Habitat preferences of *Papilio alexanor* Esper, [1800]: implications for habitat management in the Italian Maritime Alps

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ABSTRACT

Papilio alexanor Esper, [1800] is a threatened European butterfly species listed in Annex IV of the Habitats Directive and in Appendix II of the Bern Convention, being considered extremely vulnerable to climate change. According to some projections (e.g., Bambu, a scenario of moderate climate change), it would be expected to lose 63% of its European climatic niche by the year 2050 and 77% by 2080. The few remaining populations are expected to become concentrated in the Maritime Alps. In 2009 and 2010, we studied what is probably the densest *P. alexanor* population in the Italian part of this area. It occurs in a series of dry, xerothermic grasslands, also partially occupied by an abandoned limestone quarry, where the larval food plant is *Ptychotis saxifraga* (L.) Loret & Barrandon. Females lay eggs in July, choosing patches where the food plants are higher and more abundant. The habitat preference, conservation status and survival of the early instars larvae of *P. alexanor* have been investigated in order to draw up conservation strategies for this species in the Italian Maritime Alps.

KEY WORDS
conservation,
butterflies,
restoration ecology,
oviposition,
larval development.

RÉSUMÉ

Préférences d'habitat de Papilio alexanor *Esper, [1800]: implications pour la gestion de l'habitat dans les Alpes-Maritimes Italiennes.*
Papilio alexanor Esper, [1800] est un papillon diurne menacé en Europe et inscrit à l'Annexe IV de la Directive Habitats dans l'Appendice II de la Convention de Berne. Cette espèce est considérée comme particulièrement sensible aux changements climatiques. Selon quelques projections (ex. Bambu, un scénario de changement climatique modéré), elle serait susceptible de perdre 63 % de sa niche climatique européenne d'ici à l'année 2050 et jusqu'à 77 % d'ici à 2080. On peut s'attendre à ce que les quelques populations survivantes soient concentrées dans les Alpes maritimes. En 2009 et 2010, nous avons étudié la population de *P. alexanor* probablement la plus dense parmi celles qui habitent la portion italienne de ce territoire. Elle occupe une série de friches semi-naturelles aussi bien qu'une

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carrière de roches calcaires aujourd'hui désaffectée. Dans notre aire de travail la plante nourricière des chenilles est *Ptychotis saxifraga* (L.) Loret & Barrandon. Les femelles pondent leurs œufs au mois de juillet, choisissant les sites où les plantes nourricières sont particulièrement hautes et abondantes. Les préférences écologiques, l'état de conservation et la survie des premiers stades du développement larvaire ont été étudiés, en vue de proposer une stratégie pour la conservation durable de cette espèce dans les Alpes maritimes italiennes.

INTRODUCTION

Papilio alexanor Esper, [1800] is a swallowtail butterfly with a highly fragmented Euro-Central Asiatic range. It occurs in the pre-Alps and sub-Mediterranean areas of SE France, from Provence to the French Maritime Alps, while in Italy it is restricted to a few sites of the Ligurian and Italian Maritime Alps. Outside of this range, its distribution shows a very wide gap and it occurs again in the southern Balkans, thereafter extending eastwards as far as Central Asia (see Kudrna *et al.* 2011). The first records of *P. alexanor* in the Italian Alps date back to the 1970s, when it was found in the Ligurian Alps (Balletto & Toso 1976). In the Maritime Alps, apart from an old, unconfirmed report by Turati & Verity (1911-12; "Col de Fenestre") and a vaguely localized record by Barajon (1957: "upper Val Tanaro"), its occurrence was confirmed only much later (Baldizzone 1971; Balletto *et al.* 1982). More recent reports include those by Ortali & Bertaccini (1987), Prola & Prola (1990), Sala & Bollino (1991), Audisio & De Biase (1993), David & Sanetra (1994) and Arnscheid (2000). The presence of this species in the general area had, however, already been known to amateur collectors for a number of years. Populations from the Italian Maritime Alps were later described as "ssp. *radighierii*" Sala & Bollino, 1991. Elsewhere in Italy, although *P. alexanor* was sometimes observed in some parts of Calabria and NE Sicily (see Fig. 2), it does not have any stable populations there and the records probably refer to stray adults having reached the Italian Peninsula by flying from the Balkans.

In NW Italy, the species is found in mountainous or hilly regions, from around 500 to 1200 m a.s.l., but at least occasionally reaching up to 2100 m, at Col de Tende (E. Balletto, personal observation). *Papilio alexanor* is a thermophilous species that prefers calcareous areas, on south-facing, sometimes steep and rocky slopes. This is probably a consequence of the ecological needs of its food plants, some of which are pioneering species selecting eroded and poor soils. The larvae feed on various Umbelliferae mainly *Ptychotis saxifraga* (L.) Loret & Barrandon in the Maritime Alps, but eggs can also be laid on *Trinia glauca* ssp. *glauca* (L.) Dumort (C. Forte, pers. comm.; Nel & Chauliac 1983; Bollino & Sala 2004). At lower elevations (500-800 m) of the southern slopes of the Ligurian Alps, caterpillars are found on *Opoponax chironium* (L.) Koch (see Reche 1978), while populations from the Balkans and Central Asia may use several species of *Ferula* (see de Freina 1996). As observed by Nel (1991), each population (or group of populations) of *P. alexanor* generally shows a selected trophic preference for a single Umbelliferous species, although the use of up to three species, each having different blooming time, has been reported locally for some populations from central Greece (*Pimpinella* sp*., O. chironium, Ferulago* sp., see Bollino & Sala 2004). Similar local plant-shifts are also reported for French populations, where larvae of *P. alexanor*, occurring on opposite slopes of the same hill, select *O. chironium* on the northern side and *P. saxifraga* on the southern. The same authors (Bollino & Sala 2004) argue that the capability of exploiting various food plants having spaced-out blooming times may represent an important adaptation in the case of species having a prolonged emergence period. *Papilio alexanor* is invariably monovoltine: adults may fly from late March to late July, depending on local climatic conditions (Bollino & Sala 2004). *Papilio alexanor* overwinters as a pupa, and is known to stay in diapause for up to three years (Nakamura & Ae 1977; Bollino & Sala 2004).

Although *P. alexanor* is listed in Annex IV (species of community interest) of the Habitats Directive (H.D.) and in Appendix II (strictly protected species) of the Bern Convention, no immediate or major threats to its survival have been identified at the European level and it is considered a species of "least concern" (van Swaay *et al.* 2010). In 2007 its conservation status under Article 17 (H.D.) was assessed as "favourable" for the Alpine region and "unknown" for the Mediterranean area.

Papilio alexanor, however, is known to be particularly vulnerable to climate change and Settele *et al.* (2008) have listed it as an "Extremely high climate change risk (HHR)" species, in their Climate Risk Atlas of the European butterflies. Indeed, climate change will soon represent a real threat for *P. alexanor*, which, according to currently available climatological scenarios, is expected to lose 63% of its European climatic niche by 2050, and 77% by 2080 (Bambu scenario). Given its good dispersion ability, it is likely that *P. alexanor* will respond to climate change by colonizing new, climatically suitable areas, as suggested by recent observations of isolated individuals far north from its actual range along the Rhone Valley, especially during the warmest years. However, sites in the SW Alps will be among the very few to offer suitable conditions for its long-term survival, so that it is extremely important to protect all populations in the Maritime and Ligurian Alps, in order to mitigate the severe effects that climate change will have on this species.

Fig. 1. — *Papilio alexanor* Esper, [1800]. Photograph: Davide Piccoli.

Even though no population extinction is known to have affected *P. alexanor* on Italian territory (Bonelli *et al.* 2011a) and all known Italian populations occur within protected areas (Bonelli *et al.* 2011b), we recently estimated as "inadequate" the overall conservation status of this species, on the basis of its "future prospects". Apart from climate, the other threats that Italian populations are facing, and which may eventually undermine the long-term persistence of this species, are mainly connected with the abandonment of traditional pastoral systems and the return of natural forestation (H.D. Article 17 assessment; Balletto *et al. in press*).

Perhaps the most severely threatened Italian population of *P. alexanor* occurs in Valdieri, in the Italian Maritime Alps (Maritime Alps natural Park – SCI and SPZ IT1160056). Adults occur there in a semi-natural habitat (calcareous rocky slopes, Annex I Habitats Directive, 8210) and in an abandoned quarry. Among the most important factors threatening this population we can cite: 1) over-collecting of both adults and larval stages; 2) habitat loss, as a consequence of natural forestation; and 3) possible opening of new quarrying activities in the area.

We investigated this population in the years 2009 and 2010 within the framework of the programme "Inventorying biodiversity in the Mercantour/Marittime", funded by the European Distributed Institute of Taxonomy (EDIT).

The main aims of our study are listed below:
– field study of the local larval food-plant. There is growing evidence of polyphagous butterfly species that are monophagous at the local level. This would have strong influence for *in situ* conservation plans and general habitat management (see Dolek *et al.* 2013);
– assess habitat preferences and food-plants use. We wanted to evaluate whether females select oviposition sites on the basis of microhabitat characteristics or of some specific plant features, as observed in other butterfly species (e.g., Patricelli *et al.* 2011);
– assess the conservation status of *P. alexanor* at Valdieri sites. Since swallowtails are large butterflies and require substantial amounts of food to reach their final instars, it will be useful to estimate the food plant density and the area of favourable habitat needed to guarantee the long term survival of this population.

Fig. 2. — Stable range of *P. alexanor* Esper, [1800] in Italy (Balletto *et al.* 2007), observations from S Italy are interpreted as being based on vagrant specimens from the Balkans, the arrow indicates the Valdieri study area.

MATERIALS AND METHODS

During the spring-summer period of 2008, preliminary inspections were made to verify the persistence of the *Papilio alexanor* population and confirm that *Ptychotis saxifraga* is the larval food-plant in the study area.

STUDY AREA

Papilio alexanor adults and eggs occur in both natural and semi-natural/replacement habitats.

The butterfly was detected in the abandoned quarry of Valdieri and in the nearby Natural Reserve for *Juniperus phoenicea*.

The limestone banks that extend to the East of Valdieri were quarried for about 35 years (1962-1997) for the preparation of cement (Ansaldi *et al.* 2006).

The Phoenician juniper (*Juniperus phoenicea* L.) is a very rare plant in this part of Italy, where it reaches its northernmost limit. A Natural Reserve for the protection of an important stand of this shrub was therefore created in 1984. It extends over the limestone and dolomitic banks occurring close to the summit of Mt Saben (1670 m), where the southern exposition and the presence of carbonate rocks favour the establishment of a microclimate that is also suitable for the survival of *P. alexanor*.

SAMPLING THE FOOD PLANTS AND THE LARVAL INSTARS

Papilio alexanor is a fast and high-flying swallowtail butterfly that always occurs at low densities, which makes studying its adult's population dynamics by the Mark-Release-Recapture method unfeasible. During the summers of 2009 and 2010, we surveyed the spatial distribution of *P. saxifraga* and focused our efforts on finding the pre-imaginal stages of *P. alexanor*.

We randomly chose 47 quadrats (25 m²) in which at least one food plant existed. In each geo-referenced plot, we collected data on the number and height of *P. saxifraga* plants. We measured the density of the vegetation cover and the proportion of bare soil, according to the Braun-Blanquet's method (Braun-Blanquet 1932). For each plot, we noted the number of eggs, larvae and/or pupae of *P. alexanor*. In 2010, the same data were collected once a week for the whole flight period of *P. alexanor* adults, to assess the in-field larval development and the microhabitat requirements of the early stages. Finally, we measured the minimum distance of each plot centre from the nearest thistle plant (e.g., *Carduus, Cirsium*), since these plants represent the only nectar sources potentially available for *P. alexanor* adults at that time of the year.

In addition to field sampling, we performed a study of the survival of larval instars in the laboratory. Ten plants bearing visible *P. alexanor* eggs were collected, carried and set in laboratory conditions. We measured the length of each larval stage during development and the number of days between each moulting until pupation.

STATISTICAL ANALYSIS

Data on plot parameters collected over the two-year samplings were not normally distributed. Therefore, we used non-parametric tests to compare the ecological factors between occupied and unoccupied plots, in separate tests.

We used the Wilcoxon test to compare the numbers and heights of *P. saxifraga* plants, the percentage of bare soil and vegetation cover, between plots occupied by *P. alexanor* in 2009 and/or in 2010. The Mann-Whitney-U test was used to assess differences in plot distances from the first colonised square and the first nectar source (thistle) between plots, either occupied or unoccupied by *P. alexanor*.

In-field larval survival was calculated for each plot, using data collected in 2010, as the number of larvae divided by the initial number of eggs. Differences in larval survival between plots occupied by increasing numbers of food-plants were analysed with the Friedman two-way analysis of variance by ranks test.

RESULTS

During the summer of 2008, we confirmed the persistence of a *P. alexanor* population in the surroundings of an abandoned quarry in the Valdieri area. Larvae were feeding only on *P. saxifraga*.

SURVEY OF *P. SAXIFRAGA*

In 2009, we surveyed the food-plants and counted *P. alexanor* eggs, larvae and pupae. We identified 47 quadrats, spanning in altitude from 700 to 950 m, where *P. saxifraga* was present. At the base of the quarry, the food-plant was located
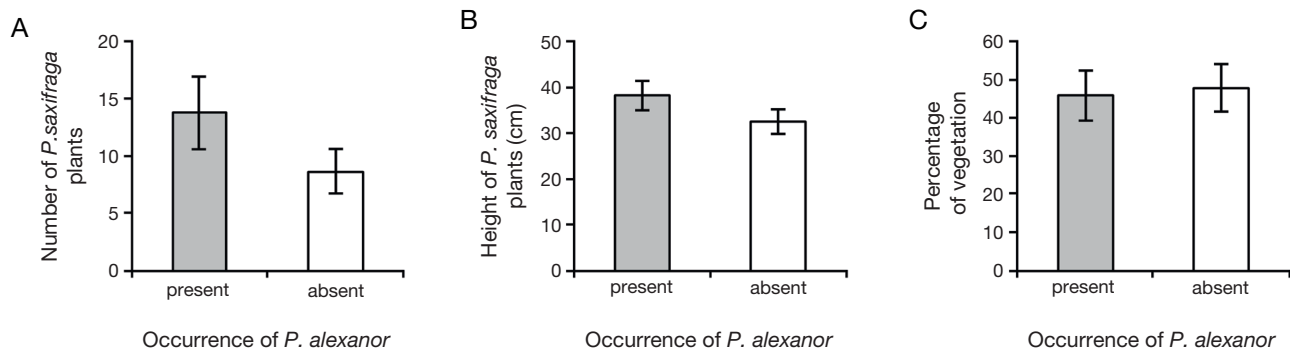
Fig. 3. — Comparison of mean number (**A**) and height (± SD) (**B**) of *P. saxifraga* (L.) Loret & Barrandon and average percentage (± SD) of vegetation cover (**C**) between occupied and unoccupied plots by *Papilio alexanor* Esper, [1800].

mostly in the low-lying areas colonised by pioneer vegetation, while at higher altitudes it occurred at the edge of the rocky terraces and on the south facing rocky slopes. The data collected in 2009 allowed us to estimate *P. saxifraga* coverage: about 1.8 hectares out of a total of 29.5 hectares surveyed, while in 2010 the proportion of habitat occupied by the food-plant had slightly decreased, to 1.5 ha. In 2009, 594 plants were scanned: 538 of them (90.5%) did not present any trace of *P. alexanor* eggs, while 56 (9.5%) were exploited by the butterfly and occurred in 28 out of 47 quadrats.

Within each quadrat we counted from a minimum of one plant up to a maximum of 50. The average height per plot of the *P. saxifraga* plants varied between 20 and 60 cm.

In 2009 we counted a total of 65 eggs, as well as 70 first, 43 second, 12 third and four final (IV and V) instar larvae, and 5 pupae of *P. alexanor*.

In 2010, we monitored the same 47 patches surveyed in 2009. The distribution of *P. alexanor* was similar to that observed in 2009, but nine plots were no longer occupied in 2010, while five patches unexploited in 2009 were colonized by *P. alexanor* in 2010.

The comparison between the quadrats monitored in our two-year study showed that occupancy depends on the number of *P. saxifraga* plants (Wilcoxon test: Z = –2.745, p = 0.006) as well as on the percentage of plant cover (Wilcoxon test: Z = –2.251, p = 0.024) (Fig. 3).

Quadrats colonized by *P. alexanor* also showed a statistically significant larger average height of the food-plants (Wilcoxon test: Z = –2.506, p = 0.012) (Fig. 3). The percentage of bare soil showed no statistically significant correlation, while the percentage of other vegetation was lower in the quadrats occupied by the butterfly (Wilcoxon test: Z = –2.254, p = 0.024).

In 2010, 21 patches were exploited by *P. alexanor* while 26 were unoccupied. A total of 423 *P. saxifraga* plants were examined, 356 of which (84%) did not bear any pre-imaginal *P. alexanor* pre-imaginal instars, while 67 (16%) were occupied by the butterfly. Inside quadrats we surveyed a minimum of one plant up to a maximum of 32 plants. In quadrats with *P. alexanor* we examined an average (± SD) of 11.2 ± 8.6 plants.

Comparing distances between quadrats, we found that plots where *P. alexanor* was absent were much more isolate
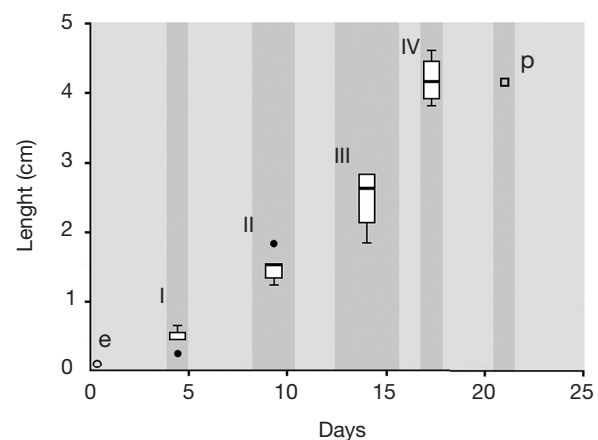

Fig. 4. — Pre-imaginal development of *Papilio alexanor* Esper, [1800] under laboratory conditions; box plots illustrate increases in larval length; vertical lines: median larval length; box: 25th-75th percentiles; whiskers: minimum and maximum observed values; • outliers; dark grey band width represents the standard deviations of mean development intervals (days). Abbreviations: **e**, egg; **I-IV**, larval instars; **p**, pupa.

than those where the butterfly was present (Mann-Whitney U = 84.000, p = 0.18), the distance between the occupied quadrats and the nearest quadrat was lower (15.81 ± 4.23 m, mean ± SE) than the distance between unoccupied quadrats (27.22 m ± 4.50; mean ± SE) (Fig. 3). Distances from the nearest potential nectar source (thistles) were similar for plots where *P. alexanor* was present and those where it was absent (Mann-Whitney U = 155.5, p = 0.950).

LARVAL SURVIVAL IN THE LABORATORY

On average, larval development lasted 22 days and the transition from one stage to the next took 4.1 ± 0.7 days (Fig. 4). Larval body length changed from 0.4 ± 0.15 cm (first instar larvae) to a maximum of 4.3 ± 3.5 cm (final instar larvae).

The development of the last instars was faster than that of first instar larvae: *P. alexanor* took about a week to pass from third instar larva to pupa (Fig. 4). Two butterflies hatched in the laboratory and were transported, along with the reared pupae, to their site of origin.
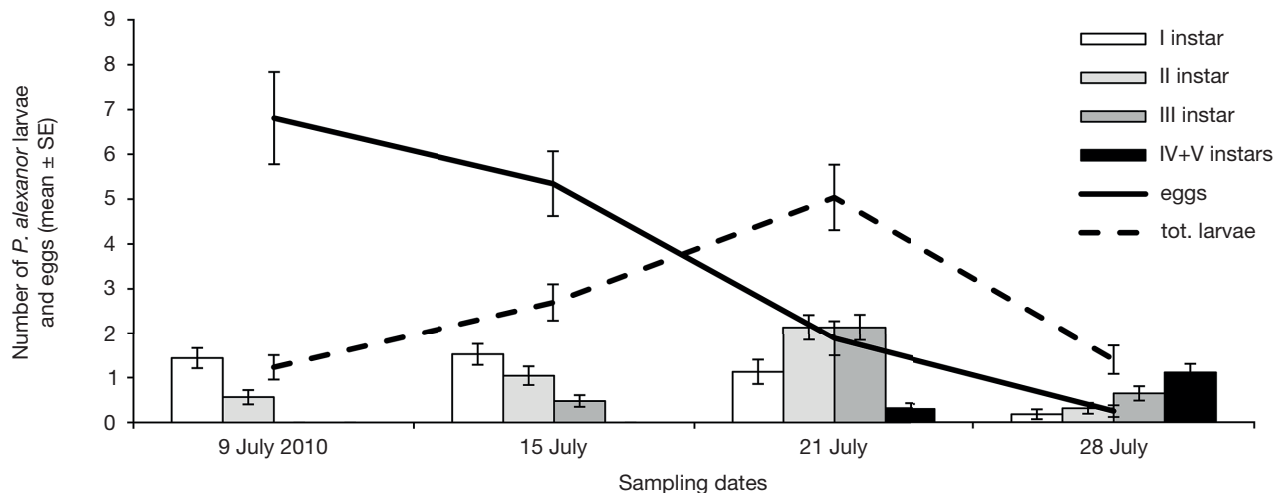
Fig. 5. — Pre-imaginal development of *P. alexanor* Esper, [1800] in the field. Mean (± SE) number of eggs and larvae of *P. alexanor* collected during the four sampling events (2010).

DEVELOPMENT OF *P. ALEXANOR* IN FIELD CONDITIONS

During 2010, we observed a total of 369 eggs and 268 larvae. *P. alexanor* females laid on average 2.4 ± 0.99 eggs (mean ± SD) on each plant, but in quadrats where the availability of plants was more limited (one or few *P. saxifraga* plants), we found a higher number of eggs per plant (up to 20 eggs per plant). Within quadrats, depositions occurred on an average of 2.6 ± 1.6 plants (min 1; max 5), even when plant availability was high.

As can be seen in Fig. 5, the highest number of eggs was found in the first week of sampling (6.81 ± 1.02 eggs per quadrate), whereas this value decreased during July, as the number of caterpillars increased. The highest number of larvae was observed during the third sampling (on average 5.04 ± 0.73 larvae per quadrat). In total, 24 larvae at fourth or fifth instar were found during the last two sampling events, as well as a single pupa (Fig. 5).

We calculated the survival rates of three larval stages, from the second to the final instar larva. Survival was similar for second and the third instar larvae, while it was significantly lower for final instar larvae. Comparing the average larval survival within each quadrat with the available number of food-plants, we observed that larval survival increased when the number of plants was higher than 15 (Friedman's test: Z = 6.000; p = 0.05) (Fig. 6).

DISCUSSION

Our results show that *P. alexanor* is locally monophagous: in the study area it strictly exploits *Ptychotis saxifraga*, whereas at a locality situated 70 km away (above Latte, in the province of Imperia) it exclusively feeds on *Opoponax chironium*.

Local exploitation of a single food-plant species commonly occurs in otherwise polyphagous butterflies (e.g., Finke & Scriber 1988), including Papilionidae Latreille, 1802. For example, *Papilio glaucus* (Linnaeus, 1758) is considered one of the most polyphagous species among Papilionidae (563 species in the world), using more than 14 different families as food-plants in North America, yet this species is monophagous in Florida (Scriber 1986). Studies carried out under laboratory conditions have shown that the larvae of *Papilio troilus* (Linnaeus, 1758) are associated with various species of Lauraceae, depending on the geographical area. More specifically, they can survive on three different plants, but growth rates are influenced by the essence selected (Nitao *et al.* 1991). *Euphydryas maturna* (Linnaeus, 1758) is another example of a butterfly locally using different plants. Females lay their eggs on the leaves of *Fraxinus excelsior* L. and the whole pre-hibernation development takes place on this plant. After winter diapause, larvae are known to feed on various common herbaceous species, such as *Pulmonaria officinalis* L., *Lonicera coerulea* L., *Veronica longifolia* L., *Viola* sp. and *Plantago lanceolata* L. (see Freese *et al.* 2006). Nonetheless, at the local level the butterfly selects only one plant species to feed on, even where many more are available (Dolek *et al.* 2013).

Theoretical studies predict that butterflies, like many other phytophagous insects, will tend to specialise, moving from polyphagy to monophagy, since any new mutation that increases fitness on the primary host plant, and thereby lowers the relative fitness on secondary host plants, will be favoured by selection (Bernays & Graham 1988, Futuyma & Moreno 1988, Futuyma 2008). Furthermore, at least in some cases, additional advantages may be achieved by entering relatively competitor-free new spaces (Wiklund & Friberg 2008).

Local adaptations to single host plants may have favoured differentiation between populations, which might eventually culminate in speciation. In fact, the two populations from Latte (IM) and from Valdieri have been described as separate subspecies (respectively *P. alexanor alexanor* Esper, 1799 and *P. alexanor radighierii* Sala & Bollino, 1991) and should at least be considered separate ESUs (Casacci *et al.* 2013). Differences between them may have become fixed and maintained by the temporal shift (about 15 days) in the blooming of the

two locally selected host plants. Nevertheless, in standard field guides the descriptions of many butterfly species are accompanied by long lists of food-plants. Exact information on regional food-plant variation is, in contrast, relatively scanty, or provided independently from information on the ecological context.

In our study area, oviposition took place at the end of June, in agreement with the phenology of *P. saxifraga*, and larval development occurred in July. The females laid few eggs per plant (2.4 ± 0.99 on average), as previously reported (Bollino & Sala 2004), and used on average 2.6 plants close to each other for oviposition (no more than five plants per plot), even when many plants occurred in 5 × 5 m plots. Females scattered their eggs and this may increase their offspring's fitness. As observed in field and laboratory conditions, *P. alexanor* larvae need to feed abundantly to exponentially increase their body mass in about 20 days. Moreover, it is likely that females lay few eggs per plot to prevent cannibalistic behaviour, which is very frequent among butterfly caterpillars.

If we assume that: 1) the sex ratio in the *P. alexanor* population is balanced; 2) a single *P. alexanor* female lays about 70/80 eggs during a season (C. Forte, pers. comm.); and 3) the area covered by *P. saxifraga* was of 1.5 ha, having sampled the egg density, the adult population size in the study area can be estimated at about 170 individuals. Nevertheless, it seems that the Valdieri population, and therefore also its ovipositing preferences, may be considered representative of the whole "subspecies *radighierii*", which often occurs in small, but constant and isolated areas, supported by a few hectares of suitable habitat (Bollino & Sala 2004).

Our results indicate that the number of food-plants and their height are among the factors that affect the number of eggs laid by *P. alexanor* females on *Ptychotis saxifraga* plants. Female preference for plots with high numbers of plants is confirmed by the fact that larval survival is higher in those plots where the number of *P. saxifraga* was more than 15 plants (Fig. 6), probably because larvae need to consume a great amount of food. Selection for oviposition of higher plants, usually having a larger number of flowers, is common in butterflies (e.g., Myers *et al.* 1981; Courtney 1984; Bonelli *et al.* 2005; García-Barros & Fartmann 2009). The most likely explanation is that gravid females choose visually prominent plants as their main targets. The fact that the distances of occupied plots from the first patch with *P. saxifraga* plants were lower than between unoccupied plots suggested that, as for other Lepidoptera (Thompson & Pellmyr 1991), *P. alexanor* females accept or reject certain plants as oviposition sites on the basis of their relative position in the food-plant community. On the contrary, we did not observe any difference in distances from the nearest nectar source between occupied and unoccupied patches. This is consistent with the high vagility of *P. alexanor* adults, which can easily move from nectar sources to oviposition sites, as well as with the relative abundance of thistle plants, which were probably sufficient to support the whole *P. alexanor* population.

In agreement with observations by Bollino & Sala (2004), eggs took about seven days to hatch in the field, but developed
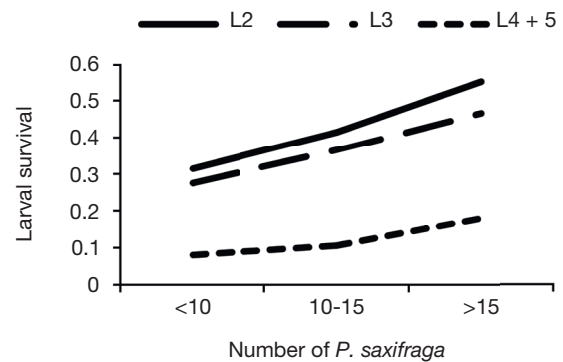

Fig. 6.— Comparison of mean values of larval survival rates calculated for the 21 (occupied) plots ranked by increasing total number of *P. saxifraga* (L.) Loret & Barrandon plants.

slightly faster under laboratory condition (about five days). As noted in the literature, and observed in the field, larvae were easy to observe, not only because of their aposematic colours, but also for their strong heliotropism, which causes them to remain on a flower stem and rarely abandon it. Just before pupation, the caterpillar usually abandons the plant and pupates near the ground, indicating a negative phototaxis (Nakamura & Ae 1977). The low number of individuals observed belonging to the last two stages may be related to the difficulty, already noted by other authors (Bollino & Sala 2004), of finding the last instar larvae and the mimetic pupae of *P. alexanor* in field conditions.

CONSERVATION REMARKS

In order to ensure the persistence of the population in the study area, we suggest that it is important to take into account both the ecological features of the resident *P. alexanor* population (e.g., the correlation between food plant's phenology and larval development) and the most significant local threats. In particular it will be crucial to discourage collectors of both adults and larvae. Sampling could be authorized only for justified scientific reasons and surveillance of the area should be ensured, at least during June-July.

At the same time, to ensure the long-term persistence of the species it would be essential to create new habitats, or restore old ones, where suitable growth condition for *P. saxifraga* can be assured. In this context, the restoration of the abandoned quarry would generate very good opportunities for *P. alexanor*.

Butterflies frequently benefit from areas transformed by human activity, such as pastures or areas under non-intensive cultivation, and suffer rapid decline when these habitats are abandoned or altered (Balletto *et al.* 2007; Skorka *et al.* 2007). Less common, but relatively well known, are cases of colonisation of quarry areas. A study performed in Bedfordshire (UK) (Turner *et al.* 2009) has shown the settlement of a riodinid butterfly, *Hamearis lucina* (Linnaeus, 1758), at an abandoned chalk quarry, fostered by the availability of its larval food plants. The latter benefit from disturbance caused by occasional landslides on unstable ground and prefers steep slopes, in the lee of the wind. Thus, as also demonstrated by

the present study, abandoned quarries may harbour a significant number of plants, many of which may be characterized by peculiar ecological requirements. Results of a comparative study of butterfly communities, carried out in 21 limestone quarries at the Moravian Gate (Czech Republic), showed that quarries can provide secondary habitats for xerophilous species, replacing the calcareous grasslands once densely populated by butterflies (Benes *et al.* 2003). Butterflies benefiting from these areas are rare xerophilous species and/or sedentary species. Their abundance, even during extraction activities, confirms the idea that quarries can contribute significantly to the conservation of these butterflies.

Unfortunately, the ecological requirements of these species are rarely considered in the management commonly practiced in the dry grasslands of Central Europe, which typically aims at protecting sites where charismatic plants (e.g., orchids) are growing (Balmer & Erhardt 2000; Kahmen *et al.* 2002).

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