ASPECTS OF THE REPARTITION OF THE SAPROXYLIC BEETLES IN FORESTS (FRENCH ALPS)

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RÉSUMÉ. — *Aspects de la répartition des coléoptères saproxyliques en forêt (Alpes françaises).* — Cette étude des coléoptères saproxyliques et du bois mort dans 4 forêts alpines montre que les communautés saproxyliques présentent de fortes individualités correspondant au secteur géographique mais également aux types d'essences en présence. La distinction se fait entre taxons vivant à partir des bois de feuillus (principalement des mycophages et des saproxylophages) et de résineux (principalement des xylophages). Nos données confortent la relation théorique entre la quantité d'habitat et la diversité biologique puisque le nombre de fragments ligneux explique mieux la richesse taxinomique que le volume total.

Mots-clés: Quantité d'habitat, bois mort, coléoptères saproxyliques

SUMMARY. — This study of the saproxylic beetles and the dead wood in 4 alpine forests shows that the saproxylic communities are individualized according to the geographical area. The type of dead wood is a key parameter of this distribution. Softwood gathers mostly xylophagous species while hardwood is occupied by mycophagous and zoophagous taxa. Our data underline the theoretical relationship between quantity of habitat and biological diversity because the number of woody fragments is explaining the taxonomical diversity better than the total volume does.

Keywords: Habitat quantity, dead wood, saproxylic coleoptera

Dead wood is a key habitat largely threatened by forest activities (Ehnström, 2001). Indeed, trunk export is short-circuiting the cyclic development of the forest by excluding three essential phases from the forested stand: over-maturity, senescence and death (Odum, 1989; Christensen & Emborg, 1996; André, 1997). The reduction of dead wood availability is one of the main threats pressing on the saproxylic beetles, a particularly abundant and diversified group of insects. In Sweden for example, the beetle red list includes nearly 50% of forest species among which 85% are saproxylic (Jonsell *et al.,* 1998).

An effective management of dead wood and its biodiversity in commercial forests needs the development of new procedures and a good knowledge of these two elements. Many authors have already proposed some adapted modes of management but frequently these ones are related to a local context or to particular types of dead wood (Davies *et al.,* 2006). For example, Lindhe *et al.* (2005) have focused on the interest of high-stumps creation for the saproxylic beetles. Thus, these investigations are far from being completed. It is necessary to increase our knowledge on both dead wood and saproxylic insects if one wishes to manage these two elements as well as possible.

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This study aims to know better the ecology of the saproxylic beetles, *i.e*. the relations they establish with dead wood stocks. The following questions were approached:

(1) Are abundance and species richness related to dead wood amount? We investigated this aspect for the total volume of dead wood and for the number of dead woody elements.

(2) How are saproxylic beetles distributed among forests differing in fuel composition and in management history? Are some species restricted to special forest types?

STUDY AREA

The study sites are located in the north of the French Alps. In this area, slope, economic context and geography are currently unfavourable to the wood sale. In the least accessible sectors, the accumulation of living or dead wood is substantial (Ministère de l'agriculture et de la pêche, 2000; Vallauri & Poncet, 2002; Dodelin *et al.,* 2004).

Ten stations were selected in four forests. These sites have important dead wood stocks and forest continuities (canopy cover) are more than 200 years old (Tab. I). The stations were preferably chosen in the old phases of the forest cycle, which are interesting for their high content of dead wood (Siitonen *et al.,* 2000; Carmona *et al.,* 2002). Three forests belong to the beech complex and one to the spruce forests group (Ozenda, 1985).

TABLE I

Study sites (stations) with a short description of the works carried out

Forest	Coordinates	CORINE and (Bear) classifications	Dominant trees (ordered according to dominance)	Station	Maturity and brief history	Number of window traps	Transects for the dead wood inventory
La Charmette	N: 45,324 E: 05,737 Z: 1300	42.1 & 42.2 (13-F5b)	*Picea abies* *Abies alba* *Fagus sylvatica*	C1	Selective logging. Last management in 2002 (1 year before this study)	4	Parallels (0,599 ha)
				C2	Selective logging. Last management in 1997 (6 years before this study)	3	Parallels (0,104 ha)
Les Écouges	N: 45,185 E: 05,510 Z: 1050-1300	41.1, 41.4 & 42.2 (13-F5b)	*Picea abies* (plantation)	E1	Old growth forest	2	Crossed (0,081 ha)
				E2	Mature plantation	2	Crossed (0,080 ha)
			Fagus sylvatica *Picea abies*	E3	Intensively logged approx. 5 years before this study	2	Crossed (0,072 ha)
				E4	Old growth forest. Last management approx 20 years before this study	2	Crossed (0,086 ha)
			Fagus sylvatica *Picea abies* *Abies alba* *Quercus* sp.	E5	Young stand	2	Crossed (0,080 ha)
Méolans-Revel	N: 44,388 E: 06,485 Z: 1200-1650	42.2 (1-D9)	*Picea abies* *Abies alba* *Pinus sylvestris* *Larix decidua* *Quercus* sp. *Salix* sp.	M1	Old growth forest. Last management >50 years	5	Parallels (0,264 ha)
				M2	Old growth forest. Last management >50 years	4	Parallels (0,260 ha)
Rhonne	N: 45,659 E: 06,407 Z: 650-1000	42.1 & 42.2 (13-F5b)	*Picea abies* *Abies alba* *Fagus sylvatica*	R1	Selective logging. Old growth forest. Last management in 1988 (25 years before this study)	6	Parallels (0,300 ha)

METHODS

Our working principle was an inventory of the dead wood and a sampling of the saproxylic beetles in the same stations.

Dead wood stock inventory and forest description

Dead wood inventory was realized with the strip surveying method (Ståhl *et al.,* 2001). Transects were 100 to 250 m long and 2 m wide. In forests which are heterogeneous at a large scale they were installed along orthogonal crosses; this in order to inventory approximately 1-ha homogeneous sectors (homogeneity in terms of dead wood, forest structure and type). In the relatively homogeneous forests, transects were placed on parallel lines separated by 100 m.

The pieces of dead wood were measured if at least one diameter equalized or exceeded 7.5 cm for the standing dead trees and 10 cm for the other fragments. The number of elements and the total volume of dead wood per hectare were noted (see Dodelin *et al.* (2004) and Dodelin (2006) for more details).

Forest description variables used were the forest type, the history of the management and the stand structure.

Data concerning saproxylic beetles

Saproxylic beetles sampling was realized with 32 window traps, a systematic system with no favoured direction. These very effective traps are described at length in the entomological literature (Økland, 1996; Brustel, 2001, 2003). The traps were emptied every fifteen days from the end of spring to autumn in each of the 10 stations.

Specimen identification was detailed at least to the family for the beetles and to the species for saproxylic beetles. Some families with delicate taxonomy were identified by E. De Laclot (Scolytidae) and L. Micas (Buprestidae, Cerambycidae). Four taxonomical groups were used to gather the species which are difficult to separate: *Cis* (Ciidae) differing from *C. boleti* (Scopoli), *Enicmus* (Corticariidae) differing from *E. testaceus* (Stephens), *Cartodere* differing from *C. nodifer* (Westwood) and the others Corticariidae.

The ecology of each species is taken from the Nordic Database, a database coordinated by J. Stokland, that is synthesizing most of the entomological works published for Finland, Norway and Sweden (see: http://www.saproxylic.org/). A broad French entomological bibliography and our personal data were used to complement the Nordic Database.

Statistical methods

The univariate relations were explored by means of linear regressions to account for the effect of the volume of dead wood and the number of dead wood pieces on individual abundance and taxonomic richness.

To explore the link between species and forest types and management history, we used the IndVal software provided by Dufrêne & Legendre (1997). For each species *i* in each site group *j*, the IndVal program computes the mean abundance of species *i* in the sites of group *j* (A*ij*) compared to all groups in the study, by B*ij*, the relative frequency of occurrence of species *i* in the sites of group *j*, as follows:

A*ij* = N individuals *ij* / N individuals *i*

B*ij* = N sites *ij*/ N sites *j*

IndVal*ij* = A*ij* * B*ij* * 100

Where IndVal is the Indicator Value of species *i* in site cluster *j*.

RESULTS

More than 445 beetles species (8137 individuals) were counted, among which 198 taxa belonged to the saproxylic group (almost the same number of species) with 3483 individuals.

The relation between abundance of individuals and quantities of dead wood (volume or number of fragments) is positive but the regression coefficients are low (R^2 = 0.097 for the number of fragments and R^2 = 0.127 for the volume, see Fig. 1).

On the other hand, the relation is clearer between the taxonomic richness and the number of elements (R^2 = 0.335) while the volume seems to have a minor effect on the taxonomic richness (R^2 = 0.175).

In this first analysis, dead wood stocks characteristics of all forest types have been melted. One can expect that saproxylic species are occurring only in forests where suitable dead wood is present. That means for example forests with dead wood of the right host tree.

To investigate the influence of forest types on saproxylic beetles distribution, we used the IndVal program and selected all maximal individual values equal or superior to 50% and statistically significant at 5%. These indicator species ranged as figured in Fig. 2.

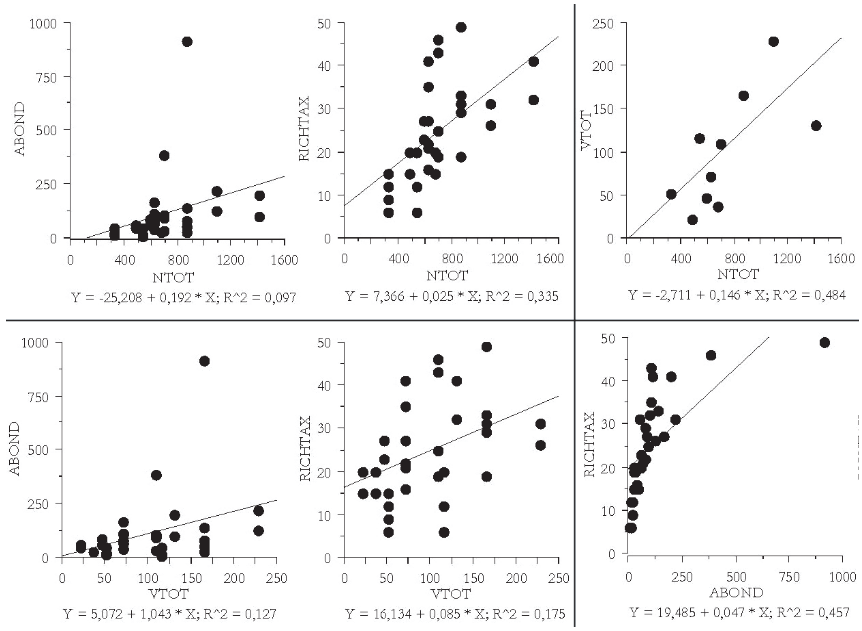

Figure 1. — Linear regressions between the dead wood volume/ha (VTOT), the number of pieces of dead wood/ha (NTOT), the abundance (ABOND) and the taxonomic richness (RICHTAX).

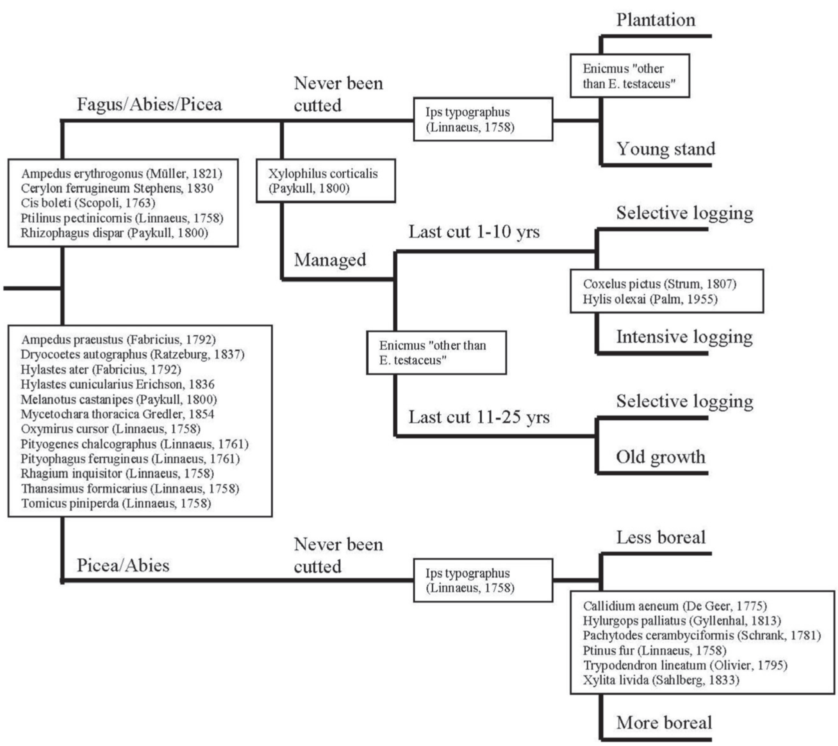

Figure 2. — Distribution of indicator species between forests types after the IndVal routine. Only species with IndVal ≥ 50% and statistically significant at 5% level are shown.

Species composition of forest types is strongly different between mixed forests with beech and spruce dominated forests without beech. Beech mixed forest are represented by species like *Ampedus erythrogonus*, *Cerylon ferrugineum*, *Ptilinus pectinicornis*, etc. while coniferous forests are dominated by *Ampedus praeustus*, *Melanotus castanipes*, *Mycetochara thoracica*, five Scolytidae and associated species, two Cerambycidae. In this second forest type, some species have a preference for the boreal climatic conditions while no species can be related to the more temperate part of the forest located at the slope base. Some of these species, like *Xylita livida*, are known to be boreal species.

Because of the lack of sampling replication in this study, mainly due to the weak quantity of traps, it is difficult to get detailed information with the IndVal method. Species belonging to the genus *Enicmus* are largely distributed among plantations and stands cut ten or twenty years before. *Coxelus pictus* and *Hylis olexai* seem to prefer recently cut stands with a strong management pressure. In these places, most of the woody debris is sun exposed because the canopy is largely open (this is not true for the stand managed with selective logging). Like these two species, the Eucnemid *Xylophilus corticalis* is indicating managed stands (*i.e.* regularly managed). This may surprise because this species is regularly found in stands with large amount of dead wood (Dodelin *et al.,* 2003). It must be noticed that these managed stands contain quantities of dead wood largely superior to what is usually observed in low altitude forests. It is a case of an artificial large supply of dead wood consecutively to wood exploitation.

DISCUSSION

The total volume of dead wood is used by many authors as a measurement of the diversity of the resources available for the saproxylic beetles. A traditional interpretation states that the habitats are multiplied when the total volume of dead wood increases at the forest scale or also at the dead wood fragment scale (Hilt & Ammer, 1994). This may enhance the possibilities of coexistence for the species. Thus, in the presence of greater quantities of dead wood one can expect to observe a greater diversity of saproxylic beetles (Sprecher-Uebersax, 1989; Økland *et al.,* 1996; Welti, 1998; Endrestøl, 2003). In our study, it seems that this relation is verified once again, since the number of dead wood elements, expressing the diversity of the dead wood habitats more precisely than the volume, is positively correlated with the taxonomic richness.

We showed that the forests had a strong individuality corresponding to the fuel composition and, in this particular study design, geographical area (because spruce forests are located in the centre of the Alps while mixed beech forests are on the Alps border). We have shown that it exists indicator species for each of these two forest types. Few taxa are related to banal forest stands like plantations. Some species belong expressly to the managed forests, indicating that the special features of mountain forests management, namely leaving on the floor stumps, branches and trunks parts with no commercial value, can have a positive impact on specific saproxylic beetles.

In the saproxylic beetles, the specificity for a host plant is more frequent in the groups initiating the disorganization of wood, which are mainly the xylophagous organisms. It is for example the case of the Scolytidae (Chararas, 1986). This specificity seems to decrease when the decomposition advances. In the Swedish red list of saproxylic beetles, the most recent decomposition class includes significantly more monophagous species than the second (43% against 31%) which includes some more than the third class (23%), the latter similar to the fourth class (Jonsell *et al.,* 1998). According to these reports, our observation of preferences for forest types raises new questions. For example, do mixed coniferous forests host more monophagous species than forests composed by broadleaved and coniferous trees? Are species hosted by hardwood mainly dependent on lignicolous fungi or on the fuel type of their woody hosts? Solving these questions will indubitably require more researches.

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