Parts of the life history of Osmoderma eremita's metapopulations in two study areas in the West of France (Coleoptera, Cetoniidae)

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Parts of the life history of *Osmoderma eremita*'s metapopulations in two study areas in the West of France (Coleoptera, Cetoniidae)

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The Hermit beetle, *Osmoderma eremita* (Coleoptera, Cetoniidae), is a beetle living in cavities of old deciduous trees. Its populations are met in forest habitats and man-made habitats such as hedgerow networks and orchards. Our two studied areas are in these two types of habitat of substitution. We have observed a synchronous variation of the metapopulation size between the two sites despite of a distance of 120 km (from south to north). The periods of small size of the metapopulation represent probably a risk for the viability of the populations. The rate of dispersal is the same as that observed in Sweden (14–15 %). The distance is also quite similar with a longest distance of 310 m in a single flight and a maximum of 700 m in consecutive flights. Habitat fragmentation has run for at least 60 years in the hedgerow network in the Orne department and started more than 100 years ago in orchards of chestnut trees in the Sarthe department. The occupation rate is low and decreases strongly. During our 10 years survey, we also observed a temporary occupation of some cavities by *Osmoderma*. The medium size of these populations was low. The low density and the strong decrease of the occupation rate seem to have an effect on the risk of extinction. Without conservation efforts, these populations have a low probability of surviving. The hedgerow network in the Orne department has been protected in the land consolidation program. The orchard of chestnut trees in the Sarthe department is protected and maintained by an implemented plan of restoration by the department of the Sarthe. The preservation of the last metapopulations is urgent but difficult to implement because of the important duration of habitat restoration.

Keywords: *Osmoderma eremita*, habitats, metapopulations, viability, conservation

INTRODUCTION

The Hermit beetle, *Osmoderma eremita* (Coleoptera, Cetoniidae), is a beetle living in cavities of old deciduous trees (Tauzin 1994a, 1994b; Luce 1995). Nearly the whole activity of the larvae and adult stage proceeds in the cavity of a tree. A cavity sheltering the species constitutes a population (Ranius 2000a). Approximately 15 % of the adults emerging from a cavity disperse and the dispersion ability is limited to about 200 meters (Ranius & Hedin 2001). Thus, stands of trees located less than 250 meters from each other constitute a metapopulation (Ranius 2000b; Hedin 2003; Ranius *et al.* 2005).

Osmoderma eremita is a specialized species of cavities in deciduous trees with wood mould (Ranius *et al.* 2005). It is an «umbrella species» which is always accompanied by a succession of mostly rare species (Ranius 2000a). This beetle has strongly decreased with the fragmentation of its habitats (Ranius *et al.* 2005).

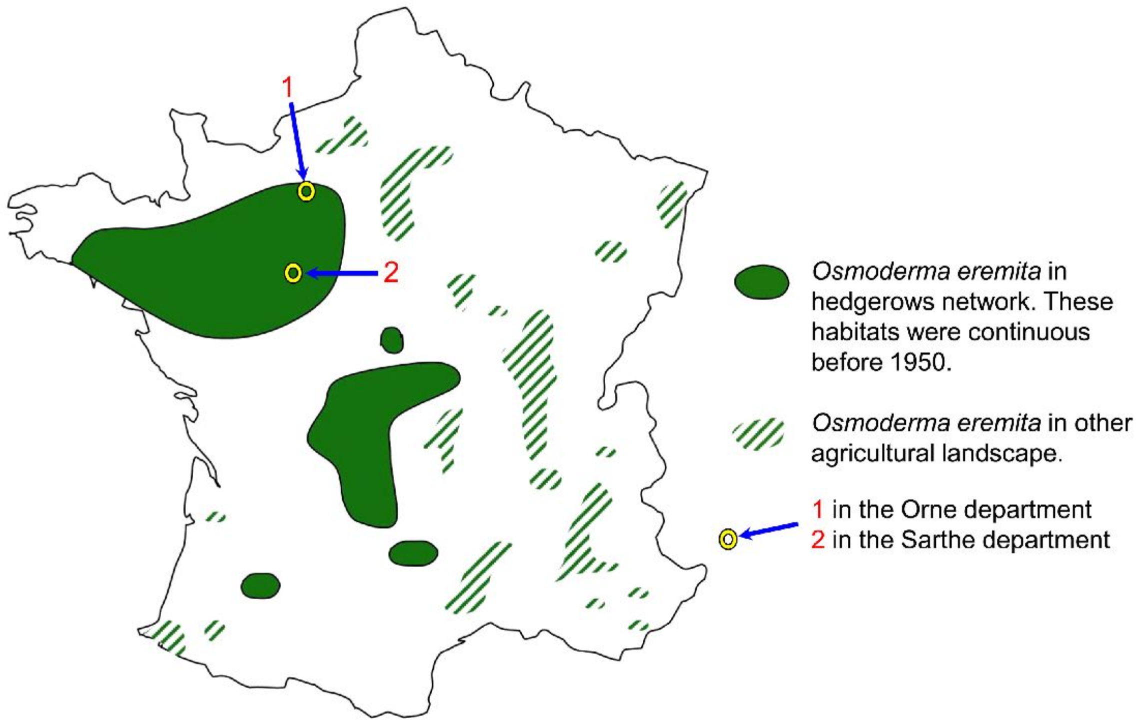

Fig. 1: Location of the two study areas in the distribution area of *Osmoderma eremita* in France.

In Western Europe, particularly in France, the main habitats of *O. eremita* are found in traditional rural landscapes structured by old trees: man-made habitats such as hedgerow networks and orchards (Vignon 2005, 2006).

The aim of our study was to assess the impact of the construction of the A28 motorway on *Osmoderma eremita*. Studied populations were located in agricultural landscape.

METHODS

All the studies lasted 16 years 1997–2013 in the Sarthe department (Cofiroute company, Vinci Autoroutes) (Blandin *et al*. 1999) in chestnut (*Castanea sativa*) orchards and 7 years 2001–2008 in the Orne department (Alis company) in hedgerow networks (Fig. 1).

Catches were made using pit fall traps in the cavities. Altogether, the survey was carried out during summer and required 950 days with 14 persons. The monitoring of the dispersal was carried out by telemetry, using Holohil LB2 transmitters (Ranius & Hedin 2001) (fig. 2).

RESULTS

Elements of life history

We caught and released 612 individuals, 346 adults in the Sarthe department (2004–2013) and 266 adults in the Orne department (2004–2008).

In our study areas, the adults emerged from the end of June to the end of August with a emergence peak between 10 and 15 July. In the Orne department, a second emergence peak was observed between 25 and 29 July probably due to the delayed temperature rise in the largest cavities.

Fig. 2: A male of *Osmoderma eremita* with LB-2 transmitter ©V. Vignon.

Let's examine the processes which underlie the functioning of the populations in time and in space.

A synchronous variation of the metapopulation size

During the survey, we observed a synchronous variation of the metapopulation size between the two studied sites despite a distance of 120 km (from south to north). A maximum size of the two metapopulations occured in 2007. It seemed that there was a cycle of 6 or 7 years period, that is the length of time about two generations of *Osmoderma* (Fig. 3). In contradiction of those observations, Ranius (2000b) in Sweden observed asynchronous population size combining a stable number of individuals at a metapopulation level. The asynchrony might greatly increase persistence time at the metapopulation level (Ranius 2001). In our study area, the periods of small size of the metapopulation represent probably a risk for the viability of the populations.

A temporary occupation of certain cavities by Osmoderma eremita

When during at least three years no adults were observed in a cavity, it may be due to a discontinuity of the presence of the species (Fig. 4). We observed this in 3 hollow chestnut trees at most, out of 17 inhabited by the species. These observations must be taken with precaution because they rest on a supposed absence of the species. The low rate of capture of the adults, in particular females and the low probability to see larvae incites to be cautious to assert the absence of *Osmoderma* in a cavity.

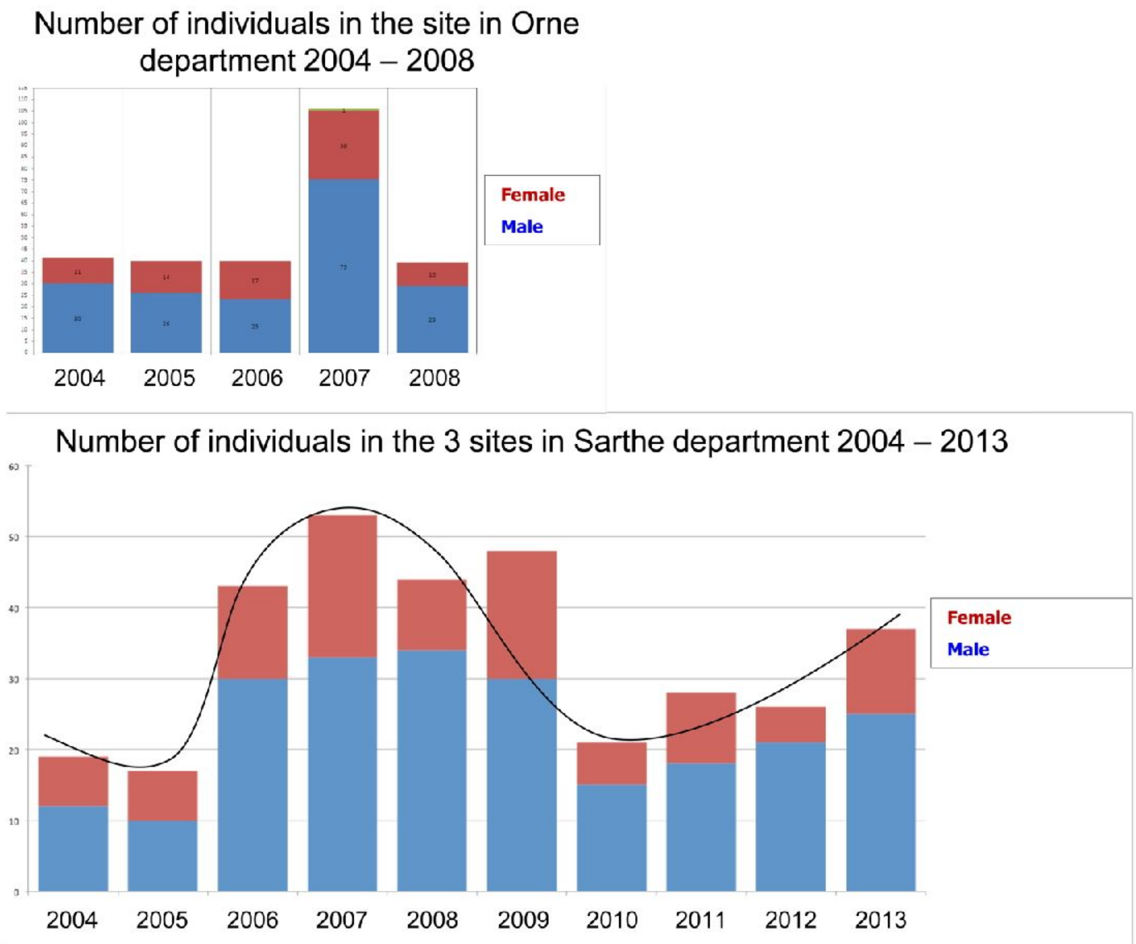

Fig. 3: A synchronous evolution of the size of the studied metapopulations despite a distance of 120 km (from south to north).

Evolution of the availability of the resources

During 10 years, we could collect every year emerging beetles from a pollarded oak, which was cut down and moved during the construction of the motorway in the Sarthe department. We could show that the weight of the beetles gradually decreased with time. On Fig. 5, we show the evolution of the beetle weight in the dead oak and we compare it to that of 17 other *Osmoderma* populations dwelling in living trees in the Sarthe department:

In the cavity of the dead oak, for ten years, the average weight of the adults gradually decreased from 2,2 g to 1,5 g. This dead oak is one of the 4 trees in which adults emerged every year during 10 years of monitoring among 17 studied populations. Three other trees were chestnuts in orchards. The decrease of the weight of the adults, and also our observations of malformed individuals during the last years of the monitoring, could correspond to a decrease of the resources of the cavity of the dead oak.

The evolution of all the trees shows an opposite evolution between the abundance of the adults and their average weight. It is a plausible hypothesis that this evolution corresponds to the sharing of a limited quantity of resources between

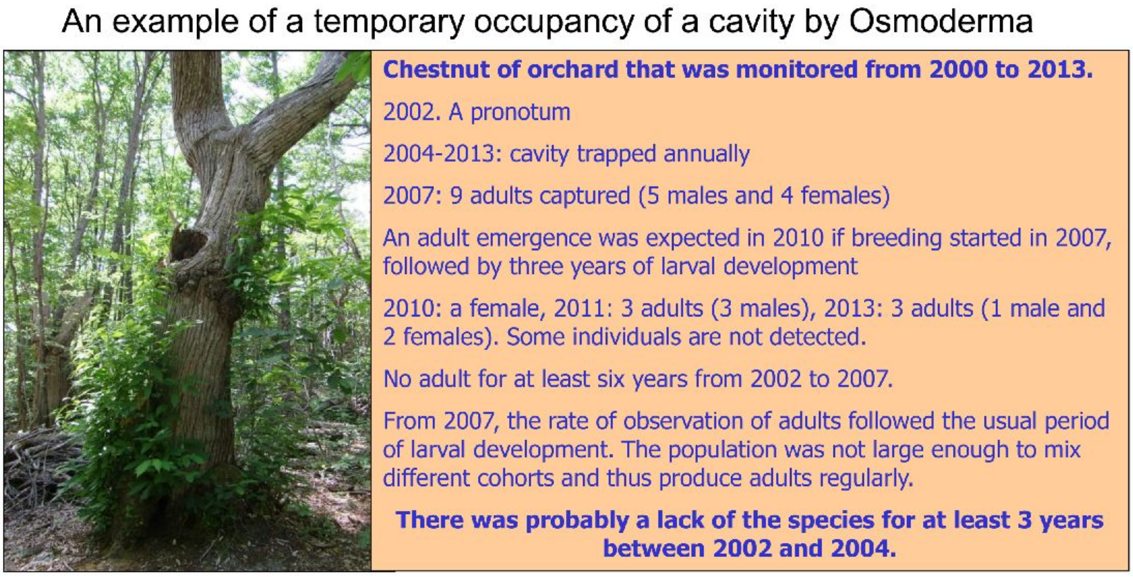

Fig. 4: An example of a discontinuous occupancy of a cavity by *Osmoderma*.

the individuals. With many individuals, larvae had to share the resources before the metamorphosis and as a consequence the emerging adults were less corpulent. This hypothesis is nevertheless not supported by food availability measurements.

Dispersal

Among the individuals followed by telemetry in the Sarthe department, the rate of dispersal was the same as the one observed in Sweden (15–16 %) (Ranius & Hedin 2001). The distance of dispersal observed in the Sarthe department includes a longest

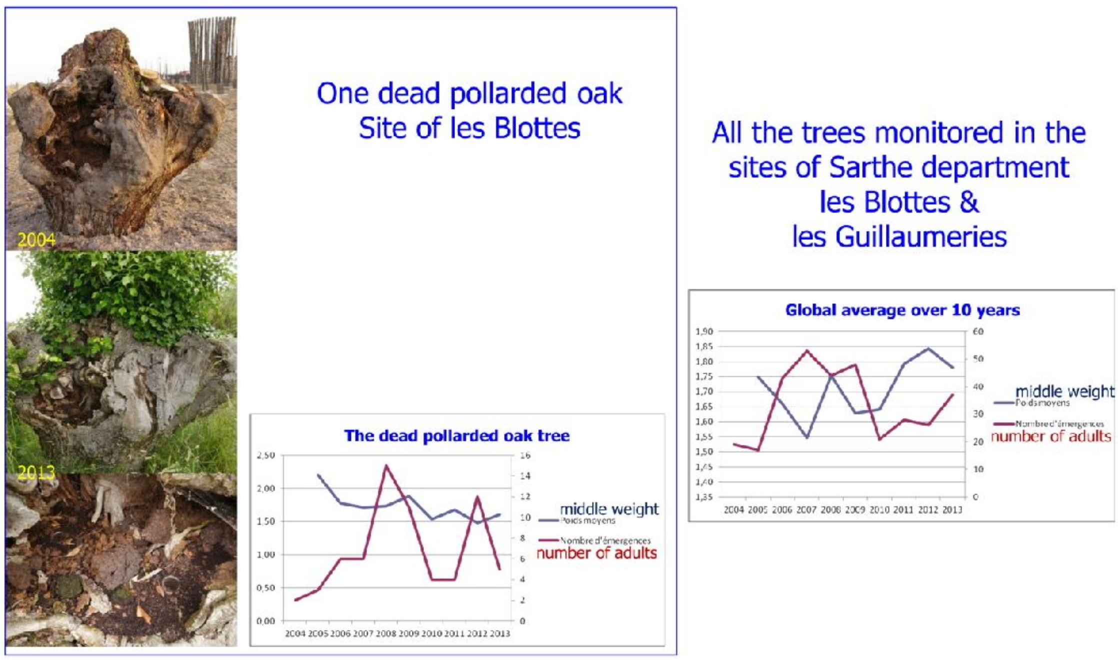

Fig. 5: Population size and average weights based on available resources (data from the sites in the Sarthe department).

				Type of monitoring		Type of dispersal			
Number of the individual	Distance (m)	male	female	Radio telemetry	mark-recapture	between two occupied cavities	led to an unoccupied cavity	Ended on ground	Predation likely
n°16/2005	700		■	X				X	
n°32/2009	310		■		X	X			
n°27/2008	170		■	X			X	X	
n°21/2007	120		■	X		X			
n°28/2007	110		■	X			X		
n°41/2008	70	■		X					
n°2/2012	60	■			X	X			
n°26/2006	50		■	X					X
n°5/2006	30		■	X				X	
n°15/2006	15	■		X					
n°43/2009	15	■			X		X		
n°1/2013	10		■	X		X			
n°40/2006	2		■	X					X

Fig. 6: Observed dispersal of *Osmoderma* in chestnut orchards in the Sarthe Department.

distance of 310 m in a single flight and a maximum of 700 m in consecutive flights (Fig. 6). This is in order of magnitude of the distances of dispersal found in Sweden and in Poland (Ranius & Hedin 2001; Oleksa *et al.* 2013), but they were lower than the observations realized in Italy in a Mediterranean context up to 1500 m (Chiari *et al.* 2013).

Globally, all the dispersals observed in the Sarthe were made after the peak of emergence (in July 10–15th). The average date of the dispersal was on July 20th. There were approximately twice as many females as males which tried to disperse.

During his thesis, Dubois (2009) showed that the dispersal ability was higher for females especially when they were at the end of their adult life with more need of dispersal, realizing a larger number of flights and a higher flight speed. It could be a strategy which would optimize the colonization of new cavities after mating in the emergence cavity. This strategy would meet the requirements for a species living in a temporarily stable but spatially fragmented habitat (Dubois *et al.* 2010).

During the 10-year monitoring, half of the dispersing *Osmoderma* reached annother cavity, whether it was or not occupied by the species. In one third of the dispersal cases, dispersing adults reached annother cavity inhabited by *Osmoderma*. Finally, one fifth of the dispersing individuals ended on the ground. In the later case, they were lost for the metapopulation. We noticed the difficulties for *Osmoderma* in a dense coppice where the individuals did not succeed in avoiding twigs and fell to the ground (Dubois & Vignon 2008).

At a site in Sweden, all the individuals that dispersed moved to another cavity inhabited by *Osmoderma*, which in 62 % of the cases was the nearest cavity (Hedin *et al.* 2007). In that study, there was no coppice between the old trees and thus no constraint of flight for these insects.

In the Sarthe department, the development of coppices in the orchards of chestnut trees constitutes a part of processes of fragmentation of *Osmoderma*'s habitat due to the difficulty for *Osmoderma* to fly in the dense coppice. Furthermore, the coppice leads to colder conditions in the cavities. This is negative as the larvae development of *Osmoderma* is favored by the sun heating the trees.

The fragmentation of *Osmoderma*'s habitat is mainly due to the cutting down of chestnut groves and to the fact that they have not been renewed any more since the late 19th century. In the Orne department, such fragmentation is also due to the cutting down of trees and the lack of renewal of hedges and pollard practices since 1950.

Under these conditions, habitat fragmentation has run for at least 60 years in the hedgerow network in the Orne department and started more than 100 years ago in orchards of chestnut trees in the Sarthe department.

The occupation rate is low and decreasing. In a group of orchards of chestnut trees including 235 trees with cavities (Sarthe department), 25 trees showed evidence of *Osmoderma* occurrence. Among these 25 trees equipped with traps only 15 trees produced adults (60 %). In hedgerow network (Orne department), among 26 trees showing evidence of *Osmoderma* occurrence and equipped with traps only 19 trees produced adults (73 %). The species is very rare in this landscape. In hedgerow network *Osmoderma* occurred in 1 % of the pollarded trees. In the orchards of chestnut trees *Osmoderma* occurred in 2 to 6 % of the trees. The medium size of these populations was low: 8 adults per year in apple tree orchards in the Orne department and only 4 adults per year in chestnut tree orchards in the Sarthe department.

In Chestnut orchards (Sarthe department), the regression could correspond to the following mechanisms both combined in time and space:

— First hypothesis: a 40 % decrease of the populations during the time of disappearance of *Osmoderma*'s indices. We do not know this duration. A part of the indices can certainly persist decades, in particular body segments of chitin and probably also excrements in dry conditions.
— Second hypothesis: the total number of occupied cavities has a low variation. A part of them lose their population, whereas others are re-colonized or are temporarily colonized. In spite of the continuous searching effort for new occupied or reoccupied cavities, we may have missed some of them. If this is the case the reduction is not so important as what we observe.

DISCUSSION

What to say about the viability of metapopulations?

The evaluation of the viability of the populations in a metapopulation is a complex subject. Small populations, that is the case for *O. eremita*, are vulnerable to the risk of losing a part of their genetic diversity and of local extinction caused by natural risks.

A key point is the definition of a cluster of trees which we have to consider as hosting a metapopulation. Another key point is the dispersal ability (Ranius 2006). Beyond a certain distance, the probability that individuals occupy new trees is so low that we have to consider that they are not a member of the same group. This distance, less important than the maximum one, is an essential factor of the viability of the metapopulation. The evaluation of this distance which allows the adults to connect the populations with efficiency depends most probably on the spatial organization of trees with cavities and on characteristics of the landscapes.

The evaluation of the viability is based in particular on the following criteria:

— The number of favorable cavities connected with old grouped trees.
— The quality of cavities for *Osmoderma* (exposure, humidity, size, resources…).
— The spatial organization of trees with cavities which determines the size of the clusters of trees hosting metapopulations connected to the landscape.
— The occupation rate of the available cavities which influences the orientation of the dispersing adults. The female adults are sensitive to pheromones emitted by males (Larsson *et al.* 2003).
— The quality of the mosaics of natural habitats surrounding trees with cavities…

In our two study areas we observed the following items:

— Populations subsisted in areas where few changes occurred with time in hedgerow density, revealing the sensitivity of this habitat-tracking species to landscape changes in a complex human made landscape (Dubois *et al.* 2009)
— Low densities of *Osmoderma* in cavities and at the level of the landscapes in the Orne and Sarthe departments.
— A synchronous variation of the size of the metapopulations which probably represents a risk for the viability of the populations during the period of low size.
— A part of the adults gets lost during dispersal,
— During at least the last 60 years there have been a fragmentation of the habitat and an important loss of habitat.
— A strong decrease of the occupation rate of cavities by *Osmoderma*.

The strong decrease of the occupation rate seems to be an effect of an extinction debt. Without efforts of preservation, these populations have a low probability of survival.

In our two study areas, habitats are protected, but the viability of *Osmoderma*'s population is not ensured:

— Hedgerow network of the Orne department has been protected in the land consolidation program but they are not maintained by an implemented plan of restoration.
— The main orchard of chestnut trees in the Sarthe department is protected and maintained by an implemented plan of restoration by the Council of the Sarthe department. This Council also realized a renewal of chestnut orchards by grafting more than a thousand chestnut trees.

These observations confirm that for most localities located in agricultural landscape in France, the populations of *Osmoderma* are seriously threatened

(Vignon, 2008). The preservation of the last metapopulations is urgent but difficult to implement because of the important duration of habitat restoration.

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