

Distribution and ecological patterns of orchids in Monte Pellegrino Reserve, Palermo (Sicily, Italy)

Vincenzo Bertolini^{1*}, Anne Damon¹, Javier Valle Mora¹ & Angel Natanael Rojas Velázquez²

¹Colegio de la Frontera Sur (ECOSUR). Carretera Aeropuerto Antiguo Km 2.5, Tapachula, Chiapas, México; e-mail: vbertolini@ecosur.mx

²Autónoma de San Luis Potosí, Facultad de Agronomía, Alvaro Obregon # 64 Colonia Centro, CP 78000, San Luis Potosí, S. L. P., México

*Corresponding author

ABSTRACT

Despite heavy human impact through the ages, the Monte Pellegrino Reserve maintains an interesting orchid flora currently estimated as 33 taxa, with 9 endemic elements, including *Ophrys lunulata* Parl. (priority species for the European Commission) and *O. sphegodes panormitana* (Tod.) Kreutz, which has its locus typicus in Monte Gallo, another reserve close to Monte Pellegrino. The chorological types most represented in this study were Mediterranean and Atlantic Mediterranean. The distribution of the orchids in this site was correlated to various environmental parameters, depending upon species and chorological type. The endemic species were the only chorotype that was positively correlated to two habitats that are relicts of the original Sicilian vegetation: clearings in deciduous thermophilic forest (*Rhamno alaterni-Quercetum ilicis* subassociation *Pistacietosum terebinthi*) and *Ampelodesmetum meadows* (*Helictotrico convoluti-Ampelodesmetum mauritanici*). Prevailing wind direction and seasonality were determining factors for orchid distribution. Identification of the correlation patterns between chorological types and habitats could be useful for predicting species presence within areas with similar biogeographical characteristics, facilitate species mapping and serve as a tool for the design and implementation of conservation strategies.

KEY WORDS

orchids; chorotype; relict natural vegetation; Mediterranean ecosystems; priority species.

Received 11.05.2012; accepted 21.10.2012; printed 30.12.2012

Proceedings of the 1st International Congress "Insularity and Biodiversity", May 11th-13th, 2012 - Palermo (Italy)

INTRODUCTION

The Monte Pellegrino (Palermo, Sicily, Italy) is a natural area which has been incorporated into the European ecological network Natura 2000, designated as a S.I.C. (Sito d'Interesse Comunitario: Site of Community Interest) code ITA 020014 Monte Pellegrino, due to the presence of rare and endemic species and habitats, such as the priority species *Ophrys lunulata* Parl. (Natura 2000 code: 1905), the species of community interest *Dianthus rupicola* Biv. (Caryophyllaceae), (code: 1468), as well as the

priority habitats, residual scrub forest with *Laurus nobilis* L. (Lauraceae) (Natura 2000 habitat code: 5230) and residual scrub forest with *Zyziphus lotus* L. (Lam.) (Rhamnaceae), (code: 5220) and the habitat of community interest substeppe, or meadow, with grasses and annual herbs *Thero-Brachypodietea* (code 6220) (Gianguzzi et al., 1995).

The Monte Pellegrino Reserve (38°11'42.60"N - 38°08'53.01"E and 13°21'53.95"E - 13°19'58.82"E) is partially surrounded by the city of Palermo towards the south and south-east, and by the sea in the north and north-west. The perimeter of the re-

serve is characterized by numerous steep slopes and sea cliffs at altitudes of 100-150 m which prevent access (Quartarone et al., 1995). The reserve is situated on dolomitic limestone rock; the lithosoils contain 30 to 80% sand, 20% clay and a low humus content with a mostly neutral pH (6.8-7.5) (Montanari, 1964; Raimondo & Venturella, 1996; Fierotti, 1997). The original vegetation of the area consists of Mediterranean scrub forests with key species: *Chamaerops humilis* L. (Arecaceae), *Euphorbia arborescens* Salm-Dyck (Euphorbiaceae), *Pistacia lentiscus* L. (Anacardiaceae), *Olea europea* L. (Oleaceae), *Ceratonia siliqua* L. (Fabaceae), as well as deciduous thermophilic forest featuring *Quercus ilex* L. (Fagaceae) and lithophytic vegetation on exposed rock faces (Quartarone et al., 1995; Raimondo & Venturella, 1996; Raimondo et al., 1996a).

Territories that surround the Monte Pellegrino Reserve have been colonized by humans from pre-historic times (Vigliardi, 1991) and natural resources have been exploited for centuries, leading to the almost total elimination of forest cover by the XIX century, as witnessed by Goethe (1905). However, from the beginning of the 19th century the government has intervened with plans to reforest the hills to reduce erosion although the species used for reforestation have not always been the most appropriate and have not taken into account the biogeographical features of the site. Today, vast areas planted to alien species can be observed, including *Pinus halepensis* Mill. and *P. pinea* L. (Pinaceae), *Cupressus sempervirens* L. (Cupressaceae), *Eucalyptus globulus* Labill. and *E. rostrata* Schlecht. (Myrtaceae) as the main elements, but also including *Acacia saligna* (Labill.) H.L. Wendl. (Fabaceae), *Opuntia ficus-indica* (L.) Mill. (Cactaceae), *Jacaranda mimosifolia* D. Don 1822 (Bignoniaceae), *Koelreuteria paniculata* Laxm. (Sapindaceae), *Schinus molle* L. (Anacardiaceae), amongst others (Scrofani, 1949). Other exotic species that have invaded the site are *Pennisetum setaceum* (Forssk.) Chiov. (Poaceae) within the steppe grassland habitat, and occasional populations of *Ailanthus altissima* (Mill.) Swingle (Simaroubaceae), *Agave* sp. (Asparagaceae), *Nicotiana glauca* Graham (Solanaceae), *Acacia karoo* Hayne (Fabaceae) and *Parkinsonia aculeata* L. (Fabaceae) (Gianguzzi et al., 1996). In addition, Mazzola & Di Martino (1996) report the use of exotic, ornamental species in the areas with most human impact. Although the history of the site

has clearly provoked extensive alteration to the natural vegetation of Monte Pellegrino, Raimondo & Venturella (1996) mentioned that of the 741 species and hybrids that constitute the present day vascular flora, 716 are native in origin. Considering the cryptogamic flora, mosses account for 76 of the present taxa, lichens for 83 and fungi for 53 (Raimondo & Venturella, 1996; Venturella, 1996). Extensive areas of the territory are heavily affected by cattle grazing, wood extraction and burning, the dumping of non-biodegradable residues and the contamination of the air with traffic fumes (Raimondo et al., 1996a; Venturella, 1996).

The climate of the area is Mediterranean, with xerophytic and thermomediterranean sub sections (Gianguzzi et al., 1996). The sea, towards the north and north west, gives rise to humid air currents throughout the year, which mitigate and influence local microclimates (Raimondo & Venturella, 1996; Raimondo et al., 1996b) making the north of the area cooler and more humid as compared to the more xerophytic south; the average annual relative humidity is 67%, with a minimum of 58% in October and a maximum of 74% in March (Albaria, 2011). In the north of the area, environmental conditions favour deciduous thermophilic *Rahmno alaterni-quercetum ilicis* subassociation *pistacietosum terebinthi*, which in turn favor the presence of *Celtis australis* L. (Ulmaceae), *Fraxinus ornus* L. (Oleaceae) and *Rhus coriaria* L. (Anacardiaceae) (Gianguzzi et al., 1996). Towards the south, the dominant species of the xerophytic scrub are *Oleo sylvestris-Euphorbietum dendroidis* subassociation *euphorbietosum bionae* and *Chamaerops humilis*.

According to G.I.R.O.S. (2009), Italy has about 200 taxonomic entities, for Orchidaceae, of the total of almost 700 registered for Europe and circum-Mediterranean countries, within which Sicily is one of the regions of Italy with the highest incidence of orchids, with 90 taxa, including species and subspecies (Bartolo & Pulvirenti, 1997). The province of the city of Palermo has an extension of 5000 km², with 60 taxa registered (Giardina, 2005), and includes the Madonie National Park which plays a principal role with extensive forested areas and environmental legislation in action which guarantees the protection of the biodiversity of this important natural lung, with a total of 57 orchid taxa (Puccia, 1995). The first data for the Monte Pellegrino Reserve were collected by the Sicilian botanist Filippo Parlatore

(1858) who reported 9 taxa, whereas in more recent floristic and vegetation studies, Gianguzzi et al. (1996) and Raimondo et al. (1996b) determined the presence of 28 orchid species in the reserve. Finally, Bertolini & Giardina (2008) and Bertolini (2009a, b), mentioned a total of 27 species and 4 natural hybrids, within 5 genera (*Anacamptis*, *Barlia*, *Ophrys*, *Orchis* and *Serapias*). Additionally, Grasso (2009) reported the discovery of *Ophrys incubacea* Bianca subsp. *incubacea*, and its hybrids, as well as a population of *Serapias lingua* L., albino type (Bertolini, personal unpublished data).

Studies on the population dynamics of native North American terrestrial orchid species have shown that the probability that a seed will germinate and that the plant will reach maturity depends upon a multitude of biotic and abiotic factors (Diez, 2007). In the case of the genus *Goodyera* (Diez, 2007), and Australian terrestrial orchids (Perkins & McGee, 1995) the seed has a greater probability of germinating if it falls close to an adult plant of the same species, which will already be inoculated with suitable fungi, and where a low pH (acid), and presence of organic matter favour proliferation of the fungi.

The presence of grazing animals may be damaging to orchid populations as the animals may eat the aerial, reproductive parts of the plants, or even the whole plant (Hutchings, 1987). Human intervention thus modifies natural habitats, artificially affects the natural distribution and habitat preferences of the orchids and that of their mutualists also (Bergman et al., 2006). To design appropriate conservation strategies for terrestrial orchids, the first step is to evaluate the distribution of each species, as related to climate and habitat characteristics (Sanford, 1969) and determine the identity and distribution of mutualist organisms, such as mycorrhizal fungi and specialized pollinators (Brys et al., 2008). The distribution of hybrids and subsequent process of specialization, adaptation and speciation also depends upon the distribution of the pollinators and the habitat colonized by the orchids (Schatz, 2006). Strategies may include ex situ conservation, as well as ex situ propagation and cultivation to contribute towards the restoration of in situ populations, of both the orchids and their symbionts (Swarts et al., 2007). Due to the rarity of many of the Mediterranean orchids, descriptions of preferred habitats and environments are limited, but the literature mentions wide distributions and plasticity as

typical of these orchids (Pignatti, 1982; Del Prete & Tosi, 1988; Delforge, 2005; G.I.R.O.S., 2009), such as in the case of *O. lunulata*, a rare endemic Sicilian species present in Monte Pellegrino and found at 1000 m asl, in a variety of habitats such as pasture, meadows, Mediterranean scrub, forest clearings and full sun. From the data available, we sought to identify ecological patterns and correlations between orchid chorotypes and habitat type in Monte Pellegrino, with emphasis on endemic, Mediterranean and Atlantic Mediterranean species, to statistically confirm empirical observations. We propose a model that could be applied to coastal Mediterranean areas in general.

In this study we set out to analyze the spatial distribution of terrestrial orchids within the Monte Pellegrino Reserve to determine distribution patterns and correlations with habitat type for each orchid chorological type. Using the data generated in Monte Pellegrino Reserve as a model, we sought to test the hypothesis that habitat type within the coastal zone of Sicily could be used to predict and designate priority areas for orchid conservation.

These biogeographic relationships on a small scale are revealing components of orchid ecology which could then be used to design strategies for orchid conservation on a larger scale and for other areas. This type of analysis could also be applied to studies concerning the impact of habitat modification due to climate change.

MATERIALS AND METHODS

The study was carried out during the period 2007-2009 with visits to the sites throughout the year except for the months of July and August. The whole of the Monte Pellegrino Reserve was mapped and described before being divided into sections, according to observable, predominating habitat characteristics as defined by Gianguzzi et al. (1996); inaccessible areas were not included.

A detailed survey of the orchid species present was carried out in plots of approximately 20-30 ha each, 8 such plots were completed in the first year, 7 in the second year and 3 in the final year. Due to the rarity and patchy distribution of the orchids we did not use quadrants; instead, the populations were discovered using transects, with a sampling effort of 4-6 hrs. per session (day), a total of 12 sessions per

month and an estimated linear distance of 10-12 km, covering 4.8 hectares. Each session consisted of walking the transect and localizing orchids within approximately 2 metres in all directions. Once the orchid populations were localized, termed “points of interest” (PI), the site was sampled intensely. The PI were then visited monthly to monitor flowering and extraction of individuals (Bertolini, 2009a).

PI coordinates were recorded with a GPS Magellan eXplorist XL and other data were recorded with a handheld Sony PEG-TJ35/U, including date of first register for each PI, altitude, date of flowering, no. of individuals, habitat type, direction of light exposition, and general observations.

Species determination was carried out using the descriptions of G.I.R.O.S. (2009), as well as consultation with experts where necessary. For chorological data we referred to Grünanger (2001).

The distribution of orchids was studied in the following habitat types, according to the classification of Gianguzzi et al. (1996): clearings in deciduous thermophilic forest (Cl.DTF) (*Rhamno alaterni-Quercetum ilicis* subassociation *pistacietosum terebinthi*), clearings in areas reforested with pine (Cl.RPF) (*Pinus halepensis*, *P. pinea*), clearings in areas reforested with a mixture of *Pinus* and *Eucalyptus* (Cl.RPEF) (*Eucalyptus camalduenis*), xerophytic nitrophilic grassland (XNG) (*Carlino siculae-Foerulum communis* with *Asphodelus microcarpus*), *Ampelodesmetum* meadows (MA) (*Helictotrico convolute-Ampelodesmetum mauritanici*), transition between xerophytic nitrophilic grassland and pine forest (XNG-PF), Mediterranean scrub (MS) (*Oleo-Euphorbietum dendroidis* subassociation *euphorbietosum bivonae*), eroded wasteland (EW) and steppe grassland (SG) (*Pennisetum setacei-Hyparrhenietum hirtae*).

The geographical coordinates or “marks” (x_i, y_i , combined into one unit) that define each orchid plant or group of plants, effectively correspond to a random distribution, as these points were discovered at random, which creates a stochastic spatial process. Therefore the present study contemplates a random, spatial process with “marks”:

$$y = \{(x_1, m_1), (x_2, m_2), \dots, (x_n, m_n)\}, x_i \in W \subset R^2, m_i \in M$$

where x_i are the PI registered and m_i are the corresponding “marks”. The analysis was carried out using the software R, specifically Spatstat (Baddeley & Turner, 2005; Bivand et al., 2008; R Deve-

lopment Core Team, 2011). As a descriptive tool, and preliminary analysis, the spatial data was plotted graphically against each of the “marks” mentioned previously. The correlation between orchid species and habitat type was analyzed by constructing a spatial process using the “marks” M , which in this case are of type 1, 2. The value of 1 refers to habitat type e.g. “i”, and 2 refers to the orchid species, e.g. “j”. The first step is to plot a graph of the distribution pattern against the “marks”.

To verify whether there was a correlation between the occurrence of the “marks” and the PI, we determined the function of the “marks” corresponding to a stationary process, which is a measurement of the dependence between the “marks” of two points in the process, with a distance between them of r . This can be defined as follows

$$\rho_f(r) = \frac{E[f(M_1, M_2)]}{E[f(M, M^1)]}$$

where M_1, M_2 are the “marks” of the two points which are separated by a distance r ; while M, M^1 are processes independent of the marginal distribution of the “marks”.

Function f is understood in this case as

$$f(m_1, m_2) = 1_{\{m_1 = m_2\}}$$

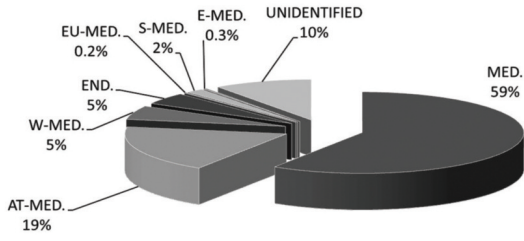
as a function of the categorical “marks”. The correlation function is not a measure of correlation in the usual, strict statistical sense. A value of 1, indicates no correlation; i.e. that the occurrence of the “marks” is completely random.

We also applied a randomization test to the data, by which we tested the hypothesis that the “marks” are conditionally independent and have identical distributions. The test was constructed considering the coordinates as fixed points and using a process of repeated sampling.

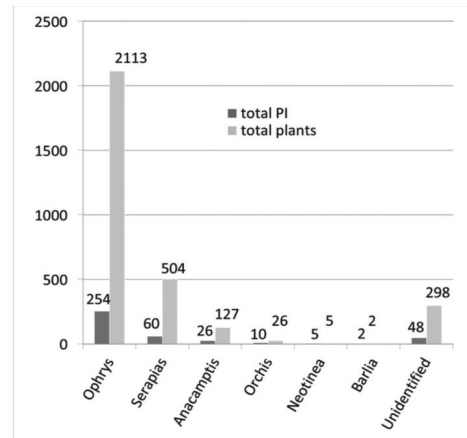
RESULTS AND DISCUSSION

Chorology and populations

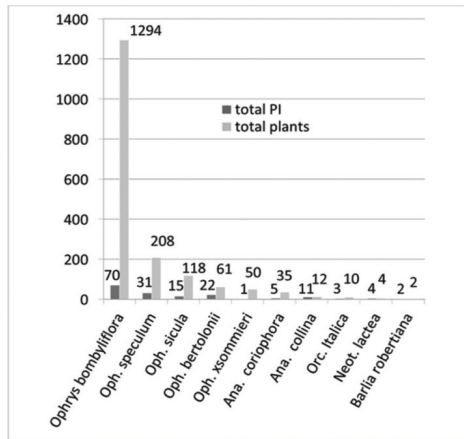
As a result of the three years study in the region, we registered 33 taxa and 404 PI, with an estimated total of 3000 individuals classified into 6 genera (*Anacamptis*, *Barlia*, *Neotinea*, *Ophrys*, *Orchis* and *Serapias*), giving a total of 28 taxa and 5 natural hy-



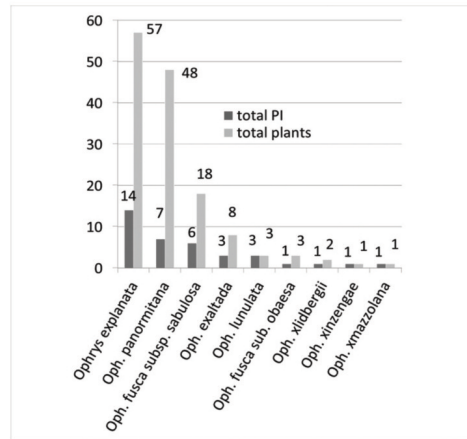
1



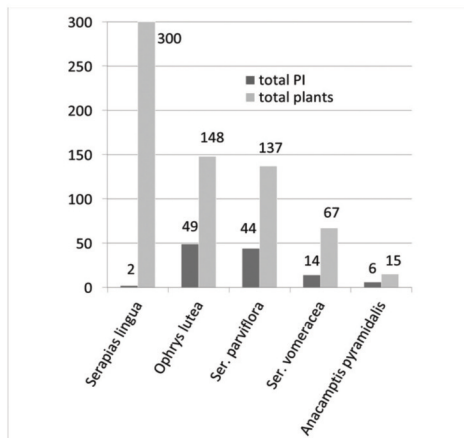
2



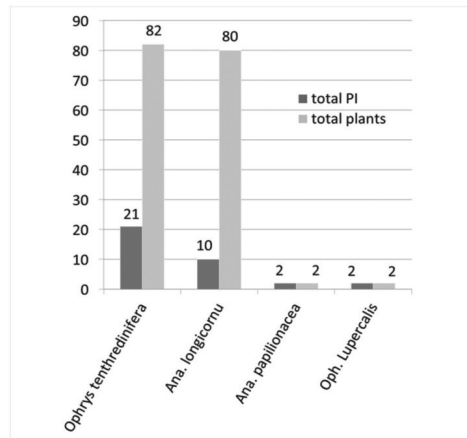
3



4



5



6

Figure 1. Percentage contribution of chorological types, within the orchid population of the Monte Pellegrino Reserve, Sicily. Figure 2. Total number of points of interest (PI) and individual plants, per genus. Figure 3. Total number of points of interest (PI) and individual plants, per species, within the Mediterranean (MED) chorotype. Figure 4. Total number of points of interest (PI) and individual plants per species/hybrid, within the Endemic (END) chorotype. Figure 5. Total number of points of interest (PI) and individuals per species, within the Atlantic Mediterranean (A-MED) chorotype. Figure 6. Total number of points of interest (PI) and individuals per species, within the West Mediterranean (W-MED) chorotype.

brids (plus one unidentified hybrid, possibly derived from *O. incubacea*). The orchid species were distributed between the chorological types as follows: Mediterranean (MED) (31%), Endemic (END) (27%) Atlantic Mediterranean (AT-MED) (15%), West Mediterranean (W-MED) (12%), Euro-mediterranean (EU-MED) (6%), Stenomediterranean (S-MED) (6%) and East Mediterranean (E-MED) (3%). A small number of plants (298) distributed amongst 48 PI could not be identified, as flowering was not observed. In terms of individual plants, again the chorotype MED was the most abundant (1794 individuals), followed by AT-MED (567), W-MED (166) and END (141).

The E-MED, S-MED and EU-MED types are the least represented chorotypes (11, 52 and 7, respectively) (Fig. 1). Analyzing the data for consistency of chorotypes, *Ophrys* is the genus that most influences the data with a total of 254 PI and 2111 individuals, as compared to the genus *Barlia* which is least influential with only two individuals in 2 PI (Fig. 2). Within the MED chorological type, *Ophrys bombyliflora* Link has the most PI and the highest number of individuals. Together with *O. speculum* Link and *O. lutea* subsp. *minor* (Tod.) O. Danesch et E. Danesch these are the most abundant orchid species, while *Neotinea lactea* (Poir.) R.M. Bateman, Pridgeon et M.W. Chase and *Barlia robertiana* (Loisel.) Greuter, are the rarest (Fig. 3). Within the END type, *Ophrys bertolonii* subsp. *explanata* (Lojac.) Soca and *O. sphegodes* subsp. *panormitana* (Tod.) Kreutz both have locus typicus in the Monte Gallo reserve (Parlatore, 1858), close to the study site, and have the highest number of individuals within this group. *Ophrys lunulata*, is a priority species according to the European Commission, and is very scarce within the study area, with only three individuals.

All the hybrids found, with the exception of *O. × sommieri* E.G. Camus unidentified individuals and others that have been recognized as parental *O. incubacea* subsp. *incubacea* (Bertolini, personal unpublished data), have been placed within the END group, having at least one endemic parent. Hybrids were infrequent, and limited to few individuals (Fig. 4). *Serapias lingua*, *Ophrys lutea* subsp. *lutea* Cav. and *S. parviflora* Parl. are among the orchid species with highest frequencies and number of individuals within the AT-MED group. In particular, *S. lingua* was found in 2 PI, one of which contained

approximately 200 individuals and the other had close to 100 individuals of an albino variety. In both cases the total area occupied was limited to a few square meters probably due to the capacity of this species to clone itself by extending stolons (Fig. 5). Within the W-MED group, the most abundant species were *Ophrys tenthredinifera* Willd., 1805 and *Anacamptis longicornu* (Poir.) R.M. Bateman, Pridgeon et M.W. Chase, whereas the least frequent was *Ophrys lupercalis* J. Devillers-Terschuren et P. Devillers with only two individuals in 2 PI (Fig. 6). The E-MED group had 11 individuals of *Ophrys lutea* subsp. *phryganae* (Devillers-Tersch. et Devillers) Melki, 2000, in 2 PI.

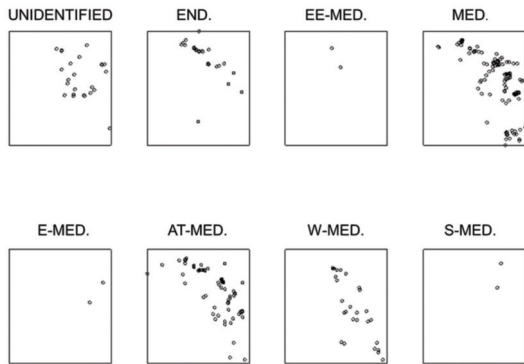
Another infrequent species were *Ophrys sphegodes* subsp. *sphegodes* Mill. Huds., belonging to the EU-MED group, each found in only 1 PI. The S-MED group was represented only by *O. incubacea* subsp. *incubacea*, with 2 individuals plus some hybrids.

Distribution

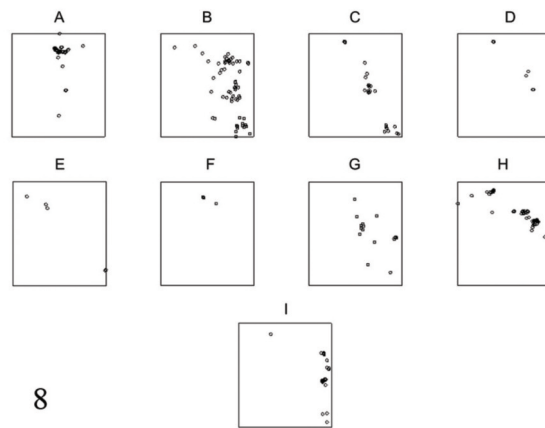
Analysis of the distribution of the different chorological types, distinct groups, or sub-populations can be observed, in agreement with Perkins & McGee (1995) and Diez (2007), who stress that the possibilities of seed germination are reduced with increasing distance from an adult plant, which could explain the discrete patches of plants observed empirically and graphically in this study.

Orchids that remained unidentified and could not be assigned to a chorological type appeared to have a random distribution as compared to identified individuals assigned to a chorological type. In particular, the chorological types END, MED, AT-MED and W-MED showed clear patterns of colonization (Fig. 7). However, the limited number of individuals assigned to the other chorological types was insufficient for analysis.

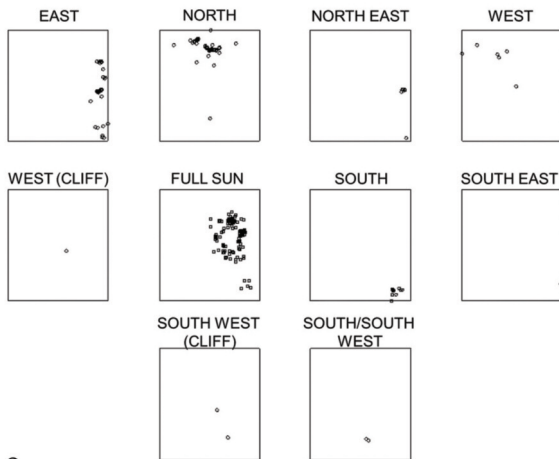
The prevailing winds could play an important role in the distribution of orchids, by transporting the seed and influencing the behaviour of pollinators. Observing the distribution patterns of the orchids, areas towards the east (right of the maps) are more densely populated. Orchid seed capsules mature and dehisce during the dry season, from May to September, and the prevailing winds at that time blow towards the north-east (Albaria, 2011), favouring population increase and colonization in that di-



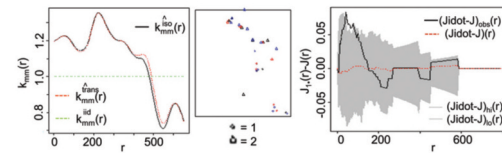
7



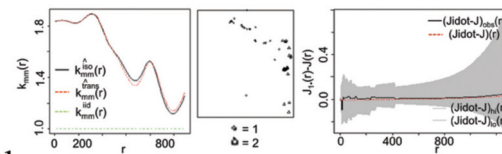
8



9



10



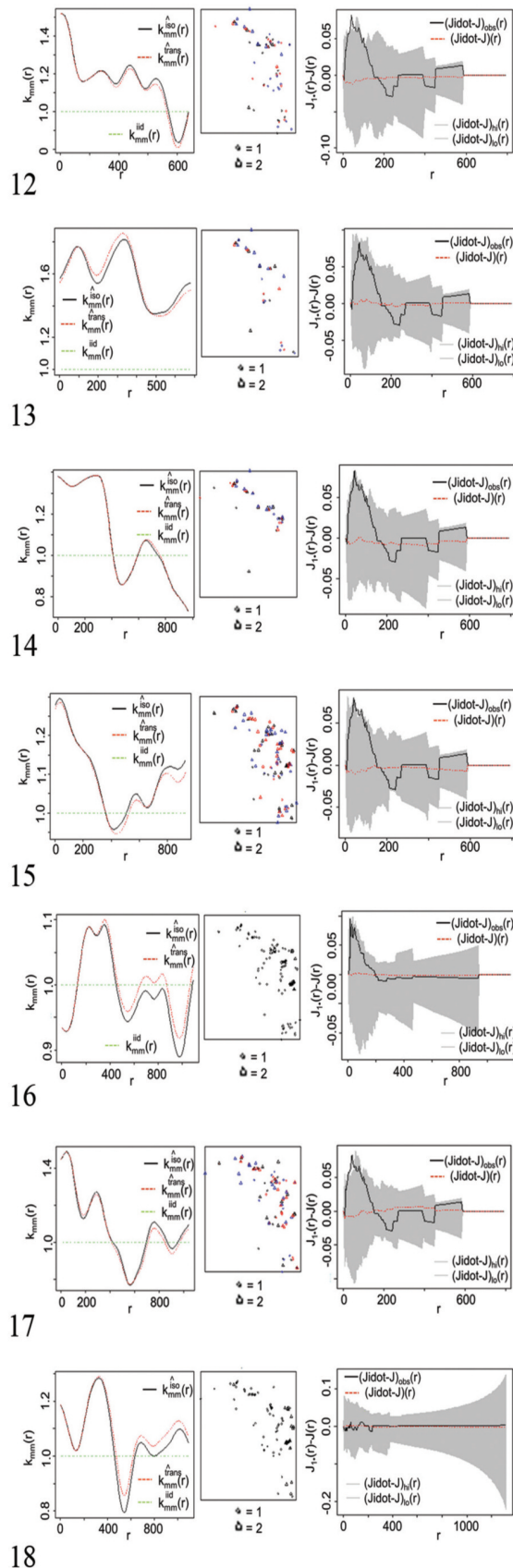
11

Figures 7-11. Distribution and Ecological Patterns of Orchids in Monte Pellegrino Reserve, Sicily. Fig. 7: Spatial distribution of orchids by chorotype. Fig. 8: distribution of orchids within the 9 habitats that characterize the Monte Pellegrino Reserve. Fig. 9: distribution of orchids according to light exposure. Fig. 10: Correlation function, Spatial dispersion and test of Random Labeling, for the distribution of Endemic (END) chorotype orchids and the habitat Clearings in deciduous thermophilic forest (Cl.DTF). Fig. 11: Correlation function, Spatial dispersion and test of Random Labeling, for Endemic (END) chorotype orchids and the habitat *Ampelodesmetum* Meadows (MA), in the Monte Pellegrino Reserve, Sicily.

rection, but ultimately limited by the seafront. It is possible that these populations had their origin in areas that now correspond to the city of Palermo towards the south. Very few orchids were found towards the western side of Monte Pellegrino Reserve, not only because of the winds, but also because of unfavourable environmental conditions, as the western perimeter of the reserve is highly disturbed, with extensive grazing of goats which are destructive to the vegetation, and invasion by steppe grasses (*Pennisetum setacei-Hyparrhenietum hirtae*), which in combination with other species of *Pennisetum*, out-competes other plant species.

During the months of January to April almost all angiosperms found in the study site are in flower and at this time the prevailing winds blow towards the south-east, which may serve to bring pollinators from the deciduous, thermophilic forest towards the north, which is the most species rich habitat in the area. In the case of hybridization, almost all the individuals were found close to at least one parent, considering the possibility that the winds might have brought pollinaria-carrying bees from populations of other orchid species towards the north.

The distribution of the orchids of Monte Pellegrino Reserve varies depending on the habitat in question, and Figure 8 demonstrates that Cl.DTF,



CI.RPF, CI.RPEF, MS, XNG and MA are the preferred habitats in Monte Pellegrino. The areas reforested to pine, and XNG species are found towards the north of the study area and are traditionally given over to cattle pasture. Cows cause less damage to vegetation than sheeps and goats and deposit substantial amounts of manure which propitiates excellent growing conditions for orchids, with favourable pH and C/N ratio (Diez, 2007) which is particularly important in areas where the soil is leached and eroded with exposed rocks. The variable topography and vegetation cover of the study area affects light exposure and creates unusual microclimatic conditions. The results of this study demonstrate that exposure to the east, north and full sun are related to higher numbers of orchids (Fig. 9). Along the limits of the reserve, exposure towards the north and east also benefits from cool, humid air streams coming off the sea. The areas in full sun are the flat tops of the hills reforested to pine, and with XNG species largely dedicated to cattle pasture. For the END chorotype, there was a positive correlation with CI.DTF, CI.RPF and CI.RPEF, XNG, MA and MS. The correlation between END species and CI.DTF is positive, with a high probability of finding another individual within a radius of approximately 250 m (Fig. 10), for CI.RPF there is a high probability of

Figures 12-18. Distribution and Ecological Patterns of Orchids in Monte Pellegrino Reserve, Sicily. Fig. 12: Correlation function, Spatial dispersion and test of Random Labeling for Endemic (END) chorotype orchids and the habitat Clearings in areas reforested with pine (CI.RPF). Fig. 13: Correlation function, Spatial dispersion and test of Random Labeling, for Endemic (END) chorotype orchids and the habitat Clearings in areas reforested with a mixture of *Pinus* and *Eucalyptus* (CI.RPEF). Fig. 14: Correlation Function, Spatial dispersion and test of Random Labeling, for orchids of the Endemic (END) chorotype and the habitat Substeppe xerophytic nitrophilic grassland (XNG). Fig. 15: Correlation Function, Spatial dispersion and test of Random Labeling, for orchids of the Mediterranean (MED) chorotype and the habitat Clearings in areas reforested with pine (CI.RPF). Fig. 16: Correlation function, spatial dispersion and test of Random Labeling, for orchids of the Mediterranean (MED) chorotype and the habitat *Ampelodesmetum* Meadows (MA). Fig. 17: Correlation function, Spatial dispersion and test of Random Labeling for orchids of the Atlantic Mediterranean (AT-MED) chorotype Clearings in areas reforested with *Pinus* (CI.RPF). Fig. 18. Correlation function, Spatial dispersion and test of Random Labeling for orchids of the Atlantic Mediterranean (AT-MED) chorotype and the habitat *Ampelodesmetum* Meadows (MA).

finding another individual within smaller distances, approximately less than 50 m (Fig. 12), in the case of Cl.RPEF the distance is estimated at 100-350 m (Fig. 13) and finally, in XNG the distance is estimated at 350 m (Fig. 14). For the case of MA habitats, the positive correlation presents a random distribution. This may be due to the fact that the total area is limited and fragmented, so the distribution pattern may be acting on a larger scale (Fig. 11).

The distribution of the END species is peculiar, but predictable, in that this is the only group with a positive correlation with the habitat Cl.DTF, which consists of residual fragments of the original forest of the Monte Pellegrino area and it is logical that the endemic species would have an affinity for this older, conserved habitat where mutualist species are more likely to be present. Similarly, the fraction of soil explored by the hypogean parts of the orchids benefit from relatively elevated quantities of organic matter derived from the process of humification of the leaf litter from the native trees, implying an elevated and specific cryptogamic flora and fauna, of which rhizoctonious fungi are of particular interest. This situation would be beneficial for the seeds of orchids, more than the situation occurring in disturbed areas with alien species and different dynamics of organic matter recycling.

None the less, the END chorotype was also positively correlated to other habitat types, such as XNG, due to the fact that some of the endemic species were numerous, for example *O. explanata*, had 57 individuals (Fig. 5), which were also distributed in these habitats. These species are probably less demanding and colonize nutrient poor habitats, unlike endemics such as *O. lunulata* with only 3 individuals and all found in Cl.DTF. The MED chorotype is positively correlated to Cl.RPF, with a high probability of finding another individual within a radius of 50 m (Fig. 15). This is the chorotype with the widest distribution and includes the most abundant species, *O. bombiliflora*, with a total of 1294 individuals (Fig. 4). No positive correlation was found with MA (Fig. 16). The non-random distribution assigned to the MED chorotype is justified by the high number of individuals, in contrast to the small numbers of individuals for the species in the END chorotype, distributed within the same habitat with a random distribution but positively correlated to the habitat. The AT-MED chorological group displays a positive correlation with the

Cl.RPF with a high probability of finding another individual within 100 m (Fig. 17). No such correlation was found with the MA (Fig. 18).

In conclusion, the results shown are interesting for conservation purposes of Mediterranean orchids, because contribute to understand distribution patterns of Orchidaceae family in coastal environments. Moreover, we can apply this kind of knowledge to analyze other Natura2000 reserves that are close and similar to Monte Pellegrino, in terms of microclimate and geographical patterns as, for example, Monte Gallo or Monte Catalfano in order to better understand Orchidaceae distribution at a larger scale.

ACKNOWLEDGEMENTS

We thank Dr. S.A. Giardina for taxonomical determination of the uncertain individuals.

REFERENCES

- Albaria, 2011. Meteorological data. <http://www.albaria.com/meteo/mondellometeo.htm>, visited 2/06/2011.
- Baddeley A. & Turner R., 2005. Spatstat: an R package for analyzing spatial point patterns. *Journal of Statistical Software*, 12: 1-42.
- Bartolo G. & Pulvirenti S., 1997. A check-list of Sicilian orchids. *Boccone*, 5: 797-824.
- Bergman E., Ackerman J.D., Thompson J. & Zimmerman J.K., 2006. Land-use history affects the distribution of the saprophytic orchid *Wulfschlaegelia calcarata* in Puerto Rico's Tabonuco Forest. *Biotropica*, 38: 492-499.
- Bertolini V., 2009a. Le Orchidaceae della Riserva Naturale Orientata "Monte Pellegrino", Palermo. Ph.D. thesis, University of Palermo, Palermo.
- Bertolini V., 2009b. Le orchidee di Monte Pellegrino. Il tesoro della Santuzza. Il Brigantino, Palermo, 90 pp.
- Bertolini V. & Giardina S.A., 2008. Checklist delle Orchidaceae del Monte Pellegrino (Palermo) (Orchidaceae Checklist in Monte Pellegrino (Palermo)). *Journal Europäischer Orchideen*, 40: 575-586.
- Bivand R.S., Pebesma E.J. & Gómez-Rubio V., 2008. *Applied spatial data analysis with R*. Springer, New York, 378 pp.
- Brys R., Jacquemyn H. & Hermy M., 2008. Pollination efficiency and reproductive patterns in relation to local plant density, population size, and floral display in the rewarding *Listera ovata* (Orchidaceae). *Botanical Journal of the Linnean Society* 157: 713-721.

- Delforge P., 2005. Guide des orchidées d'Europe d'Afrique du Nord et du Proche d'Orient. Delachaux et Niestlé, Paris, 640 pp.
- Del Prete C. & Tosi G., 1988. Orchidee spontanee d'Italia (Wild Orchids of Italy). Mursia, Milano, 172 pp.
- Diez J.M., 2007. Hierarchical patterns of symbiotic orchid germination linked to adult proximity and environmental gradients. *Journal of Ecology*, 95: 159-170.
- Fierotti G., 1997. I suoli della Sicilia (Soils of Sicily). Con elementi di genesi, classificazione, cartografia e valutazione dei suoli. Dario Flaccovio, Palermo, 359 pp.
- Gianguzzi L., Lo Valvo F. & Papini F., 1995. SIC card of Monte Pellegrino http://www.artasicilia.eu/web/natura2000/schede_natura_sicilia/SCHEDA_PDF/ITA020014_Monte%20Pellegrino.pdf, visited, 5/01/2012.
- Gianguzzi L., Ilardi V. & Raimondo F.M., 1996. La vegetazione del promontorio di Monte Pellegrino (Palermo) (The vegetation of Monte Pellegrino mount (Palermo)). *Quaderni di Botanica Ambientale e Applicata*, 4: 79-137.
- Giardina S.A., 2005. Distribuzione delle Orchidaceae della provincia di Palermo e relativa rappresentazione cartografica (Orchidaceae distribution in Palermo district and relative cartography). Sc.B. thesis, University of Palermo, Palermo.
- G.I.R.O.S., 2009. Orchidee d'Italia (Orchids of Italy). Il Castello, Cornaredo (Milano), 304 pp.
- Goethe J.W., 1905. Viaggio in Italia. Mondadori, Milano.
- Grasso S., 2009. Presenza di *Ophrys incubacea* Bianca nella Riserva di Monte Pellegrino (Palermo, Sicilia) (Presence of *Ophrys incubacea* Bianca in the Monte Pellegrino Reserve (Palermo, Sicily)). *Giros Notizie*, 42: 18.
- Grünanger P., 2001. Orchidacee d'Italia (Orchidaceous of Italy). *Quaderni di Botanica Ambientale e Applicata*, 11: 3-80.
- Hutchings M.J., 1987. The population biology of the early spider orchid, *Ophrys sphegodes* Mill. I. A demographic study from 1975 to 1984. *Journal of Ecology*, 75: 711-727.
- Mazzola P. & Di Martino C., 1996. La florula decorativa del promontorio di Monte Pellegrino (Palermo) (Decorative plants in Monte Pellegrino mount). *Quaderni di Botanica Ambientale e Applicata*, 4: 35-48.
- Montanari L., 1964. Geologia del Monte Pellegrino (Palermo) (Geology of Monte Pellegrino (Palermo)). *Rivista Mineraria Siciliana*, 88-89: 173-197.
- Parlatore F., 1858. Flora italiana ossia descrizione delle piante che nascono selvatiche o si sono inselvaticite in Italia e nelle isole ad essa adiacenti; distribuita secondo il metodo naturale. Tipografia Le Monnier, Firenze, 3, 690 pp.
- Perkins A.J. & McGee P.A., 1995. Distribution of the orchid mycorrhizal fungus *Rhizoctonia solani* in relation to its host *Pterostylis acuminata*. *Australian Journal of Botany*, 43: 565-575.
- Pignatti S., 1982. Flora d'Italia. Edagricole, Bologna, 3 Vol., 2302 pp.
- Puccia A., 1995. La famiglia delle Orchidaceae nella flora delle Madonie, aspetti ecologici e distributivi (Orchidaceae family of Madonie flora, ecological and ditributive aspects). Sc.B. thesis, University of Palermo, Palermo.
- Quartarone C., Casaccio S. & Lisa L., 1995. Il Territorio guidato, Il monte Pellegrino a Palermo (Guided Territory, the mount Pellegrino in Palermo). ILA Palma, Palermo, 159 pp.
- R Development Core Team, 2011. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, 1706 pp.
- Raimondo F.M. & Venturella G., 1996. Lineamenti fisici e biogeografici del promontorio di Monte Pellegrino (Palermo) (Fiscal and biogeographical aspects of Monte Pellegrino mount (Palermo)). *Quaderni di Botanica Ambientale e Applicata*, 4: 7-11.
- Raimondo F.M., Venturella G. & Ilardi V., 1996a. Carta forestale del promontorio di Monte Pellegrino (Palermo) 1:10000 (Forestal map of Monte Pellegrino mount (Palermo) 1:10000). *Quaderni di Botanica Ambientale e Applicata*, 4: 145-152.
- Raimondo F.M., L. Gianguzzi & C. Di Martino, 1996b. La flora vascolare del promontorio di Monte Pellegrino, Palermo (Vascular flora in Monte Pellegrino mount, Palermo). *Quaderni di Botanica Ambientale e Applicata*, 4: 13-34.
- Sanford W.W., 1969. The distribution of epiphytic orchids in Nigeria in relation to each other and to geographic location and climate, type of vegetation and tree species. *Biological Journal of the Linnean Society*, 1: 247-285.
- Schatz B., 2006. Fine scale distribution of pollinator explains the occurrence of the natural orchid hybrid \times *Orchis bergonii*. *Écoscience*, 13: 111-118.
- Scrofani S., 1949. Rimboschimento del Monte Pellegrino (Reforestation of Monte Pellegrino). Camera di Commercio, Industria ed Agricoltura, Palermo, 18 pp.
- Swarts N.D., Batty A.L., Hopper S. & Dixon K.W., 2007. Does integrated conservation of terrestrial orchids work? *Lankesteriana*, 7: 219-222.
- Venturella G., 1996. Contributo alla conoscenza della flora micologica del promontorio di Monte Pellegrino (Palermo). *Quaderni di Botanica Ambientale e Applicata*, 4: 69-77.
- Vigliardi A., 1991. L'arte paleolitica del Monte Pellegrino, le incisioni rupestri delle grotte dell'Addaura e di grotta Niscemi (Paleolithic art of Monte Pellegrino, rocky paintings of Addaura and Niscemi cave). Centro di documentazione e ricerca per la Sicilia antica "Paolo Orsi". S.T.Ass, Palermo, 93 pp.