

Field and breeding data on the European species of the genus *Saga* (Orthoptera: Tettigoniidae)

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Abstract

This paper provides statistical data on five European Saginae based on field data of *Saga pedo* (Pallas, 1771) in France, and breeding in the natural environment for all species. For *S. pedo*, almost 800 locations are known. The preferred altitude lies between 50 and 400 meter of altitude, mainly on limestone.

Minimum duration of egg incubation is two years, with longer mean duration for three of the species (*S. pedo*, *S. rammei*, *S. campbelli*). The average hatching date is roughly the same in all species and from one year to another, in the same location. Correlation computation with environmental parameters have been performed. Statistical data on life duration of juvenile and adult stages are provided. The juvenile development varied from 55 to 70 days depending on the species. The adults lived on average between 55 to 75 days, standard deviation being around 30 days.

Zusammenfassung.

Dieses Beitrag präsentiert verschiedene statistische Daten zur Biologie von fünf Arten der Untergattung Saginae. Sie sind das Ergebnis von Freilandbeobachtungen an *Saga pedo* (Pallas, 1771) in Frankreich und von Zuchtversuchen im natürlichen Habitat aller europäischen Arten. Es wurden Wechselbeziehungen von Umweltparametern untersucht und statistische Werte für die Lebensdauer von Jugend- und Adultstadien ermittelt.

Von *S. pedo* sind annähernd 800 Vorkommen bekannt. Die bevorzugte Höhe liegt zwischen 50 und 400 m üNN und zumeist auf Kalkboden. Die Eientwicklung dauert mindestens zwei Jahre, bei drei Arten durchschnittlich länger (*S. pedo*, *S. rammei*, *S. campbelli*). Am jeweiligen Standort ist der durchschnittliche Schlupfzeitpunkt bei allen Arten von Jahr zu Jahr weitgehend konstant. Die Larvalentwicklung dauert je nach Art zwischen 55 und 70 Tage. Die Imagines leben im Schnitt 55 bis 75 Tage bei einer Standardabweichung von 30 Tagen.

Introduction

The authors present an analysis of various statistical results on the genus *Saga* in Europe, based on:

- Field data on *Saga pedo* (Pallas, 1771) in France, recorded through a survey via the internet, involving a large number of entomologists, between 2004 to 2007, lead by the "Observatoire Naturaliste des Ecosystèmes

Méditerranées" (O.N.E.M.) and gathered by its coordinator, Christophe Bernier. The first two years the results were published on the website of the ONEM only. (BERNIER, 2005-2006). Note that *S. pedo* is one of two Orthoptera species present on the annexes of the Habitats Directive.

- Data from breeding experiments were gathered in the natural environment of all European species of Saginae, except *S. rhodiensis* Salfi, 1929. This study is part of the general study on the genus *Saga*, performed by the G.E.E.M. since 2004. Up to now, breeding experiments were limited (BÉRENGUIER 1905, 1907, QUIDET 1988) or performed in an artificial environment (KALTENBACH 1970, SCHALL 2002).

Methods

Saga pedo records in France

In France, *S. pedo* is the only representative of the Saginae. The data collection in France involves many observers since 2004, enabling us to gather more than 1300 data.

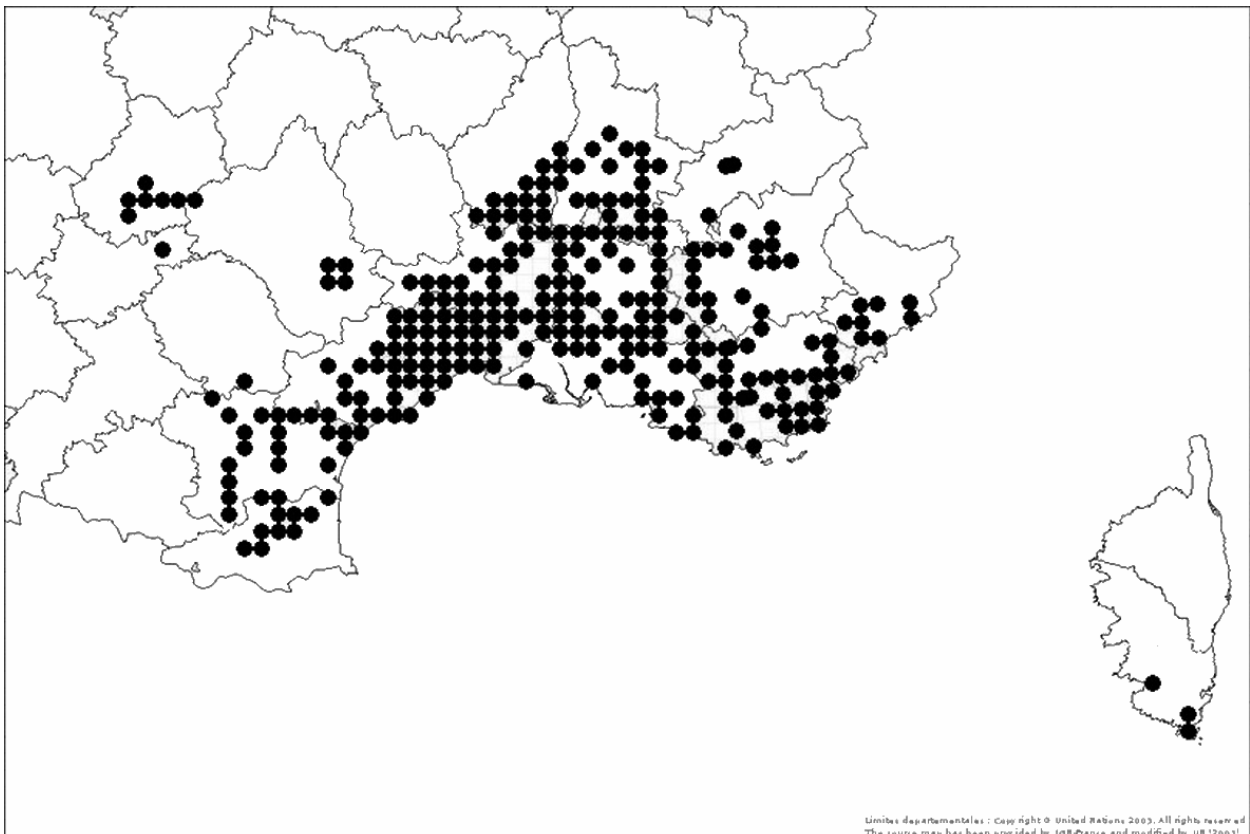


Fig. 1: Overview of known *Saga pedo* locations in France.

French department Number	Number of Contacts	Number of Recorders	Number of Stations	Number of administrative districts
34	338	134	204	107
30	249	110	148	52
83	165	57	83	52
13	140	75	100	42
07	108	62	60	32
26	70	44	61	37
84	65	35	40	32
04	36	28	22	17
06	30	13	17	13
66	29	11	12	10
11	27	17	24	21
20	14	8	8	3
46	12	7	7	7
12	10	13	7	6
05	8	6	8	4
81	2	2	2	2
82	1	1	1	1

Table 1: Synthetic overview of the distribution of the records of *Saga pedo* within French administrative departments.

Saginae breeding process

The breeding experiments were performed at Callian, France, in the central Var area at 250 m altitude. Here *S. pedo* is present and the climate is very similar to that of the parts of Greece where specimens of the other species have been collected.

Usually, males and females from the same species and location were raised together in small groups, in big cages up to the J3 stage. Once adult, most specimens were placed in individual cages.

Eggs were stored in a wood cabin in the garden, protected from the frost of winter nights. This cabin has two windows to provide daylight. The only attention given to the eggs is watering done on a regular basis, aimed to replicate typical Mediterranean conditions.

Source populations for breeding

***Saga natoliae* Serville, 1839**

The distribution area of this insect extends from the Balkans (south of Dalmatia, Albania, Republic of Macedonia (F.Y.R.O.M.) and north-east of Greece, through Anatolia into Syria. Length of the body: ♀ 60-88,6 mm, ♂ 51,5-81,5 mm.

Specimens have been collected from the north of Greece, Chalkidiki, in occidental Macedonia (Gomati, Ierissos) in the summer of 2004 and 2005.

***Saga hellenica* Kaltenbach, 1967**

This species occurs all over Greece, the far north-east excluded, Albania and Republic of Macedonia (F.Y.R.O.M.). Length of the body: ♀ 55,8-78,0 mm, ♂ 48,0-76,0 mm.

Specimens have been collected between 2004 and 2007 in the north of Greece, in occidental Macedonia (Nimfeo, Aetos, Kristallopigi), in Epirus (Petas, Morfio, Pardalitsa, Aghia Kiriaki) and in Thessaly (Skepari).

***Saga rammei* Kaltenbach, 1965**

Known from Republic of Macedonia (F.Y.R.O.M.), south of Bulgaria and Greek Macedonia. Length of the body: ♀ 49,6-71,0 mm, ♂ 45-60 mm.

In 2003 and 2005, two breeding samples have been collected in the north of Greece, Chalkidiki area, in occidental Macedonia (Olympiada, Ierissos).

***Saga campbelli* Uvarov, 1921**

Recorded from Greece (Macedonia and Thrace), up to the south-east of Romania, European part of Turkey and islands located in the north of Aegean sea (Samothrace, Limnos). Length of the body: ♀ 49,5-58,5 mm, ♂ 53,0-68,5 mm.

One breeding sample collected in 2005 from the Thrace area, in north of Greece (Messi).

***Saga pedo* (Pallas, 1771)**

This species has a large pan-Mediterranean distribution extended into eastern countries. From the Iberian peninsula up to the north-west of China (Xinjiang), through the centre and south of Europe, the southern part of Russia, Ukraine, Caucasus and Republics of Kazakhstan and Turkmenistan. It can be found in the Balkans including Greece (LEMONNIER-DARCEMONT et al. 2008) and probably in Albania. In the south, it occurs up to Sicily. Length of the body: ♀ 50-78 mm.

The specimens used for breeding were collected between 2002 and 2006 in southeastern of France, in Alpes-Maritimes (Vence, Coursegoules) and Var (les Mayons).

Results

Statistical data from *Saga pedo* records in France

The general distribution of *S. pedo* in France is now well known, from more than 800 locations, spread over 17 French departments. This species is mainly present in the following French departments: Hérault, Gard, Var and Bouches-du-Rhône. More than half of the known locations in France are situated in the four regions above. An additional survey campaign in other departments in the south-east of France should soon allow one thousand distinct locations to be reached.

Character of the locations with *Saga pedo*

Saga pedo seems to be able to live in a wide variety of open and sunny habitats. Most of the recorded data (83%) are from calcareous lands (mainly limestone from Cretaceous and Jurassic). It is also recorded on more acid lands (shale, granites, sand) but less frequent (17%). This may be linked to the reduced amount of food on siliceous lands.

Number of known locations per altitude

Saga pedo is observed from sea level up to 1750 meters altitude (in Alpes-de-Haute-Provence: Siron, Pic de Couard, Montagne de Gâche, Cheval Blanc). Based on the 574 stations with known altitude, figure 2 shows:

- The species is found mostly at low altitudes, mainly between 50 and 400 meters.
- The number of locations at less than 100 meters is lower than between 100 and 200. This may be caused by the fact that urbanisation and agriculture has rendered the landscape in the plain less suitable for *S. pedo*.
- The number of locations decreases significantly above 400 meters and becomes significantly reduced at 1700 meters of altitude.

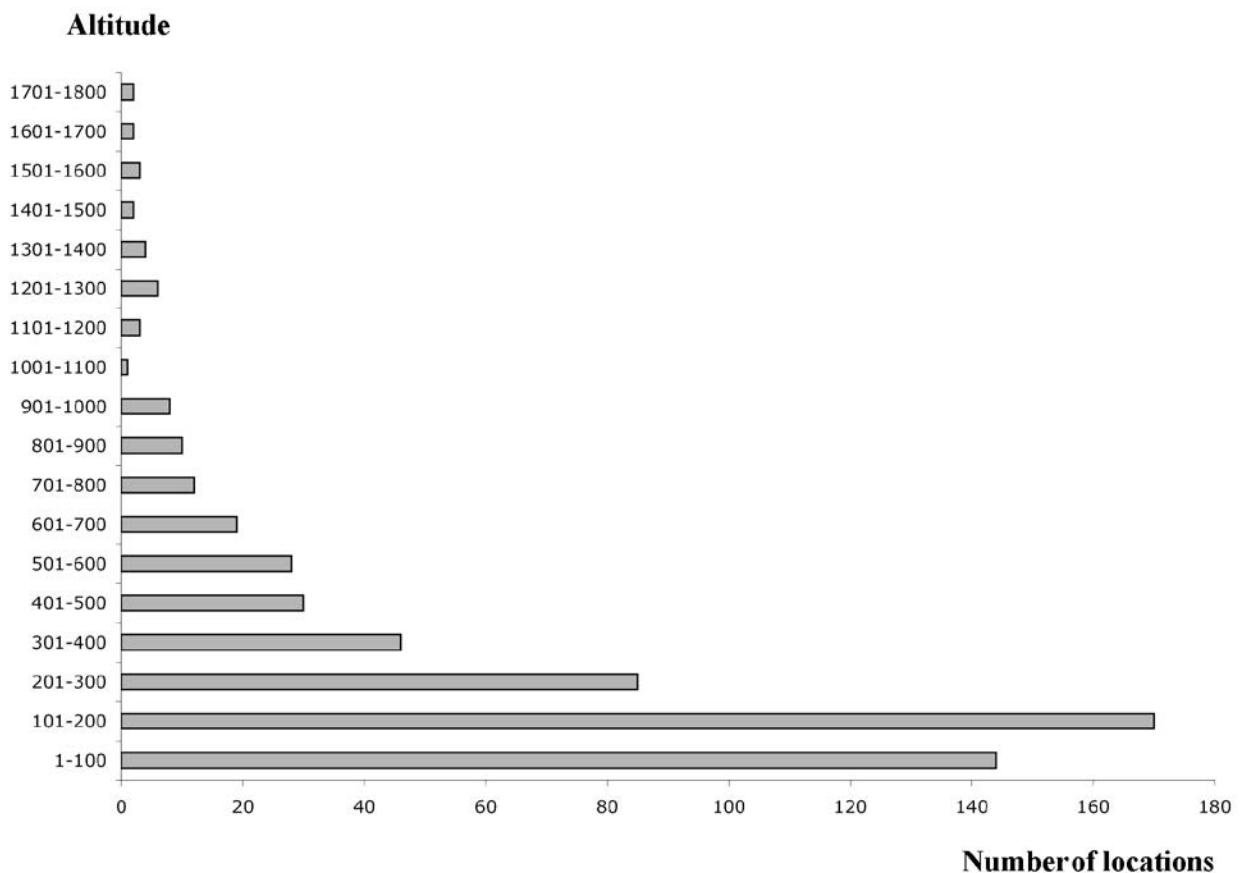


Fig. 2: Number of locations of *Saga pedo* per altitude, in France.

S. pedo can be found in grasslands (scrub, field with *Brachypodium retusum*, dry meadow) and agricultural area (fallow land and fields with *Brachypodium phoenicoides* bush). It can be found in undergrowth with clearings and scrub.

Daily activity

At low altitude in summer, in Mediterranean climate, *S. pedo* is a night hunter and, at twilight, can be found at the edge of roads. As shown in figure 3, half of the observations in France occurs at twilight (between 9 and 11 p.m. in summer). Despite of regular and systematic prospecting performed on roads during night, no *Saga* has been observed between 3 and 6 a.m. This can be correlated with

the overall reduction of activity of katydids from the middle to the end of the night. During the day, the activity figure shows two peaks: from 10 to 11 a.m. and from 3 to 4 p.m. The reduced number between these two peaks can be explained partially by the lunch time of observers but also by the hotter temperature. Note also the significant reduction of recorded data between 5 to 8 p.m., before the major peak starting at twilight.

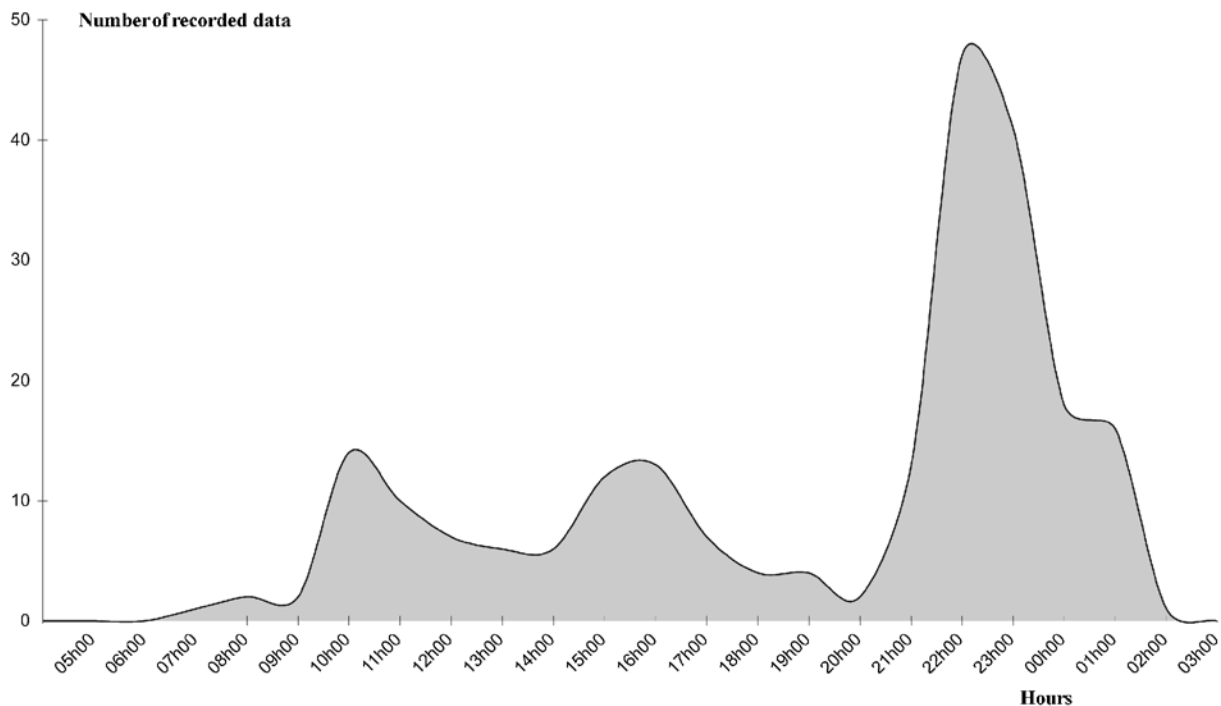


Fig. 3: Daily activity of *Saga pedo* in France.

We think that figure 3 gives a realistic picture of the daily activity of *S. pedo*, mainly because so many recorders (500) and some surveys could be combined with other studies, such as those on bats (at night) and birds (at dawn). Moreover, the numerous travels by car during nights in summer (C. Bernier, personal observations) show a lack of *Saga pedo* on the Mediterranean roads during the second half of the night.

Phenology

In France, *Saga pedo* occurs during 7 months, mainly between May and July (Figure 4).

Juveniles can be observed from early April (plain) to mid-July (mountain), last stages 5 and 6 (Sub adults) occurring from mid May to mid July. Adults occur since mid May up to mid October.

It has not been possible to correlate these data with altitude due to the lack of homogeneous recorded information.

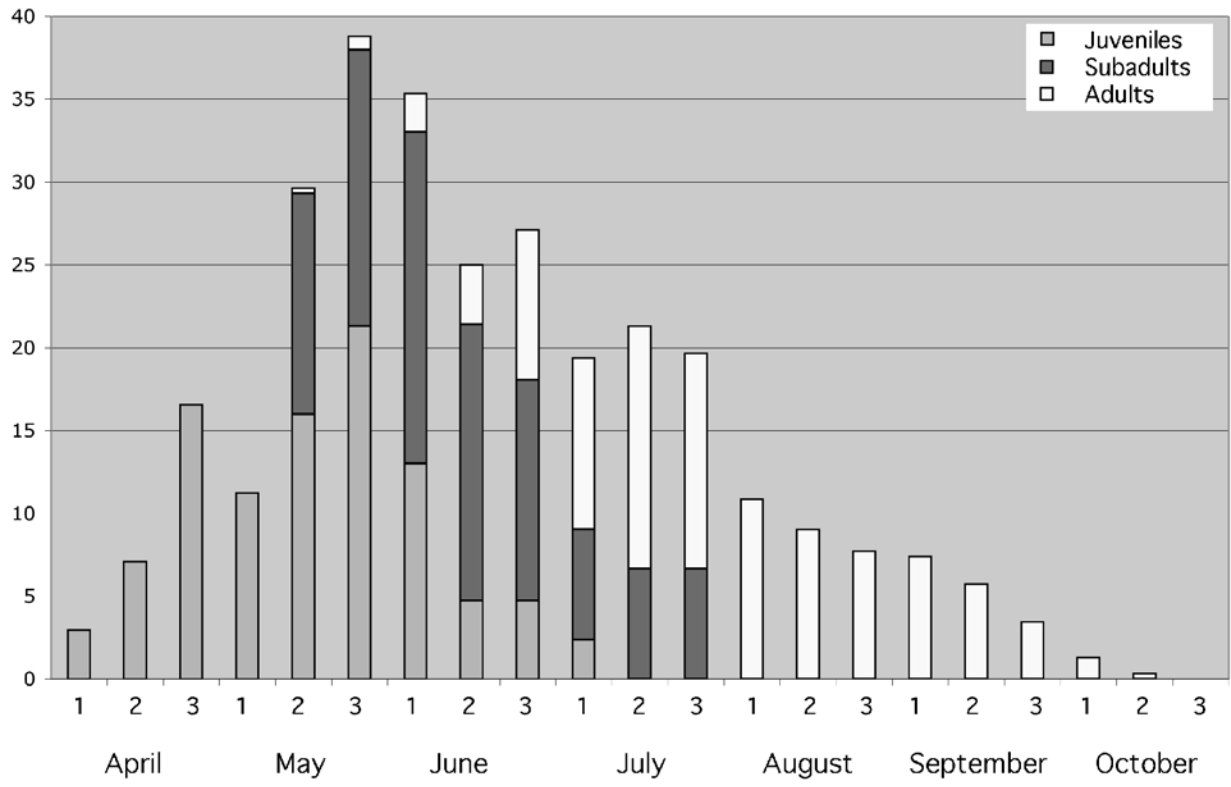


Fig. 4: Phenology of *Saga pedo* in France.

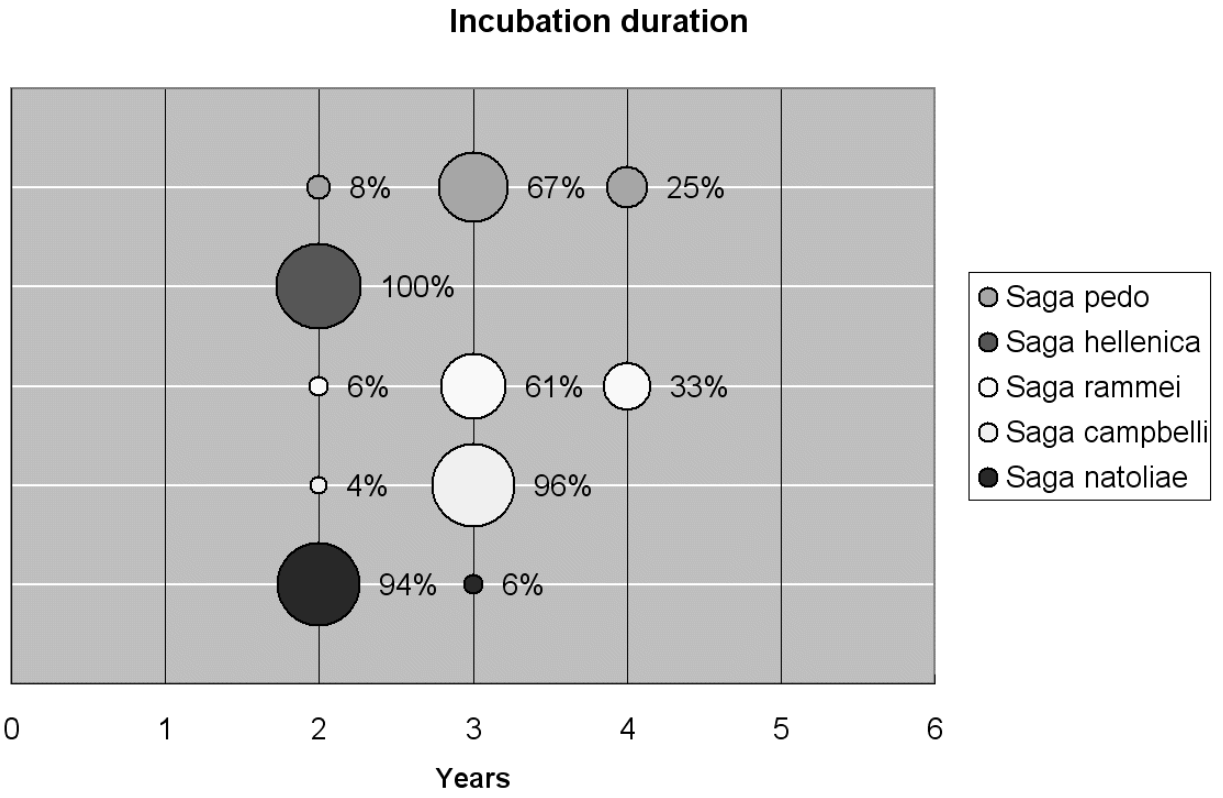


Fig. 5: Incubation duration per species.

Statistical data from all *Saga* species breeding

Egg incubation duration

Figure 5 shows the distribution of incubation duration per species. According to these result, we can distinctly classify the species into two categories:

- 2 year incubation for most of the eggs: *S. natoliae* and *S. hellenica*. This duration is common for a lot of Ensifera species.
- 3 year incubation for most of the eggs: *S. pedo*, *S. campbelli* and *S. rammei*. The percentages are based on the successful hatching of eggs. We have not measured the mortality of eggs because we were unable to count, the number of eggs laid without interfering with the incubation process. However, we continue to keep the flowerpots in the same conditions in case of some eggs hatch in the coming year(s). This could slightly refine the results.

Our first experiment with *S. rhodiensis* shows that some hatchings occurred after only one year. The detailed data will be provided after several years of measurement.

Date of hatching

Hatching data are summarized in two figures:

- Figure 6 shows the average hatching date per species and the differences between the years.
- Figures 7 to 9 show the development of the mean temperature during the months before and during the hatching period, for 2006 to 2008. These figures have been based on 47 hatchings of all species in 2006, 52 hatchings in 2007, and 196 hatchings in 2008. According to the hatching distribution of each species and the similar variation of the average date between years, we decided to lump all hatching data together per year. Each day, air temperature was recorded and the mean temperature results from the average of 288 raw data recorded every 5 minutes. Then, in the figures, the mean temperature data have been smoothed according the following recursive formula: $Y_N = K \cdot T_N + (1 - K) \cdot Y_{N-1}$.

N: Day; T_N : Mean temperature recorded in air during the day N; K : Integration parameter; Y_N : Smoothed mean temperature for the day N; Y_{N-1} : Smoothed mean temperature for the day preceding the day N.

The aim of this smoothing is to try to simulate the temperature variation at the egg level, taking into account the environment. We had no temperature measurement in the soil close to eggs. We have set the parameter $K = 0.1$.

The left vertical axis is the number of hatchings, the vertical axis on the right is the temperature in °C.

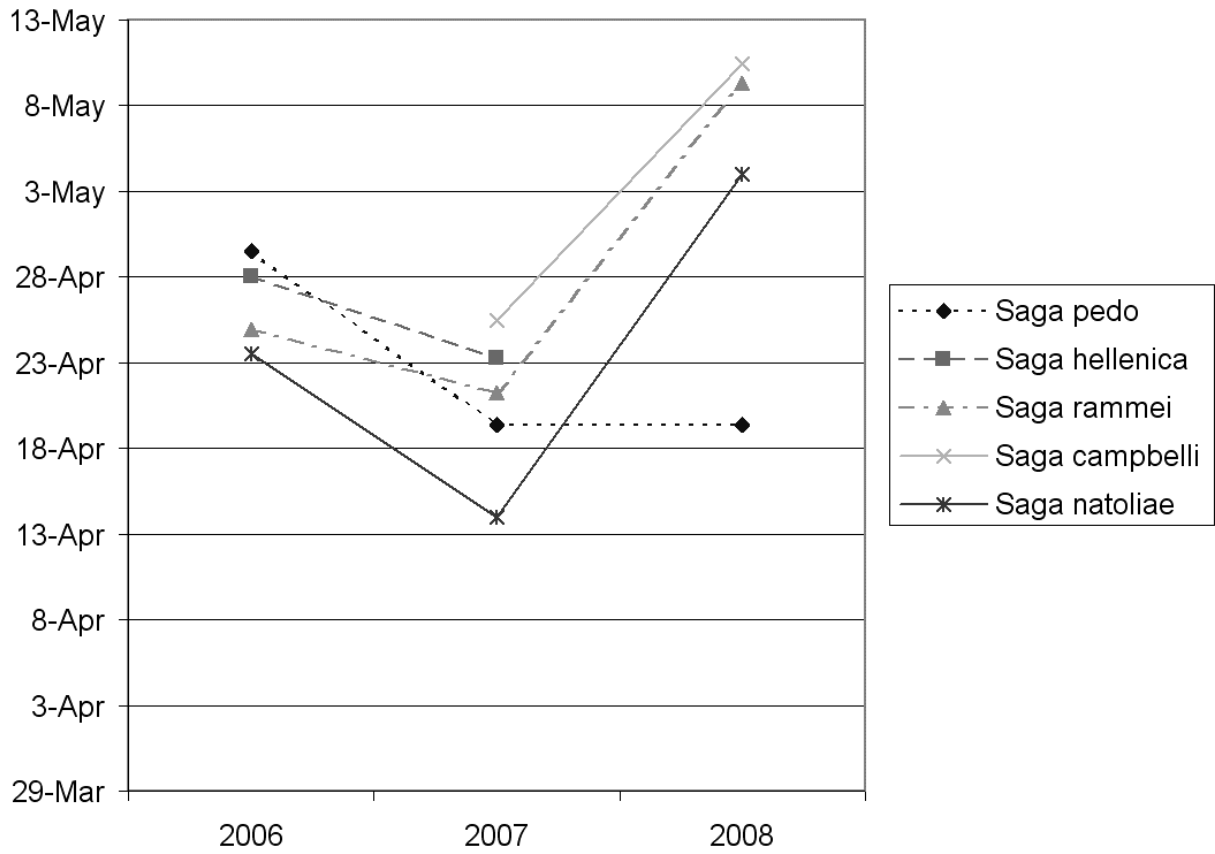


Fig. 6: Average date of hatching per species and per year.

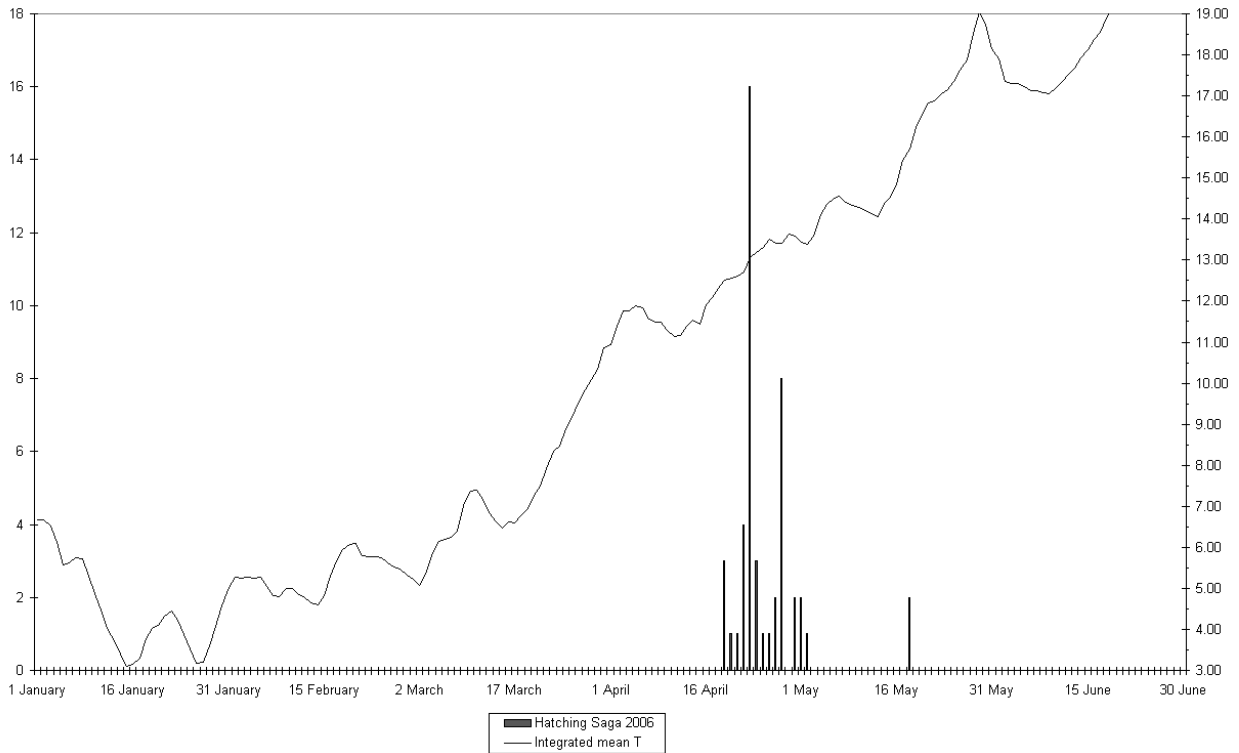


Fig. 7: Integrated mean temperature in winter and spring, and distribution of hatching dates of Saga in 2006.

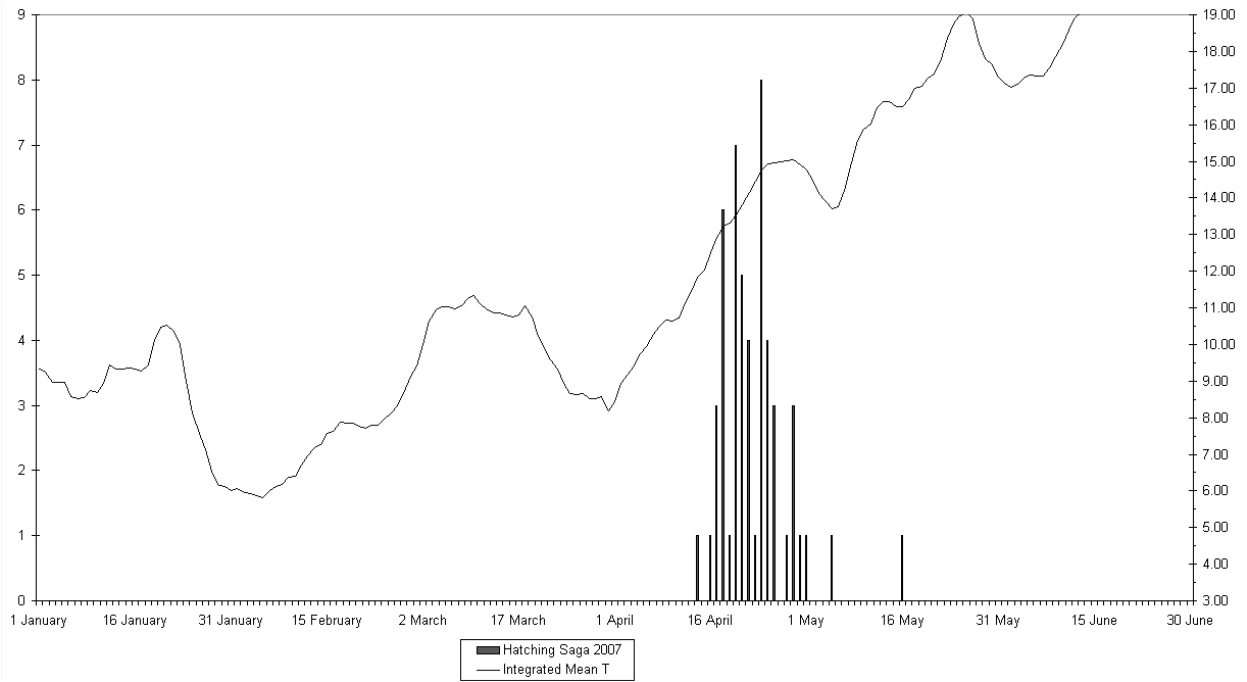


Fig. 8: Integrated mean temperature in winter and spring, and distribution of hatching dates of *Saga* in 2007.

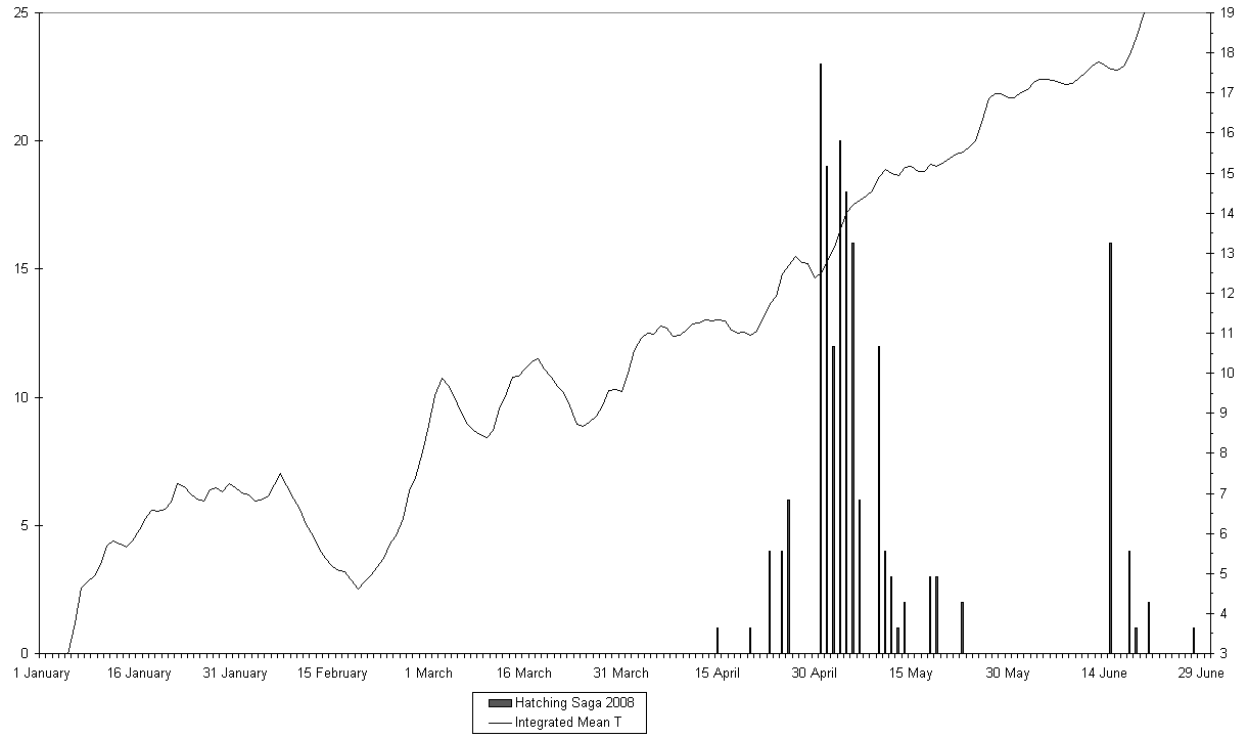


Fig. 9: Integrated mean temperature in winter and spring, and distribution of hatching dates of *Saga* in 2008.

From these data, we can draw the following conclusions:

- We can note the similarities between the hatching graphs among the different species. There is one exception in 2008 for *S. pedo*, but not significant (limited to only three hatchings that year).
- The shift of the average hatching date can be explained by the warmer winter in 2007 compared to 2006 and 2008, however, there is no significant parameter to explain the difference in average hatching dates, between 2006 and 2008.
- Among the different correlations tried (development of temperature, number of hours above X °C per day, average power provided by sun), we think that the smoothed mean temperature could be among the main parameters for hatching prediction. However, it seems that it is not a simple question of threshold, the slope of the curve could be also a parameter.
- The distribution of hatching around the average date is quite complex. We tried unsuccessfully to correlate the environmental parameters with the hatching date and distribution structure. A lot of recorded parameters have been analysed and correlated without significant result: temperature (min, max, at ground level, underground), wind, humidity, rain, sun (sunshine percentage and average power). Of course we have to take into account the fact that the flowerpots were located in a wooden cabin. We did not observe hatching during a rainy day, but some during a cloudy day with sparse rain. We have noted that the windy days were not favourable for hatching and that mostly the hatching occurred in the morning. We were unable to explain with the environment parameters, why some of the hatching days were far from the mean point.

General life duration

Figure 10 shows the average duration of juvenile stages and the average life of the adult stage. This corresponds to life duration in natural climatic conditions of the department of Var, without predation.

In addition, figure 11 shows the average date of end of life of adults (in the environment as stated above). In this figure, we have added the data for *S. rhodiensis*, collected in the early juvenile stage and reared.

Average time between moulting to the adult stage and first mating

The average time from the last moult up to the first reproduction is 15 to 20 days. At this stage, we don't have enough data to discern differences between species.

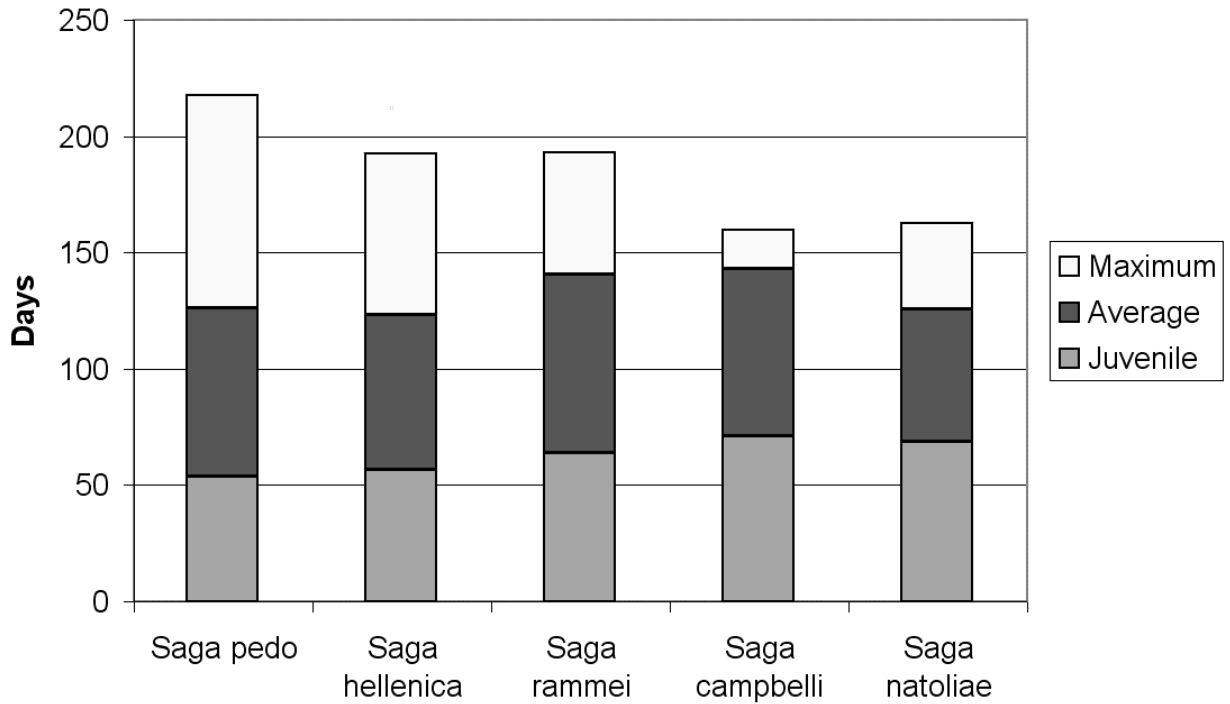


Fig. 10: Life duration per species.

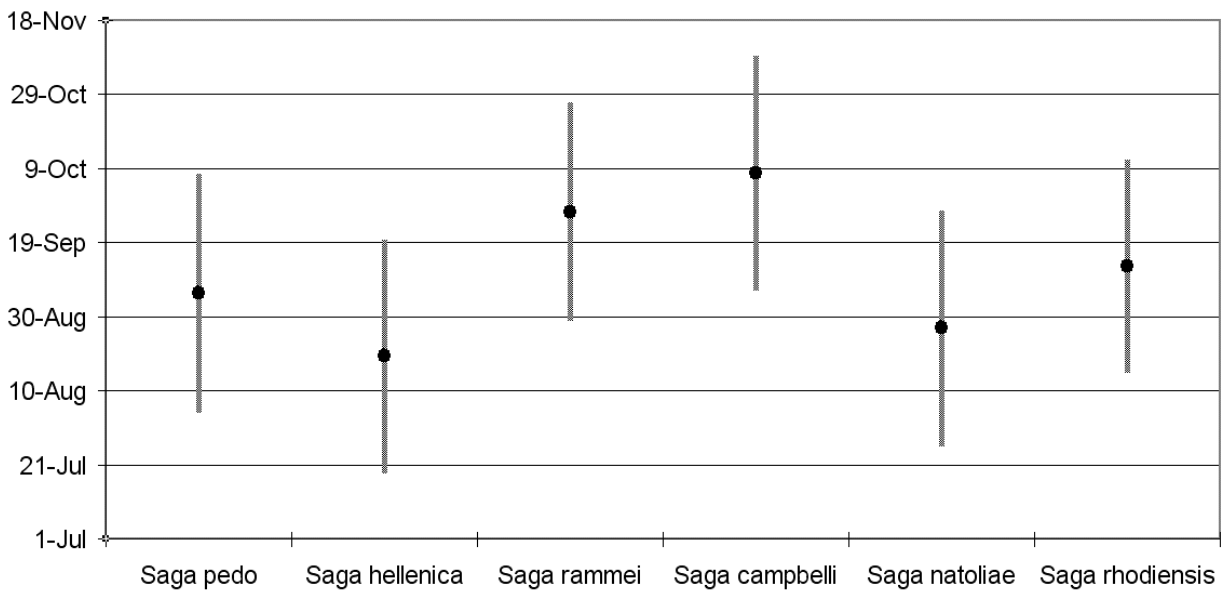


Fig. 11: Average date of death per species.

Conclusion

These first statistical results have taken benefit of several years of records in the field and of breeding experience. This adds to a better understanding of the genus *Saga*.

However, several additional years of data recording will be necessary to refine the role of the environmental parameters, by performing new correlations or computations with external parameters.

Moreover, the survey of *S. pedo* launched in France a few years ago has been a success and is a key factor in the better knowledge of its habitats. Therefore, this experience needs to be now extended to Europe.

Acknowledgements

The knowledge of *Saga pedo* in France has benefited greatly from the contributions of 560 orthopterists. We wish to express our thanks to them. Special thanks are due to scientific council of O.N.E.M. for its support and to David Delon, Antoine Foucart, Yoan Braud, Jean-Jacques Peres, Jean-Michel Faton and Alain Schall for their help to the *S. pedo* survey.

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