ALPBIONET2030

Integrative Alpine wildlife and habitat management for the next generation

Climate change effects on migratory species in the Alps and the EUSALP territory and their need of permeable landscapes

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Introduction

Climate change is readily observable in the Alps. Mountainous regions and the species that inhabit them are dependent on and defined by climatic conditions that vary along elevation gradients. As a result, changes in climatic parameters have a strong impact on both the physical environment and the living world.

Rapid changes in the climate have been recorded on a global scale since the beginning of the industrial era. These developments are characterized by increases in temperatures, changes in precipitation patterns and an increase in the frequency and intensity of extreme climatic events (heat waves, droughts).

The effects of climate change on alpine flora and fauna are noticeable and are already contributing to changes in species distribution and abundance, as well as the timing of seasonal events. Will biodiversity be able to adapt to these rapid climate change-related changes in their environment? Combined with habitat disturbance caused by human activities, climate change is the main challenge faced today by plant and animal species.

In order to survive changes in climate, species can either migrate to follow the climatic conditions to which they are best suited, or they can change their physiology or seasonal behaviour to adapt to new environmental conditions.

Over the past few decades, with the warming of the climate, a rise in elevation of most animal species has been observed, ranging between 30m to 100m per decade. In addition, a shift of species distribution ranges towards the north can be observed.

Species need to adapt to the new climatic conditions and their effects on ecosystems by moving towards areas offering them the requested adapted living conditions. In this context they may be confronted with landscape fragmentation and its effects on landscape permeability, hindering necessary migration possibilities.

The link between ecological connectivity and climate change has been highlighted by the experts of the Alpine Convention working group on ecological connectivity (see document next page). It is clearly stated that, in order to best preserve the alpine biodiversity, ecological connectivity is a key factor.

Nevertheless, clear scientific evidence on how climate change affects alpine migratory species, which migratory processes are ongoing and how exactly ecological connectivity affects them is still lacking. Therefore, in the frame of the ALPBIONET2030 project only first attempts of answering to these interrogations could be started. The present report presents two papers offering first elements to address the issue by studying different type of species and their adaptation of the climate change effects.

ALPINE CONVENTION

Permanent Secretariat of the Alpine Convention info@alpconv.org www.alpconv.org

The Important Role of Ecological Connectivity for Adaptation to Climate Change Impacts in the Alps

A statement by the

Platform "Ecological Network" of the Alpine Convention

Climate change in alpine-ecosystems

Climate is one of the most important abiotic factors influencing ecosystems, and alpine systems are in particular sensitive to climate change. The prevailing populations of plants and animals are highly adapted to site characteristics. Other than lowlands, alpine systems - due to their topography - have many sites with a specific microclimate. This is one of the reasons for the high biodiversity, but also for the vulnerability towards climatic change. In the European Alps, temperatures increased by 2 °C in the last hundred years - twice the global average. As a result suitable habitats are reduced and species are forced to move to higher altitudes where temperatures are more conductive to their survival.

Impacts of habitat shifts on species

Shifts in habitat ranges can induce a range expansion for some species, for others it means a range reduction or a movement into less hospitable habitats or increased competition. Some species will have nowhere to move as they are already at the extreme margin of their habitat. In many cases movements will confront species with geographical obstructions or man-made barriers, which will need to be overcome. For numerous species, the climate of their habitat - or different habitats they use over the year - influences key stages of their annual life cycle, such as migration, blooming, and mating. The changing climate conditions can lead to mismatches in the timing of life cycle events, making growth or survival more difficult or even impossible.

Consequences of biodiversity loss for alpine-ecosystems and their services

A loss of biodiversity in the Alps, as induced by climate change, decreases the resilience of the entire ecosystem. A high number of species - as species are considered a major component part of the system - ensures the functionality of the ecosystem. Its multi-functionality can be achieved by supporting and regulating ecosystem services (such as pollination, pest, flood, and erosion control), which also provide for cultural, recreational and aesthetic ecosystem services. Furthermore, the direct and indirect effect of climate change also interacts with other stressors, which cause only minor impacts when acting alone, but their cumulative impact may lead to dramatic ecological changes intensified by the loss of biodiversity.

Ecological connectivity – a necessary response to climate change in the Alps

In order to increase ecosystem resilience and to avoid species extinction, it is crucial to provide plant and animal species with sufficient space and favorable conditions to shift their areas of occurrence. As natural colonization by species is the result of dispersal movements of individuals from a neighboring population, such a process could be promoted by providing habitat and habitat connectivity.

The pan-alpine ecological network aims to interlink existing protected areas - as main areas for species conservation - and to improve the permeability of the landscape matrix, by creating natural elements in a landscape in the form of corridors or stepping stones. As these measures enhance the colonizing capacity of alpine species, which are sensitive to climate change, they are key element to climate change adaptation.

Necessity of a trans-sectorial approach

The main artificial barriers to ecological connectivity are settlements and transport infrastructures. Land use for other purposes such as agriculture, energy production or distribution, or tourism can also hinder the movement of animal and plant species. An integrated spatial planning is thus needed to provide suitable corridors for the fauna and flora between protected areas.

Creating a coherent network of existing protected areas, embedded in a multifunctional landscape allowing mutual support, can only be effective when implemented at a multinational level throughout the entire mountain range.

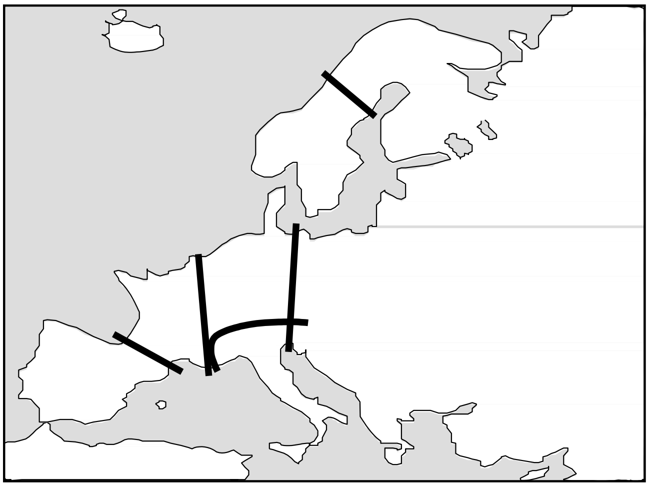
A. Importance of ecological connectivity between Alps and Dinaric Mountains in view of climate changes

dr. Irena Bertoncelj, dr. Igor Dakskobler, dr. Aleš Poljanec

1 Historic importance of the Balkan Peninsula as glacial refugia

One of the three major European peninsulas (Iberian, Italian and Balkan) acted as glacial refugia to almost all European species of Mediterranan origin (Schmitt, 2007). Among the four different paradigms of postglacial re-colonisation of Central and Northern Europe by Mediterranean species, the Balkans played a role in three of these (Hewitt, 1999; Schmitt, 2007): the **“hedgehog”** (postglacial expansion from all three southern European differentiation centres), the **“butterfly”** (expansion of the Adriatic- and the Pontic-Mediterranean lineages, but trapping of the Atlantic-Mediterranean lineage by the Pyrenees), the **“grasshopper”** (major expansion to Central Europe only from the Balkans and trapping of the Atlantic- and Adriatic-Mediterranean lineages by the Pyrenees and Alps, respectively). In the “grasshopper” example the importance of the Balkan Peninsula is most pronounced which has been shown for species such as black alder (*Alnus glutinosa*), common beech (*Fagus sylvatica;* (Magri, 2008)) and great crested newt (*Triturus cristatus*).

During the postglacial range expansion, the species from the Pontic-Mediterranean refugia in the south of the Balkan peninsula came into secondary contact with species from other refugia (Taberlet, Fumagalli, Wust-Saucy, & Cosson, 1998) along the **eastern Central Europe suture-zone** running along the eastern borders of Germany and through the eastern Alps (Schmitt, 2007). The south end of this hybridization zone runs roughly along the border between Alps and Dinaric Mountains.



Source of figure: Schmitt, Frontiers in zoology 2007, 4/11

The role of the Balkan Peninsula as a glacial refugium, its high environmental stability, topographic and climatic diversity and the presence of land bridges underline the complex processes leading to high levels of endemism and high importance as **biodiversity hotspot of Europe** (Griffiths, Kryštufek, & Reed, 2004).

2 Mountain ranges of the Balkan Peninsula

The current topographic configuration of the Balkans is largely a function of Alpine orogenic activity. Almost 70 % the Balkan Peninsula is high relief comprising several mountain chains: Dinaric Mountains in the west, Pindus Mountains in the south, the southerly Carpathian Bend, Balkan Mountains, Rhodopes (Griffiths et al., 2004).

The Dinaric Mountains run in the NW-SE direction and **merge with southern Julian Alps in Slovenia without a clear boundary**. From geological perspective a part of Julian Alps belongs to Dinaric Mountains which are dominated by carbonate rocks (Griffiths et al., 2004).

3 Exchange of species between the Alps and Dinaric Mountains in view of climate change

3.1 Plants

There are no clear and sharp borders between the Alpine and Dinaric flora and vegetation which meet in the area of Slovenia. This is apparent both on the levels of species and plant communities. For example typical Dinaric forest community (*Seslerio autumnalis-Fagetum*) can also be found in the southern Julian Alps (in the valleys of Zadlaščica, Kneža and Bača (Dakskobler, 1991, 1997)) and even on foothills of the Savinja Alps (Seliškar & Dakskobler, 2013). On the other hand, black pine community typical of the South-Eastern Alps (*Fraxinio orni-Pinetum nigrae*) grows also on the northern edge of Dinaric Mountains (Trnovski Gozd, hills south of Ljubljana and valley of river Iška (Accetto, 2010; Dakskobler, 1998, 1999).

Similarly, the transition of plant species is not sharp with some typically Alpine species growing in the northern edge of Dinaric Mountains: European larch (*Larix decidua*), *Campanula zoysii* and *Aquilegia iulia.* There are also several opposite examples where typically Dinaric plant species grow on the southern fringes of the Alps: *Rhamnus fallax* which also grows in the Southeastern Alps (Slovenia, south Austria and northeastern Italy); *Drypis spinosa* subsp*. jacquiniana, Hypericum richeri* subsp. *grisebachii* and *Cardamine glauca* which can be found in the Kamnik Alps (Wraber, 1995, 2007).

This area therefore provides a transition zone between two floristic groups in which ecological connectivity is especially important. The later example of Dinaric species already reaching the southern fringes of the Alps provides an incentive for maintaining this link in the future especially in view of climatic changes. Although it is very difficult to estimate sensitivity of individual species to climate change these Dinaric species have a potential to spread towards the higher elevations in the Alps.

3.2 Animals

The same pattern as with plants could be noticed also within different animal taxa. According to predicted shifts in vegetation, the ecological niches of many animal species will change. The most threatened will probably be species bound to cooler and more humid habitats. A typical example is Western Capercaillie (*Tetrao urogallus*).

Capercallie adult male, foto: Miran Krapež, Source: LIFE-Kočevsko website

This large bird species of the Grouse family is confined to the Palearctic region of the Eurasia east to c 125°E. It is still relatively abundant in the northern boreal forest, where it has a contiguous distribution. However, south-central and western European populations are highly fragmented and reduced (EU Wildlife and Sustainable Farming project, 2009). Species is included in Annex I of the EU Birds Directive and is therefore subject of special conservation measures concerning their habitat in order to ensure their survival and reproduction.

In Slovenia capercaillie breeding sites (leks) were present at the south-eastern edge of the Alpine metapopulation and at north-western edge of Dinaric metapopulation (Čas, 2010). Regular monitoring of capercaillie population at leks by hunters and foresters revealed a decline in the number of leks in the Eastern Slovenian Alps and Julian Alps between 1980 – 2000, after which the population stabilized (Čas, Kobler, & de Groot, 2017). However, the number of leks in the Dinaric Mountains in the south of Slovenia declined steeply throughout the entire monitoring period 1980 – 2010 (Čas et al., 2017). A similar trend was recorded in the Dinaric Mountains of Croatia (Frković, 2012). In 2015 monitoring of capercaillie in Kočevsko Natura 2000 areas in southern Slovenia did not record any remaining active leks (Potočnik, Perušek, & Kos, 2015).

Hunters and foresters listed several potential reasons for capercaillie decline in Slovenia such as logging of old growth forests, increase in the number of predators (martens, wild boar) and increase in mountain tourism (Čas, 2010). Among other factors climate change also seems to be affecting capercaillie populations with some studies showing a decline in reproductive success (Baines, Aebischer, & Macleod, 2016; Jahren, Storaas, Willebrand, Fossland Moa, & Hagen, 2016; Selås et al., 2011) but others with opposite effects (Wegge & Rolstad, 2017).

If climate change is an important factor driving the decline of capercaillie population in the Dinaric Mountains, the importance of ecological connectivity between the Alpine and Dinaric population will increase. In the future the Alpine population will present a potential source of individuals for recolonization of the habitats in the Dinaric Mountains.

4 Conclusions

Predictions of future climate change impacts in different parts of Europe under +1.5°C and +2°C scenarios foresee strongest warming in North-Eastern Europe including the Balkan Peninsula (Jacob et al., 2018). In addition models predict a strong decrease in precipitation in the summer months in parts of the Balkans (Jacob et al., 2018). Unsurprisingly the models also showed that under +2°C global warming the most vulnerable regions are ecosystems of the Balkans, Italy and Eastern Europe (Jacob et al., 2018).

Climate change will influence species physiology, phenology and distribution (Bellard, Bertelsmeier, Leadley, Thuiller, & Courchamp, 2012) resulting in extinction for those unable to adapt. Estimates of extinctions due to climate change are alarming. (Thomas et al., 2004) predicted that 15-37 % of species will be committed to extinction by 2050 on the basis of mid-range climate-warming scenarios.

One of the ways species are adapting to climate change is by shifting their range (Hughes, 2000). Due to large difference in elevation in mountain regions the obvious shift is expansion to higher elevations as has been shown in models and confirmed in reality (Chen et al., 2009; Pauli, Gottfried, Reiter, Klettner, & Grabherr, 2007).

Models of climate change threats for European plant species showed projected habitat loss is greater for species distributed at higher elevations (Engler et al., 2011; Thuiller, Lavorel, Araujo, Sykes, & Prentice, 2005). Depending on the climate scenario, (Engler et al., 2011) found 36–55% of alpine species, 31–51% of subalpine species and 19–46% of montane species will lose more than 80% of their suitable habitat by 2070–2100.

We conclude that maintaining ecological connectivity between Dinaric Mountains and the Alps will be especially important for species living at higher elevations in mountain ranges of the Balkan Peninsula. Ecological connectivity with the Alps will present a potential for their spread towards the north and towards higher elevations in the Alps.

Well-preserved forests and landscape mosaics as well as large Natura 2000 areas in the area connecting Julian Alps with Dinaric Mountains are an important background to preserve ecological connectivity. Close to nature forest management with integrated biodiversity conservation, extensive agricultural practices and harmonized landscape management are key tools for ensuring long term connectivity in this region.

5 References

Accetto, M. (2010). Rastlinstvo Iškega Vintgarja. Praprotnice in semenke. *Folia Biologica et Geologica*, *51*(4).

Baines, D., Aebischer, N. J., & Macleod, A. (2016). Increased mammalian predators and climate ch1ange predict declines in breeding success and density of Capercaillie *Tetrao urogallus*, an old stand specialist, in fragmented Scottish forests. *Biodiversity and Conservation*, *25*(11), 2171–2186. doi: 10.1007/s10531-016-1185-8

Bellard, C., Bertelsmeier, C., Leadley, P., Thuiller, W., & Courchamp, F. (2012). Impacts of climate change on the future of biodiversity: Biodiversity and climate change. *Ecology Letters*, *15*(4), 365–377. doi: 10.1111/j.1461-0248.2011.01736.x

Čas, M. (2010). Distrubances and predation on capercaillie at leks in Alps and Dinaric Mountains. *Šumarski List*, (9–10).

Čas, M., Kobler, A., & de Groot, M. (2017). Evaluating the spatiotemporal indicators of the population decline of a threatened large forest grouse. *European Journal of Wildlife Research*, *63*(3), 45. doi: 10.1007/s10344-017-1099-0

Chen, I.-C., Shiu, H.-J., Benedick, S., Holloway, J. D., Chey, V. K., Barlow, H. S., … Thomas, C. D. (2009). Elevation increases in moth assemblages over 42 years on a tropical mountain. *Proceedings of the National Academy of Sciences*, *106*(5), 1479–1483. doi: 10.1073/pnas.0809320106

Dakskobler, I. (1991). Gozd bukve in jesenske vilovine - *Seslerio autumnalis-Fagetum* (Ht. 1950) M. Wraber (1957) 1960 v submediteransko-predalpskem območju Slovenije. *Scopolia*, (24).

Dakskobler, I. (1997). Geografske variante asociacije *Seslerio autumnalis-Fagetum* (Ht.) M. Wraber ex Borhidi 1963. *Razprave 4. Raz. SAZU*, *38*(8).

Dakskobler, I. (1998). *Vegetacija gozdnega rezervata Govci na severovzhodnem robu Trnovskega gozda (zahodna Slovenija)*. Conference Proceedings. The 19th Forestry Days, Univeristy of Ljubljana, Ljubljana, pp. 269-301.

Dakskobler, I. (1999). Contribution to the knowledge of the association *Fraxino orni-Pinetum nigrae* Martin-Bosse 1967. *Wissenschaftliche Mitt. Niederösterr. Landesmuseum*, *12*.

Engler, R., Randin, C. F., Thuiller, W., Dullinger, S., Zimmermann, N. E., AraúJo, M. B., … Guisan, A. (2011). 21st century climate change threatens mountain flora unequally across Europe: CLIMATE CHANGE IMPACTS ON MOUNTAIN FLORAE. *Global Change Biology*, *17*(7), 2330–2341. doi: 10.1111/j.1365-2486.2010.02393.x

EU Wildlife and Sustainable Farming project. (2009). *Capercaillie - Tetrao urogallus factsheet*.

Frković, A. (2012). *Tetrijeb gluhan u Gorskom kotaru*. Rijeka: Lovački savez Primorsko-goranske županije.

Griffiths, H. I., Kryštufek, B., & Reed, J. M. (Eds.). (2004). *Balkan biodiversity: pattern and process in the European hotspot*. Dordrecht: Kluwer Acad.

Hewitt, G. M. (1999). Post-glacial re-colonization of European biota. *Biological Journal of the Linnean Society*, *68*(1–2), 87–112. doi: 10.1111/j.1095-8312.1999.tb01160.x

Jacob, D., Kotova, L., Teichmann, C., Sobolowski, S. P., Vautard, R., Donnelly, C., … van Vliet, M. T. H. (2018). Climate Impacts in Europe Under +1.5°C Global Warming. *Earth's Future*, *6*(2), 264–285. doi: 10.1002/2017EF000710

Jahren, T., Storaas, T., Willebrand, T., Fossland Moa, P., & Hagen, B.-R. (2016). Declining reproductive output in capercaillie and black grouse – 16 countries and 80 years. *Animal Biology*, *66*(3–4), 363–400. doi: 10.1163/15707563-00002514

Magri, D. (2008). Patterns of post-glacial spread and the extent of glacial refugia of European beech (*Fagus sylvatica*). *Journal of Biogeography*, *35*(3), 450–463. doi: 10.1111/j.1365-2699.2007.01803.x

Pauli, H., Gottfried, M., Reiter, K., Klettner, C., & Grabherr, G. (2007). Signals of range expansions and contractions of vascular plants in the high Alps: observations (1994?2004) at the GLORIA master site Schrankogel, Tyrol, Austria. *Global Change Biology*, *13*(1), 147–156. doi: 10.1111/j.1365-2486.2006.01282.x

Potočnik, H., Perušek, M., & Kos, I. (2015). *Evidentiranje izhodiščnega stanja divjega petelina (Tetrao urogallus) na projektnem območju v NATURA 2000*. Ljubljana: Lovska zveza Slovenije.

Schmitt, T. (2007). Molecular biogeography of Europe: Pleistocene cycles and postglacial trends. *Frontiers in Zoology*, *4*(1), 11. doi: 10.1186/1742-9994-4-11

Selås, V., Sonerud, G. A., Framstad, E., Kålås, J. A., Kobro, S., Pedersen, H. B., … Wiig, Ø. (2011). Climate change in Norway: warm summers limit grouse reproduction. *Population Ecology*, *53*(2), 361–371. doi: 10.1007/s10144-010-0255-0

Seliškar, A., & Dakskobler, I. (2013). Two associations with *Sesleria autumnalis* in the foothills of the Savinja Alps (northern Slovenia). *Folia Biologica et Geologica*, *54*(2).

Taberlet, P., Fumagalli, L., Wust-Saucy, A., & Cosson, J. (1998). Comparative phylogeography and postglacial colonization routes in Europe. *Molecular Ecology*, *7*(4), 453–464. doi: 10.1046/j.1365-294x.1998.00289.x

Thomas, C. D., Cameron, A., Green, R., Bakkenes, M., Beaumont, L. J., Collingham, Y., … Williams, S. (2004). Extinction risk from climate change. *Nature*, *427*.

Thuiller, W., Lavorel, S., Araujo, M. B., Sykes, M. T., & Prentice, I. C. (2005). Climate change threats to plant diversity in Europe. *Proceedings of the National Academy of Sciences*, *102*(23), 8245–8250. doi: 10.1073/pnas.0409902102

Wegge, P., & Rolstad, J. (2017). Climate change and bird reproduction: warmer springs benefit breeding success in boreal forest grouse. *Proceedings of the Royal Society B: Biological Sciences*, *284*(1866), 20171528. doi: 10.1098/rspb.2017.1528

Wraber, T. (1995). Notulae ad floram Sloveniae. 21. *Cardamine glauca* Spr. *Hladnikia*, *4*.

Wraber, T. (2007). Bodičnik in sinja penuša. Balkansko-apeninski rastlini v Kamniških Alpah. *Planinski Vestnik*, *107*(7).

B. Collection of experiences of Italian Alpine parks on migratory species indicators of climate change

Dr. Giuseppe Dodaro

1 Report on the Italian survey on the impact of climate change on migratory species

Aims

In this review, in order to identify species with concrete difficulties in migrating both to the north and in altitude due to climate change and the resulting reduction of their habitats in areas at lower altitudes or placed further south, we collected information (i) on the global threat represented by climate change, and (ii) about the research about these sensitive targets carried out on Alps, with particular focus on protected areas. Finally, we discussed the data obtained focusing on the evidence available and highlighting lack of information. Moreover, we suggested some points for further field research and reviews which could be carried out by single protected areas through a general strategy coordinated by FEDERPARCHI.

A. Methods

This review has been carried out following (a) a traditional bibliographic approach (consulting paper-format documents: short notes, scientific papers, technical reports, atlases, books), (ii) a digital research through a scientific-based web motor-engine (Google Scholar), focusing on different types of files belonging to the topic "Experiences of Italian Alpine parks on migratory species indicators of climate change"

Regarding scientific literature about the eco-zoological arena, we considered mainly ornithological (for birds) and theriological (for mammals) Journals, considering that, at our latitudes, both birds and, among mammals, bats, includes species performing regular/irregular migratory movements at short, medium and large (continental) scale, erratic dispersion or vagrancy.

Among Italian ornithological Journals we consulted:

Rivista italiana di Ornitologia (RIO: paper format: years 1985-1986, 1999-2018; web-available digital format: all the available issues on the website of Società Italiana di Scienze Naturali: http://scienzenaturali.org/riviste/archivio-rio/, updated as: https://sisn.pagepress.org/rio/index);

Gli Uccelli d'Italia (UDI: paper format, the only available, years 2001-2017; note: on the website of this Journal it as not been possible download the papers: http://www.soi-udi.it/numeri-arretrati-di-udi/);

Picus (paper format: years 2005, 2006, 2007, 2009; a further analysis has been carried out on the website but here it as not been possible download the papers (http://www.cisniar.it/riviste/picus/index.php, edited by Centro Italiano Studi Nidi Artificiali, CiSNiAr);

Avocetta (paper format: years 1983-1987 e 1999-2018; digital format: all the years, excluding short communications, from the website: http://www.avocetta.org/), edited by Centro Italiano Studi Ornitologici, CISO;

Alula (all numbers in paper and digital format: 1992, 1995-2017; index on the website: http://www.sropu.org/alula.html), edited by Stazione Romana Osservazione e Protezione Uccelli, SROPU.

Regarding mammals, the only Italian theriological Journal available is Hystrix, an International scientific magazine edited by Associazione Italiana di Teriologia (ATIt; all the numbers are available both in paper and digital format on web-site: http://www.italian-journal-of-mammalogy.it/).

Finally, we reviewed the following Italian Journals: Biologia ambientale (paper format: from 2006 to today: site http://www.cisba.eu/rivista/tutti-i-numeri-della-rivista) and Ecologia urbana (paper format, digital format not available on website: http://www.ecologia-urbana.com/index.html).

About the web research has been carried out using the Google Scholar motor engine, we searched for any type of report, paper, book and other document using the following key-words: birds, Alps, climate, parks, protected areas, indicators, migrants, migratory, migration, climate change, both in English and in Italian (uccelli, Alpi, parchi, aree protette, migratori, migrazione, indicatori, cambiamenti climatici), changing the order of comparison and number of the single terms.

More particularly, we used the following combinations (both in Italian and in English:

Uccelli, Alpi, parchi, aree protette, migratori, migrazione, indicatori, cambiamenti climatici

Alpi, migratori, cambiamenti climatici

Alpi, migratori, parchi, cambiamenti climatici

Alpi, migratori, aree protette, cambiamenti climatici

Uccelli, Alpi, migratori, migrazione, indicatori, cambiamenti climatici

Birds, Alps, climate, parks, protected areas, indicators, migrants, migratory, migration, indicators, climate change

Alps, migrants, climate change

Alps, parks, migrants, climate change

Alps, protected areas, migrants, climate change

Birds, Alps, climate, parks, indicators, migrants, migratory, climate change.

For each set of terms we extrapolated the first ten Scholar pages, utilizing an opportunistic criterion to select files, deleting papers, books and other formats not referring to the topic.

All the documents have been included in a Excel table containing the following fields: complete citation (authors, title, Journal/book/other, volume/issue, pages), abstract (if available), pdf availability (yes/not; signing with X its availability). All the documents have been analysed subdividing them for sub-topics. In the final review, all references are reported following this style: Author (s) (year).Title. Journal (or book), number: pages. When available, we downloaded the pdf format. Therefore, these documents are available on request.

B. Results

Totally, we selected 121 documents: 44 references (papers, books, reports, uncorrected proofs, others) from International scientific documents (by Scholar Google motor engine research) and 77 references from Italian scientific Journals, atlases and books (including ‘grey’ literature). We added a number of websites to our research. Among them, to arrange this review, we selected 30 references from International scientific documents, 29 references from Italian scientific Journals, atlases and books and three websites. All data contained in the selected files have been used to perform the following review.

C. Review (Main document)

1. Introduction

1.1 Effects on ecosystems and biological components

The Earth's climate has already warmed by 0.5° C over the past century and global change may be considered a current and future environmental threat. Although evidence of effects of global changes is still scarce and has been mostly limited to northern latitudes, there are still few data for the Mediterranean area. However, first evidence indicate that average annual temperatures in NE Spain have increased by

1.4°C between the 1952 and 2000, with the stronger changes both in temperature occurred in the last 25 years (Peñuelas et al., 2002).

Effects of these anthropogenic changes on ecosystems are yet evident, at all levels of ecological organization: from population to communities, ecosystems and landscapes (McCarthy, 2001; Walther et al., 2002; Reid, 2006; Feehan et al., 2009; Bässler et al., 2010).

'Climate change and severe weather' has been considered a 'threat family' in the IUCN threat taxonomy (family code: 11; Salafsky et al., 2008; review in Battisti et al., 2016), including 'species threats' as 'habitat shifting and alteration' (code 11.1), 'droughts' (code 11.2), 'temperature extremes' (code 11.3), 'storms and flooding' (code 11.4).

At individual level, climate change affect physiology (e.g. stress) and behaviour (Scridel et al. 2018, web link n. 1 in references).

At population level, these ecological effects can be linked to recent population declines and to both local and global extinctions of species, species-traits changes (e.g. shift in phenology), changes and shifts in altitudinal and geographic ranges (e.g. expansions in thermophilous species), new colonizations (of thermo-xerophilous species towards temperate rages), changes in life history traits, extinction debt and immigration credits.

At community level , there are evidence of changes in species composition of communities, in species richness, diversity and turnovers, cascade effects (changes in predator-prey relationships and inter-specific competition).

At ecosystem level changes refer to the structure and functioning of ecological systems and on ecosystem services (McCarthy 2001; Jackson and Sax 2010). For example, the lengthening of plant growing season in this and other northern hemisphere regions may contribute to a global increase in biospheric activity (Vittoz et al., 2003).

However, global change act on ecosystems adding your effects to other threats as, for example, habitat fragmentation and alien species. For example, landscape fragmentation can impede the colonization of populations of plain species towards mountain areas.

Consequently to these causes, effects and interactions the ecosystem responses can show lags, paradoxes, uncertainty, with temporary phenomena, as biodiversity surplus or deficit (Fiedler, 2009, Jackson and Sax, 2010). Moreover, it exist an ecosystem inertia which can mask some ecological response, for example in species with long life cycle.

1.2 Effects on different biological taxa

A large set of biological species/guilds and communities can be affected by climate changes in different ecosystems, including alpine ones. Among plant communities, while in plain areas, the increase in drought periods may affect the survival of tree species in hygrophilous habitats, in alpine contexts, high temperature and reduced rainfalls could impact on flora through water stress, soil/habitat disruption. Plant communities can change abruptly along altitudinal gradients (Walther et al. 2002; Peñuelas et al., 2002): for example a sensitive belt was located between 1100 and 1200 m a.s.l. (Bässler et al., 2004). With climate change, plant species move towards higher habitats, with a consequent increase of flora richness (Pauli et al. 2001; Grabherr et al. 2001a). Moreover, in the Mediterranean area, Peñuelas et al. (2002) showed that leaves unfold on average 16 days earlier, leaves fall on average 13 days later, and plants flower on average 6 days earlier in 2000 when compared to 1952.

Climate variations affect also phenology also in invertebrates and vertebrates: Peñuelas et al. (2002) showed as butterflies appear 11 days earlier, but spring migratory birds arrive 15 days later in 2000 when compared to 1952.

Among birds, climate change affects the timing of migration, phenology (e.g. , first arrival dates of long-distance migratory birds; phonological disjunction), range distribution and reproduction in birds living in Europe and the Northern Hemisphere (Böhning-Gaese and Lemoine 2004; Crick 2004; Rubolini et al. 2007; Lehikoinen et al., 2014).

The more sensitive groups are long-distance migrants, northern species, and species living in agricultural environments: all these species are declining in north-eastern Europe (Laaksonen and Lehikoinen, 2013) . However, birds show a high potential of resilience to adapt even complex behavior such as breeding or migration to changing environments—either through evolutionary mechanisms acting on the genetic basis of behavior or through available phenotypic plasticity. A high degree of agility and mobility might have helped birds to adapt better to new conditions than other organisms might have done. Therefore we may distinguish among bird species both ‘winners’ and ‘losers’ in respect of their responses (adaptive or not) to climate change (see the ‘Move, adapt, or die’ model: Fiedler, 2009; Maggini et al., 2011).

Finally, among mammals, bats include many migratory species which may be affected from climate changes (Jones and Rebelo, 2013).

1.3 Global change and alpine ecosystems

Alpine biota offers a wide range of habitats that can be monitored in the long term (grasslands, forests, peat bogs, steppes, glaciers). Among these, environments that are not anthropized are particularly suitable for monitoring changes distinguishing those determined by internal factors (natural dynamics) from external factors (anthropogenic; Grabherr et al., 2001). More specifically, the Mediterranean mountains are very vulnerable to climate change (Viterbi et al., 2013).

Future scenarios have been defined for the Mediterranean mountains by analyzing the patterns of temperature and meteoric precipitation: for 2055 (range: 2040-2069) an increase from 1.4 to 5.1 ° C is expected. Instead for 2085 (range: 2070-2099) an increase from 1.6 to 8.3 ° C is expected, in both cases with a reduction in precipitation, mainly in spring. Unlike the Mediterranean areas, in the non-Mediterranean mountains a reduction in precipitation is not expected in spring (Bravo et al., 2008).

The consequences of these changes are already evident. In a study carried out in Bavaria, sudden changes in vegetation were observed particularly evident between 1,100 and 1,200 m a.s.l. (Bässler et al., 2004). At higher altitudes one can see an increase in species richness with altitude due to the shift of the area towards higher altitudes(Grabherr et al., 2001a).

Scridel et al. (2018) reported as alpine birds may be affected from interactive effects of climate, elevation, latitude and land use. In the light of global climate change these authors evidenced as, at global level, specialized mountain species will be more negatively impacted than non-mountain species. For example, climate change, besides other possible environmental changes, already influences populations of migrant and sedentary alpine birds with particularly adverse impacts on high-altitude species, such as Anthus spinoletta. These species will experiment future range contractions due to warming climate into the Alps (Flousek et al., 2015).

2. Indicators of climate change: a selection for monitoring

It is possible to identify the most important physical variables that can be used to monitor the effects of climate change on specific biological groups. For example, Bässler et al. (2010) identified temperature as the main driver physical variable (pressure indicator) for all selected high-montane plant species. However, other physical and environmental variables can also be used as the snow cover, the volume and the surface of the glaciers, the availability of water (Bravo et al., 2008). For Italian Alps, ARPA Piemonte (2012) selected a set of physico-ecological categories of indicators for the Alpine environments (thermo-sensitive species, peri-glacial soils, peatbog habitats, herbaceous phenology, pollens, climatic variables, bird phenology).

At level of biodiversity, appropriate indicators (of state/condition and impact, following a DPSIR approach) can be selected: for example, vascular plant richness represents a good indicator of state variation (Pauli et al., 2001; Walther et al., 2002; Peñuelas et al., 2002).

Among animals, since birds are easy to observe, are present in all parts of the world with many species and individuals, and are objects of interest to many people, they are ideal flagships to observe the consequences, and the impacts, of future environmental changes on ecosystems (Fiedler, 2009).

At single species level, it may be useful identify the main species-specific ecological traits that make sensitive a taxon to climate changes (Lindenmayer and Likens, 2011; Pacifici et al., 2015). For example, the species that show a high sensitivity to temperature variations and to the availability of water, which have a reduced dispersive capacity, and which show specific trophic characteristics can be considered sensitive and used as indicators.

Some characteristics (traits) can also be proposed as indicators to monitor the effects of climate change in the short (<10 years), medium (<50), long (> 50 years; Grabherr et al., 2001): the phenology of blooms in vascular plants, the composition abundance of mosses (short term); the floristic composition and the structural parameters of the plant communities (e.g., frequency, cover, biomass), the disappearance and acquisition (turnover) of soil species, alien species and pathogens (medium term); finally, the configuration and spatial patterns of habitats, in particular at the limit of the arboreal vegetation (Grabherr et al., 2001).

Useful indicators, sensitive to climate change, have been selected by ARPA Piemonte (2012) for the Alpine birds using data from ringing station: (i) last pentades of occurrence (5-days periods) during the spring (for nesting migrants) for long-distance migrants as Acrocephalus sp. and Motacillidae; (ii) first pentades of arrival (for long-distance migrants as Muscicapa striata and Sylvidae); (iii) breeding success and other nesting and post-breeding parameters (e.g. for Hirundinidae). Also ecological suitability models, evidencing altitudinal and geographical range shifts, can facilitate the definition of future scenarios per specific species (e.g. alpine Galliformes; ARPA Piemonte, 2012).

Recently, Bagne et al. (2011) defined an useful system for assessing vulnerability of species (SAVS) which identifies the relative vulnerability of species basing on 22 predictive criteria to create vulnerability scores. Six scores have been produced: an overall score denoting level of vulnerability or resilience, four categorical scores (habitat, physiology, phenology, and biotic interactions) indicating source of vulnerability, and an uncertainty score, which reflects user confidence in the predicted response. This a-priori expert-based approach can be applied a set of migratory species occurring in alpine parks.

Once the set of species-level indicators and the most appropriate metrics (variables) have been defined, it will be necessary to set up monitoring networks for large-scale and long-term environmental changes to trace intrinsic or extrinsic (anthropogenic) factors determining the change in ecosystems (Grabherr et al., 2001, Magurran et al., 2010; Lehikoinen et al., 2014). Also tools already available, such as the biological atlases, can be used to monitor the spatial changes over time (Lehikoinen et al., 2014), even if a problem is constituted by the fact is that, over long periods of time, the methods are changed used and the comparison can become difficult.

3. Experiences of Italian Alpine parks

Several conservation measures may be needed to help migrant populations, ranging from protecting habitats (through nature reserves) to agricultural policies at a national and/or international level (Bulgarini et al., 2009; Laaksonen and Lehikoinen, 2013). In this sense, parks can be considered strategic sites where (i) carry out monitoring programmes aimed to assess the effect of climate change on biodiversity, (ii) promote conservation measures to mitigate this threat.

In 2007, three alpine parks in N-W Italy started a field program to determine the factors which influence animal biodiversity and identify the most appropriate methods for periodically repeatable monitoring. The aim was to assess the distribution of different taxa along altitudinal gradients and the relative influence of geographical, environmental and climatic factors. In this study five taxonomic groups (carabids, butterflies, spiders, staphylinids, birds) were systematically sampled and topographic, environmental and micro-climatic variables were recorded (Viterbi et al., 2013). First data show as species richness and community composition of invertebrates are mainly determined by altitude and microclimatic conditions, whereas birds (also migratory) are more sensitive to habitat structure. For invertebrates, the strong relationship with temperature suggests their potential sensitivity to climatic variations (e.g. due to climate change at global/regional level).

Regional agencies (for example, ARPA Piemonte, 2012) recently defined protocols for monitoring biodiversity changes in the Alps (including protected areas). However, our review highlight a paucity of data about the effects of climate changes on migratory species indicators of climate change inside Alpine parks, at least about large-scale strategies through networks of parks. Therefore our first review would stimulate further studies and monitoring programmes focused on this target (migratory species indicators) in this Mediterranean context.

In this regard, lacking available data, we think that the role of ‘grey’ literature might be strategic. There are a large number of research on migrant species (mainly birds and bats but also on invertebrates as butterflies) on national or local scientific Journals. Although these research have not been carried out having as main aim to test the effect of climate change on biodiversity, they can be however utilized, representing an useful historical step of comparison. Carrying out further research in the same areas on the same taxa using comparable methods could provide information on the effect of human-induced climate change. For example, among birds there are many studies at community level carried out in Alpine contexts (often in Special Areas of Conservation or protected areas) that we selected for a possible future comparisons: in Carnic Alps, Rassati (2009) analysed in-depth breeding and wintering bird communities, including many migrant species; Battisti and Dodaro (2012) studied breeding birds in a morain pre-alpine landscape.

Sampling carried out many decades ago (‘80s) could be used to compare possible changes distinguishing effects due to regional/global change from effects due to local threats: Saporetti (1986) studied the breeding birds in an alpine heath in 1986. After thirty years it could be useful repeat this census.

Also atlases can be utilized in this regard. Many protected areas (e.g. Dolomiti Bellunesi national park, AA.VV., 2011) recently published atlases at local (park) area, an useful tool for periodical comparisons. An example of comparisons is reported in Fornasari et al. (2005). These Authors compared the distribution of breeding birds from the first national Atlas ('80s) to today highlighting the role of climate change (particularly showing a rarefaction of mountain Apennine species).

However, periodical monitoring at regional level are yet started. The Friuli-Venezia Giulia region started in 2010s a monitoring programme of breeding birds (including migrants) at regional level (Florit et al., 2012), focusing on Carso and other pre-alpine and alpine areas with Special Areas of Conservation (sensu 92/43, 79/409/CEE and 147/2009 Directives)

Local check-lists can be also utilized for time comparisons but this type of publications lack of a variables (abundance, distribution) that could provide information regarding the effect of climate changes. However, these lists can be used to verify new colonizers or extinctions interpreting these facts as consequences of human-induced processes (local threats, global change). Also in this case for birds there are many references for alpine and subalpine contexts available also for different historical periods from '80s (e.g. Silvano, 1985) to today (e.g. Casale et al., 2014, for the Val Grande National Park).

At single species level, local phenological data could represent an useful resource to obtain information on the effect of climate change. In this regard, there are examples from alpine and pre-alpine ecosystems (e.g. Micheli, 1998). Also data form altitudinal bird migrants (as Nucifraga c. caryocatactes) can be utilized: Mezzavilla et al. (2012a) studied in pre-alpine contexts the autumnal migration of Coccothraustes coccothraustes. In the Alps, Venuto et al. (2005) observed variations in breeding parameters of a passerine (Petronia petronia) from 1991 to 2004, probably due to climatic changes.

Bird ringing stations provide a large amount of data. In the Alto Garda, Fornasari et al. (2002) studied the phenology of autumn migration for a large set of species; Bordignon (2002) studied the migration patterns in the Maritime Alps. Many data are also available from the network of ringing stations included in the 'Alpi Project' (Pedrini et al., 2002). Not only ringing techniques can be utilized: other research carried out through visual points have been promoted to study autumn migration on prealpine contexts (Mezzavilla et al., 2012b).

Monitoring at single species level (sedentary or migratory ones), focused on priority species, have been carried out in alpine contexts: Florit and Rassati (2012) carried out a research on Crex crex in Friuli-Venezia Giulia.

Also short notes regarding first unusual nesting observations of Mediterranean migrant species in alpine contexts (see Micheli, 1991, for Oenanthe hispanica melanoleuca in Trentino; Rassati, 2016, for Caprimulgus europaeus in Carnic Alps), outside their altitudinal (e.g. Bionda 1997, Charadrius dubius, Alpe Veglia and Devera, Piedmont) or distributional range (e.g. Bocca, 1999, Sylvia melanocephala, and Bocca and Maffei, 2000, Sylvia cantillans in Aosta Valley) or unexpected wintering of migrant species (Cairo 2004, Ptyonoprogne rupestris) are available and can be utilized to verify the causal factors inducing these changes in patterns.

Demographic trend analyses have been carried out comparing birds between decades at regional level (Longoni et al., 2015 for waterbirds in Lumbardy; see also web ref. n. 2). In these data sets there are many information that can be analyzed.

Web platform as Ornitho (www.ornitho.it) can be also included among the tools useful to delineate an arrangement of the ’global change’ topic for Alps. Reviewing the large amount of data periodically added from ornithologists at this platform could allow to define specific patterns in demography, phenology, and distribution. For example, Saporetti (2018) reviewed all the Ornitho data available from Lumbardy focusing on a migrant group (waders, genus Tringa). Analogous analytical reviews can be carried out for alpine migrant species (raptors, passerines, etc.). Moreover, in Ornitho platform data on other migrant groups apart birds (e.g. bats) are available.

Proceedings of specific meetings focused on alpine species may include interesting data. In the recent ‘European meeting on Snowfinch Fringilla montifringilla’, Mattia Brambilla reported evidence about a possible interference between climate change and distribution and foraging habitat selection of this species (see Brambilla et al. in website n. 3 of reference list). Also national ornithological congresses include interesting, although still rare, contributes about the effects of climate change on Alpine birds (e.g. Bocchiola & Pirovano, 2012, for Tetrao tetrix).

National projects (not only focused on Alps, but including them) as MITO, oriented to monitoring of common (sedentary or migrant) species, can be utilized to specific aims, as the effects of climate changes (Pruscini et al., 2009). In this study the authors observed evident effects of the summer 2003 (characterized by high temperatures and scarce rainfall) on a large set of common birds. Moreover, many data set, check-lists and other information are available on museal websites (e.g.: http://biodoor.muse.it:8080/wordpress). Reviews and updated reports regarding single sensitive groups and their nesting sites/areas (e.g. waders as herons) can be utilized for time comparisons in a climate change vision (see n. 2 in web references).

Finally, some approaches to biodiversity estimation have been proposed for the Alpine birds, in priority areas (Trivellini et al., 2012). These tools can be used to compare in different times bird populations and communities.

4. Conclusions

Our review evidenced as a large amount of data o international scientific Journals are available about the topic of global change and its effects on ecosystems. Nevertheless, data for Alpine parks are yet limited at context, species and community level. Birds are widely studied (also if research aims focused on the effects of climate change are scanty): Data for other groups including migrant species (bats, invertebrates) are very rare.

In our review we can highlight as it is strategic for alpine parks obtain check-lists of sensitive species indicating the response of ecosystems to climate change. Often responses of these species are complex, counter-intuitive and unexpected because not only climate change but other local human-induced threats can confound the patterns obtained. In this regard, list of species can be obtained: (a) a-posteriori, after focused research on biological targets, analyzing their responses to climate change. This type of study is difficult and often not representative if carried out a local scale. In this sense, parks should define network for monitoring defining common standards on large spatial and temporal scales; (b) a-priori, using expert-based approaches. In this case, knowing which are the more sensitive ecological traits of the species to climate change and checking in each species the characteristics of these traits it is possible assign scores at each species, obtaining indirectly a list of sensitive species which can utilized as indicators. In this regard, we suggest to FEDERPARCHI to adopt, as soon as possible, the system for assessing vulnerability of species to climate change (SAVS) proposed by Bagne et al. (2011).

Concluding, since the lack of information available on this specific topic (response of migrant species to climate change in Alpine parks), we suggest:

- the use of historical and recent bibliographic data regarding altitudinal, distributional, phenological shifts of species in alpine/pre-alpine contexts;

- a call for all researchers to carry out studies on this specific arena: they should repeat their research in the same sites using comparable methods to assess possible change at species (density, phenology, distribution) and community level (richness, diversity, evenness). To evidence possible stress at community level there are many approaches (Abundance/Biomass comparisons, k-dominance plots, Whittaker plots; see Magurran, 2004) which can be applied:

- the selection of a-priori check-list of sensitive species to climate change obtained form expert-based approaches.

Last but not least, it is necessary obtain information also for a further problem regarding the protected areas. In fact, often the areas to be conserved are identified (boundaries, zoning) without taking into account future developments in terms of climate change. In this sense it is necessary adopt new policies to avert this risk. Araujo et al. (2011) assessed the effectiveness of protected areas and the Natura

2000 network in conserving a large proportion of European plant and terrestrial vertebrate species under climate change. These researchers observed as by 2080, 58±2.6% of the species would lose suitable climate in protected areas, whereas losses affected 63±2.1% of the species of European concern occurring in Natura 2000 areas. Protected areas are expected to retain climatic suitability for species better than unprotected areas, but Natura 2000 areas retain climate suitability for species no better and sometimes less effectively than unprotected areas. In this regard, as stated by Araujo, the risk is high that ongoing efforts to conserve Europe's biodiversity are jeopardized by climate change.

References

Aa.Vv. (2011). Atlante degli uccelli nidificanti nel Parco Nazionale delle Dolomiti Bellunesi. Rapporti 8. Lipu, Parco nazionale delle Dolomiti Bellunesi.

Araújo, M.B., Alagador, D., Cabeza, M., Nogués-Bravo, D., Thuiller, W. (2011). Climate change threatens European conservation areas. Ecology letters, 14: 484-492.

ARPA Piemonte, 2012. Clima e Biodiversità. Esperienze di monitoraggio in ambiente alpino. Torino.

Bagne, K.E., Friggens, M.M., Finch, D.M. (2011). A System for Assessing Vulnerability of Species (SAVS) to Climate Change. Gen. Tech. Rep. RMRS-GTR-257. Fort Collins, CO. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 28 p.

Bässler, C., Förster, B., Moning, C., Müller, J. (2008). The BIOKLIM-Project: biodiversity research between climate change and wilding in a temperate montane forest–the conceptual framework. Waldökologie, Landschaftsforschung und Naturschutz, 7: 21-33.

Bässler, C., Müller, J., Hothorn, T., Kneib, T., Badeck, F., Dziock, F. (2010). Estimation of the extinction risk for high-montane species as a consequence of global warming and assessment of their suitability as cross-taxon indicators. Ecological Indicators, 10: 341-352.

Battisti, C., Dodaro, G. (2012). Breeding bird communities in a morain landscape (Affi, North-Western Venetia): a preliminary survey. Rivista Italiana di Ornitologia, 81: 89-96.

Battisti, C., Poeta, G., Fanelli, G., 2016. An Introduction to Disturbance Ecology. A road map for wildlife management and conservation. Springer, Switzerland.

Bionda, R. (1997). Nidificazione di Corriere piccolo, Charadrius dubius, a quota inusuale nel Parco Naturale dell'Alpe Veglia e Devero (Piemonte). Rivista Italiana di Ornitologia, 67: 95-95.

Bocca, M. (1999). Nidificazione dell'Occhiocotto, Sylvia melanocephala, in Valle d'Aosta. Rivista italiana di Ornitologia, 69: 216-216.

Bocca, M., Maffei, G. (2000). Nidification de la Fauvette passerinette, Sylvia cantillans, en Vallée d'Aoste (Alpes occidentales italiennes). Rivista Italiana di Ornitologia, 70: 115-120.

Bocchiola D., Pirovano A., 2012. Impact of climate change upon Black Grouse Tetrao tetrix in the Italian Alps. Atti XVI Convegno Italiano di Ornitologia, Cervia 21-25 settembre 2011.

Böhning-Gaese, K., Lemoine, N. (2004). Importance of climate change for the ranges, communities and conservation of birds. Advances in Ecological Research, 35: 211-236.

Bordignon L. (2002). Dati sulla migrazione attraverso le Alpi Marittime piemontesi. Rivista Italiana di Ornitologia, 72: 233-244.

Bravo, D.N., Araújo, M.B., Lasanta, T., Moreno, J.I.L. (2008). Climate change in Mediterranean mountains during the 21st century. AMBIO: A Journal of the Human Environment, 37: 280-285.

Bulgarini F., Calvario E., Celada C., Fraticelli F., Massa B., Montemaggiori A., Spina F. (2009). La tutela delle specie migratrici. Alula, 16: 69-71.

Cairo E. (2004). Lo svernamento della Rondine montana, Ptyonoprogne rupestris , a Bergamo Alta: dati e considerazioni. Rivista Italiana di Ornitologia, 74: 3-10.

Casale, F., Movalli, C., Bionda, R., Laddaga, L., Mosini, A., Piana, M. (2014). Gli uccelli del Parco Nazionale della Val Grande e delle aree limitrofe (Verbano Cusio Ossola, Piemonte, Italia). Rivista Italiana di Ornitologia, 83: 3-52.

Crick, H.Q. (2004). The impact of climate change on birds. Ibis, 146: 48-56.

Feehan J., Harley M., Van Minnen J. (2009). Climate change in Europe. 1. Impact on terrestrial ecosystems and biodiversity. A review. Agronomy for Sustainable Development, Springer Verlag/EDPSciences/INRA, 29 (3).

Fiedler, W. (2009). Bird ecology as an indicator of climate and global change. In: Climate Change (pp. 181-195).

Florit, F., Rassati, G. (2012). Monitoring of a priority species for European Union promoted by autonomous Region of Friuli-Venezia Giulia: the Corncrake, Crex crex. Rivista Italiana di Ornitologia, 82: 177-179.

Florit, F., Ota, D., Parodi, R. (2012). The monitoring of breeding birds in Friuli-Venezia Giulia. Rivista Italiana di Ornitologia, 82: 196-197.

Flousek J., Telenský T., Hanzelka J., Reif J. (2015). Population Trends of Central European Montane Birds Provide Evidence for Adverse Impacts of Climate Change on High-Altitude Species. PLoS ONE 10(10): e0139465.

Fornasari L., De Carli E., Cucé L., Vigorita V., 2002. Studio della fenologia della migrazione autunnale nella Stazione Ornitologica del Passo di Spino (Alto Garda, BS). Rivista Italiana di Ornitologia, 72: 161-183.

Fornasari L., De Carli E., Buvoli L., La Gioia G., Tellini Florenzano G. (2005). Variazioni di areale a media scala: è cambiata la distribuzione degli uccelli nidificanti in Italia dall'Atlante ad oggi? Avocetta, 29: 76.

Grabherr, G., Gottfried, M., Pauli, H. (2001). High mountain environment as indicator of global change. In: Global change and protected areas (pp. 331-345). Springer, Dordrecht.

Grabherr, G., Gottfried, M., Pauli, H. (2001a). Long-term monitoring of mountain peaks in the Alps. In: Biomonitoring: General and applied aspects on regional and global scales (pp. 153-177). Springer, Dordrecht.

Jackson, S. T., Sax, D. F. (2010). Balancing biodiversity in a changing environment: extinction debt, immigration credit and species turnover. Trends in Ecology and Evolution, 25: 153-160.

Jones, G., Rebelo, H. (2013). Responses of bats to climate change: learning from the past and predicting the future. In: Bat evolution, ecology, and conservation (pp. 457-478). Springer, New York, NY.

Laaksonen, T., Lehikoinen, A. (2013). Population trends in boreal birds: continuing declines in agricultural, northern, and long-distance migrant species. Biological Conservation, 168: 99-107.

Lehikoinen, A., Green, M., Husby, M., Kålås, J. A., Lindström, Å. (2014). Common montane birds are declining in northern Europe. Journal of Avian Biology, 45: 3-14.

Lemoine, N., Bauer H.G., Peintinger, M., Böhning-Gaese K. (2007). Effects of climate and land-use change on species abundance in a central European bird community. Conservation Biology, 21: 495-503.

Lindenmayer, D.B., Likens, G.E. (2011). Direct measurement versus surrogate indicator species for evaluating environmental change and biodiversity loss. Ecosystems, 14: 47-59.

Longoni, V., Rubolini, D., Pinoli, G., Fasola, M. (2015). Population trends of wintering waterbirds in Lombardy between 2002 and 2013. Rivista Italiana di Ornitologia, 84(2).

Maggini, R., Lehmann, A., Kéry, M., Schmid, H., Beniston, M., Jenni, L., Zbinden, N. (2011). Are Swiss birds tracking climate change?: Detecting elevational shifts using response curve shapes. Ecological Modelling, 222: 21-32.

Magurran A.E. (2004). Measuring biological diversity. Blackwell.

Magurran, A.E., Baillie, S.R., Buckland, S.T., Dick, J.M., Elston, D.A., Scott, E.M., Watt, A.D. (2010). Long-term datasets in biodiversity research and monitoring: assessing change in ecological communities through time. Trends in Ecology and Evolution, 25: 574-582.

McCarty J. P. (2001). Ecological consequences of recent climate change. Conservation Biology, 15: 320-331.

Mezzavilla, F., Martignago, G., Lombardo, S., Boscain, L., Silveri, G. (2012a). Hawfinch, Coccothraustes coccothraustes: autumnal migration over Trevigiane Prealps. Years 2004-2010. Rivista Italiana di Ornitologia, 81 (2).

Mezzavilla, F., Martignago, G., Lombardo, S. (2012b). Visible autumn migration of Passeriformes in the Prealpi Trevigiane. Rivista Italiana di Ornitologia, 82 (1-2).

Micheli A. (1991). La Monachella orientale, Oenanthe hispanica melanoleuca, nidifica nel Trentino. Rivista Italiana di Ornitologia, 61: 130-132.

Micheli A., (1998). Dati fenologici e morfometrici di Nocciolaie beccogrosso, Nucifraga c. caryocatactes, catturate nelle Prealpi Bresciane. Rivista Italiana di Ornitologia, 68: 218-220.

Pacifici, M., Foden, W. B., Visconti, P., Watson, J. E., Butchart, S. H., Kovacs, K. M., Corlett, R. T. (2015). Assessing species vulnerability to climate change. Nature Climate Change, 5: 215.

Pauli, H., Gottfried, M., Grabherr, G. (2001). High summits of the Alps in a changing climate. In: “Fingerprints” of Climate Change (pp. 139-149). Springer, Boston, MA.

Pedrini P., Spina F., Negra O., Rizzolli F., Pallaveri A., Rossi F. (2002). Il Progetto Alpi. Rivista Italiana di Ornitologia, 72: 185-194.

Peñuelas, J., Filella, I., Comas, P. (2002). Changed plant and animal life cycles from 1952 to 2000 in the Mediterranean region. Global Change Biology, 8: 531-544.

Pruscini F., Tellini Florenzano G., Buvoli L., Santolini R. (2009). La banca dati MITO2000 come strumento per prevedere gli effetti dei cambiamenti climatici sulle specie comuni nidificanti. Alula, 16: 312-314.

Rassati G. (2009). Le comunità ornitiche nidificanti e svernanti presso il Lago di Cavazzo (Prealpi Carniche, Friuli-Venezia Giulia). Picus, 35: 7-18

Rassati G. (2016). Expansion of the breeding range and probable high-altitude nesting of the European Nightjar Caprimulgus europaeus in the Carnic Alps (North-eastern Italy). Avocetta, 40: 88-89.

Reid H. (2006). Climate Change and Biodiversity in Europe. Conservation and Society, 4: 84–101.

Rubolini, D., Ambrosini, R., Caffi, M., Brichetti, P., Armiraglio, S., Saino, N. (2007). Long-term trends in first arrival and first egg laying dates of some migrant and resident bird species in northern Italy. International Journal of Biometeorology, 51: 553-563.

Salafsky, N., Salzer, N., Stattersfield, A.J., Hilton-Taylor, C., Neugarten, R., Butchart, S.H.M., Collen, B., Cox, N., Master, L.L., O'Connor, S., Wilkie, D. (2008). A standard lexicon for biodiversity conservation: unified classifications of threats and actions. Conservation Biology, 22: 897-911.

Saporetti F. (1986). Censimento dell'avifauna nidificante in una brughiera prealpina. Avocetta, 10: 97-101.

Saporetti, F. (2018). Il ruolo delle zone umide della Regione Lombardia durante la migrazione dei limicoli: un'analisi per il genere Tringa ricavata dal portale www.ornitho.it. Rivista Italiana di Ornitologia, 87: 15-28.

Scridel, D., Brambilla, M., Martin, K., Lehikoinen, A., Iemma, A., Matteo, A., Jähnig, S., Caprio, E., Bogliani, G., Pedrini, P., Rolando, A., Arlettaz, R., Chamberlain, D. 2018. A review and meta-analysis of the effects of climate change on Holarctic mountain and upland bird populations. IBIS, in stampa. DOI: 10.1111/ibi.12585

Silvano F. (1985). Aggiornamento all'elenco degli uccelli della Valle Scrivia, Alessandria (Piemonte). Rivista Italiana di Ornitologia, 55: 99-102.

Trivellini, G., Preatoni, D., Cantini, M., Belardi, M., Ludovici, A., Tosi, G. (2012). A quantitative approach to biodiversity estimation: application to birds in Alps Ecoregion - priority area H1. Rivista Italiana di Ornitologia, 82: 115-116.

Venuto G., Tavecchia G., Taverniti E., Mingozzi T. (2005). Effetti di variazioni termoclimatiche sui parametri riproduttivi di una popolazione alpina di Passera lagia Petronia petronia. Avocetta, 29: 74.

Viterbi, R., Cerrato, C., Bassano, B., Bionda, R., Hardenberg, A. V., Provenzale, A., Bogliani, G. (2013). Patterns of biodiversity in the northwestern Italian Alps: a multi-taxa approach. Community Ecology, 14: 18-30.

Vittoz, P., Cherix, D., Gonseth, Y., Lubini, V., Maggini, R., Zbinden, N., Zumbach, S. (2013). Climate change impacts on biodiversity in Switzerland: A review. Journal for Nature Conservation, 21: 154-162.

Walther, G. R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T. J., Bairlein, F. (2002). Ecological responses to recent climate change. Nature, 416 (6879): 389.

Websites:

1. http://biodoor.muse.it:8080/wordpress/index.php/2018/07/16/si-fa-presto-a-dire-montagna/ (reporting a synthesis of the paper of Scridel, D., Brambilla, M., Martin, K., Lehikoinen, A., Iemma, A., Matteo, A., Jähnig, S., Caprio, E., Bogliani, G., Pedrini, P., Rolando, A., Arlettaz, R., Chamberlain, D. 2018. A review and meta-analysis of the effects of climate change on Holarctic mountain and upland bird populations. Ibis, in press. DOI: 10.1111/ibi.12585

2. http://biodoor.muse.it:8080/wordpress/index.php/2018/11/05/pubblicato-il-resoconto-del-censimento-2017-delle-garzaie-di-veneto-e-trentino-alto-adige/

3. http://biodoor.muse.it:8080/wordpress/index.php/event/1-meeting-europeo-sul-fringuello-alpino/