody* [*Meteorological stations' observation data on air temperature and precipitations from 1940 to 2008*]. Available from the State Administration for Hydrometeorology, Dushanbe.

State Committee for Environment Protection and Forestry (SCEPF). (2005). *Gosudarstvennaya programma razvitija OOPT na 2005–2015* [*State program on protected areas development in 2005–2015*]. Dushanbe: Gosudarstvennyi Komitet Ohrany Okruzhajushei Sredy i Lesnogo Khozjaistva RT.

Thomas C., Cameron A., Green R., Bakkenes M., Beaumont L., Collingham Y., Erasmus B., Siqueira M., Grainger A., Hannah L., Hughes L., Huntley B., Jaarsveld A., Midgley G., Miles L., Ortega-Huerta M., Peterson T., Phillips O., & Williams S. (2004). Extinction risk from climate change. *Nature 427*, 145–149.

Valdez R. (2008a). *Capra falconeri*. IUCN Red List of threatened species. Version 2018-1. Retrieved from: [Electronic resource]: URL: http://www.iucnredlist.org/apps/redlist/details/3787/0 [consulted 11 September 2018].

Valdez R. (2008b). *Ovis orientalis*. IUCN Red List of threatened species. Version 2018-1. Retrieved from: [Electronic resource]: URL: http://www.iucnredlist.org/apps/redlist/details/15739/0 [consulted 11 September 2018].

Vitt P., Havens K., Kramer A., Sollenberger D., & Yates E. (2010). Assisted migration of plants: changes in latitudes, changes in attitudes. *Biological Conservation 143*, 18–27.

Willis K. & Bhagwat, S. (2009). Biodiversity and climate change. *Ecology 326*, 806–807.

Willis S., Hole D., Collingham Y., Hilton G., Rahbek C., & Huntley B. (2009). Assessing the impacts of future climate change on protected area networks: A method to simulate individual species' responses. *Environmental Management 43*, 836–845.

World Wide Fund for Nature Protection (WWF). (2008). *Econet — web for life*. Moscow: World Wide Fund for Nature Protection.

Zaumyslova O. (2006). Influence of climate change on population dynamics of large mammals in the Sikhote-Alinsky state nature reserve. In *Climate change impact on ecosystems of the Amur river basin* (pp. 76–82). Moscow: World Wide Fund for Nature.

Personal communications

Boboev Zikriyo. Head of the Hydrological Station "Khirmandjou", located on the territory of *Dashtidjum Zakaznik*. Informal interview. Dashtidjum, 17 April, 2010.

Dustov Saidakhmad. Deputy Head of the State Administration for Hydrometeorology. Formal interview. Dushanbe, 9 April, 2010.

Karimov Khurshed. Vice-President of the Academy of Sciences of the Republic of Tajikistan. Director of the Institute of Plant Physiology and Genetics, Academy of Sciences of the Republic of Tajikistan. Formal interview. Dushanbe, 13 April, 2010.

Faizov Ismoil. Community Development Specialist of the Aga Khan Foundation. Informal interview. Dashtidjum, 17 April, 2010.
Muminov Nuriddin. Senior Research Officer of the Institute of Zoology and Parasitology, Academy of Sciences of the Republic of Tajikistan. Formal interview. Dushanbe, 16 April, 2010.
Murodov Rustam. Senior Research Officer of the Institute of Zoology and Parasitology, Academy of Sciences of the Republic of Tajikistan. Formal interview. Dushanbe, 16 April, 2010.
Nadjmidinov Todjidin. Deputy Director of the Institute of Zoology and Parasitology, Academy of Sciences of the Republic of Tajikistan. Formal interview. Dushanbe, 16 April, 2010.
Safarov Neimatullo. Head of the Research Laboratory for Nature Protection, Committee on Environment Protection of the Government of the Republic of Tajikistan. Formal interview. Dushanbe, 16 April, 2010.
Saidov Abdusattor. Director of the Institute of Zoology and Parasitology, Academy of Sciences of the Republic of Tajikistan. Formal interview. Dushanbe, 14 April, 2010.
Sangov Radjabali. Head of the Department of Forest Protection, State Administration for Forestry and Wildlife Service of the Republic of Tajikistan. Phone communication. Dushanbe, 15 April, 2010.
Sattorov Rakhmatullo. Associate Professor of the Botany Faculty of the Tajik State National University. Formal interview. Dushanbe, 13 April, 2010.
Shermatov Khisrav. National Focal Point for CBD Programme of Work of Protected Areas, Head of the Department of National Biodiversity and Biosafety Center. Informal interview. Dushanbe, 13 April, 2010.
Ustjan Ivan. Head of Department on Reserves and National Parks of the State Administration on Protected Areas, Committee on Environment Protection of the Government of the Republic of Tajikistan. Formal interview. Dushanbe, 14 April, 2010.
Zagrebelnyi Ivan. Deputy Director of the Research Pharmaceutical Center of the Ministry of Healthcare of the Republic of Tajikistan. Former specialist on protected areas of the State Agency “Tajik National Park”. Informal interview. Dushanbe, 8 April, 2010.