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Habitat selection and morphology of *Saga pedo* (Pallas, 1771) in Alps (Susa Valley, Piedmont, NW Italy) (Insecta: Orthoptera, Tettigoniidae, Saginae)

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Abstract
This paper is a contribution to the knowledge of *Saga pedo* (Pallas, 1771), summarizing the results of a field study carried out on a population of the Italian W Alps. The peculiar eco-ethological traits of this species make its observation difficult in nature and overall also its biology is little known, especially in Italy. The habitat selection is outlined from 34 unpublished presence data, collected between 2016 and 2018. Moreover, some biometric traits are compared between adult individuals observed in two different and disjointed survey areas. The results show that the environments in which this species lives in Susa Valley should not be referred exclusively to xerothermic oases in strict sense. This species appears to be also associated, in fact, with xeric environments of agricultural origin, mostly abandoned vineyards. These land uses (especially viticulture) could have guaranteed the survival of *S. pedo* over time. The closure of these open areas by shrub and tree vegetation, constitutes an important threat factor. Phenology and morphology of this species in Susa Valley, seem do not differ from those reported for other European populations. However, from the biometric analysis some significant differences emerge ($p < 0.05$) among the individuals sampled in the two areas, that are difficult to interpret. The observation of imagoes, always combined with high densities of potential prey and sometimes grouped, suggests some hypotheses that it would be interesting to test, to learn more about the ethology and ecology of this enigmatic protected species.

Key words: *Saga pedo*, Habitats Directive, biometrics, ecology, Maxent software, conservation.

Introduction

In the European natural landscape, *Saga pedo* is considered one of the biggest insects (Kaltenbach 1967; Bellmann et al. 1995; Kolics et al. 2008; Fontana 2014; Mateleshko & Mirutenko 2018) and the largest among Orthoptera (Willemse 1996; Massa et al. 2012; Trizzino et al. 2013). At the same time, the study of this species can be difficult, due to its strong cryptic mimicry and the prevailing nocturnal activity (Willemse 1996; Lemonnier-Darcemont et al. 2009; Pascual et al. 2016). These characteristics, combined with a low density since obligate predator of (prevalently) other Orthoptera (Kaltenbach 1970; Fontana & Cussigh 1996; Massa et al. 2012), certainly pose severe practical limits to carry out field studies on this species.
S. pedo reproduces by parthenogenesis (Matthey 1941, 1948; Kaltenbach,1970; Lemonnier-Darcemont et al. 2009; Kolics et al. 2012) and lays several eggs in the ground through a long ovipositor, which hatch even after more than 3 years (Schall 2002; Lemonnier-Darcemont et al. 2009). The imago is wingless and appears after 5-6 instars (Schall 2002; Holuša et al. 2013). The existence of male specimens was documented only on one occurrence, in Switzerland (Baur et al. 2006), although according to Lemonnier-Darcemont et al. (2016) it was a case of gynandromorphism.
S. pedo exhibits a Sibiric-European chorotype (Fontana et al. 2005); it was also introduced into the U.S.A. (Cantrall 1972). It is the only species of the subfamily Saginae present in Italy, where it is infrequent (Fontana & Cussigh 1996; Galvagni & Prosser 2004; Massa et al. 2012). It is thermophilic (Kaltenbach 1970) and in the Alpine biogeographical region it is considered closely associated with areas characterized by Mediterranean or submediterranean vegetation, called "xerothermic oases" (Magistretti & Ruffo 1959; Fontana & Cussigh 1996; Galvagni & Prosser 2004; Massa et al. 2012; Vergari et al. 2017). In Piedmont, it is extremely localized (Sindaco et al. 2003, 2012).
The monitoring of this species in recent decades poses some important questions, also related to its actual abundance throughout its geographic range (Holuša et al. 2009). The recent discovery of this species in poorly investigated regions of Italy (Fabbri & Ambrogio 2013; Vergari et al. 2017) and the difficulty of reconfirming its presence even in several sites where it was recorded in the past (Fontana & Cussigh 1996; Willemse 1996), indicate, in fact, relevant knowledge gaps on Italian distribution and abundance of this enigmatic species. *Saga pedo* is included in Appendix II of the Berne Convention and in Annex IV of the "Habitats Directive" 92/43/EEC, and in addition it is classified as VU (Vulnerable) in the European IUCN Red List of Threatened Species.

Materials and methods

Study area

Saga pedo is probably an element of Eastern Mediterranean origin, penetrated in the Italian peninsula from the Adriatic coast, during the Pleistocene (La Greca 1996). Its presence in the Susa Valley, recorded for the first time at the beginning of the VIII century near Susa (Fruhstorfer 1921), is to be considered interesting, as possible relict of a warmer post-glacial period in Alpine and subalpine refugia. These refugia are also characterized by the presence of numerous Mediterranean plant species, distributed in some warm areas of this and others Alpine valleys (Montacchini & Caramiello 1969). To date, *S. pedo* is known in few locations in the mountainous and hilly zones on the left side of the valley, where it reaches the maximum altitude for Piedmont (Sindaco et al. 2012). The present work focuses on two survey areas where it is present, approximately 10 km apart and separated by some barriers difficult to cross for the species (Kaltenbach 1970): the first is placed on the municipality of Exilles and Chiomonte, referred in this study to HVA (High Valley Area), while the second is placed on those of Bussoleno and Mompantero within the protected area named SCI IT1110030 "Oasi xerotermiche della Valle di Susa - Orrido di Chianocco e Foresto", in this study referred to MVA (Middle Valley Area). The MVA hosts vegetation characterized by numerous Mediterranean and steppic floristic elements absent from the surrounding territory (Sindaco et al. 2009), according to the definition of "xerothermic oasis" proposed by Magistretti & Ruffo (1959). In HVA these characteristics of the vegetation are not evident, while the pioneer shrub and tree vegetation and some anthropic land uses appear dominant. However, this sector of the valley exhibits particular mild microclimatic conditions, also evidenced by the presence of some active and abandoned vineyards, placed at the highest recorded altitude in Italy (Mercalli & Cat Berro 2018).

Data collection

The data were collected between May 2016 and October 2018. The survey were concentrated on the biotopes considered suitable within the survey areas selected. In particular, open areas were inspected, even with variable presence of rocks, bushes, trees and anthropic elements. Each observed individual were documented, georeferenced and immediately released. In the years 2016 and 2017 the surveys were limited to the identification of specimens at various instars, conducting the research in spring and summer months through visual census. This technique is effective on this species only with practice (pers. obs.). To do this, several random transects were executed at slow speed (about 10 m /min), in dry weather conditions and during the daytime hours. The inspection was performed in bands of about 2 meters wide, as indicated by Italian Institute for Environmental Protection and Research (Massa et al. 2016). A stick of 1.20 m length was used, useful to quickly inspect the tufts of grass as already tried out by Holuša et al. (2013). In 2018 the research was concentrated between late August and early October, in order to collect biometric data, only on the individuals at the imaginal stage. During these months *S. pedo* lays its eggs (Quiddet 1988; Schall 2002; Baur et al. 2006; Krištín & Kaňuch 2007, Lemonnier-Darcemont et al. 2009). Measurements were made on site with a digital caliper, noting the body length (from the vertex of the head to the end of the sub-genital plate), as well as the length of pronotum, ovipositor and hind femur, according to the scheme used by Kolics et al. (2012). In this context the vegetation on which the individuals were found was noted, as well their local behavior, and a list of the Orthoptera species present within a radius of about 5 meters (also expressing a visual evaluation of their approximate density). To avoid repeating the measurements on the same specimens, a slight marking with non-toxic paint in the pronotal zone was applied (Gangwere et al. 1964). Capture-marking-recapture protocol was not possible due to time limitations, proved to be an extremely determining factor in the research, given the particular difficulties in finding the specimens. The duration of each survey session in the 2018 study period was also noted.

Data analysis

The georeferenced points, relative to individuals observed in the overall study period, were used to develop a species distribution model able to provide information on habitat selection of this species, in particular to understand which environmental variables are most informative. For this purpose the software open-source Maxent (version 3.4.1) was chosen. This tool uses only presence data (Phillips et al. 2006) and is able to give useful results even with limited samples (Papeş & Gaubert 2007). Maxent provides different outputs: for evaluate the efficiency of the model the attention is focused on the AUC value (area under the curve), while to evaluate the information content of each variable, reference is made to the percentage contributions and the results of the jackknife test (Bradie & Leung 2016). Phillips & Dudík (2008) recommend to keep the default settings in case of reduced number of points. The only parameter that was set is the "default prevalence", namely the probability of contacting the species in any presence site (Elith et al. 2011). This value was lowered from 0.5 to 0.4, given the exceptional difficulty in detecting this species even where its presence is certainly documented (Fontana & Cussigh 1996; Willemse 1996). The environmental variables chosen were those considered more informative among available parametres: of continuous type like aspect, elevation and slope (derivatives from Digital Terrain Model) and of categorical type like land cover and lithology (Phillips and Dudìk 2008). The land cover used (Piedmont Land Cover) distinguishes different categories of open areas, based on a primary classification between agricultural and semi-natural. It was not possi-

ble to use climatic variables such as temperatures, because sufficiently detailed maps are not available. To better contrast the environmental variables (Merow et al. 2013), extension of the background sample to the whole Susa Valley and the dimension of the pixels of 10 m x 10 m were chosen. The preparation of environmental data was performed using QGIS (ver. 2.18.25).

Finally, biometric data collected on imagoes (2018 study period) were used to compare the samples between the two survey areas. Statistical analysis were performed with RStudio (ver. 1.1.463).

Results

Data collection

Overall, 34 individuals were found during the study period, considerably increasing the presence data for the territory of the Susa Valley (Fig. 1). In 2018 were observed 18 individuals at the imaginal stage: 13 in the MVA and 5 in the HVA; in this survey the contact frequency was 0.3 individuals/hour. The use of a stick to inspect vegetation was useful in some occasions: it was observed that individuals make short perceptible movements during the warmer hours, due to the sudden movement of the vegetation on which they stay.

The youngest specimen was found on May 28th, 2017, identified as a 4th instar according to the descriptions provided by Bereinguer (1907) and Schall (2002). Based on this and other findings made in this study, it can be assumed that the hatching of eggs could take place in April. The earlier adult specimen was observed towards the beginning of the summer (Jun 24th, 2017), while the later one was found at the beginning of autumn (Oct 1st, 2018).

Individuals were almost always observed motionless on the herbaceous vegetation (Fig. 2), in particular the imagoes sampled in 2018 have been localized at height between 0 and 50 cm from the ground (mean = 15 cm, s = 10 cm). The plant species on which individuals stayed on these occasions were mostly Gramineae species (n = 10), in particular *Setaria italica* for the HVA and *Festuca ovina* for the MVA, or on spiny plants (n = 7) like *Cirsium acaulon*, *Cirsium vulgare* ed *Echinops ritro*. One specimen was found on a hemp cultivated plant.

Habitat selection

Overall, the observations were between 470 m and 1070 m (mean = 762 m, s = 158 m). Research at higher elevations gave negative results. The site orientation measured in the points ranged between East and South-West, on average South (mean = 163°, s = 31°) and the slope between 0 and 43% (mean = 24%, s = 9%).

Regarding land cover, most of the individuals have been observed in areas belonging to the agricultural category "stable meadows and pastures" (n = 31), except for some individuals found in more general "open areas with sparse vegetation" (n = 1), inside "vineyards" (n = 1) or in "discontinuous urban fabric" (n = 1). The land cover "stable meadows and pastures" concerned the majority of observations on both survey areas (Fig. 3). In the field it was possible to further detail these categories, observing some elements in the biotopes (also of anthropic origin) that can provide additional information (Fig. 4): most were found in grasslands with variable shrubs resulting from abandonment of agricultural activity, especially vineyards (n = 25). Moreover, some individuals were observed inside or at the edges of small plots still cultivated (n = 5), in particular of grape vine, hemp and potato. For further classifications it was also possible to use the data made available by European Xero-grazing LIFE Project (LIFE12 NAT/IT/000818) in order to investigate in more detail the habitats, at least in the MVA. By this data the grasslands are

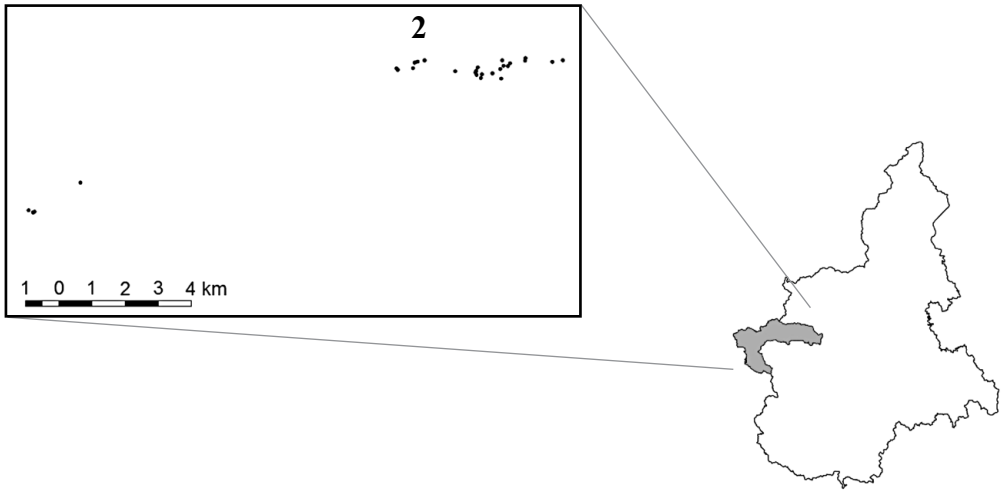


Fig. 1 – Observed individuals (black points) in overall study period in Susa Valley (Piedmont, Italy): **1**, HVA and **2**, MVA. Exhaustive indications on the location are not provided for reasons of conservation.

Fig. 2 – Some cryptic *S. pedo* imagoes observed in 2018 study period in their original position: **1**-**2**, in the HVA and **3**-**4**, in the MVA.

distinguished according to the dominant grasses. The *S. pedo* specimens observed in this survey area were mostly in grasslands characterized by *Stipa pennata* (n=12) and *Bromus erectus* (n=11), in evidently lower frequency *Festuca ovina*, *Chrysopogon gryllus* and others unclassified types (Fig. 5).

As mentioned in the introduction, the MVA was involved in a fire during the autumn 2017. In this regard it is important to underline that 12 out of the 13 individuals sampled in the following year, were collected inside the burnt area, with no evidence of substantial changes of the herbaceous vegetation (pers. obs.).

To better understand the climatic features, the data recorded by two meteorological stations within the study areas were examined. In addition, the average lapse rate calculated for the Susa Valley of -0.54 °C every 100 m of elevation (Mercalli & Cat Berro 2018) has been used to infer the average monthly temperatures trends at the extreme of the altitudinal range of our observations in each survey area, assuming that the precipitations are approximately the same along the altitudinal gradient. The graphs obtained reveal some differences (Figs 6-7), but according to the commonly used classification both the areas are to be referred to a submediterranean climate: the rainfall (expressed in mm) is approximately equal or less than twice the temperature (expressed in °C) for at least one month (Bagnouls & Gaussen 1957). However, the HVA generically shows less arid conditions than MVA.

Regarding the lithology, the observed individuals fall on basic substrates such as marble (n = 18) and calcschists (n = 9) but also on acid substrates like gneiss (n = 5) or on mixed morenic substrates (n = 2).

The geo-referenced points associated with individuals observed throughout the entire period considered (n = 34) were used to estimate a predictive spatial model with Maxent. With an AUC of 0.996 the model demonstrates an excellent predictive ability, because greater than 0.90 (Swets 1988). Land cover is the variable that contributes the most to the model (Table 1). Also in the jackknife test this environmental variable provides the highest gain when used in isolation and when it is omitted it decreases the gain in greater way (Fig. 8). For this reason land cover should be considered highly informative to predict the distribution of *S. pedo.*

Others ecological features

Regarding the availability of potential preys, exhaustive information is not available for the HVA, while for the MVA we can refer to a list of 26 species of Orthoptera, surveyed in this area by Giuliano et al. (2017). According to this study the dominant species is *Calliptamus italicus.* To this checklist should be added the same *S. pedo*, due to its recorded cannibalism (Kaltenbach 1970), except between imagoes (Kolics et al. 2008). *Mantis religiosa*, indicated elsewhere as potential prey (Kaltenbach 1970; Mcgrath 2018), was also present in the same site.

Consumption was observed only in one case (Jun 20th, 2017, in the early afternoon; Fig. 9), involving a grasshopper identified as *Stenobothrus fischeri* (Eversmann, 1848). During the 2018 surveys, the Orthoptera species present within a radius of 5 m from each imago was recorded. The total number of species in these occurrences resulted relatively low (n = 7, Table 2), probably due to the different phenology of the involved species, tending to decline in abundance towards the end of the summer (Krištín & Kaňuch 2007; Landmann 2017). The species *Calliptamus Italicus* was sampled on all occurrences for both survey areas (n = 18). The other most frequent elements in both survey areas are members of the complex *Chorthippus* (*Glyptobothrus*) gr. *biguttulus* (Massa et al. 2012), present on all occurrences in the HVA (n = 5) and on some of those in the MVA (n = 5). The species *Oedaleus decorus* was sampled only in MVA area (n=10). It needs to be underlined that the most sampled species was observed with discontinuous density throughout the explored transects, but *Saga pedo* were always observed in presence of high density of potential prey. In addition, on two occurrences (Sep 3rd, 2018 and Sep 4th, 2018) two very close imagoes were found, distanced of 1 m and 3 m respectively, within the MVA.

Biomentric analysis

During the 2018 study period only individuals at the imaginal stage were found, between August 25th and October 1st. Summary statistics relating to these individuals are shown in Table 3. The length of ovipositor resulted the biometric trait exhibiting the greatest variability in the overall sample (n= 18, s = 3.3 mm).

Given the extremely limited and unequal number of observations (n1 = 5, n2 = 13) and the consequent difficulty in satisfying the assumptions of parametric tests, the Wilcoxon-Mann-Whitney test (WMW or Wilcoxon Rank-Sum test) was chosen, to compare the measurements between the two unpaired samples collected in the two survey areas (Whitlock & Schluter 2008). The results show that the samples are significantly different ($p < 0.05$) only for the length of the pronotum (Table 4, Fig. 10). Considering the overall sample measured (n = 18), no significant correlation was found between each biometric traits and the relative elevation.

The imagoes observed during the 2018 research showed a green background color. In some there were dark ornamentations on the pronotum and on the tergites, while in others these were absent (Fig. 11). The individuals with ornamentations (n=13) were more than twice of those with uniform coloring (n = 5). However, from observations made by some authors, it seems that *Saga pedo* is able to control its coloration, for example varying it according to the nature of the substrate (Lang 1930; Kaltenbach 1970; Schall 2002). For this reason, it was not considered prudent to take these characteristics to compare the two samples.

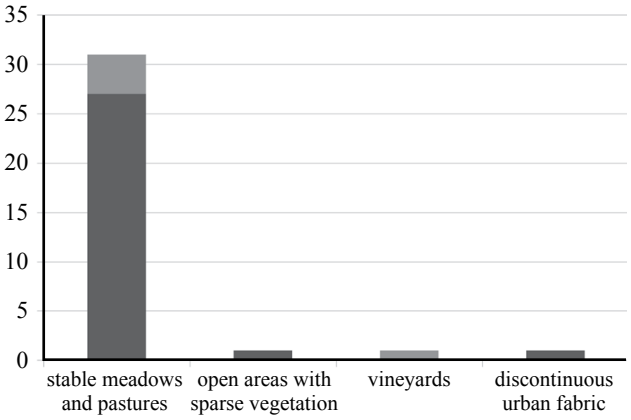


Fig. 3 – Histogram of land cover selected by *S. pedo* observed during the entire study period: in black the portion in the MVA, in grey the portion in the HVA.

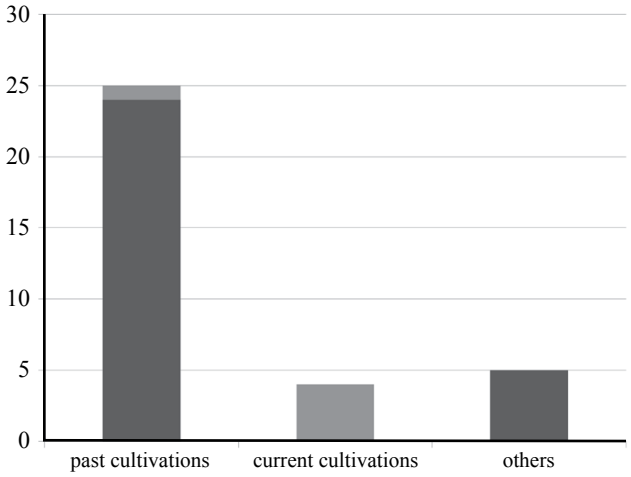


Fig. 4 – Histogram of the land uses selected by *S. pedo* observed during the entire study period: in black the portion in the MVA, in grey the portion in the HVA.

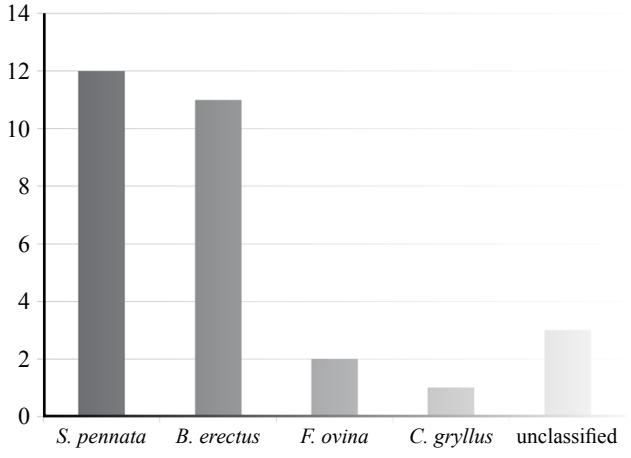
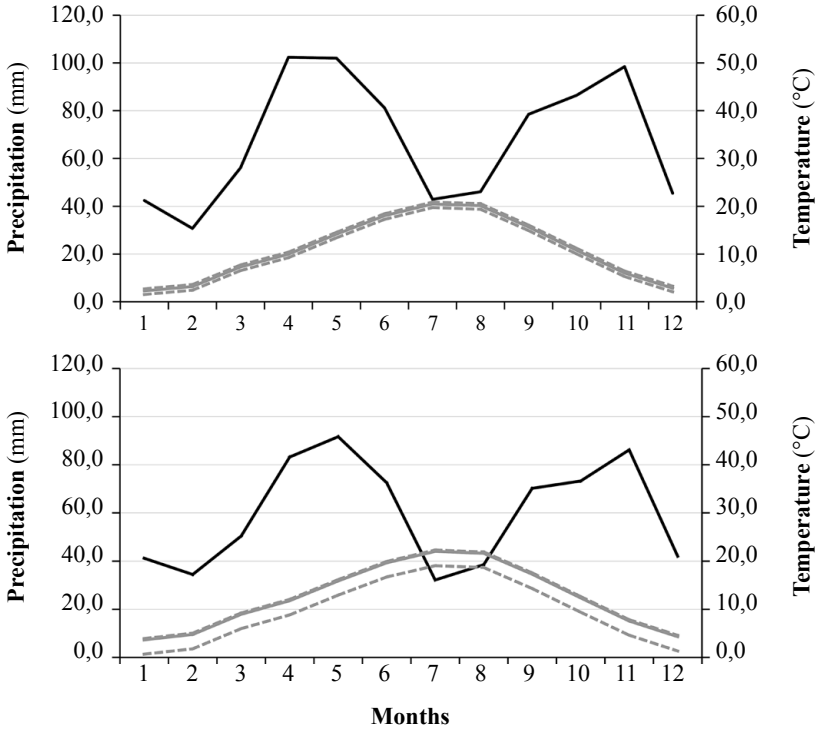


Fig. 5 – Histogram of dominant Gramineae species in grasslands positively selected by *S. pedo* imagoes, observed in the 2018 study period in MVA.

Discussion

Habitat selection

The environments where *Saga pedo* was observed correspond approximately to those described by various authors, in particular to be characterized by sunny, dry slopes with tall, dense grass with shrubs (Kaltenbach 1970, 1990; Berg et al. 1997; Olmo Vidal 2002; Lupu 2007a, 2007b; Monnerat et al. 2007; Lemonnier-Darcemont et al. 2009; Pricop et al. 2012), even within vineyards or other kind of cultivations (Kaltenbach 1970, 1990; Lemonnier-Darcemont et al. 2009), mainly on basic soils (Kenyereset al. 2002; Lemonnier-Darcemont et al. 2009; Keyneres & Szinetár 2018). The maximum elevation detected (1070 m) is



Figs 6-7 – Bagnouls-Gaussen's diagrams for the two survey areas: the total monthly precipitations in black and the medium monthly temperatures in gray, recorded from 1991 to 2017 by the meteorological stations (**1**, Chiomonte- Finiere-813 m for HVA and **2**, Susa-Pietrastretta-520 m for MVA); in dotted gray the inferred average temperatures within the limits of the altitudinal range identified in each survey area.

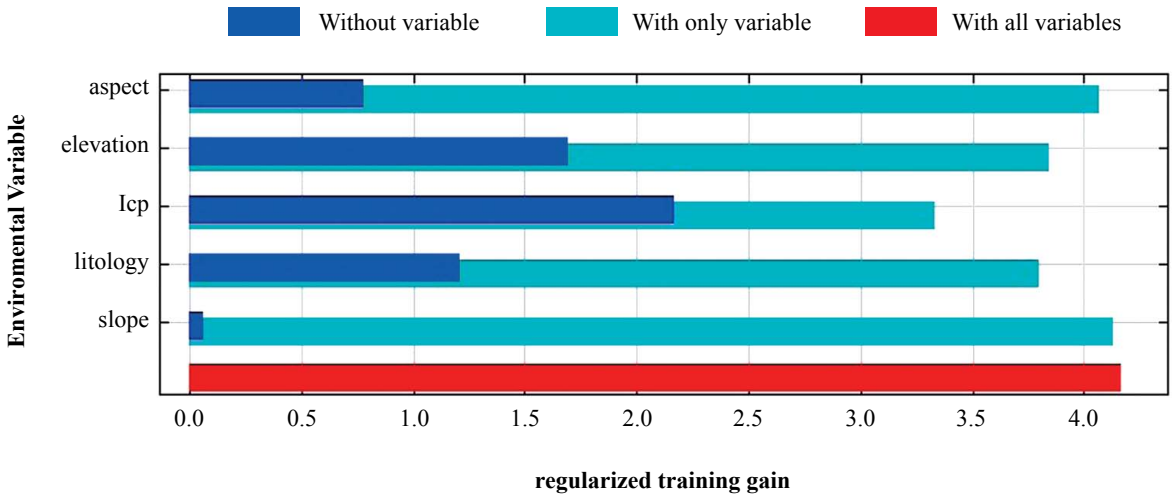


Fig. 8 – Histogram of the jackknife test returned by the model.

Table 1 – Contributions of variables in the Maxent's model.

Analysis of variable contributions	
Variable	Percent contribution
land cover	50.7
lithology	28.3
elevation	12.0
aspect	7.9
slope	1.1

within the range considered for the southern populations (Mattitey 1941; Kaltenbach 1970; Mossot 1999; Thorens & Nadig 1997; Lemonnier-Darcemont et al. 2009; Ladrón De Guevara et al. 2011; Curto 2017). According to the available bibliography it would represent the maximum recorded altitude for Italy (Fontana & Cussigh 1996; Galvagni & Prosser 2004; Massa et al. 2012; Sindaco et al. 2012; Baroni 2015; Vergari et al. 2017). The average slope is similar to that reported by the only study where this variable was treated in detail (Krištín & Kaňuch 2007).

From the in-depth analysis of the habitats, carried out thanks to the data provided for the MVA by the Xero-grazing LIFE Project, it is clear that *S. pedo* occupies mainly grasslands with prevalence of plant species related to arid environments. About half of these have steppic characteristics, recognizable by the dominance of species like *Stipa pennata* and *Chrysopogon gryllus* (Pignatti, 1982).

According to the model developed, land cover is the most informative environmental variable to predicting *S. pedo* distribution. The fact that almost all positively selected habitats are of agricultural origin, underlines the capacity of colonization as parthenogenetic species (Mittwoch, 1978) and suggests a coexistence with present-day and past man activities on these mountain slopes, such as cultivation (in particular vineyards), mowing, pasture and others that probably do not make excessive soil disturbance (Fig. 12). At the same time, with the abandonment of these activities, we can foresee a natural succession of these open areas towards a dramatic closure, due to the increasing growing of shrubs and tree vegetation. As observed by Holuša et al. (2013), the woods are not crossed by *S. pedo*, even if they constitute a band of only 10 meters. Moreover, Krištín & Kaňuch (2007) have detected density up to 10 times lower in areas more invaded by bushes and trees, compared to more open sites.

Finally, by examining the differences in vegetation and micro-climatic conditions in the two stations, it can be affirmed that in the Italian Alps *S. pedo* is not exclusive of xerothermic oases in the strict sense (according to the definition by Magistretti & Ruffo 1959), as already noted by Galvagni & Prosser (2004) basing on a finding in Trentino-Alto Adige (NE Italy). In fact, the HVA does not show Mediterranean vegetation. Moreover, according to the definitions proposed by Bagnouls & Gassen (1957), it is characterized by submediterranean climate, but is less arid than the MVA and perhaps this is one of the reasons why the local vegetation appears dissimilar.

Others ecological features

The phenology of the herein studied Alpine population is in agreement with observations on other European populations (Bérenguier 1905; Mingaud 1907; Kaltenbach 1970; Berg et al. 1997; Schall 2002; Lemonnier-Darcemont et al. 2009; Krištín & Kaňuch 2007; Kolics et al. 2008; Pricop et al. 2012; Holuša et al. 2013), mainly those from other areas of the Alpine biogeographical region (Baur et al. 2006; Landmann 2017). From the observation of potential food resources in the surroundings of adult individuals, it is clear that the most frequent preys are *Calliptamus italicus* and *Chorthippus* (*Glyptobothrus*) gr. *biguttulus* (at the end of summer in both sites investigated). Among the several species sampled on these occasions, these are the potential preys with the most precocious and prolonged phenology (Landmann 2017), and consequently they could be among the most available preys even during the develop-

Table 2 – Checklist of the potential preys sampled within a radius of 5 m from adult *Saga pedo* (n = 18). For the nomenclature, reference is made to Massa et al. (2012); for the chorology (CHO) to Stoch & Vigna Taglianti (2005); for phenology (FEN) to Landmann (2017), except for cases with one asterisk (*) where reference is made to Massa et al. (2012) and two asterisk (**) where data are from personal observations.

species	**CHO**	**PHE**	**HVA** (n=5)	**HVA** (n=13)
Platycleis grisea (Fabricius, 1781)	CAE	IV-XI	0	6
Chopardius pedestris (Fabricius, 1787)	CEU	VII-IX**	2	0
Calliptamus italicus (Linnaeus, 1758)	ASE	III-XI	5	13
Calliptamus siciliae Ramme, 1927	MED	VI-X*	0	5
Oedaleus decorus (Germar, 1826)	CAM	VII-X	0	10
Chorthippus (Chorthippus) parallelus (Zetterstedt, 1821)	SIE	IV-X	2	0
Chorthippus (Glyptobothrus) gr. *biguttulus*	EUR	I-XII	5	5

Table 3 – Statistics of biometric traits of *S. pedo* imagoes.

	Overall sample (n=18)			
length (mm)	mean	s	min	max
body	59.4	2.8	53.8	63.0
pronotum	10.2	0.6	9.5	11.3
ovipositor	30.5	3.3	27.7	40.1
hind femur	39.2	1.9	36.4	43.4

Fig. 9 – Consumption of prey: *Stenobothrus fischeri* (Eversmann, 1848), observed in MVA on Jun 20th, 2017 at 12:20 pm.

ment of the *S. pedo* nymphs. *Calliptamus italicus* was also abundant in most of the *S. pedo* stations studied by Krištín & Kaňuch (2007) at the northern edge of its geographic range.

The finding of adult individuals always in occurrence of high densities of others Orthoptera, could be related to the need for prey due to the production of eggs and their oviposition, which according to some authors becomes maximum in the imaginal stage (Kaltenbach 1970; Schall 2002). The observation of *S. pedo* specimens among high prey densities is also reported for Romania, where it has been noted that the accumulation of garbage attract insects, favoring the presence of this predator (Lupu 2007a). In this regard, the finding on two occurrences in late summer of grouped adult individuals, may not be due to causality, considered the periods of maximum density registered for *S. pedo* (Krištín & Kaňuch 2007; Holuša et al. 2013) and despite the cryptic mimicry that certainly did not allow to find all the actually present specimens. It seems also useful to add these observations to a short but interesting list of observations of close individuals collected by some authors, all dating to the second half of the summer and therefore during the period of oviposition: 11 adult females in a "relatively small" area on Aug 8th, 1964 in Lower Austria (Kaltenbach 1970); 6 individuals "together" on a roadway on Sep 23rd, 1984 in France[1]; 10 females "moving together" at night on a roadway on Aug 20th,1971 in Sardinia (Italy) (Fontana & Cussigh 1996); "unexpected groupage" of individuals crossing on a roadway at night in "rapid migration" on Jul 30th, 1998 in France (Carrière 2004). To these observations we could add some of those collected by "citizen science" in the French inquest on *S. pedo* lead by O.N.E.M. (Observatoire Naturaliste des Ecosystèmes Méditerranéens, http://www.onem-france.org/saga), between 2005 and 2014. Much of these fall in August, summarized here briefly: 2 individuals "twenty meters away from each other" on August 2005; 2 adult individuals "in the same place" on Aug 12th, 2005; 2 individuals "under a juniper" on Aug 14th, 2005; 6 individuals "grouped" on May 25th, 2006; 4 individuals "within 20 meters of each other" on Jun 20th, 2006; 3 adult females "inside a flowerbed of mint" on Aug 20th, 2006; 2 adult individuals "at few meters from each other" on Jul 12th, 2007.

These grouping events are difficult to explain for a species that does not mate, even more if they are temporally far from hatching, at which time it would be right to expect a higher density of individuals. These observations tend to reinforce the hypothesis that at the end of the season, when the abundance of prey declines (Landmann 2017; Krištín & Kaňuch 2007), this predator moves

Table 4 – Statistics of biometric traits of *S. pedo* imagoes for the two survey areas and results of WMW test: asterisk (*) indicates the statistically significant difference ($p < 0.05$).

	HVA (n=18)					**MVA** (n=13)					**WMW test**	
length (mm)	median	mean	s	min	max	median	mean	s	min	max	W	p-value
body	60.5	59.9	1.8	57.8	61.8	60.1	59.2	3.1	53.8	63.0	33	1.0
pronotum	9.6	9.7	0.3	9.5	10.1	10.4	10.4	0.5	9.5	11.3	9	0.019*
ovipositor	31.2	33.8	5.0	29.4	40.1	29.2	29.2	1.0	27.7	30.9	49	0.117
hind femur	39.3	39.3	1.1	38.2	40.8	38.6	39.2	2.2	36.4	43.4	34	0.924

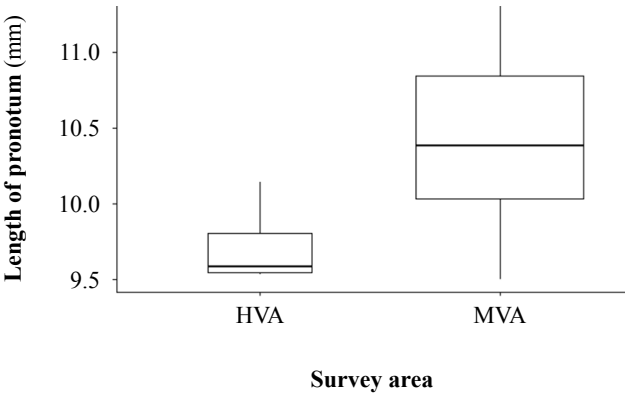


Fig 10 – Box and whiskers diagrams: lengths of the pronotum of the samples collected in the two survey areas.

Fig. 11 – Detail of the tergites in 3 imagoes observed in the 2018 surveys in the MVA: according to the scheme proposed by Kaltenbach (1970), we distinguish: **a**, homochromic individuals and **b-c,** individuals with ornamentations.

Fig. 12 – Biotope of *S. pedo* in the MVA, with evident signs of abandonment of agricultural plots (stone walls for the cultivation of vineyards).

to reach the areas with greater food availability. In this regard it was noted that the movements of individuals are greater during the adult stage, reaching a maximum of 37.5 m in one night (Holuša et al. 2013). However, Kaltenbach (1970) reports a reduction in the need for nutrition from the second half of the imaginal period. Another hypothesis that cannot be excluded is that at the end of the summer *S. pedo* and its potential prey actively seek the same microhabitats, to survive or reproduce. In this case it would be a potential advantage for the predator to lay eggs in these sites, given the phenology of the most sampled species in the surroundings and therefore the potential available prey for the first instars of nymphs. However, the hatching of *S. pedo* would take place generally after 2-3 years (Schall 2002; Lemonnier-Darcemont et al. 2009). Anyway, it can be assumed that in these micro-areas, where *S. pedo* seems to be attracted, it deposes more eggs. If confirmed, it would be an important ecological aspect to know for its conservation.

As evidenced by the observations in 2018, the fire which involved the MVA in the previous year did not negatively affected the presence of *S. pedo*. This is certainly an interesting event, perhaps due to a particular resistance of the eggs of this insect or for the special characteristics of the fire itself, which quickly traveled the MVA driven by strong wind[2] and that did not seriously involve the topsoil, as evidenced by the good vegetative growth in the following spring (pers. obs.). According to other examples, the effects of the fire can be different, such as in a case reported in Hungary where the existing population disappeared in the areas involved (Garai 1995) and also according to Olmo Vidal (2008) which identifies fires as an important threat to the species.

Biometric analysis

The biometric traits of the overall *S. pedo* measured sample are within the range considered by different authors for others populations, even if residing in other biogeographical areas (Kaltenbach 1967; Lemonnier-Darcemont & Darcemont 2008; Holuša et al. 2013). This also applies to the proportions between the main colorations reported by Kaltenbach (1970).

[1] Bernier C. 2006. Synthèse 2005 de l'enquête nationale sur la Magicienne dentelée. Observatoire Naturaliste des Ecosystèmes Méditerranéens, 22 pp. Unpublished.

[2] Arpa Piemonte. 2017. Rapporto tecnico sulla qualità dell'aria e sulle attività dell'Agenzia a supporto dell'emergenza per gli incendi boschivi in Piemonte nel mese di ottobre 2017. Dipartimento Territoriale del Piemonte Nord-Ovest, Torino, 68 pp.

The difference in the length of the pronoun between the samples collected in the two survey areas and the high variability of some other measurements in the overall sample are difficult to interpret, especially considering the small samples examined and despite the efforts to limit the measurement error, due to the mobility of some individuals once approached. Net of these aspects, the differences could be due to different individual developments in different environments, both to the particular characteristics of this parthenogenetic species. In future studies, genetic analysis could clarify these results.

Conclusions

The aim of this work was mostly to describe some biological features of *Saga pedo*, in a fragmented landscape along a W Alpine valley. The results derive from a rather small sample, mainly due to the objective difficulty in finding and observing the specimens. However, they could be useful, given the previously available poor information about the Italian populations of this species, combined with the national obligations to monitor the protected species listed by the Directive 92/43/EEC.

The most relevant results concern the habitat selection: the environments in which this species lives in the Susa Valley are not to be exclusively referred to xerothermic oases in the strict sense ("xerothermic oases": Magistretti & Ruffo 1959). Moreover, these environments derive essentially from past and present-day anthropic use of the territory. Some agricultural activities (in particular viticulture) have perhaps guaranteed the presence of this species over time avoiding a total closure by the shrub and tree vegetation, often considered among the main threat factors (Nagy et al. 1984; Willemse 1996; Krištín & Kaňuch 2007; Olmo Vidal 2008; Presa & Gómez 2012; Holuša et al. 2013; Fontana 2014). This can be taken into consideration to evaluate any intervention aimed at maintaining *S. pedo*, for example through some disused agricultural or extensive pastoral activities (Krištín & Kaňuch 2007), that are however highly compatible with the biology of this species. In this sense, precisely the contrast of this dynamic of ecological succession is the basis of the restoration carried out by the European Xero-grazing LIFE Project (LIFE12 NAT/IT/000818) on the territory of SCI IT1110030 "Oasi xerotermiche della Valle di Susa - Orrido di Chianocco e Foresto", which includes one of the survey areas. Although these interventions (shrub-clearing and sheep grazing) are aimed at the long-term conservation of protected habitats and plants, they must also be considered positive to conserve *S. pedo*.

Always regarding habitat selection, the importance of the variables returned by the model (in particular for the land cover) could be useful in attributing the weights for the variables in the elaboration of environmental suitability maps for conservation purposes, at least for this or others Alpine valleys.

Another sensible aspect concerns the availability of prey for *S. pedo*. The species *Calliptamus italicus*, present close to all the sampled individuals of *S. pedo* in the period of oviposition, is probably an important resource for their survival in the study area.

This potential prey is however a recipient of non-mandatory health interventions throughout Piedmont, given its ability to make pullulations harmful to agriculture (Chersi et al. 2009). Given the importance of the conservation of *S. pedo*, it could be suggested to avoid the use of chemical or biological control in the areas where present, which could result in local extinctions of this predator, already useful (at least in part) to contain "harmful" grasshoppers (Kaltenbach 1970).

Finally, the other information obtained from this study and the hypotheses discussed can recommend further investigations, aimed at better understanding the ecology of this important species not only during its typical monitoring period in early Summer, but also during the delicate period of oviposition.

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