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Mapping the distribution of the Eurasian Hoopoe *Upupa epops* and the Pine Processionary Moth in Lebanon based on a Citizen Science approach

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Abstract - The Pine Processionary Moth (PPM) *Thaumetopoea wilkinsoni* has long been attacking Mediterranean forests. In its management strategy, Lebanon has focused mainly on pesticides, leaving natural predators as an understudied control option. This study aims to understand the distribution of the Eurasian Hoopoe *Upupa epops*, by assessing the damage caused by the PPM. We attempted to explain the distribution of the two species, their relation to other factors and, with a Citizen Science (CS) approach, we developed their distribution maps. We found that the varying PPM damage between cadastral units was linked to Important Bird Areas (IBAs), highlighting the importance of multiple birds, including the Eurasian Hoopoe, as natural predators of this pest and calling for their conservation. As understudied species in Lebanon, this paper sets the path and offers guidelines for future researchers willing to work on similar crucial research in a climate change context and reveal the underlying relation between the two species.

Keywords: Citizen Science, Eurasian Hoopoe, Pine Processionary Moth, Distribution maps, Lebanon Biodiversity

INTRODUCTION

The Pine Processionary Moth (PPM) *Thaumetopoea wilkinsoni* is the most significant pine defoliator in the Mediterranean region (Battisti et al. 2015). Larvae consume pine needles in forests causing defoliation, and making trees more vulnerable to other pests, diseases and fires (Hodar & Zamora 2004). This species has long been found in Lebanon where it attacks the Aleppo Pine *Pinus halepensis*, the Calabrian Pine *Pinus brutia* and in some rare cases the Stone Pine *Pinus pinea*, highly valued for its economic returns (Wilkinson 1927, Huchon & Démolin 1970, Battisti et al. 2015). As pine trees are the most widespread species in Lebanese coniferous forests (MoA 2005), a serious human and animal health hazard is present, due to the setae released by the caterpillars that

cause severe skin irritation and respiratory disorders (Ziprkowski & Rolant 1972, Bonamonte et al. 2013, Battisti et al. 2017).

The Eurasian Hoopoe *Upupa epops* adopts a diverse diet consisting of insects, arachnids, annelids, crustaceans, reptiles and more (Annessi et al. 2022). In Lebanon, while several natural predators feed on PPM adults (Tohme G. & H. 1986), only the Hoopoe is able to feed on PPM larvae buried underground (Battisti et al. 2000), as they pupate at a depth of 5-20 cm (Demolin 1969). The first direct evidence was provided by Battisti (1986) who found that Eurasian Hoopoes were able to locate and extract up to 60% of the PPM pupae in the Italian Venetian Pre-Alps pine forests, generating an interest in assessing the status of the two species in Lebanon.

Lebanon is a "bottleneck" site; a narrow area along the migratory flyway where an exceptional concentration of species at risk is exposed to increasing threats (Zalles & Bildstein 2000, MoE 2014). The current checklist includes 404 bird species (Ramadan-Jaradi & Itani 2019), out of which 6.3% are threatened and 32% rare (MoE 2015). Across the country there are 15 global Important Bird Areas (IBA) (http://datazone.birdlife.org/country/lebanon/ibas).

The Eurasian Hoopoe adopts a partial migration strategy, making this species exposed to numerous anthropogenic risks. The density of illegal killing/taking of birds is remarkably high in Lebanon, reaching an estimate of 528,000–924,000 individuals per year (Brochet et al. 2016). Raine et al. (2021) highlighted that the main reason behind illegal hunting is recreation, where playback practices, mist-nests and flashlights to attract birds into traps are used to remove a massive number of individuals from the population. The scenario is furtherly worsened by urban and rural area mismanagement which leads to the loss of nesting and feeding habitats (MoE et al. 2016).

Humans have been altering the natural balance resulting in the PPM left with only a few predators to control its spread (Habre 1992) with its expansion ranging both in altitude and latitude (Battisti 2005). Chemical and biological control methods have been previously applied in Lebanon, however the techniques used and their timing proved to be neither very cost-effective nor hold optimal efficiency (Houri & Doughan 2006). This highlights the importance of natural predators to control this pest, especially in the context of climate change, and increased pest-outbreaks (Mitri 2007).

All the abovementioned factors led us to investigate this topic by adopting a Citizen Science (CS) approach, a methodology allowing to study large-scale events in nature (Bonney et al. 2009). Our study aims to define the status of the Eurasian Hoopoe population by assessing the damage caused by the PPM, mapping the two species and quantifying a potential correlation between their distributions. Prompted by our results we attempt to shed light on IBAs and the role of birds as natural predators and, most importantly, setting up a pathway for further research in this field.

MATERIALS AND METHODS

Data collection

This study is based on a CS approach, a useful methodology in ornithology, when scientists would not be able to collect massive data without the citizen help. This method allowed us to collect data from all parts of the country through a non-selective sampling. The entire population residing in Lebanon was targeted and each record about the bird and the PPM occurrence was added to the database.

A detailed, cross-sectional, non-anonymous, Google Form (https://forms.gle/8iTGFXdGspFgFrN96) was developed in English and Arabic, with spatio-temporal questions related to the Eurasian Hoopoe and the PPM sightings in Lebanon, in addition to basic contact information. The form was shared nationally among individuals, groups, universities, networks, NGOs, pages, municipalities, and ministries all over the country from the 25th of June to the 15th of October 2022.

Passive data were also collected mainly from Facebook (the most used social media platform in Lebanon), where keywords were entered into the

search engine and spatio-temporal filters were applied to identify posts from 2017 to October 2022.

Personal communications with ministries, municipalities, hunters, bird-watchers, photographers, hikers, scientists and nature-lovers occurred over the phone, where any input (observation, date, location, photographs, notes) was collected.

Finally, data were collected from eBird (https://ebird.org/), a user-friendly online database programme that documents observations of different bird species. The downloaded subset for Lebanon contained 252 observations of the Eurasian Hoopoe with a record range from the beginning of 2017 to the 15th of October 2022.

Following data collection, a systematic pre-processing was carried out to filter the collected data, and classify them in a chronological sequence for easier handling, mapping and comparison.

Creating distribution maps

The collected data stored in Excel sheets were uploaded to Google maps (bit.ly/3wh7Ivn). Eurasian Hoopoe distribution was set up in a separate layer for each year, while the PPM observations, due to the prolonged presence and persistence of the nests throughout the years, were all visualized in a single layer of a different color.

After this preliminary step, a dataset was created by merging all the points and the coordinates of their location. Data were integrated into ArcMap desktop version 10.3 resulting in an XY event layer with the geographic locations of all the points. The event was then exported as a shapefile, and the attributes were split by date to get separate layers for each year from 2017 to 2022. Lastly, in order to visualize Lebanon's administrative divisions, Lebanon's shapefile was downloaded from GADM data version 4.1 (https://gadm.org/maps/LBN.html) and added to the main ArcMap file, leading to the generation of all the layers and maps.

BirdLife International and the Society for the Protection of Nature in Lebanon highlighted eight Responsible Hunting Areas (RHA) in Lebanon (SPNL 2015). Those are Protected Areas away from the path of migratory birds, where hunting is allowed under strict conditions to balance the needs of wildlife and people. IBA and RHA layers were overlayed with our Eurasian Hoopoe and PPM distribution maps to assess the bird status.

Assessing moth damage

In total, 57 PPM and 110 Eurasian Hoopoe observations spanning over 16 Cazas (cadastral units) were considered from a larger database in order, to conduct the statistical test on common and parallel data of the two species.

We conducted an independent samples t-test comparing the varying PPM damage per Cazas with an arbitrary continuous index ranging from 0 (no damage at all) to 1 (all the trees are severely damaged), between two groups (within or outside IBA) (Statistica® software version 12).

RESULTS

A preliminary summary of the responses from the Google Form showed that approximately the same number of people spotted the bird (69.1%) and the PPM (73.7%). The 391 Eurasian Hoopoe and 87 PPM records from all sources allowed us to build six maps (i.e., each per study year) on ArcMap, representing the distribution of the Eurasian Hoopoe (red dots) and PPM (black dots). In addition to a compiled map with an overlay of all layers (Fig. 1). We also overlayed IBAs (shaded red areas) and RHAs (shaded black areas) with the distribution of the two species.

The Eurasian Hoopoe was commonly found in most of the Cazas including RHAs. Remarkably, Anjar (one of the eight RHAs) showed the highest number of observations of the Eurasian Hoopoe reaching 56 records.

As for the PPM damage between Cazas within and outside IBAs, our results (Tab. 1) showed a statistically significant lower index in Cazas within IBAs *versus* those found outside (Fig. 2).

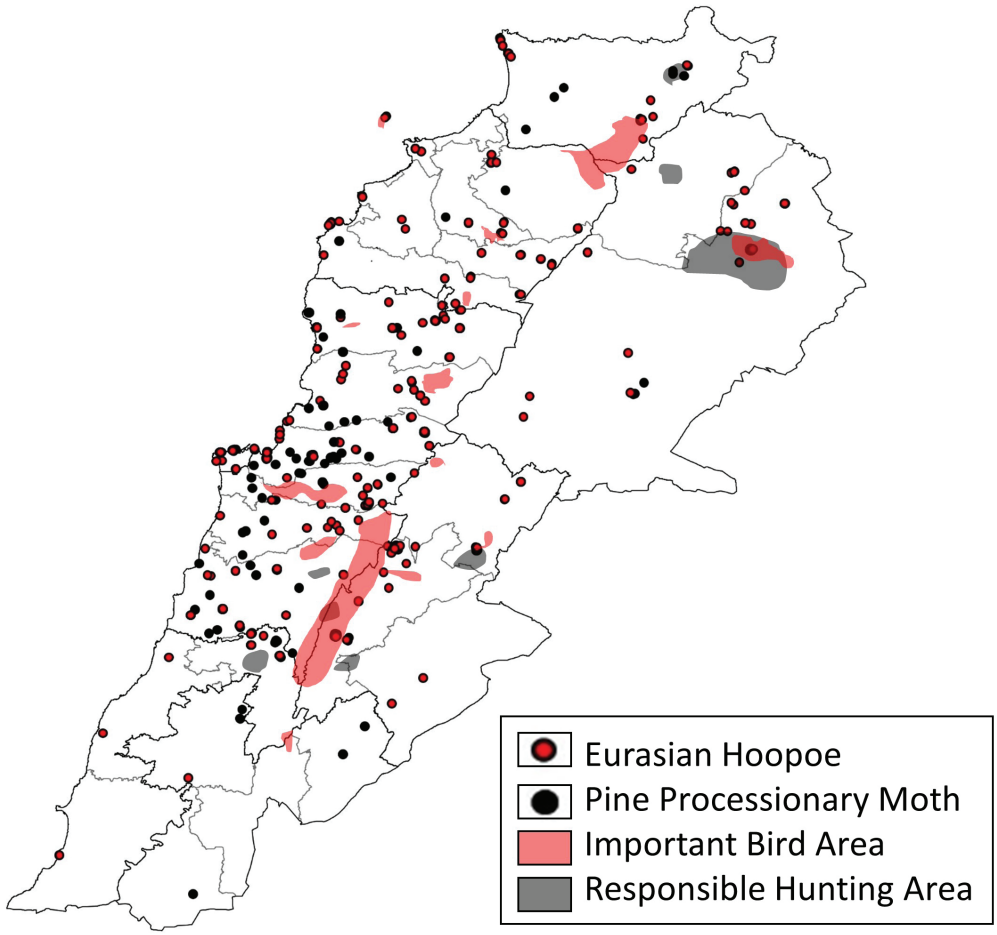

Figure 1. Eurasian Hoopoe, PPM, RHA and IBA distribution in Lebanon as recorded from 2017 to 2022.

Table 1. Variation of PPM damage index in Cazas within versus outside IBAs analyzed using an independent samples t-test. Significant values: * = p< 0.05.

Variable	n	Mean	SD	t-value	t-critical	df	P
PPM Damage Index Outside IBAs	4	0.80	0.28				
PPM Damage Index Inside IBAs	11	0.46	0.21	2.55*	2.16	13	0.024*

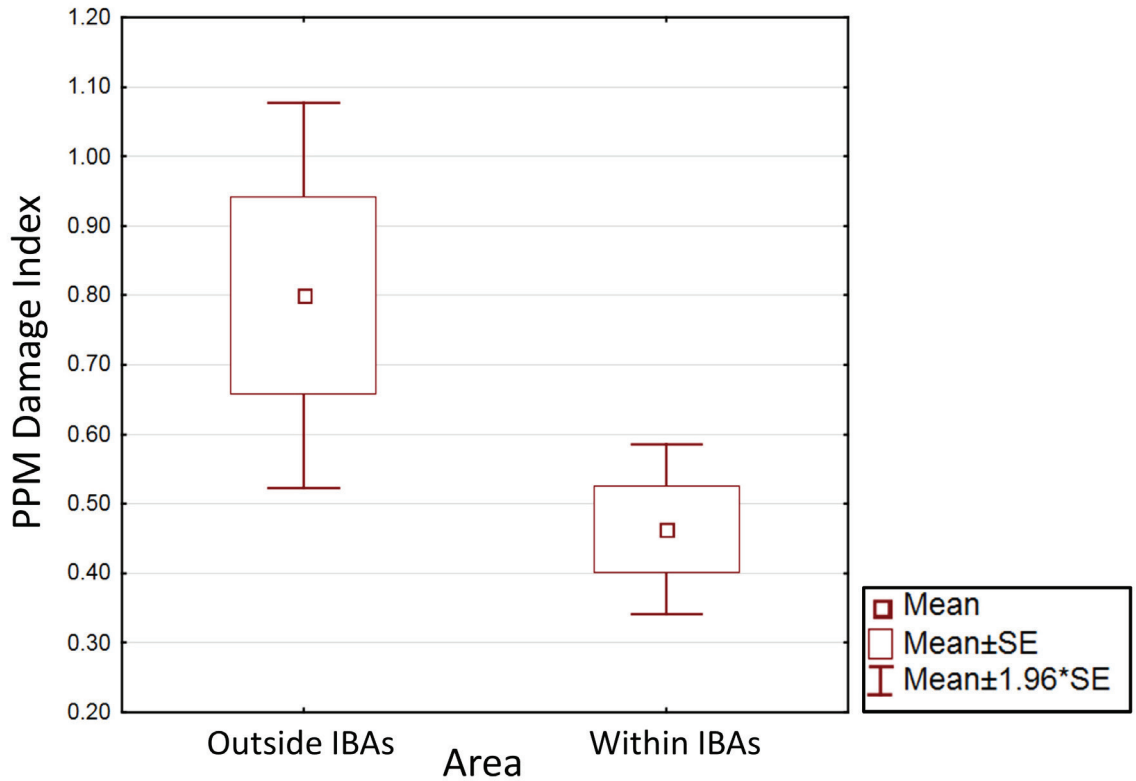

Figure 2. Means (± SE) of PPM damage index in Cazas within versus outside IBAs.

DISCUSSION

As Barbaro and Battisti (2011) closely linked the PPM and the Eurasian Hoopoe, this study was conducted as an attempt to assess the status of the two species in Lebanon.

The Google Form responses gave signs of a certain correlation in terms of presence/absence of the two species. In addition to a visual overlap between the species in the distribution maps, this research, however, could not lead to any significant statistical correlation.

Remarkably, Anjar, one of the Lebanese villages, which signed an agreement in 2014 to initiate a sustainable Public Hunting Area (PHA) (LEF 2015), is a Eurasian Hoopoe hotspot based on the data collected in this research, as we recorded there the highest concentrations. In addition to an important Eurasian Hoopoe density in all other Cazas containing RHAs. This finding highlights how environmental awareness impacts biodiversity conservation.

The variability of the PPM damage among Cazas is clearly linked to IBAs, highlighting the potential importance of a rich avifauna diversity, including the presence of the Eurasian Hoopoe, as a natural predator of this pest.

In our opinion our results set the path for a large-scale research studying additional factors, conducted in a controlled environment or potentially based on Artificial Intelligence for data analysis (GPAI 2022), with the aim of linking the PPM and the Eurasian Hoopoe populations. A bullet list is offered to future researchers working on the same objectives to reveal the underlying correlation between the two studied species (ESM 1).

Lastly, given the fact that biodiversity conservation actions are still wanted in Lebanon (MoE 2015),

we call key stakeholders to join forces and encourage further scientific research, influence evidence-based policies, and mobilize communities, in order to ensure a safe Eurasian Hoopoe passage, stay and nesting in Lebanon.

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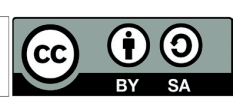

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