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Research Article

The value of eco-volunteer projects for biodiversity conservation: butterfly monitoring in Krka National Park (Croatia) with an updated checklist

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Abstract

The biogeographical importance of Dalmatia, bordered by the Dinaric Alps and the Adriatic Sea, is evident through the rich biodiversity of this region and its network of protected areas. One of those areas, Krka National Park (NP), supports a wide range of natural habitats, but rapidly increasing tourism puts high pressure on its ecosystems, despite its protected status. Accurate knowledge of species and their distributions within natural places such as Krka is essential to direct and prioritize future conservation efforts. As collecting biodiversity data is time and resource-intensive, alternative ways to obtain this information are needed. One possibility is monitoring based on eco-volunteering. From June to August of 2019, an Operation Wallacea/BIOTA scientific team surveyed a section of Krka NP and its surrounding boundaries, within the vicinity of the village of Puljane, to study its butterfly richness and abundance. Pollard walks and static count surveys were conducted with the help of eco-volunteers, testing the effectiveness of gathering field data through this approach. Overall, 57 butterfly species were found throughout the study, including four new records for Krka NP. Three further new species for the park were detected close to its boundaries and are also expected to occur within its borders. Here, we present an updated butterfly checklist for Krka NP, highlighting the positive impact of

eco-volunteering initiatives and the importance of combined research efforts to study and protect the rich biodiversity and ecosystems of protected areas.

Keywords: Citizen Science, Entomology, Inventory, Lepidoptera, Protected areas

Introduction

The Mediterranean biodiversity hotspot (Myers *et al*. 2000) supports a significant butterfly richness, with numerous endemic species often constrained to small isolated populations (Numa *et al.* 2016). Croatia and especially Dalmatia - the southern region of the country bordered by the Dinaric Alps and the Mediterranean Sea - is mainly characterized by high endemism and high diversity of taxa (Williams *et al.* 2000, Van Swaay and Warren 2003, Jelaska *et al.* 2010, Koren and Laus 2013, Ćaleta *et al.* 2015, Ivković and Plant 2015, Ozimec *et al*. 2015). Located within this biogeographically important region, Krka National Park (NP) represents a natural stronghold for many species, with its extensive areas of relatively undisturbed ecosystems (Fig. 1). However, Croatian National Parks have experienced a sharp increase in tourism in recent years (Albolino 2014), with detrimental effects being noted on some of the more popular spots such as Plitvice NP (Ružić and Šutić 2014, Vurnek *et al.* 2018). With rapidly increasing urbanization rates, these environmental challenges put substantial pressure on natural ecosystems, increasing the need to change management plans and protect biodiversity. Therefore, to secure optimal decision making and prioritize conservation efforts, assembling accurate data on both species' presence and their distribution inside these protected areas is vital.

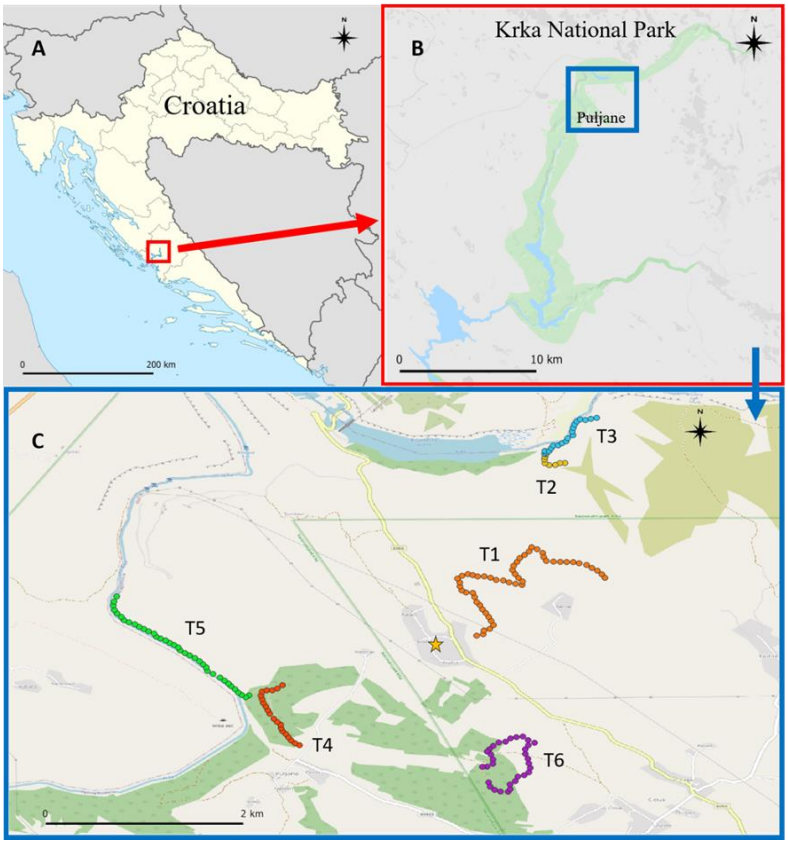

Figure 1. Map showing **A)** Location of Krka National Park within Croatia; **B)** Location of Puljane within Krka NP; **C)** Location of transects nearby Puljane, both inside Krka NP and on its surrounding boundaries. A pale green line indicates the Park border. The yellow star represents the location of Bračići town within Puljane.

High-resolution data collection tends to be costly in both time and money, with detailed surveys requiring longer study times and being thus limited by budgetary and logistical constraints. On the other hand, an increasingly common approach to data collection is through eco-volunteer initiatives (Silvertown 2009). Although not all taxa are equally suitable for citizen scientist-driven inventory projects (Dickinson *et al*. 2012), butterflies are often well-suited due to their high dispersal capacity, conspicuous nature, relatively large population sizes (at least for most species), and relative ease of identification (for most species) (Dennis *et al*. 2017). Additionally, butterflies are also good bioindicators of ecosystem quality, given their high sensitivity to small changes in environmental conditions (Van Swaay *et al.* 2008). As such, monitoring data from this group can, to some extent, be used to determine further optimal niche conditions and demographic trends in more cryptic taxa (Thomas 2005).

The scientific knowledge of the Croatian Lepidoptera has dramatically improved during the last decade, with some regions of the country becoming very well studied (Lorković 2009, Koren *et al.* 2011, 2015a, 2015b, 2015c, 2018, 2019, Mihoci *et al.* 2011, Tvrtković *et al.* 2012, Koren and Laus 2013, Verovnik *et al*. 2015). Consequently, the first checklist of Croatian butterflies was published in 2011, listing 195 species (Šašić and Mihoci 2011), and the first butterfly checklist for Krka NP was published in 2017 (Kučinić *et al*. 2017). However, further fieldwork is still necessary to gather accurate knowledge on the true richness of Dalmatia's butterfly communities.

In this work, we evaluated the value of a large scientist-coordinated eco-volunteer project in Krka NP and the surrounding area, collecting butterfly diversity data with transect based and opportunistic surveys while also assembling an updated butterfly checklist for the park.

Material and methods

Study site

Krka NP is a 142 km^2 protected area located in the Dalmatian region of Croatia, in the foothills of the south-western Dinaric mountains (Beran 2016, Ivković and Pont 2016), with underlying geology dominated by quaternary karstic limestones (Ivković and Pont 2016). It was founded in 1985 to protect a 50 km stretch of the Krka River between the towns of Knin and Skradin, giving the park a relatively linear shape, which follows the course of the river and its gorge (Beran 2016). The area possesses a hot-summer Mediterranean climate (*Csa* on the Köppen-Geiger system, Peel *et al*. 2007) with temperatures at Knin averaging 23ºC in July and 5ºC in January (Krka National Park Authority 2020). Precipitation averages 1078 mm per year, with most falling between October and February (Krka National Park Authority 2020).

Survey methods

Between June and August 2019, an Operation Wallacea/BIOTA lepidopterist team surveyed the north-eastern region of Krka NP and its exterior boundaries, in the vicinity of the village of Puljane, to study the butterfly richness and abundance of this area (Fig. 1). To collect standardized data, six transects were set up for Pollard walks (Pollard and Yates 1993) which covered juniper grasslands, burnt grasslands, rocky valley slopes, mixed Mediterranean juniper-oak scrub habitats, and riverine forests (Table 1). Additionally, 10-minute static counts (with a radius of 20 meters) were added at specific locations on these transects. Surveys were carried out five days per week, during which Pollard walks conducted on the transects, with the observers stopping at the defined intervals for the respective butterfly static counts.

Throughout the study, almost two hundred eco-volunteers helped scientists gather field data, divided into groups of 5-10 volunteers per day. All eco-volunteers (high school students aged 16-18 and university students aged 20+, with

the former being often accompanied by teachers) were briefed on survey methods and species before helping a team of two lepidopterists to collect and count butterflies on the Pollard walks and static counts.

On both surveys, eco-volunteers helped to catch butterflies with seine nets (diameter 30 cm), and the coordinating scientist supervised species identification in the field. To further guarantee the data's reliability, a picture of each butterfly caught was taken and stored in a supplementary photographic database. Butterfly records from formal surveys were compiled into a single database, while an additional database of opportunistic observations was also assembled. Opportunistic observations occurred whenever formal surveys were not being conducted, either on the transects or in other park sections. All records were aggregated when assembling the full list of butterfly species found throughout the whole study and the transects where each species was encountered.

Table 1. Summary information for the transects used in the 2019 Operation Wallacea/BIOTA butterfly surveys in Krka National Park, Croatia.

Transect number	Habitat represented	Length (m)	Coordinates	Static counts per transect
1	Juniper grassland and burnt grassland	2600	Start: 43.98832, 16.04937; End: 43.994172, 16.060951;	7
2	Juniper grassland	350	Start: 44.00583, 16.05732; End: 44.00671, 16.05561;	2
3	Riverine forest	900	Start: 44.00676, 16.05548; End: 44.01041, 16.0602;	5
4	Rocky valley slope	1000	Start: 43.97719, 16.03329; End: 43.98328, 16.03175;	3
5	Riverine forest	1800	Start: 43.98254, 16.02773; End: 43.99021, 16.017157;	5
6	Mixed Mediterranean oak-juniper scrub habitat	1540	Start: 43.973416, 16.050413; End: 43.974991, 16.049849;	5

Results

By the end of the season, a total of 1362 butterfly observations were entered in the database, obtained from 61 transect Pollard Walks and 149 static counts, which together comprised over 92 hours of survey time. From the previous list of eighty-one butterfly species given for the whole Krka NP (Kučinić *et al*. 2017), fifty of these were also found during our field work, both inside and outside the park's border. Furthermore, we found seven other species not included in Kučinić *et al*. (2017), four of these inside the park's borders and thus new species for Krka NP: *Fabriciana niobe* (Linnaeus 1758 - Nymphalidae), *Polyommatus escheri* (Hübner 1823 - Lycaenidae), *Satyrium ilicis* (Esper 1779 - Lycaenidae) and *Spialia orbifer* (Hübner 1823 - Hesperiidae). The remaining three were found just outside the border of the park, two in the small town of Bračići (Puljane) and the other within a transect: *Pyrgus armoricanus* (Oberthür 1910 - Hesperiidae), *Iolana iolas* (Ochsenheimer 1816 - Lycaenidae) and *Tarucus balkanicus* (Freyer

1845 - Lycaenidae), respectively (Fig. 2). An updated butterfly species list for Krka NP is presented in Table S1, which also specifies the species found in the course of this project, alongside where they were found. Additionally, graphics are presented in Supplementary Material for all species encountered, showing when and where these were spotted throughout the season (Fig. S1-S5).

From the updated species list, and including the potentially new species found just outside the Park borders (Table S1), six taxa have a Near Threatened conservation status on the Red List of European butterflies (Van Swaay *et al.* 2010, IUCN 2020): *Thymelicus acteon* (Rottemburg 1775), *Iolana iolas*, *Polyommatus dorylas* (Denis and Schiffermüller 1775), *Pseudophilotes vicrama* (Hemming 1929), *Chazara briseis* (Linnaeus 1764) and *Hipparchia statillinus* (Hufnagel 1766). Additionally, seven species from the same list have a Near Threatened status within Croatia, according to the Red List of Croatian butterflies (Šašić *et al*. 2015), one of them shared with the European Red List: *Glaucopsyche alexis* (Poda, 1761), *Pseudophilotes vicrama*, *Scolitantides orion* (Pallas 1771), *Euphydryas aurinia* (Rottemburg 1775), *Proterebia phegea dalmata* (Godart 1824), *Papilio machaon* (Linnaeus 1758) and *Zerynthia polyxena* (Denis and Schiffermüller 1775).

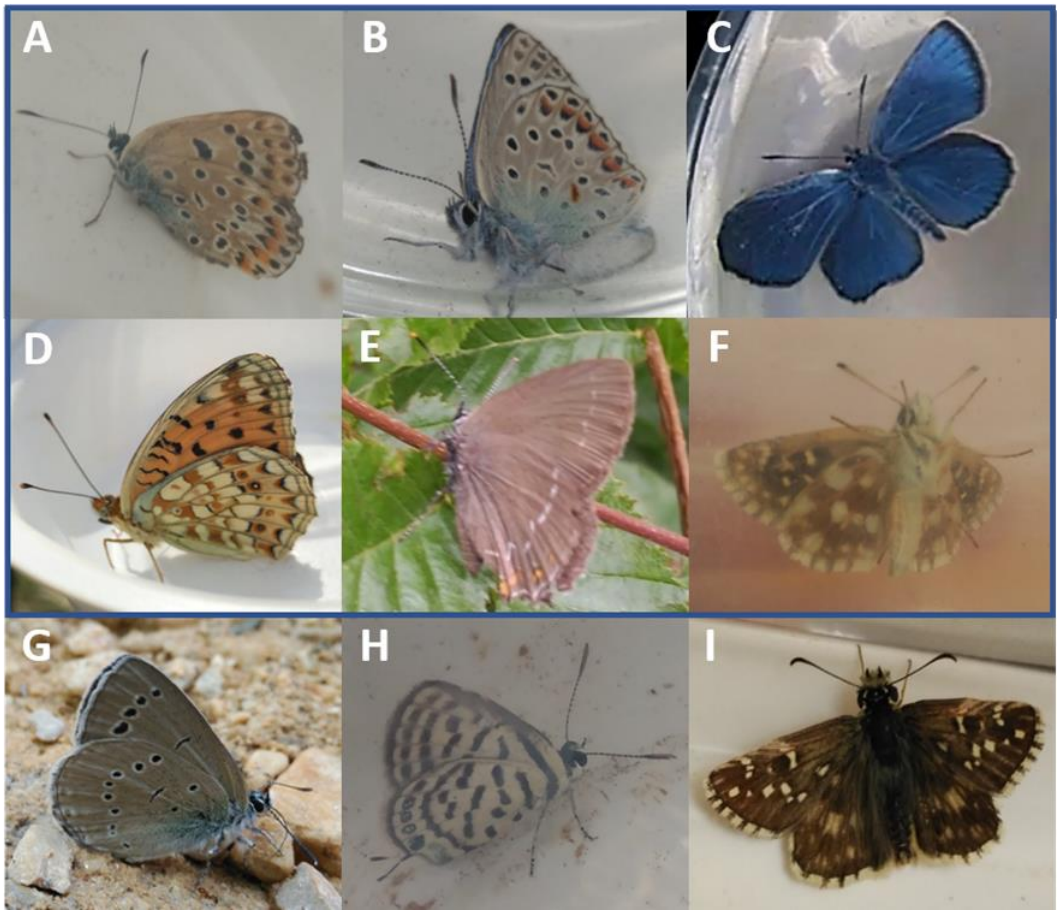

Figure 2. Photographs of the four new species discovered for Krka National Park in the course of the 2019 fieldwork (A-F) and the three potentially new species found just outside the Park (G-I): A-C) *Polyommatus escheri*; D) *Fabriciana niobe*; E) *Satyrium ilicis*; F) *Spialia orbifer*; G) *Iolana iolas*; H) *Tarucus balkanicus*; I) *Pyrgus armoricanus.*

Discussion

This first trial of scientist-coordinated eco-volunteer surveys in Krka NP has shown the potential value of this approach for biodiversity data collection and biodiversity monitoring. The sampling effort throughout the study was greatly improved with the further collaboration of eco-volunteers, increasing the human capacity for collecting and counting butterflies, while the supervision of trained lepidopterists allowed for a high level of data quality control. Overall, the fieldwork has enabled the assemblage of a consistent record database with fifty-seven species and the detection of four new butterfly species for Krka NP, as well as another three new ones just outside the park's border. A significant proportion of the butterfly species previously recorded from the Park (Kučinić *et al*. 2017) was not encountered in this study due to a probable mismatch between their flight season and our own field work (Table S1). The different timing in which each species was observed throughout the field season (see Supplementary Figures S1-S5) highlights the diversity of species flying within this National Park in different time periods and how the park is supporting butterfly biodiversity throughout most of the year. The establishment of transects covering different habitats and ecosystems facilitated the detection of a higher diversity of species, highlighting the importance of stratified sampling strategies. Moreover, small microhabitats that were included by chance in some transect paths often yielded important species records, as with the case of a small floodplain meadow on one of the riverine forest transects (T5), which yielded several Lycaenidae and Hesperiidae species not recorded elsewhere.

Of the new species recorded for the park, three had a previously known widespread distribution and their presence in Krka is not surprising: *Fabriciana niobe*, *Satyrium ilicis* and *Spialia orbifer* (Tolman and Lewington 2008, Lorković 2009, Koren *et al.* 2011, 2015a, 2015b, 2015c, 2018, 2019, Mihoci *et al.* 2011, Tvrtković *et al.* 2012, Koren and Laus 2013, Verovnik *et al*. 2015, Leraut 2016). The fourth species, *Polyommatus escheri*, has a theoretical distribution that includes the spatial area of the park but is likely at the limit of its overall range here (Tolman and Lewington 2008, Koren *et al.* 2011, 2015a, 2015c, 2018, 2019, Mihoci *et al.* 2011, Tvrtković *et al.* 2012, 2015, Verovnik *et al*. 2015, Leraut 2016). From the three potential new species found just outside the park's boundaries, *Pyrgus armoricanus* and *Iolana iolas* in the village of Puljane and *Tarucus balkanicus* in T1, the first two have a widespread theoretical distribution that covers the area of the park while the second is already approaching the limit of its range in Krka (Tolman and Lewington 2008, Lorković 2009, Koren and Ladavac 2010, Koren *et al.* 2011, 2013, 2015a, 2015b, 2015c, 2017, 2018, 2019, Mihoci *et al.* 2011, Tvrtković *et al.* 2012, 2015, Koren and Laus 2013, Koren and Letić 2014, Verovnik *et al*. 2015, Leraut 2016). We believe that these three species are likely also present inside Krka NP, as *P. armoricanus* and *I. iolas* were respectively found less than 400 m and 700 m away from its boundaries and *Tarucus balkanicus* less than 2 km away, with the hostplant of the latter, *Paliurus spina-christi* P. Mill. (Rhamnaceae), being known to occur within the Park (Vuković *et al*. 2017, Šegota *et al*. 2019). Nonetheless, the presence of these species within Krka NP still requires confirmation from additional future surveys inside its borders. Similarly, a further species of grayling, *Hipparchia fagi* (Scopoli 1763), is potentially present within Krka NP and might have been encountered in the course of our surveys. It was tentatively identified by small wing features that possibly distinguish it from the phenotypically similar *Hipparchia syriaca* (Staudinger 1871). However, as the definitive distinguishable feature between them is on the morphology of their genitalia (Lorković 1976; Jutzeler *et al.* 2009), and as this was not inspected, we decided not to include *H. fagi* in our checklist.

Overall, the results obtained in this study highlight the effectiveness of eco-volunteer surveys for yielding important data on butterfly communities, especially when these volunteers are supervised by trained lepidopterists. These results also indicate the value of a continuous scientific research effort inside protected areas such as Krka, as well as the importance of actively working and collaborating with National Park authorities for the protection of their native fauna and ecosystems. The fact that Krka NP shelters several Near Threatened butterfly species, either at the European or National level, reinforces the role of this park to impose strict measures for their protection, along with the other non-threatened species. Ultimately, these research efforts represent the bridge for future conservation plans, aiming to preserve the species' populations within the natural strongholds imposed by the Parks, and completing them with the help of eco-volunteers might be the key to speed up this process. Indeed, a highly important outcome of eco-volunteer studies is their outreach, as they provide young people from a range of different backgrounds with the opportunity to gain first-hand experience with survey work relating to the conservation of both wildlife and ecosystems while also inspiring them to step forward and stand for their protection.

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