PREDICTING POTENTIAL DISTRIBUTION OF *ORCHIS GALILAEA* IN LEBANON USING GEOGRAPHIC INFORMATION SYSTEM

Dr. Nisrine Machaka-Houri[1]

Assoc. Prof. Dr. Ahmad Houri[2]

Dr. Duncan B. Westbury[3]

Mr. Maher Ibarhim[4]

[1] University of Saint Joseph, **Lebanon**

[2] Lebanese American University, **Lebanon**

[3] University of Worcester, **United Kingdom**

[4] Khatib and Alami, **Lebanon**

ABSTRACT

Orchis galilaea is the only Lebanese orchid that is restricted geographically to Lebanon, Palestine and Jordan. It is a terrestrial orchid that attracts its pollinator by sexual deception while offering no reward. The full distribution of this orchid in Lebanon has not been determined. This study is part of ongoing research into the population dynamics of the orchid to form a management plan for its conservation. A Geographic Information System (GIS) was used to identify the habitat characteristics of *O. galilaea* and map its distribution in Lebanon by combining known locations with digital layers of environmental variables, including topography, land cover, soil type, geology and precipitation. Classes within each environmental parameter were defined and weighted according to their frequency of occurrence at extant sites. A predictive GIS model was developed by overlaying the five layers of the habitat characteristics. The predicted distribution map of *O. galilaea* was then validated by confirming presence of the orchid in the predicted locations and absence in the unsuitable areas through exploration field trips. Eighty five locations were surveyed and seven previously unknown populations of *O. galilaea* were discovered. These new *O. galilaea* locations were all correctly predicted by the model as potential habitat. The accuracy of the model was confirmed as it was significantly more likely to find the orchid in predicted suitable habitat compared with unsuitable habitat. Combining ecological habitat characteristics using GIS proved to be a useful tool to successfully predict the potential distribution of *O. galilaea* in Lebanon and will assist in planning its conservation measures.

Keywords: deceptive orchid, population, habitat, conservation, map.

INTRODUCTION

In Lebanon, the orchid family is represented by 60 terrestrial species, 80% of which are widespread in the Mediterranean, 18% are restricted to the East Mediterranean (Cyprus, Syria, Lebanon, Palestine and Jordan) and the remaining 2% (represented by *Orchis galilaea*) is restricted to Lebanon, Jordan and Palestine [4, 9].

Conservation planning and management is required to reduce and reverse the decline of species [12]. To be effective, we need not only to fully understand the ecology of target species, but we also need to have a thorough understanding of the species' abundance and distribution [12]. Mapping a species through field surveying is labour intensive and costly. However, the widespread use of Geographic Information Systems (GIS) and digital environmental layers have allowed researchers to develop new techniques to construct maps predicting suitable habitats and potential distribution of a species [13]. GIS have been used to identify the important habitat characteristics and predict the potential habitat of selected species based on known locations and information from vegetation maps, geological information, soil types, rainfall and topography [12]. Predicting species' distribution has become an important component of conservation planning in recent years such as the case of the China cedar in Tianmu Mountain Nature Reserve [13].

Orchis galilaea is the focus of our study since it is the only narrow endemic orchid (found only in Lebanon, Palestine and Jordan) among the Lebanese orchids. In addition, the only published journal paper was written by Bino et al. [3] on its pollination ecology. Therefore, there is a lack of information on its distribution, population ecology, habitat requirements and conservation status in Lebanon and the region.

Orchis galilaea is reported to occur in altitudes ranging from 100 to 1130 m above sea level [4]. It can be found growing among thorny shrubs of the phrygana, especially between plants of thorny burnet (*Sarcopoterium spinosum*). It is also found in garrigues of Palestine oak (*Quercus calliprinos*) and spiny broom (*Calycotome villosa*), as well as in open grassland surrounded by bushes of Palestine oak. It also appears in open pinewood areas. It is found on moderately dry and stony subsoil, and is associated with bleached rendzina and calcareous red soils "Terra Rossa" [9]. Like most other orchids in Lebanon, *O. galilaea* has been observed mostly on the western slopes of Mount Lebanon from North to South. However it was never reported north of Nahr Al-Bared [8, 14].

The aim of this study was to investigate the distribution of *O. galilaea* in Lebanon and to predict its potential suitable habitat using known locations, in addition to elevation, soil type, geology, mean annual precipitation and land cover layers in GIS. The specific objectives of this paper were to: (1) examine *O. galilaea* habitat in the known locations to determine habitat characteristics associated with these sites; (2) utilize GIS to predict the potential distribution of *O. galilaea* in Lebanon and (3) assess the validity of the prediction map. This study is the first to predict the potential distribution of a vulnerable plant species in Lebanon for conservation aims.

MATERIALS AND METHODS

Study area

The research was conducted in Lebanon which is located on the eastern side of the Mediterranean Sea (33°50' North, 35°50' East). The topography is varied, and is divided into four parallel belts: narrow coastal plains; western mountains reaching up to 3,088 m, known as Mount Lebanon; central plateau at 900 m altitude (Beqaa valley) and eastern dry mountains (Anti-Lebanon) rising up to 2,814 m. The mountains are mainly composed of Jurassic and Cretaceous limestone and sandstone. The karst formations (with sinkholes, underground streams and caves), shaped from limestone and found primarily on the Mount Lebanon range between 300 and 1,800 m above sea level, cover two-thirds of Lebanon's surface area [5].

The climate also exhibits variations with respect to temperature, humidity and annual precipitation. The average annual rainfall varies from less than 250 mm in the northern Beqaa to 1,750 mm in the high elevations of the western slopes of Mount Lebanon making them the wettest areas [5]. A wide range of habitats are found, including coastal sand dunes, garrigues, maquis, forests of Quercus, Pinus, Cedrus and Abies, wetlands, river banks, arid and semi-arid plains, and agricultural land.

Data collection

Most of the available locality data from the literature could not be used because locations of *Orchis galilaea* were not geo-referenced. Therefore, a field survey was conducted during the flowering season of *O. galilaea* from February to May searching for orchid populations previously cited in the literature. In addition, the survey included areas from personal communications. Most reported locations were explored whereas some sites (especially in southern Lebanon) were not accessible due to the presence of landmines and poor security conditions. Once all previously known areas were explored in 2010, other areas in Lebanon with similar habitats were then explored during 2011.

Ecogeographic data of the orchid sites were collected. Latitude, longitude and altitude were determined using a GPS (Garmin eTrex Vista with accuracy ± 3m). In addition, physical characteristics of the sites such as habitat type and aspect were recorded [2]. A minimal distance of 500 m between sites was kept [7] based on the 200m dispersal range of its pollinator, *Lasioglossum marginatum* (S. Roberts, personal communication, 2010). This was done to insure that the populations were distinct. These locations were plotted on a map of Lebanon using Google Earth, then converted to fit the GIS format using ArcMap software [6] and verified for accuracy. Locations cited in the literature where presence of *O. galilaea* was not confirmed during the field survey of 2010 and 2011 were not included in the analysis.

Creation of the distribution prediction map

GIS was used to identify the environmental characteristics of the sites containing *O. galilaea*. The analysis considered five ecological attributes that were deemed decisive in the orchid's distribution: elevation, soil type, geology, annual mean precipitation and land use/land cover type [10]. The elevation layer was produced by Esri Lebanon. The land use/land cover, soil type, geology and rainfall layers were produced by the Ministry of Environment in Lebanon with minimum mappable unit of 2000 m2. Eco-geographical data were extracted from these five ecological attributes using "spatial join" between the localities and the digital layers in GIS [2]. This technique revealed the habitat characteristics preferred by the orchid. Different groups combining variables were defined within each layer and given a weight according to their frequency of occurrence at known species locations. Therefore, preferred groups were weighted higher than those which lacked the orchid presence [12]. All the layers were converted to follow the same geographic coordinate system (GCS Clarke 1880) and projected coordinate system (Clarke 1880 Lambert Conformal Conic).

Once each of the digital environmental layers was generated, an overlay model was created to predict potential habitat. The five digital data layers were overlaid using the "union" tool in GIS to determine where combinations of important parameters cooccurred [10, 12]. The weights of the individual layers were totalled to yield an overall score (total weight) for each polygon in the union map. Using the total weight, a potential distribution map of *O. galilaea* with five ranges of habitat suitability (most suitable, suitable, unsuitable, most unsuitable, and restricted) was developed. The map was finalized by adjusting the suitable ranges to include all the known localities.

Validation of predicted distribution

The prediction distribution map of *Orchis galilaea* was tested for accuracy through exploration field trips [12] during spring (March-May) 2012. Nine field trips to search for populations of *O. galilaea* were undertaken to areas with suitable and most suitable habitat where the orchid has not been observed or found before (Southern Lebanon, West Beqaa, and Northern Lebanon). Sites with very low potential habitat were surveyed on route to sites with high and highest habitat potential. The road network of the target areas was covered with planned stops depending on the land use/cover of the site. Locations were at least 500 m apart (section 5.3.2). At each stop, an area of around 100 x 100 m was searched following a belt transect approach. Four transects of 100 m each were used to search for the orchid. Once a patch of the orchid was found, the search was stopped and moved to another location. Planning of the survey sites was done prior to field visits according to the prediction map and roads on Google Earth to maximize the effectiveness of the search. The plan was modified on the spot to take into account the actual situation in the field.

In total, 66 locations with suitable habitat and 19 locations with unsuitable habitat were searched. Ecogeographic data of the visited sites were collected irrespective of the presence of the orchid. All the searched sites were overlaid with the prediction map to validate the prediction. Due to the limited number of newly found orchid sites during the field survey, eleven sites found by colleagues and naturalists were included in accuracy assessment of the model.

RESULTS

Creation of the distribution prediction map

The elevation layer consists of altitude contour lines every 50 m. Known locations of *O. galilaea* were in the range between 200 m and 1400m. Since altitude within this range was not found to affect the presence of the orchid, the altitude map was converted into two polygons representing two groups. Group zero represents the range of altitudes less than 200 m and higher than 1400 m and was given a negative weight as the orchid has no potential of occurring at these altitudes. Group one represents the range between 200m and 1400 m and was given a weight of 90 because all the known locations occurred within this range.

Eight classes of land use/land cover, six classes of geology, seven classes of soil type and six classes of precipitation were specified based on their frequency of occurrence at known *O. galilaea* sites. Categories that included characteristics where the orchid was not observed were grouped in one class which was in turn given a weight of zero. In addition, for the land use/land cover layer, land use types where the orchid could not occur such as urban areas, sand dunes, water bodies and agricultural land were given a negative value to add restrictions on the potential distribution. Some of the sites wrongly identified in the land cover map as grassland were identified as garrigues during the field survey.

Therefore the grassland was included in the habitat suitability analysis in order to maximize the accuracy of the model.

The overlay of the five grouped environmental layers resulted in a potential distribution map with five ranges of habitat suitability (Figure 1). The classification of these ranges followed the manual method. The break values between the different ranges were set manually in a way to have all known locations (shown on the prediction map) within the suitable and most suitable habitat ranges. The last range forms a restricted habitat for the orchid either due to altitude or inadequate land use/cover such as water bodies, agricultural, or urbanized areas.

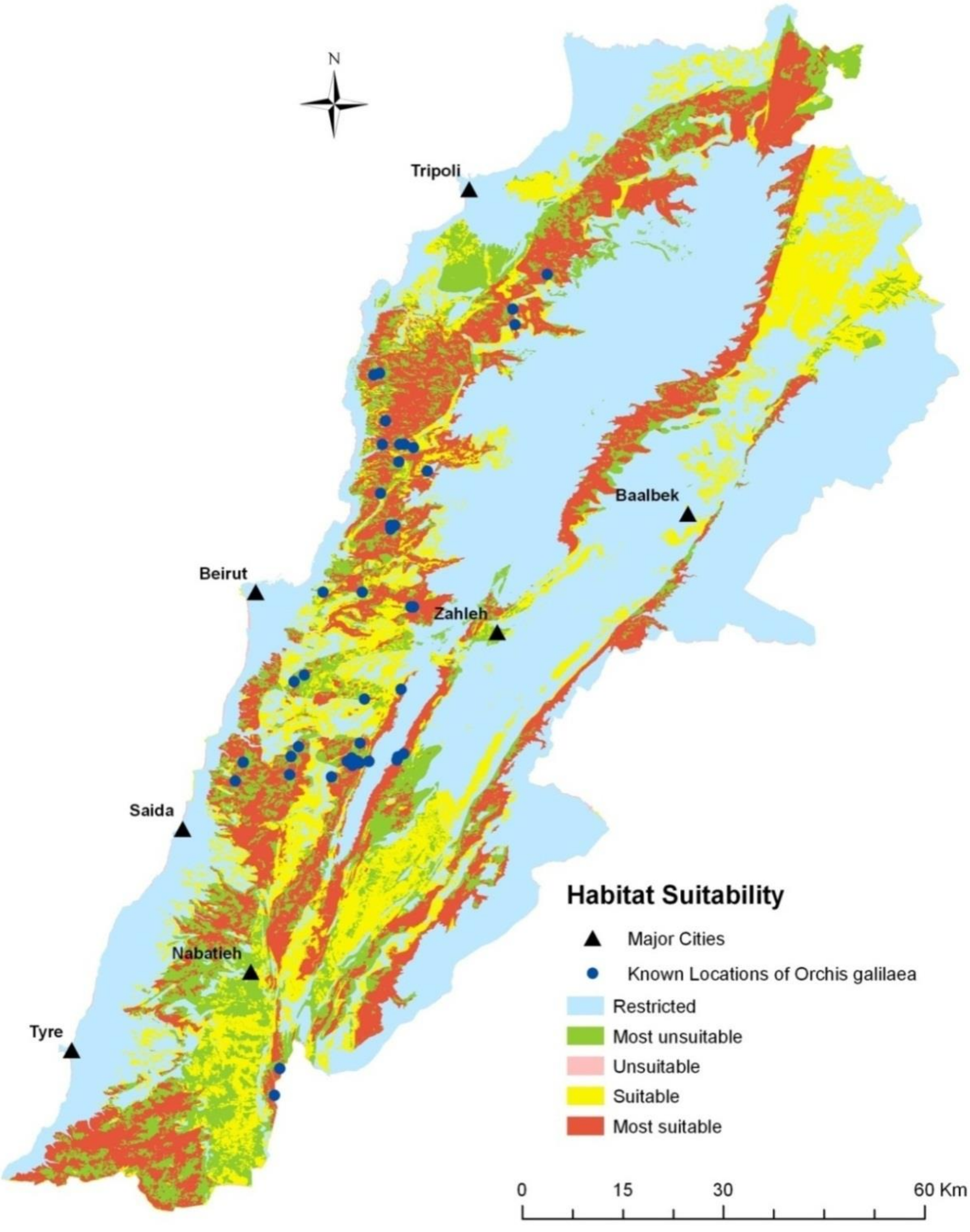

Figure 1: Predicted distribution of *Orchis galilaea* in Lebanon with the known locations

Validation of predicted distribution

Field survey of 66 sites within the potential habitat range yielded seven new locations of *O. galilaea* in areas where the orchid has not been found before. In addition, no sites of *O. galilaea* were found during the search of 19 locations within unsuitable habitat. These sites in addition to 11 *O. galilaea* sites found by colleagues were used to assess the prediction accuracy using chi-square test on the observed and predicted frequencies (Table 1).

Table 1: Number of presence and absence sites observed at suitable and unsuitable habitats

Observed frequencies			
	Suitable	Unsuitable	Total
Present	18	0	18
Absent	59	19	78
Total	77	19	96

DISCUSSION

It was found that *O. galilaea* grows in altitudes between 200 m and 1400 m. This finding gives new information on the orchid's habitat as it was previously reported to reach an altitude of 1130 m only [4]. This result could be best explained by relating elevation and climate. In Lebanon, areas below 200 m are within the coastal zone which is characterized by mild winter; whereas areas higher than 1400 m are characterized by cold, dry weather [5]. Therefore, it can be assumed that the orchid is not adapted to hot (altitudes below 200 m) or alpine environment (altitudes above 1400m). *O. galilaea* occurred in garrigues the most, then in open or dense oak or oak/pine woodlands and pines woodland the least. These typical Mediterranean habitat types include trees and shrubs that are known as food source for the pollinator of *O. galilaea*, *Lasioglossum marginatum* [11]. The association of the orchid with these vegetation communities could be explained by their association with the pollinator. In addition, these vegetation types are mostly found within the altitude range of the orchid [5]. These findings are consistent for elevation and vegetation types. *Orchis galilaea* was mostly found in areas with limestone or sandstone bed that dates back to the Jurassic or Cretaceous period. This is a characteristic of Mount Lebanon [5]. *Orchis galilaea* was mostly found on calcareous red or mixed soils and rarely in sandy soils and mass landslides. This result could be explained by the fact that calcareous soils, with pH ranging between 7 and 8.5, are suitable for the germination and establishment of many of the terrestrial orchid's seeds. Mycorrhizal fungi which are necessary for the orchid's seed germination and plant development) are known to be available in these soils [1]. The mean annual precipitation of areas where *O. galilaea* mostly occurred ranged between 1000-1300 mm. The *O. galilaea* growth season coincides with the rainy season in Lebanon (November to April) with the fruits maturing with the onset of the dry season. A possible explanation of this might be that *O. galilaea* is adapted to these rain levels to develop and thrive. Any combination of the discussed characteristics would result in a suitable habitat for the orchid.

CONCLUSION

This study considered the feasibility of using digital environmental layers in place of specific field habitat information to predict suitable habitat for *Orchis galilaea* in Lebanon. This model was then assessed for accuracy and limitation. Similar to previous studies [10, 12], GIS was utilized to identify combinations of the important habitat characteristics of a single species to locate its potential habitat. A prediction map for the potential distribution of *O. galilaea* in Lebanon was developed by taking into account a variety of environmental conditions such as soil type, elevation, precipitation, geology and land cover. The discovery of seven new sites in only nine field days (85 sites) indicated that the GIS model was useful to assist in the identification of suitable habitat for the orchid. In [12], the authors spent 24 field days (50 sites) to find nine new locations of *Isotria medeoloides*. Searches in unsuitable and restricted areas yielded no new occurrences of *O. galilaea*. This finding suggests that *O. galilaea* distribution was not random and that areas identified by the model as suitable had a significant potential for having *O. galilaea*; whereas areas identified as unsuitable did not. This prediction model provides a basis for future studies on species distribution that will help decision makers identify potential areas of special biodiversity importance for protection.

Despite the possibility of false absences within suitable habitat, the likelihood of finding sites with *O. galilaea* was significantly higher in suitable than in unsuitable habitats. In addition, the habitat suitability analysis correctly predicted all of the new *O. galilaea* sites. As such, this model provided us with a tool to rapidly identify potential distribution of *O. galilaea*, allowing us to prioritize areas for field survey to locate new occurrences.

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REFERENCES

[1] Batty, A., Dixon, K., Brundrett, M. & Sivasithamparam, K, Constraints to symbiotic germination of terrestrial orchid seed in a Mediterranean bushland, New phytologist, vol. 152, pp 511-520, 2002.

[2] Ben-David, R., Lev-Yadun, S., Can, C. & Abbo, S., Ecogeography and demography of Cicer judaicum Boiss., a wild annual relative of domesticated chickpea, Crop science, vol 46, pp 1360-1370, 2006.

[3] Bino, R., Dafni, A. & Meeuse, A. The pollination ecology of *Orchis galilaea* (Bornm. et Schulze) schltr.(Orchidaceae), New Phytologist, vol 90, pp 315-319, 1982.

[4] Delforge, P., Orchids of Europe, North Africa and The Middle East, A&C Black, London, 2006.

[5] Ecodit, Lebanon forest and biodiversity conservation assessment, final report prepared for USAID under Task Order No 86, pp. 77, 2009.

[6] ESRI, ArcGIS version 9.3, Environmental Systems Research Institute, Redlands, CA, 2009.

[7] Guisan, A. & Zimmermann, N., Predictive habitat distribution models in ecology, Ecological Modelling, vol 135, pp 147-186, 2000.

[8] Houri, A. & Machaka-Houri, N., Photographic Guide to Wild Flowers of Lebanon, Beirut, 2008.

[9] Kretzschmar, H., Eccarius, W. & Dietrich, H., The Orchid Genera *Anacamptis*, *Orchis* and *Neotinea*: Phylogeny, Taxonomy, Morphology, Biology, Distribution, Ecology and Hybridisation, EchinoMedia Verlag, Burgel, Germany, 2007.

[10] Năpăruş, M. & Kuntner, M. A GIS model predicting potential distributions of a lineage: A test case on Hermit spiders (Nephilidae: *Nephilengys*), PloS One, vol 7/issue 1, e30047, 2012.

[11] Potts, S. G., Petanidou, T., Roberts, S., O'Toole, C., Hulbert, A. & Willmer, P., Plant-pollinator biodiversity and pollination services in a complex Mediterranean landscape, Biological Conservation, vol 129, pp 519-529, 2006.

[12] Sperduto, M. B. & Congalton, R. G. Predicting rare orchid (small whorled pogonia) habitat using GIS, Photogrammetric Engineering and Remote Sensing, vol 62, pp 1269-1279, 1996.

[13] Tie, W., Mei, L. & Naiang, W., Protecting china cedar (*Cryptomeria fortunei*) habitat using GIS-based simulation, modeling of existence probability, and function zoning, Mountain Research and Development, vol 27, pp 352-358, 2007.

[14] Tohmé, G. & Tohmé, H. Illustrated Flora of Lebanon, National Council for Scientific Research, Beirut, 2007.