RECOVERY PLAN FOR THE ZULLICHI'S BLUE

Agriades zullichi

Butterfly Conservation Europe

SPECIES RECOVERY PLAN FOR THE ZULLICHI'S BLUE
Agriades zullichi

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Contents

Introduction

This document presents a summary of all the information available for *Agriades zullichi* and the results of the field studies carried out during the field seasons of 2012, 2013 and 2014. It includes also unpublished data from the project contributors, which are mentioned in the Acknowledgements section at the end of the document.

Species Recovery Plans (SRPs) are documents in which, together with relevant information about a given endangered species, an analysis is made of the threats the species is facing and pertinent actions are planned to reverse these threatening factors. If successful these actions will help protect the species from extinction and greatly improve its conservation status. SRPs are important tools for the conservation of animal and plant species. However, the amount of documents dealing with invertebrate animal species is indeed reduced and restricted to the most charismatic groups. In Spain recovery plans have never been produced for species of the Lepidoptera order, and therefore one of the aims of this document is to fill this gap and provide for the first time guidance for the conservation of species that are relevant for the fauna of this country.

This Species Recovery Plan is part of the Species Recovery Program of Butterfly Conservation Europe. The work on *Agriades zullichi* has received the financial support from MAVA Fondation pour la Nature within a project to produce a SRP for the endangered endemic species living in Spain: *Euchloe bazae, Agriades zullichi, Polyommatus(Plebicula) golgus* and *Polyommatus violetae*.

The production of this SRP involved three steps. First, we gathered all the information available for the species in the form of scientific papers, distribution records and chapters of Red Data Books or reports. Second, fieldwork was planned to visit most of the habitats of the species and record information on the threats and the ecology of the species. Finally, we discussed possible conservation actions with conservation experts and landscape managers during a workshop in 2013 and visits to the National and Natural Parks, in which we developed measures with park officials, in order to ensure the planned activities are feasible and well incorporated into the park's action plans. During the fieldwork, the following data were recorded for each population of the species: name of the locality, date, geographic coordinates, altitude, geological substrate, number of adults on transect counts, larval food plant density, aspect, threats and vegetation type. Photographs were also made from all the places where the presence of the butterfly was detected and from any relevant habitat feature.

The document is divided into three main sections. The first section summarizes the available information for the species and also shows new data gathered during the project. A second section deals with information that is relevant for the conservation of the species, particularly an analysis of the threats that have been mentioned for the species and those that were detected during fieldwork. The final section explains in detail the specific actions that are proposed for an improvement of the species conservation status. There are short and long term measures envisaged, reflecting the short and long term threats affecting the status of the species per locality. At the end of the document a comprehensive list of references and an acknowledgement section is added.

Identification

Wing morphology

The length of the forewing is 10-13 mm.

The upperside of the wings in males is dark grey, with some blue scales on its basal area (Fig. 1). This blue area has variable size in different individuals. The discal spots in the forewing are surrounded by a white suffusion. The marginal spots are black and almost vestigial, sometimes surrounded by blue scales. Fimbriae are white.

The underside of the wings is dark brown, with marked veins. The forewings have a discal spot and seven large postdiscal spots, a whole series of marginal marks and bordering them, black and white submarginal lunules. The hindwings have smaller marks, with postdiscal pupilated spots, two or three orange submarginal lunules and a whole series of v-shaped white and black marks.

Sexual dimorphism is not very pronounced. Female forewings are similar to those of the male, but the upperside is darker and the basal area with blue scales is less extended, or even absent.

Figure 1. Agriades zullichi *male viewed from the upperside (left, photo J Olivares). Female of* A. zullichi *with wings folded to show the underside (right, photo JM Barea-Azcón).*

Genitalia

The male *genitalia* have long and thin *brachia*, of the same length as *labides*, which are triangular. The *furca* is long and straight, the valves are ended in a nail and the *penis* is short. The *genitalia* are very similar to that of *A. glandon*, so it cannot be used as a distinctive character.

Immature stages

THE EGG has an average diameter of 0.55 mm, the colour is greenish when they are laid and turn to pure white a few hours later. The micropylar rosette has four elongated petals with a central dome and four micropylar openings. The rest of the annular cells show elongated dots in the inside. The tubercle-aeropyle area is formed by polygonal cells with tubercles that become larger towards the equator of the egg (Fig. 2). Tubercles have an aeropyle at their end, located in a small hollow. There are five larval instars.

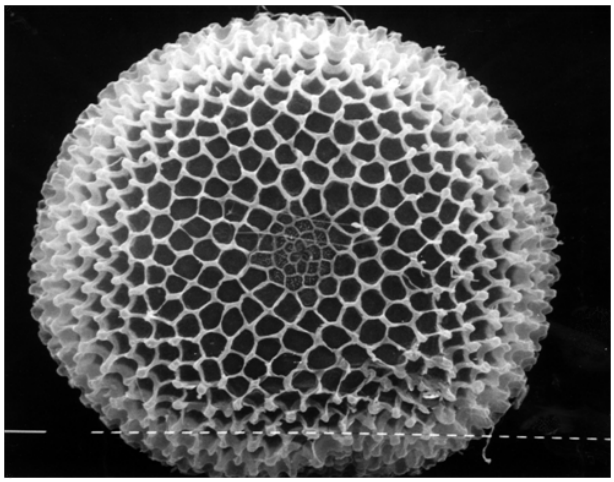

Figure 2. Scanning electron microscope picture of the egg of Agriades zullichi *(photo ML Munguira & J Martín).*

THE FIRST INSTAR is purple, which makes it cryptic among the food plant leaves. It has thick dorsal and lateral setae, and just a subdorsal pore cupola organ, except in the sixth abdominal segment, where it has two. The cuticle has a rough sculpture.

THE SECOND INSTAR is purple also and has dorsal, subdorsal and lateral short and thick setae, with club appearance.

THE THIRD INSTAR larva has not been described in detail.

FOURTH AND FIFTH instars lack tentacles and Newcomer's gland and have a very similar design, of green colour with a black oblique stripe in each segment, a dark purple dorsal band surrounded by yellow and a lateral white-yellowish band surrounded by purple (Fig. 3).

The setae of the last instars are toothed in the base, curved and club shaped; the pore cupola organs are toothed also, and they can be found in reduced number compared with other species due to the lack of other myrmechophilous organs.

Figure 3. Fifth instar larva of Agriades zullichi *feeding on the flowers of* Androsace vitaliana *(photo JM Barea-Azcón).*

THE PUPA is almost 10 mm long with the head, thorax and wing cases of olive colour (Fig. 4). The abdomen is pale brown, with a dorsal purple band and lateral and oblique purple marks. Lateral and ventral lateral areas are of pink colour. It has a well-developed stridulatory organ (dorsal area of the 5th and 6th abdominal segments), and club shaped setae scattered on all the body and anchor shaped setae in the cremaster.

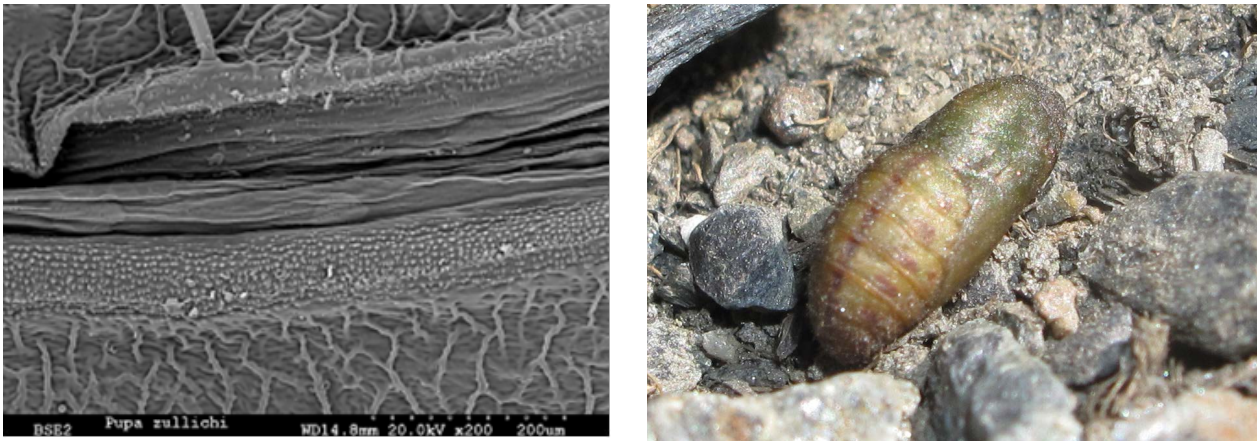

Figure 4. Pupa of Agriades zullichi *(right, photo JM Barea-Azcón) and scanning electron microscope picture of the stridulatory organ (200x, left, photo M Álvarez & ML Munguira)*

Taxonomy

Common name: Zullich´s Blue or Mariposa del Puerto del Lobo

Latin name: *Agriades zullichi* Hemming, 1933

Phyllum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Lycaenidae

The species has been considered a subspecies of *Agriades glandon*, until it was given specific status based on ecological and morphological characters (Munguira, 1989). However, some authors still regard it as a subspecies of *A. glandon* (Tolman & Lewington, 2008). It is also sometimes included in the genus *Plebejus*, but recent molecular studies support *Agriades* as a clearly distinct genus (Talavera et al., 2013). The species haplotype is n= 24, which is similar to related species such as *A. glandon*.

Synonymy: *Lycaena nevadensis* Züllich, 1928 (invalid homonym).

Figure 5. Agriades zullichi *on its food plant (photo JM Barea-Azcón).*

Distribution

Agriades zullichi is a rare Iberian endemic. Its distribution is limited to Sierra Nevada, in the provinces of Almería and Granada in southeast Spain.

The altitude range of the species is 2,400 to 3,140 m. The average altitude of the populations sampled during this project is 2,679 m. The population near El Buitre is at an altitude of 2,400 m, which is the lowest elevation ever mentioned for this taxon. Its known distribution is restricted to 39 localities (Barea-Azcón et al., 2014, Fig. 6) that are located in eight 10x10 km UTM (Universal Transverse Mercator) squares. All the populations of the species except one are within the boundaries of Sierra Nevada National Park (Parque Nacional de Sierra Nevada).

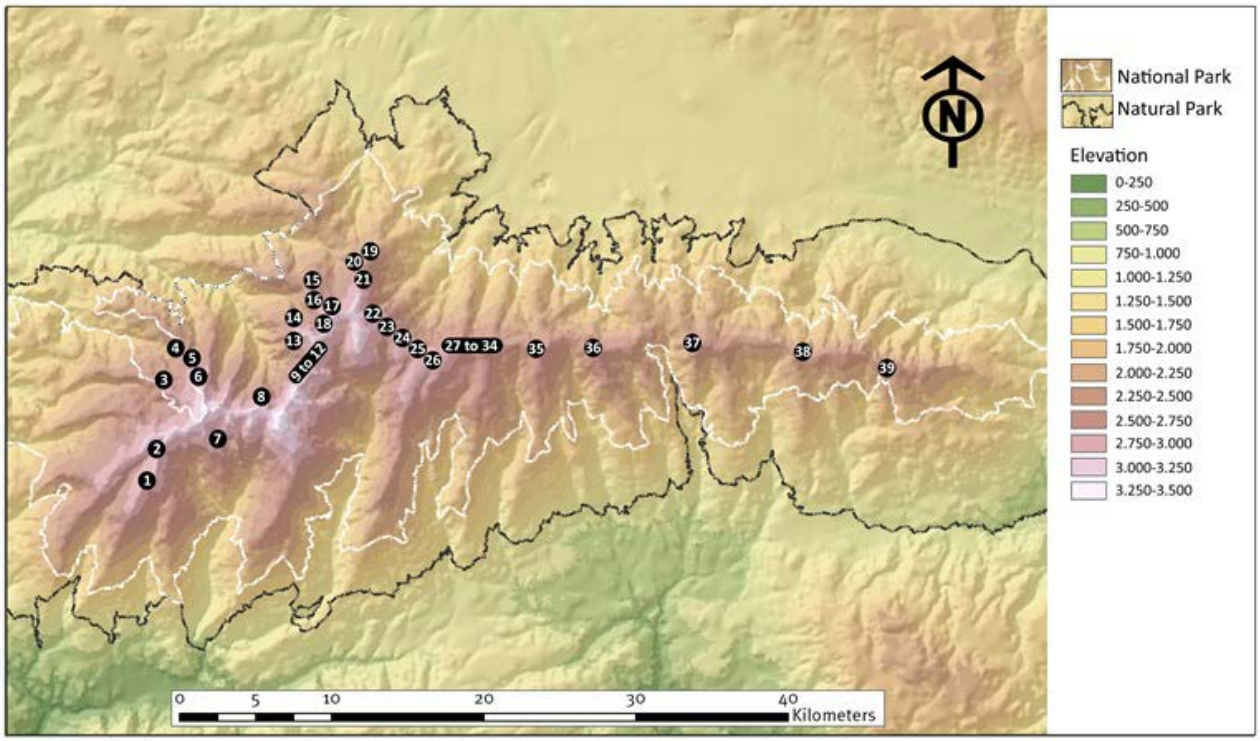

Figure 6. Distribution of the 39 localities of Agriades zullichi *in Sierra Nevada taken from Barea-Azcón et al. (2014). The boundaries of the National and Natural Parks are drawn in white and black respectively.*

Habitat

Habitat description

The habitat of the species is fragmented into 39 patches that cover 60.9 ha (Barea-Azcón et al., 2014). Habitat patches have an average of 2.3 ha. Zullich's Blue localities are mainly situated at elevated spots in relation to its surrounding area and have a specific soil composition. They are mainly located at the crest or peaks of the mountains, which is probably due to the presence of a specific soil composition at these areas. However, an early snow disappearing rate can also have a positive effect in this habitat selection pattern. In typical habitat, the vegetation grows in the spaces between stones (Figs. 7-9). *A. zullichi* is always found on wind-exposed ridges that, in the visited locations, had a northern aspect, with only one exception that has eastern aspect. Plant communities in the habitat are of the *Festucetea indigestae* class and belong to the *Berberidi hispanicae-Querceto rotundifoliae* series in El Buitre and to the *Genisto baeticae-Juniperetо nanae* in all the other visited locations. The areas where the butterfly lives show less vegetation cover than surrounding areas (Fig. 9), and have scattered grasses (*Festuca clementei*), shrubs (*Genista versicolor, Cytisus galianoi*, *Astragalus nevadensis* and *Arenaria pungens*) and junipers (*Juniperus sabina* in El Buitre and *J. communis* in all the other locations).

This species habitat is part of the Oro-Iberian *Festuca indigesta* grasslands habitat type, listed in the Annex I of the EU Habitats Directive (code 6160) as a habitat of Community Interest.

The larval food plants, *Androsace vitaliana*, grow in populations of a highly variable density, ranging from less than 100 to several thousand plants. Food plant densities measured in nine 10 x 10 m plots studied for larval surveys ranged from 36 to 572, with an average of 218 plants in 100 m^2.

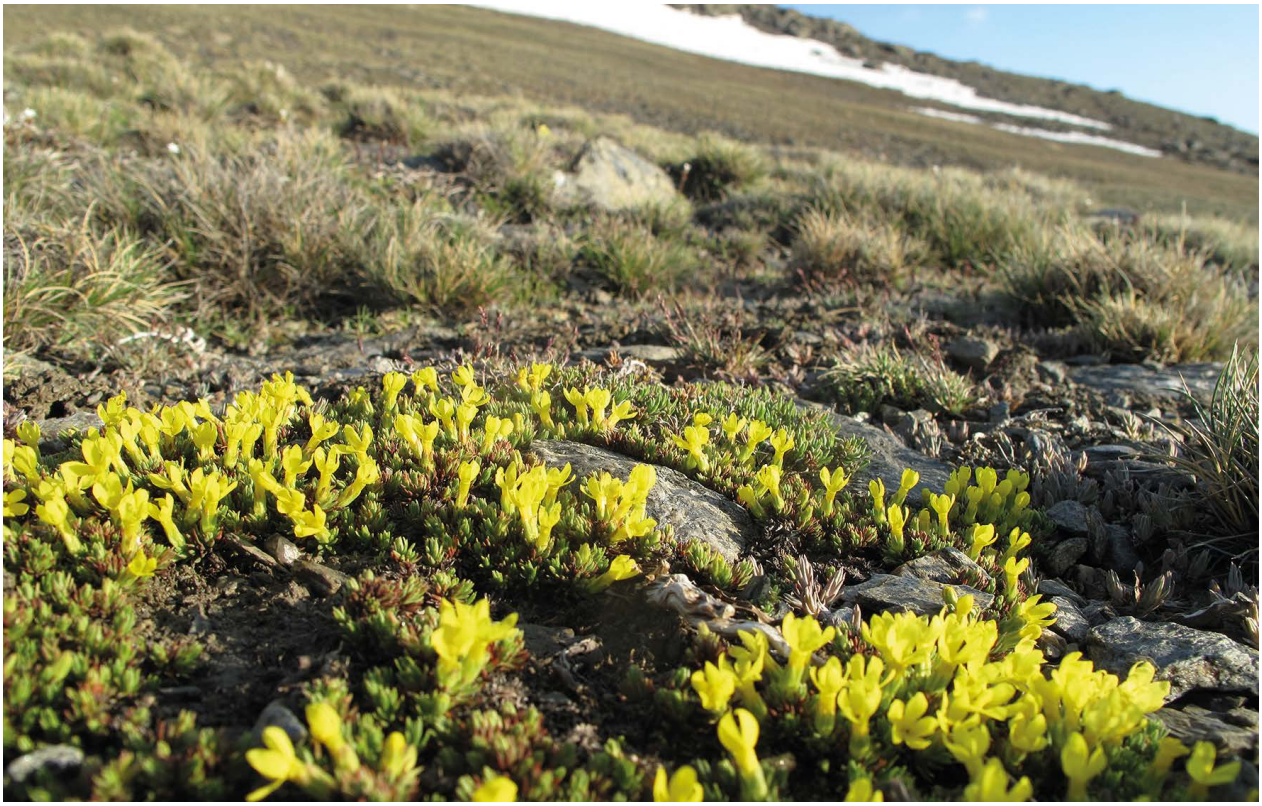

Figure 7. The habitat of Agriades zullichi *in Sierra Nevada (Granada) showing the sparse vegetation growing among schists and the larval food plant with yellow flowers (photo JM Barea-Azcón).*

Figure 8. The habitat of Agriades zullichi *on the wind exposed ridge of San Juan (2,786 m), Sierra Nevada, Granada). Sparse vegetation with* Astragalus nevadensis *and the larval food plant (brownish-red patches) grows among schist stones (photo ML Munguira).*

Figure 9. The habitat of Agriades zullichi *in the Collado del Puerto (2,800 m, Sierra Nevada, Granada) with less vegetation cover than the surrounding areas (photo JM Barea-Azcón).*

Habitat model

The aim of this habitat model is to use the information on the distribution of *Agriades zullichi* and its larval food plant to infer their potential distribution at two geographical scales: local (in the surroundings of the target localities) and regional (the Sierra Nevada Protected Area). The model can also evaluate the importance of different environmental variables. This information may be very useful for some management and conservation recommendations. This is a priority under a global change scenario, where understanding the species-environment relationships is crucial to predict how a changing environment will affect species distributions and migration possibilities in an altitudinal gradient. During field surveys carried out on 2011-2012 we obtained 4,615 GPS landmarks of different *Androsace vitaliana* individuals in localities where *Agriades zullichi* was present (Barea-Azcón et al., 2014). If two or more butterflies were seen in a patch at least once, then a breeding population was defined to be present. We processed these GPS landmarks to obtain a set of presence records of both species at a resolution of 10 meters, which resulted in 600 presence records. Additionally, two different sets of zeros were generated: absences and pseudo-absences, at two different geographical extents: local and regional.

To produce the set of true-absences we combined absences obtained during the field work (defined with GPS devices), absences extracted from GPS tracks during the field trips for *A. vitaliana* localities and absences placed over high resolution aerial images taking into account the author's field experience. Psuedo-absences were obtained plotting on the map a set of random points. From an initial set of 43 environmental variables representing five conceptual groups (temperature, water availability, solar radiation, land cover and topography) we selected a set of 10 uncorrelated variables (Fig. 10). Finally we modeled the distribution of the pair of species *Androsace vitaliana-Agriades zullichi* using the algorithm Random Forest.

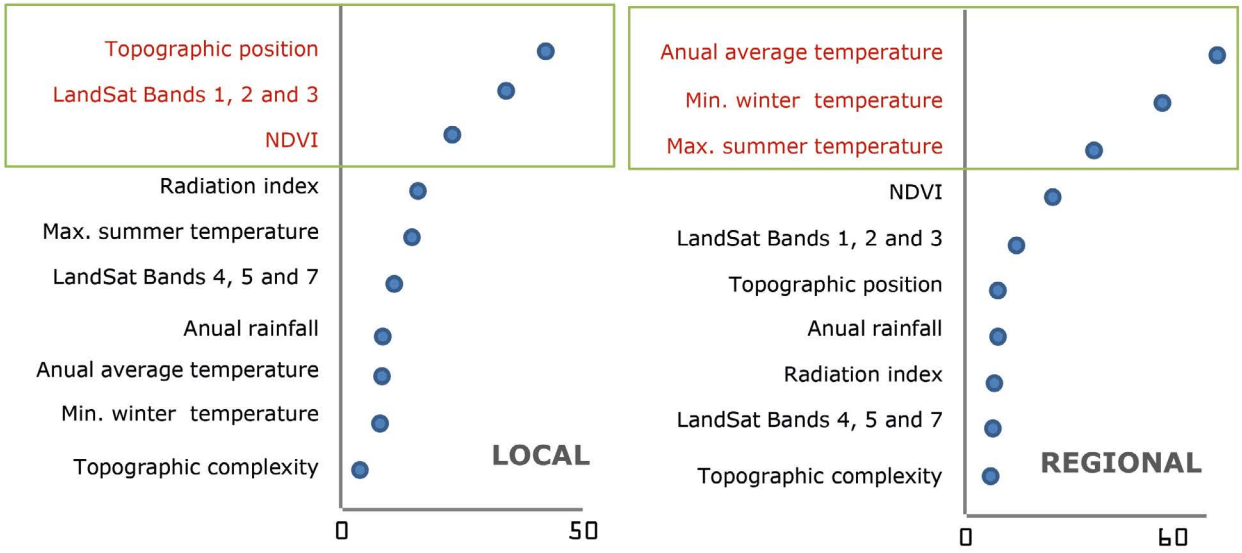

Figure 10. Relative importance of predictor variables for the habitat model of Agriades zullichi-Androsace vitaliana. *The variable importance was measured as 'increase in node purity', a standard procedure when modeling with Random Forest.*

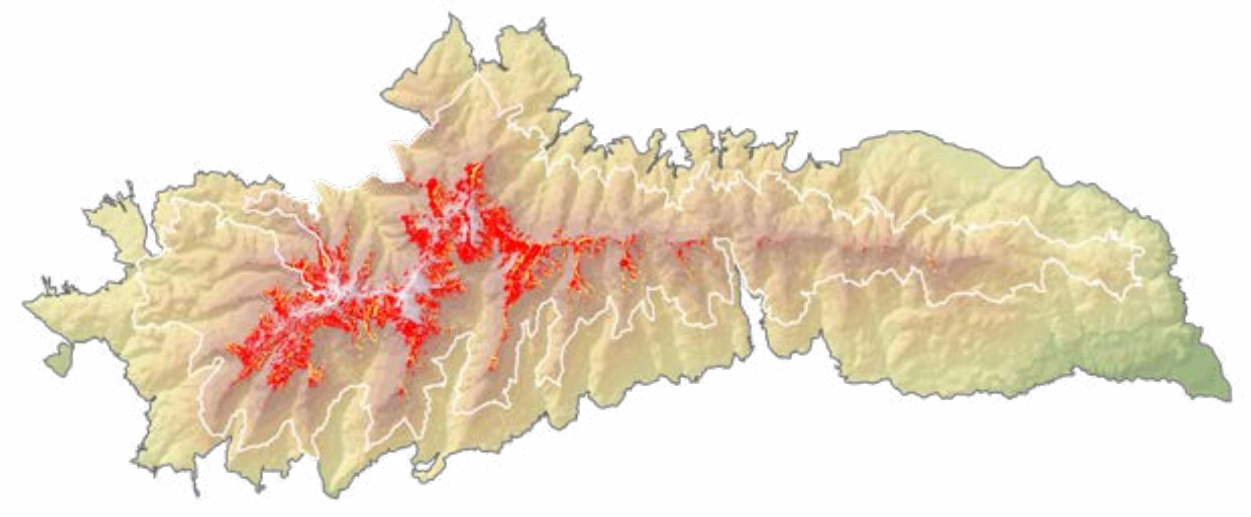

Figure 11. Local (yellow) and regional (red) distribution models of Agriades zullichi-Androsace vitaliana*.*

The results of this model show that the local and regional models explained 68.7% and 85% deviance, indicating a suitable area of 1,884.8 and 9,621.22 ha respectively (Fig. 11). The surface area of suitable area defined by the local model comprises 2,525 patches and the regional model shows a suitable area distributed on 1,869 patches. At a local scale the localities are always situated in elevated spots (summits and crests) in relation to its surrounding area. LandSat Satellite bands 1, 2 and 3, which are related to soils with a particular lithology, and the lower values of NDVI, which indicates a scarce vegetation cover, allow us to conclude that substrate and soil properties are the main drivers of *Androsace vitaliana* and *Agriades zullichi* presence. Specifically these soils consist of layers of mica schist rocks where significant presence of quartz and feldspar can be detected. This geological formation can be seen on topographic elevations due to its higher resistance to erosion and form light colour outcrops because of the mineral composition in comparison with the darker surrounding schist.

Finally, our results show how at a regional scale the climatic variables are the most important in order to explain the distribution of the species: a mean annual temperature between 6 and 10 °C, a mean winter temperature between -3 and -6°C, a mean summer temperature between 23 and 27°C. Thus, habitat structure define potential habitats for *Agriades zullichi* and its larval food plant, while climate factors play a major role at a wider scale (Barea-Azcón et al., 2014).

PHENOLOGY AND BEHAVIOUR: Adults can be found flying in the middle of July, occasionally in May and June, and it is thus a univoltine species.

Males show a characteristic flight, fast and near the ground, with small jumps between landing on vegetation or stones, which together with their cryptic coloration make them hard to see or follow (Fig. 1). They show a patrolling behaviour, spending most of their time searching for females. Mating can take place on the substrate (Fig. 13) or more rarely on the larval food plant. The females spend most of their time laying eggs, one by one, inside the leave rosettes of the food plant.

OVIPOSITION takes place when the flowering period of the plant is at its end.

NECTAR SOURCES: 70% of the 50 records of adult nectar sources were focused in three species: *Anthyllis vulneraria* (32%), *Arenaria tetraquetra* (26%) and *Thymus serpylloides* (22%). Other observed nectar sources were: *Jasione amethystina*, *Sideritis glacialis*, *Senecio boissieri*, *Silene boryi* and *Teucrium bicoloreum* (Fig. 12).

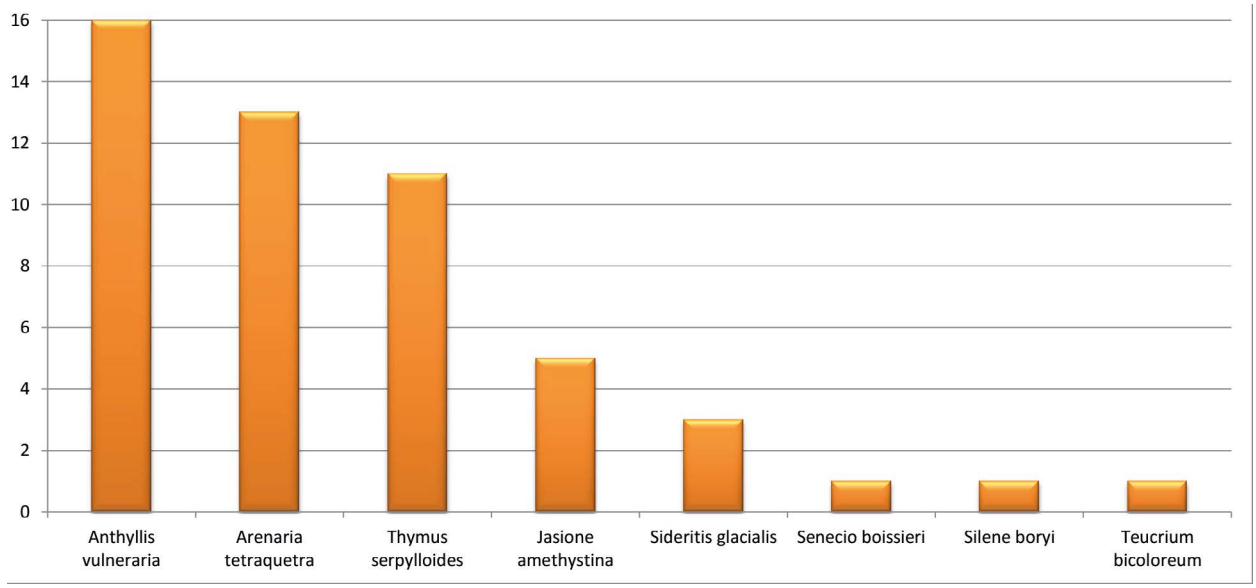

Figure 12. Number of feeding observations per food plant species of Agriades zullichi *adults per day (JM Barea-Azcón unpublished data, 2011).*

THE LARVA is monophagous and its food plant is *Androsace vitaliana nevadensis* (Fig. 14), which has been classified as a vulnerable subspecies in Sierra Nevada and is included in the Andalusian Red List of Vascular Plants. At the beginning of their development, the first and second larval instars feed on the parenchyma of the leaves, to which they access through a small hole made in the epidermis. The overwintering stage is the third larval instar and the larva hides in the rosettes of the food plant or under stones. In the fourth and fifth larval instars, they feed first on the leaves and after that on the corolla and developing fruits of *A. vitaliana*. Larvae are amyrmecophilous (ie do not not have a relation with ants) although these insects are common in the species habitat. As a result they lack Newcomer's gland and tentacles that are organs developed to interact with ants.

Figure 13. Mating pair of Agriades zullichi *on a schist stone in Sierra Nevada, Granada (photo JM Barea-Azcón).*

PUPATION takes place at the end of May or at the beginning of June, under stones close to the food plant to which the pupa is attached with some silk threads. Parasitoids have not been recorded for this species. Under laboratory conditions the pupal stage lasts for an average of 12 days, although in natural conditions it must span for a month.

Figure 14. Androsace vitaliana nevadensis*, the larval food plant of* Agriades zullichi*, a plant that is considered vulnerable in Sierra Nevada, Granada (photo J Martín).*

Population

Population density was estimated using transect counts over distances of 1 km and a width of 5 m. When the population had dimensions smaller than 1 km, shorter distances were recorded and the results extrapolated to 1 km. The samples were taken during 2013 and the results of the transect counts presented in Fig. 15, showing maximum values of 60 and minimum of 15 adults/km. The average population density estimated during the fieldwork for this project is 33 adults/km, which results in an estimate of 66 individuals/ha. This very rough estimate gives a total population number of around 4,000 adults in the total habitat of 61 ha (see above).

Larval surveys conducted during 2013 produced an average of 11 larvae per 10 x 10 m (100 m2) square (number of counts= 9). Extrapolating to the total size of the species habitat we would obtain a total of 67,000 larvae, giving an estimate significantly higher than the adults estimate. Mortality cannot account for this difference and we should consider that the real population size should be between the small and the large estimates. Based on larval counts, Munguira & Martín (1993b) estimated the population of San Juan to be of around 3,000 individuals, this data is being more in accordance with the larger estimates. Anecdotal information also shows that some populations are very small, and for example during a survey in the year 2006 of the population in Monte Morrón, in the eastern part of Sierra Nevada, we were able to find only two adults.

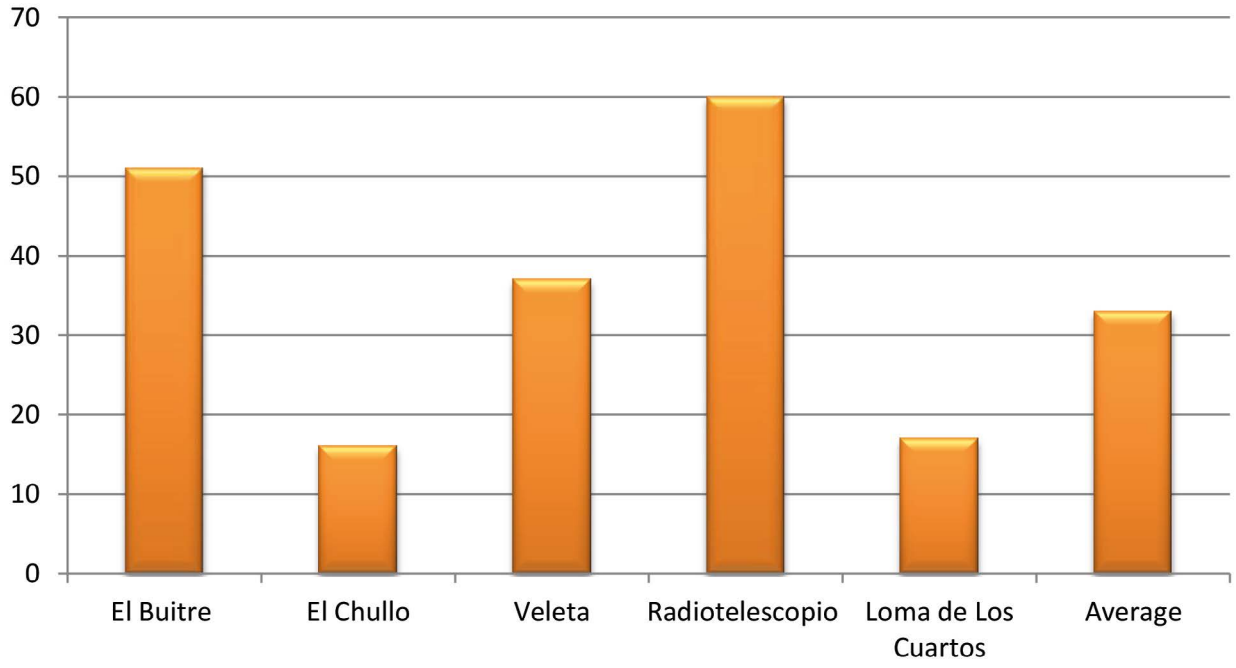

Figure 15. Average of the adult counts obtained for each locality where Agriades zullichi *was studied during the year 2013. Values represent the average density of adults on transects of variable length extrapolated to a length of 1km.*

Conservation

Legal protection

Legal protection was proposed by specialists (e.g. Munguira et al., 2009). This was achieved in 2012 when the species became protected in the region of Andalusia as "Endangered" (Catálogo Andaluz de Especies Amenazadas, Decreto 23/2012, Boletín Oficial Junta de Andalucía, 2012).

Protected areas

All its known populations are within a protected area: the Sierra Nevada National Park (Parque Nacional de Sierra Nevada). The area is also a Natura 2000 site with the code ES6140004 and a Biosphere Reserve.

Conservation status

Agriades zullichi has been given an Endangered (EN) global conservation status and the species is listed in the following international and national Red Data Books and Endangered Species Lists.

International Red Lists:

- IUCN Red List: Endangered B1b(iv)c(iv)+2b(iv)c(iv) (The IUCN Red List of Threatened Species. Version 2014.3. www.iucnredlist.org, downloaded on 13 January 2015).
- European Red List of Butterflies (van Swaay et al., 2010): Endangered.
- The species will be included in the still unpublished IUCN Mediterranean Red List of Butterflies.

Spanish National and Regional Red Lists:

- Red Data Book of the Spanish Invertebrates (Libro Rojo de los Invertebrados Españoles, Munguira et al., 2006): EN B2ac (ii,iii).
- Spanish Endangered Invertebrates Atlas (Atlas de los Invertebrados Amenazados de España, Munguira et al., 2009): EN B2ac (ii,iii).
- Andalusian Invertebrates Red Data Book (Libro Rojo de los Invertebrados de Andalucía, Travesí et al., 2008): EN B2ac.

Barea-Azcón (unpublished manuscript: *Agriades zullichi* Hemming, 1933) suggests that the species should be considered Critically Endangered (CR) due to its reduced area of occupation (AOO< 10 km2), severely fragmented population, continuous decline and extreme fluctuations of its populations (CR B2 ab (iii, iv, v) c (iv)).

Threats

Threats mentioned in the literature are urban development (roads, buildings and ski slope improvement) on the population of El Veleta, overgrazing, collection of individuals in El Veleta, landslides (this threat occurred only once and affected just one population in Valle del Dúrcal) and that some populations occur outside protected areas (this threat was mentioned before Sierra Nevada was declared National Park; now all populations are within protected areas). Other non-specific threats are also mentioned such as the low number of populations and their reduced size and climate change.

DEVELOPMENT of tourism and particularly, the development winter sports infrastructures, has seriously damaged some populations on the western distribution edge of the species, especially the one living on El Veleta area (Sierra Nevada, Granada, populations of Veleta and Radiotelescopio). Development in the area includes building new touristic complexes, roads to reach them, parking places, damage of mountain slopes to prepare them for skiing and other temporary or permanent facilities built around the resort.

CLIMATE CHANGE is the main threat to *Agriades zullichi* in the long term, because the climatic range of the species could be displaced toward higher areas where the habitat availability is lower. This fact can also lead to a drastic reduction of the distribution area. Temperature in Sierra Nevada has increased with 2°C in the last 30 years and is expected to rise 4.8°C more in the present century (Benito et al., 2011). This would cause a major reduction of the suitable area for the survival of its food plant that needs cool conditions. Monitoring the populations is important to track the effects of climate change and detect possible adaptations that can help the species survival. According to literature references, the low number of populations and their small size make *A. zullichi* very vulnerable to other risks, such as overgrazing, collection of individuals and landslides.

COLLECTING might have been a problem in the past, but the protection of Sierra Nevada as a National Park and the high fines that collecting a protected species would imply, keep the impact of this threat at a very low level.

Threats observed during fieldwork in 2012 and 2013 are shown in Fig. 16 and Table 1 and are:

- **Urban development** in two locations from the Veleta area. In this case, two threats were detected: the impact of the ski resort and the effect of roads.
- **Overgrazing** in Morrón de Laroles and El Buitre both in the eastern part of the Sierra Nevada. This threat has also been mentioned for El Chullo and some of the localities in Veleta area (Barea-Azcón, unpublished manuscript).
- **Trampling** appears as a new threat in El Cuervo, El Veleta and Vacares, all in the western side of Sierra Nevada. This threat is caused by livestock grazing and by tourists walking outside footpaths or roads.

The rest of the populations studied during fieldwork showed no evident threats, and this fact is also registered in the figure.

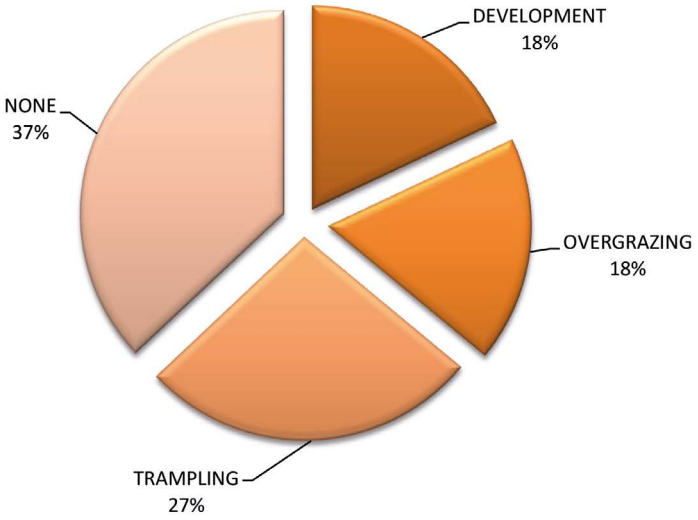

Figure 16. Threats affecting Agriades zullichi *registered during fieldwork during the years 2012 and 2013 in Sierra Nevada. Populations where no threats were observed are presented as "none".*

As mentioned above *Agriades zullichi's* preferred habitat is Oro-Iberian *Festuca indigesta* grasslands habitat type (code 6160) listed in the Annex I of the EU Habitats Directive. The "Report on the main results of the surveillance under article 11 for annex I habitat types" [1] mentions that this habitat is protected in 105 NATURA 2000 sites in Spain, few of which are in Andalusia, like Sierra Nevada and Sierra de Cazorla. In the latest EU habitats assessment, Spain has reported the current conservation status and the future prospects of this habitat as Unfavourable-Bad[2] in both cases. The trend for the range of the habitat is decreasing. The same document gives priorities for the conservation measures. Those recommended of high importance are regulating or management of the exploitation of natural resources on land and with medium importance, establish protected areas, legal protection of habitats and species and the management of landscape features.

Table 1. Threats affecting each Agriades zullichi *population detected during fieldwork during the years 2012 and 2013 in Sierra Nevada. Data were compiled from the different years of sampling and altitudes and UTM coordinates given for each location.*

LOCATION	UTM COORDINATE	ALTITUDE (m)	THREATS
EL VELETA	30SVG60	2659	Road, ski resort, trampling
RADIOTELESCOPIO	30SVG60	2700	Road, ski resort
LOMA DE LOS CUARTOS	30SVG70	2755	None
VACARES	30SVG70	3140	Trampling
EL CUERVO	30SVG70	3050	Trampling
PICO SAN JUAN	30SVG80	2779	None
MORRÓN DE LAROLES	30SVG90	2708	Overgrazing
EL CHULLO	30SWG00	2594	None
El ALMIREZ	30SWG00	2405	None
El BUITRE	30SWG10	2396	Overgrazing

[1] http://cdr.eionet.europa.eu/Converters/run_conversion?file=/es/eu/art17/envucgusw/ES _habitats_reports-13910-14715.xml&conv=350&source=remote#6160

[2] http://bd.eionet.europa.eu/article17/reports2012/habitat/summary/?period=3&group=Grasslands& subject=6160&region=MED

Species action plan

Introduction

This chapter discusses the possible actions, which, if conducted, will significantly improve the survival chances of the species. In each chapter we discuss the actions that are necessary to overcome the main threats that the species is facing. The actions have been discussed with officials and the director of the Sierra Nevada National Park, where the species is present, and with personnel from the Junta de Andalucía, that is responsible for the conservation of the species at the regional level. It is essential to monitor the populations of the species because the effectiveness of the proposed measures would only be evident if the butterfly population trends are positive. In general, the conservation actions will be mostly related to the habitat. The main goal is to avoid negative interventions orreduce their impacts to a minimum and think about possible compensation measures. Some precautionary measures are also mentioned in the following sections.

Legal protection

The species is already protected in Andalusia and its habitat is protected by the Sierra Nevada National Park. However, we recommend that the species is protected at a national level through its inclusion in the list of protected species (Catálogo Español de Especies Amenazadas). The priority of this action is **intermediate** because the species is already protected at a regional level in all the areas where it is present. Inclusion of a species in the national list needs to be proposed by the Ministry of Agriculture and Environment (Ministerio de Agricultura, Alimentación y Medio Ambiente), which means that the action should be planned for the long term. The inclusion of the species in the Annexes of the Habitats Directive is recommended as it will draw attention towards the conservation of the species and support all the actions suggested by this recovery plan.

Conservation measures

The **main actions** for the conservation of the species can be summarized in the following proposals:

High priority:

- Prevent overgrazing with exclusion fences.
- Avoid trampling by footpath management and information for the visitors.
- Stop new developments and reduce the negative effects of the existing urban developments.
- Population reinforcement to mitigate the effects of climate change.
- Monitoring of populations of the butterfly at the larval and adult stage.

Medium priority:

- Captive breeding of the butterfly and population reinforcement of the populations of the food plant.
- Public awareness campaigns including information materials, panels, and media releases with information about the species.

As the populations are very fragmented and have a very low density, they are very vulnerable to several risk factors. The 39 populations of *Agriades zullichi* are in the Sierra Nevada NATURA 2000 site ES6140004. The management plan for this NATURA 2000 site can be found on the website of the Junta de Andalucía.

However, since the species is not listed in the EU Habitats Directive species, no specific conservation measures will be required in this management plan for the species. However, the species uses a habitat type that is listed in Annex I of the Habitats Directive (HD code 6160), part of which are the small cushions of *Androsace vitaliana assoana* (=*A. v. nevadensis*), the larval food plant. In the list of the typical species for this habitat type one of the nectar plants used by *A. zullichi* is mentioned: *Jasione crispa.*

The main efforts must be directed in improvement of the management of these particular areas inhabited by the species, which means proper management of the HD habitat. Thus, ensuring the good maintenance of this habitat will certainly increase the chances for survival of *A. zullichi*.

Some of the following proposed actions are also mentioned, but still not implemented, in the Species Recovery and Conservation Plan of the High Altitudes of Andalusia (Plan de Conservación y Gestión de Especies de las Altas Cumbres de Andalucía). Relevant actions for *A. zullichi* from this plan are:

8.3.1. Promoting the reintroduction or reinforcement of populations.

8.3.5. Establish suitable livestock loads.

8.5.1. Monitoring population abundance and threatening factors.

8.8. Public awareness including education campaigns, volunteer participation and collaboration of private and social actors in the conservation of the species.

8.10.2. Coordination among conservation entities, social organizations and public bodies towards the success of the plan.

OVERGRAZING AND OCCASIONAL GRAZING

Overgrazing has been detected as a threat in Morrón de Laroles and El Buitre, both in the oriental part of Sierra Nevada (Granada). Occasional grazing takes place in most of the habitat of the butterfly, particularly in the eastern part of Sierra Nevada (for example in El Chullo, Fig. 17), but this grazing is probably not damaging the habitat of the species, as livestock usually prefer to graze areas with a better vegetation cover and only use the *A. zullichi* habitat as secondary feeding ground. Typical livestock densities for most of the administrative domains of the area are of less than 1 animal/ha, which means that overgrazing is probably a very rare event. Grazing is not necessary for the conservation of the habitat of the butterfly and therefore traditional extensive grazing can be maintained as it favours the existence of species rich grasslands. However, it is important that overgrazing is prevented.

In Sierra Nevada two **exclusion fences** are being planned, together with the National Park authorities, as an experimental action for the protection of the habitat of *Polyommatus golgus* and *Agriades zullichi*. These fences would be located one in the Veleta area and the other close to El Picón de Jeres, where two large and well known populations of the species live. These sites were not considered during our study, but have been suggested as suitable for the experimental test of the effect of grazing by experts from the area. Monitoring the effect of these fences on the populations of these two species is vital to know if this action is beneficial and could be extended to other areas where grazing can pose a problem for the habitat of the butterfly. Officials from Sierra Nevada National Park find this measure feasible and will start to plan it in the year 2015. They will also provide financial support and advice for the technical aspects. The priority of this action is **high**, because it will provide valuable information for the management of the species in the future.

Figure 17. Occasional grazing by goats and sheep over the habitat of Agriades zullichi *in El Chullo, Sierra Nevada, Granada (photo ML Munguira).*

TRAMPLING

Trampling has been observed in El Cuervo, El Veleta and Vacares as an important new threat which damages the food plant. Historically it was not mentioned as a threat, but due to the development of tourism or, locally, as a result of aggregation of livestock in specific sites, it can be a serious limiting factor for the species (Fig. 18). National Park authorities in Sierra Nevada are already trying to restore traditional footpaths and close the shortcuts in the Mulhacén area. We suggest that this action should be extended to the Veleta area. A road crosses the slopes of El Veleta, but park visitors cross the butterfly habitat using shorter alternatives. Information panels that will be set up by BCE in the area will inform visitors about this problem and explain why they should use the road. Park wardens will be informed about this topic and the bus taking visitors to the highest areas of El Veleta will give guidance about the correct behavior when walking through the area.

Compensation actions:

- To close the footpaths in the areas where the butterfly breeds, as in the Veleta area in Sierra Nevada.
- Informing the park visitors with panels that show the importance of using marked footpaths instead of shortcuts.
- Establish areas within the National Park with special visiting regimes.

We consider the priority of these measures is **high**. The information panels will be financed by the BCE as part of the current project and other actions taken by personnel would be a responsibility of the Sierra Nevada National Park.

Figure 18. The effect of trampling and the fragmentation caused by a road have negative effects on the populations of Agriades zullichi *found in El Veleta, Sierra Nevada, Granada (photo ML Munguira).*

URBAN DEVELOPMENT

Urban development such as roads, buildings and ski slope improvement, taking place on the habitat of the butterfly is a severe threat. It was mentioned in the literature and reported during the project in visits to the area in 2012 and 2013. The impact of this threat is evident in the populations around El Veleta, Sierra Nevada where the ski resort "Sol y Nieve" has been built (Fig 19).

To reduce the negative effects of urban development we suggest the following actions:

- Plans to extend the limits of the ski resort in the Monachil and adjacent valleys should be stopped. There is a repetitive demand to expand the ski resort within the boundaries of the National Park and this should clearly be opposed. Moreover, the development of new infrastructures (buildings, roads, ski courses) should be avoided near the places where populations of *A. zullichi* still survive.
- The population in the vicinity of the Radio Telescope (Radiotelescopio), that has the highest estimates of adult densities, is crossed by a ski course in one of its margins. It is important that the activities in the area during the summer are controlled so that no damage is made to the population. A correction of this course is suggested so that the area in which ski is practiced does not damage the core of the population.
- Disseminating information about the location of these highly vulnerable *A. zullichi* populations is important, because park officials can use this data to prevent any negative actions of the ski resort in the sites where the butterfly lives.
- In some marginal and damaged areas of the ski courses, the habitat can be restored, improving the regeneration of the native vegetation and removing damaging infrastructures from areas that have the potential as habitat for the species.

Figure 19. The ski resort Sol y Nieve on the slopes of El Veleta in Sierra Nevada, Granada. The photo has been taken from one of the Agriades zullichi *populations in the area (photo J Martín).*

CLIMATE CHANGE

Climate change is considered by many authors as the most threatening factor for the butterfly in the long term. The increase of the temperature in Sierra Nevada is already taking place and this will undoubtedly have an effect upon the survival of the butterfly and its larval food plant. The cool climatic conditions needed by the butterfly will eventually disappear from existing breeding areas and the butterfly will shift uphill, causing the extinction of some populations and the reduction of the range in the others. A considerable percentage of the populations inhabit peaks or tops of ridges and these populations will be more vulnerable to the changes caused by climate change (Fig. 20).

Specific solutions to the problems caused by climate change are difficult to implement, because the actions need to be taken at a global scale. Despite this, we consider that some measures must be developed in order to improve the resilience of known populations under a climate change scenario. In this sense, one of the main actions should be population reinforcement, both of the butterfly and the plant, mainly in populations living at higher altitudes as is suggested in the following section. The priority of these actions is **high** because climate change would have a very negative effect on the survival of the species.

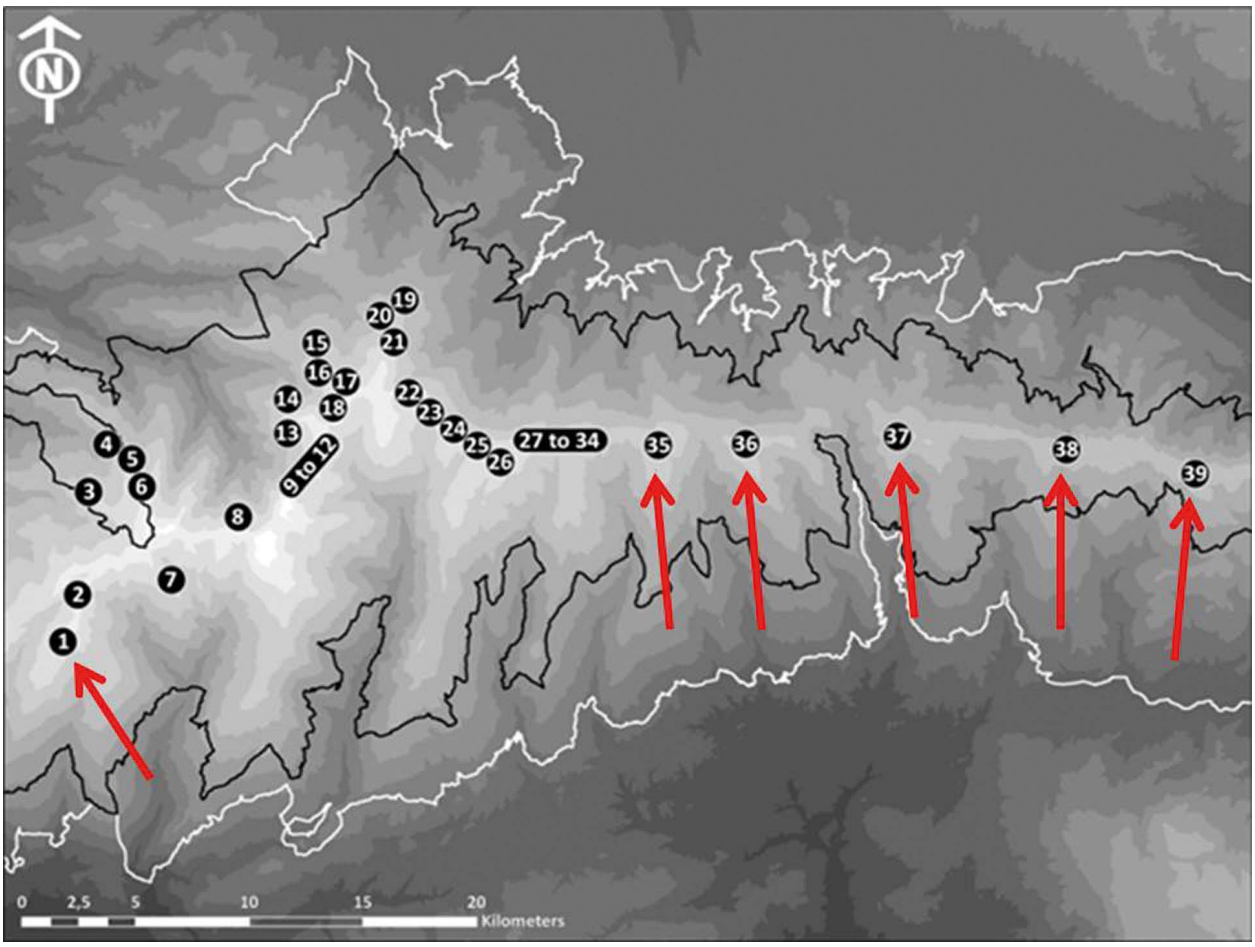

Figure 20. Populations of A.zullichi *that currently live on summits or on top of ridges in Sierra Nevada and are more vulnerable to the effect of climate change because they have not the possibility to migrate to higher elevations.*

Research

Monitoring

Adult and larval censuses should be maintained over time to ensure that the conservation status of the species improves with the implementation of the planned actions. Larval censuses started in 2013 and should be carried out at least in five different areas covering the eastern and western populations. Adult counts following the transect method could easily be continued during the end of June and the beginning of July in a selection of sites, preferably those where larval counts are carried out. Monitoring the status of the two *A. zullichi* populations inside exclusion fences planned for the species would also be important to study the effect of this action. Viability of this measure would be high if officers from the National Park could carry on with it in accordance with the butterfly monitoring scheme already taking place in the park. Following Barea-Azcón et al. (2014) it would be particularly important to analyze the phenology of *A. zullichi* and its larval food plant (*Androsace vitaliana*) to search for potential phenological mismatches under climate change scenarios that would eventually disrupt the interaction between the two organisms and threaten the survival of the butterfly.

The priority of this action is **high**, because it would be crucial to know about the effectiveness of the recovery plan.

Captive breeding and plant reinforcement

This is an important research topic that would secure, if successful, live specimens for population reinforcements. Food plant reinforcement is also important in some areas where the number of plants is low. Local scientists, managers, technicians and amateurs have the knowledge to carry out this research program, but funding by the local government or national research plans will enforce the process. This action involves two groups of activities:

- Plant population reinforcement: local experts have found that the seeds of Androsace vitaliana germinate easily. However, there is no information on the survival of the small plants in the long term. The botanic garden in Sierra Nevada National Park (Jardín Botánico Hoya de Pedraza) could help with this task, fund it and guide the actions for the reinforcement of the smallest populations of the plant.
- Captive breeding of the butterfly and adult reintroduction: this involves keeping a number of A. vitaliana plants and breeding larvae on them. The adults obtained could be released in the wild in selected populations. Populations where this action would be useful are Radiotelescopio, El Almirez, El Chullo and the population in El Veleta where exclusion fences will be built.

This action is of **medium** priority, the captive breeding program would be of great help, but is difficult to establish with success. Costly butterfly captive breeding program requires funding.

Public awareness

The people who visit the National Park in which *Agriades zullichi* lives usually have a strong interest in nature. General information and ideas about the protection of the species for visitors could encourage involvement of the public and eventually support other conservation actions.

- Leaflets with information about the importance of the species and its conservation will be produced in 2015. They will specify the actions for the recovery of the species that are already taking place, using non-technical language and showing pictures of the species and its habitat. Leaflets will be available in the information centers of Sierra Nevada National Park. They will be published both in English and Spanish. This action is of **high** priority and will be implemented in 2015.
- Publish information on websites. A digital version of the leaflets will also be produced and distributed widely to amateur and scientific organizations (butterfly conservation organizations, entomological societies and park webpages). The time of application of this action can be prolonged in the following two years.
- Produce and place information panels in Sierra Nevada with information about the importance of the species and its conservation. Panels will also contain information on the value of the butterfly fauna for each area. We suggest setting up three of these panels in Sierra Nevada: in Hoya de la Mora, the Visitor Centre and Puerto de la Ragua). Together with the information leaflets this action is considered of **high** priority and will be implemented during 2015 as part of the current BCE project.
- Guided butterfly tours should be supported in Sierra Nevada and should include information about Polyommatus golgus and *A. zullichi*. Such activities would raise awareness and the interest of visitors towards these insects, and give information about endemic and endangered species. The knowledge of butterflies acquired by people participating in these tours would also provide an added value to the visit to the National Park.
- Power Point presentations could be available for training courses. They may include information on the species already gathered during the project and will be sent to the park authorities and be available upon request. Priority of this action is **low**, but the presentations are ready and will be done within the current project.
- Media releases (newspapers) with contents related to the recovery of *A. zullichi*, have already taken place during the project and will be produced at its end and in the future. Priority is **intermediate** and this action will take place throughout the next years.

This project and the work further would not be possible without the voluntary help of all the specialists who took part and helped the project by collecting and providing data and advises, and will continue to do it in the future. Many thanks again for your devotion to saving some of the incredible biodiversity of Spain.

Acknowledgements and literature

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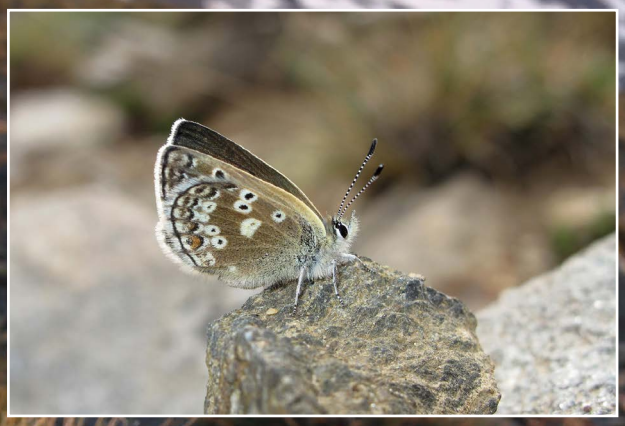

Sierra Nevada constitutes an excellent natural laboratory for studies on the climate change effects on biodiversity, but also the on impact of the management activities in a climate change scenario.

Sierra Nevada National and Natural Park works in a monitoring program aimed to track the global change effects on the ecological and socio-economical systems of this emblematic mountain range. This monitoring program is part of the Sierra Nevada Global Change Observatory. One of the main biological indicators in this program are the butterfly communities, giving special attention to endemic and endangered species as Zullich's Blue. The more important threatening factor for this species is the climate change. Tracking its effects is of major concern in order to improve the habitat management.

Recently, the Andalusia Government approved the *Species Recovery and Conservation Plan of the High Altitudes of Andalusia* (Acuerdo de 13 de marzo de 2012, del Consejo de Gobierno). This Plan has a legal consideration and targets the species included in the Andalusian Endangered Species Act. Zullich's Blue is one of these species together with other insects like the butterflies Sierra Nevada Blue and the Andalusian Anomalous Blue, the grasshopper *Baetica ustulata* and the ant *Rossomyrmex minuchae*, as well as many mountain specific plant species. This Plan aims to establish an appropriate framework for the development of an effective conservation strategy, taking into account key concepts as Global Change, adaptive management, traditional mountain land uses and public awareness.

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