Zeitschrift: Mitteilungen der Schweizerischen Entomologischen Gesellschaft = Bulletin de la Société Entomologique Suisse = Journal of the Swiss Entomological Society

Herausgeber: Schweizerische Entomologische Gesellschaft

Band: 88 (2015)

Heft: 1-2

Artikel: A three years study of saproxylic biodiversity in an alluvial forest : deadwood, beetles and fungi of the Table-Ronde Island (Rhône, France) (Coleoptera)

Autor: Dodelin, Benoît / Rivoire, Bernard / Kaskarian, Anne

DOI: https://doi.org/10.5169/seals-514989

MITTEILUNGEN DER SCHWEIZERISCHEN ENTOMOLOGISCHEN GESELLSCHAFT
BULLETIN DE LA SOCIETE ENTOMOLOGIQUE SUISSE
88: 11–21, 2015

Papers of the 8th Symposium on the Conservation of Saproxylic Beetles
Basel (Switzerland), 13–15 June 2014

A three years study of saproxylic biodiversity in an alluvial forest: deadwood, beetles and fungi of the Table-Ronde Island (Rhône, France) (Coleoptera)

Benoît Dodelin[1], Bernard Rivoire[2] & Anne Kaskarian[3]

[1] 11 rue Montesquieu, F-69007 Lyon; benoit.dodelin@laposte.net
[2] 27 route de Jalloussieux, F-69530 Orliénas; bernard.rivoire@club-internet.fr
[3] Le Chatel, F-69440 Saint-André-la-Côte; kaskarian-anne@orange.fr

Deadwood stocks and the diversity of saproxylic beetles and fungi was studied in seven stands of the alluvial forest of the Rhône river. The volumes of deadwood ranged from 22 to 184 m^3/ha. The most represented trees by volume were Poplars. Deadwood resulted from large natural collapse of mature stands driven by storms or tree-by-tree in younger stands. 133 saproxylic beetle species and 107 saproxylic fungi were found in the study sites and 200 and 130 species, respectively, when considering the overall forest. Twenty beetle species were rare at the national level or red listed at the European level. Comparisons between saproxylic beetle communities suggested a decreasing similarity with the increasing distance between sites. For fungi, two species new for science were described in the material collected and 17 species were considered as rare at the national level. We found only a weak correlation between diversity of saproxylic species and the volume of deadwood. This is likely due to a sampling effect but also to the importance of deadwood quality rather than quantity.

Keywords: Saproxylic, Biodiversity, Riparian Forest, Inventory, Aphyllophorales, Coleoptera

INTRODUCTION

With a long history of use for navigation and capable of great floods, the Rhône River was strongly remodelled by humans during the nineteenth and early twentieth century (from 1838 to 1910). Those major developments had important effects on the river and its surroundings. Embankment, canalization, dams and urbanization have dramatically reduced alluvial forest extent. Some of the remaining forests are currently protected under various statutes and some of them are open to the public.

The first scientific recommendations used to restore the naturalness of these forests were hydrology, and the survey of vertebrates and plants. Deadwood and saproxylic organisms are the keys factors of the natural forests. Locally, the lack of knowledge about those elements is not compatible with the setting up of a good nature-oriented management. Moreover, they can serve as indicators of re-naturation of degraded sites. Therefore, a series of inventories was decided to establish a first evaluation of the local situation for deadwood and saproxylic fungi and beetles.

This paper presents our results obtained on the Table-Ronde Island and in the site of Millery. For the deadwood, we measured the total volumes and the major characteristics of the deadwood stocks, including the cause of death. From these results we estimate the recent continuity of deadwood supply of each site. The strength and completion of our inventories were tested when standard methods were used (beetles). For beetles and fungi, we drew a list of species and compared it with other similar sites. Rare and red-listed species were highlighted. We searched for relationships between diversity of beetles or fungi and volumes of deadwood obtained at the same place. Last, the communities of beetles were compared to check for their heterogeneity or homogeneity among sites.

Few elements were available for discussion and comparisons. Old publications indicate some beetle species that are now considered as extinct in the region of Lyon. For beetles, the first substantial study was conducted by Moulin & Viallier (1982, 1984a, 1984b) in the surroundings of Roussillon, 45 km south of Lyon. Closer to Lyon, the Table-Ronde Island has been studied by a nature protection organization in 2009 (FRAPNA 2010). In this place, we conducted our own beetle and saproxylic fungi inventories during the years 2011 and 2012, and then in the site of Millery in 2014. For saproxylic fungi, the comparison data come from the knowledge of one of us (BR), who, during 30 years, conducted informal researches on the whole island.

MATERIAL AND METHODS

Study areas were located along the Rhône river, about 10 km south of the city-centre of Lyon (France). They are managed by the "Syndicat Mixte du Rhône des îles et des Lônes" (SMIRIL), a syndicate which groups the Rhône department, the Grand Lyon and the municipalities of Feyzin, Grigny, Irigny, Millery, Sérézin-du-Rhône, Ternay and Vernaison. The management is nature-oriented with no wood exploita-

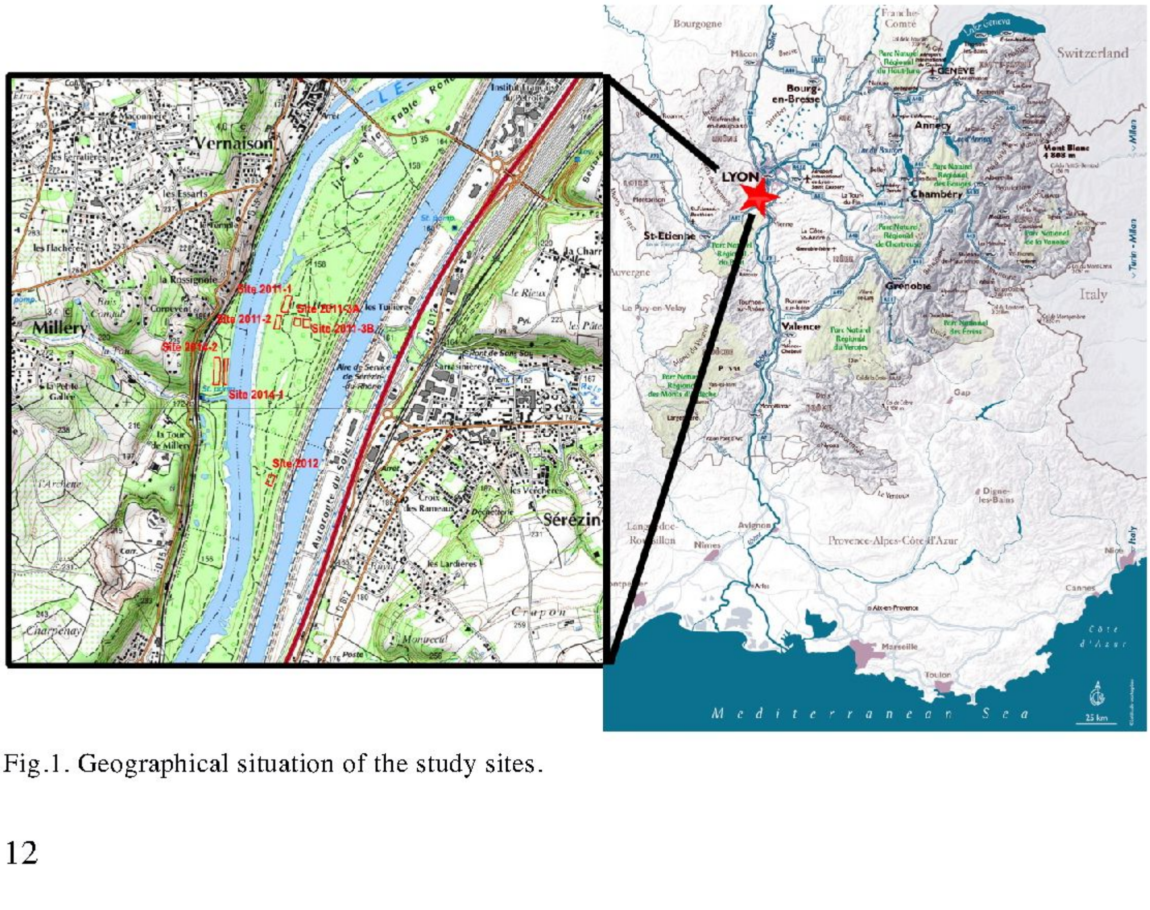

Fig.1. Geographical situation of the study sites.

Tab. 1. Elements measured during deadwood inventory (after Bruciamacchie 2005).

Elements	**Data collected**
Stump	Diameter (if $\geq$10 cm) and height (if $\geq$ 10 cm and < 130 cm)
Lying deadwood	Diameters (if $\geq$ 10 cm) and length (if $\geq$ 100 cm)
Standing deadwood	Diameters (if $\geq$ 10 cm) and height (if $\geq$ 130 cm)
Decay stage	1a: recent death (leaves still present, bark firmly attached)
	1b: recent death (wood without fungi but cambial zone is fermenting)
	1c: recent death (wood without fungi but cambial zone visible and dry)
	2: less than 1/3 of the diameter rotten
	3: between 1/3 and 2/3 of the diameter rotten
	4: 2/3 of the diameter to totally rotten
	5: totally rotten, general shape deconstructed, partly integrated in the soil
Tree species	
Cause of death	Mechanical breaking; died standing; uprooted; dead parts attached to a living tree; cut by man
Position on the ground	> 50% of the piece is lying; < 50% is lying; not in contact with the soil

tion for economical purpose. The two areas are open to the public and fit the category V of protection after the IUCN classification *).

We investigated 7 sites, distributed in the Table-Ronde Island (5 sites) and on the Rhône riverside (Millery, 2 sites) (Fig.1). On each site, we surveyed deadwood, beetles and saproxylic fungi.

Deadwood inventories followed the protocol of Bruciamacchie (2005), summarized in Tab. 1. It was applied for all woody debris occurring inside predefined areas of 2070 m² to 6800 m² (Tab. 2).

Beetles were inventoried using standard and non-attractive window traps (Økland 1996). We installed a total of 24 window traps for all sites and years (Tab. 2). Traps were activated from April to September, covering most of the flying period for beetles. They were emptied every fifteen days. The full inventory of the area was completed by means of small windows traps placed on saproxylic fungi (Kaila 1993) and seven days of hand searching. Thirty-six Kaila traps were used during 2011. They were distributed between *Fomes fomentarius* (Linnaeus) Fries, 1849 (9

Tab. 2. Study sites, surfaces, number of beetle traps and days of field survey for fungi.

Site	**Localization**	**Year**	**Area (deadwood)**	**Window traps (beetles)**	**Field days (fungi)**
Site 2011-1	Table-Ronde Island (middle)	2011	4250 m²	6	11 days
Site 2011-2	Table-Ronde Island (middle)	2011	3310 m²	0	
Site 2011-3A	Table-Ronde Island (middle)	2011	2070 m²	4	11 days
Site 2011-3B	Table-Ronde Island (middle)	2011	2340 m²	2	
Site 2012	Table-Ronde Island (south)	2012	2460 m²	6	7 days
Site 2014-1	Millery	2014	4100 m²	2	5 days
Site 2014-2	Millery	2014	6800 m²	2 (+2 neighbouring)	

*) www.iucn.org/about/work/programmes/gpap_home/gpap_quality/gpap_pacategories/

traps), *Trametella gallica* (Fries) Teixeira (1989) (8 traps), *Trametella trogii* (Berkeley) Domanski (1968) (11 traps), *Oxyporus latemarginatus* (Durieu & Montagne) Donk (1966) (3 traps) and *Daldinia concentrica* (Bolton ex Fries) Cesati & de Notaris (1863) (5 traps). Twelve Kaila traps were used in 2012: 4 on *Auricularia mesenterica* (Dickson) Persoon, 1822, 4 on *Fomes fomentarius* and 4 on *Trametella trogii*. Hand searching covered the sites dedicated to deadwood inventories and their surroundings.

Specimen identification was detailed at species level for most of the saproxylic beetles. We followed Alexander (2008) to define the group of saproxylic beetles. All specimens are conserved in the collection of Benoît Dodelin (Lyon). The taxonomy applied follows the taxonomic referential TAXREF 7 (MNHN 2003–2014).

The rarity score was given to every saproxylic species in accordance with the definitions of the patrimonial indexes given by Brustel (2001). The rarity scores range from 1 to 4:

1. Common and widely distributed species (easily observed);
2. Species sparse but widely distributed or localized but possibly abundant (difficult to see);
3. Species never abundant and localized (usually requiring specific sampling efforts);
4. Very rare species, known in less than 5 current locations or contained in a single department in France.

Saproxylic fungi were catalogued during field exploration. Between 5 and 11 days were spent in each site (Tab. 2). Basidiocarps unidentifiable in the field were sampled for detailed analysis in the laboratory. Some samples are conserved in the collection of Bernard Rivoire (University of Lyon I). The taxonomy applied follows www.mycobank.org.

Analysis of the recent continuity of deadwood supply used the «coarse woody debris profile» (Stokland 2001; Dodelin *et al.* 2004), that produces an information related to the dynamics of deadwood over time. Profiles were built with 4 categories of deadwood: «large diameters» (> 40 cm), versus «small diameters» (<40 cm), versus decay stage «recent» (decay classes 1A + 1B + 1C + 2), versus «old» (decay classes 3 + 4 + 5). Standard profiles have been defined by Stokland (2001), and several situations may arise in which the most common are:

- Strong continuity of deadwood supply, if, for each of the 4 deadwood categories, the volume is higher than 3 m^3/ha;
- Poor continuity of deadwood supply, if the volumes of small and large diameters are less than 3 m^3/ha in recent decay, and between 1 and 3 m^3/ha in old decay.

Analyses were performed on the software PAST v2.17c (Hammer 2012). Completion of the inventories was studied by means of accumulation curves produced with the function Sample Rarefaction in PAST. Linear correlations were searched between diversities of saproxylic fungi or saproxylic beetles, and deadwood volumes. Sets of saproxylic beetles found in each window trap were compared with non-metric multidimensional scaling (NMDS), analysis of similarities

(ANOSIM) and SIMPER (Similarity Percentage) (Clarke 1993, Hammer 2012). We used relative abundances, calculated as values divided by the Euclidean length of the row vector. NMDS is based on a distance matrix computed with Bray-Curtis Distance Measure. The data points are placed in a two-dimensional coordinate system in a way that the ranked differences are preserved. It indicates the quality of the result that should ideally be a straight ascending line (x=y) of dots. The R^2 values are the coefficients of determination between distances along each ordination axis and the original distances. ANOSIM is a non-parametric test of significant difference between two or more groups. It is based on the Bray-Curtis Distance Measure. It gives a coefficient of dissimilarity, R, that ranges between 0 and 1 (maximum of dissimilarity). SIMPER assesses which species are primarily responsible for an observed difference between groups of samples.

RESULTS

Deadwood Inventories

Among the 7 study sites, the volumes of deadwood ranged from 22 to 184 m^3/ha (Tab. 3). *Populus* spp. were the most represented trees in volume. In this area, poplars are fast-growing and able to reach large sizes in 50–70 years. At Millery in 2014, the volume of deadwood of the invasive Acer negundo was ca. 4.5 m^3/ha in each of the two sites. Most of the deadwood indicated as «broadleaves» in Tab. 3 may belong to this species.

The main death factor was mechanical breaking (61 % of the pieces). 19 % of the woody debris had died standing, 17 % had been uprooted, 3 % were dead parts attached to a living tree.

About 80 % of the deadwood was lying on the forest floor, while 20 % was standing or still attached to living trees.

Coarse woody debris profiles point to two sites with a strong continuity of deadwood (sites 2011-1 and 2011-3B, Tab. 4). In sites 2011-2, 2011-3A and 2011-3B, large woody debris has been noticed in advanced decay categories. The two sites studied in 2014 had a weak continuity for large deadwood, together with the site 2012. These forests do not host large dead woody debris, represented in categories «D>40 cm», even in «early decay», the category that includes large trees recently dead (Tab. 4).

Tab. 3. Deadwood inventories for the 7 study sites.

Site	Volume (m^3)	Volume/ha (m^3/ha)	Most represented tree (m^3/ha)
Site 2011-1	40.76 m^3	95.91 m^3/ha	*Populus* (83.22 m^3/ha)
Site 2011-2	12.66 m^3	38.24 m^3/ha	*Populus* (33.68 m^3/ha)
Site 2011-3A	38.25 m^3	184.78 m^3/ha	*Populus* (184.23 m^3/ha)
Site 2011-3B	32.85 m^3	140.37 m^3/ha	*Populus* (140.37 m^3/ha)
Site 2012	35.51 m^3	144.36 m^3/ha	*Populus* (116.23 m^3/ha)
Site 2014-1	9.27 m^3	22.60 m^3/ha	Broadleaves (15.72 m^3/ha)
Site 2014-2	15.38 m^3	22.62 m^3/ha	Broadleaves (8.92 m^3/ha)
Total	184.68 m^3	72.91 m^3/ha	

Tab. 4. Coarse woody debris profiles of the 7 study sites.

CWD profile Category	D<40 cm + early decay	D<40 cm + old decay	D>40 cm + early decay	D>40 cm + old decay	Deadwood continuity
Site 2011-1	4.50 m^3/ha	20.48 m^3/ha	34.57 m^3/ha	36.37 m^3/ha	Strong continuity
Site 2011-2	2.28 m^3/ha	13.34 m^3/ha	0.00 m^3/ha	22.62 m^3/ha	Recent gap for large trees
Site 2011-3A	6.07 m^3/ha	66.54 m^3/ha	0.68 m^3/ha	111.50 m^3/ha	Recent gap for large trees
Site 2011-3B	5.25 m^3/ha	62.26 m^3/ha	5.34 m^3/ha	67.52 m^3/ha	Good continuity
Site 2012	59.69 m^3/ha	33.75 m^3/ha	49.22 m^3/ha	1.69 m^3/ha	Old gap for large trees
Site 2014-1	9.19 m^3/ha	4.05 m^3/ha	9.36 m^3/ha	0.00 m^3/ha	Weak continuity for large trees
Site 2014-2	4.99 m^3/ha	10.06 m^3/ha	3.33 m^3/ha	4.24 m^3/ha	Weak continuity for large trees

Beetles Inventories

During the three years, the window traps collected 2326 specimens of 185 identified species (Tab. 5). Among them, 1086 individuals and 133 species were considered as saproxylic. The completion of the inventory realised with window traps was perfectible as shown by the accumulation curves that did not clearly reach a plateau for all species, nor for the saproxylic guild (Fig. 2 & Fig. 3).

The total of our observations was 5956 beetle specimens (231 species). This total includes windows traps, Kaila traps and hand searching. The addition of local data from 2009 extended the full inventory of the Table-Ronde Island to 302 species, of which 200 are saproxylic.

Overall, 20 beetles species found were rare or red-listed (Tab. 6) of which 5 need to be confirmed. One is considered as Endangered at European level: *Triplax lacordairii* Crotch, 1870 (Erotylidae), another is Vulnerable: *Cerophytum elateroides* (Latreille, 1809) (Cerophytidae) and 3 are near threatened. Very Rare species at regional level were *Scolytus koenigi* Schevyrew, 1890 (Scolytinae) and two Eucnemidae: *Nematodes filum* (Fabricius, 1801) and *Rhacopus sahlbergi* (Mannerheim, 1823).

The diversity of saproxylic beetles was not-significantly correlated with the deadwood volume (linear correlation $r=0.36904$; $p=0.63096$).

Multi-variables comparison indicated the overall tendency of a strong and significant dissimilarity between saproxylic communities (ANOSIM, $R=0.5614$, $p=0.0001$). When compared two by two, the communities were significantly different except for the geographically closest ones (sites 2011). The NMDS confirmed those results by showing a weaker difference between geographically neighbouring

Tab. 5. Abundance and diversity of beetles collected by window traps.

Sites	Abundance	Diversity	Abundance (saproxylics)	Diversity (saproxylics)
Site 2012	283	65	224	54
Site 2011-1 & 2	156	44	114	36
Site 2011-3A & 3B	528	92	312	79
Site 2014-1 & 2	593	102	436	65
Total	1560	185	1086	133

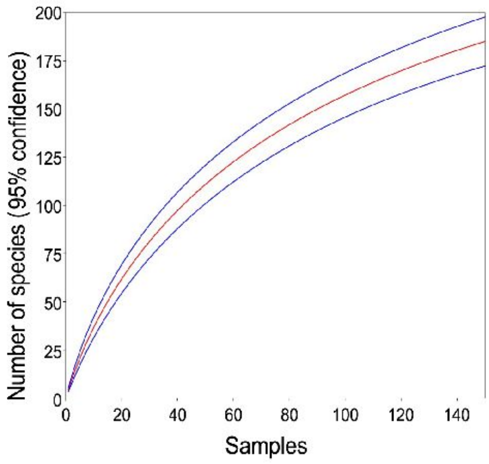

Fig. 2. Accumulation curves for all beetles collected by window traps during 3 years. One sample is one trap at one date.

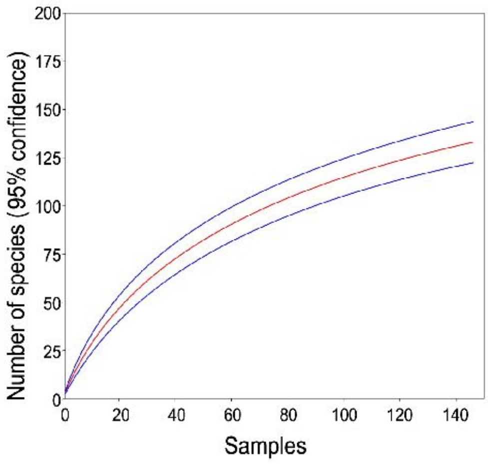

Fig. 3. Accumulation curves for saproxylic beetles collected by window traps during 3 years. One sample is one trap at one date.

sites and, conversely, a greater difference between remote sites (Fig. 4). The SIMPER method indicated 12 species responsible for 50 % of the cumulative variation (Tab. 7).

Tab. 6. Rare and red-listed species. European red list after Nieto & Alexander (2010); «Urwald» relics after Müller *et al*. (2005); Rarity after Dodelin (unpublished, see «Material and Methods»).
* Local data from 2009, species not confirmed thereafter. Abbreviations: EN: Endangered; VU: Vulnerable; NT: Near Threatened; LC: Least Concern; DD: Data Deficient.

Family	**Species**	**European red list**	**Urwald relics**	**Rarity**
Biphyllidae	*Biphyllus lunatus* (Fabricius, 1787)	0	0	3
Buprestidae	*Dicerca aenea* (Linnaeus, 1766)*	0	1	2
Buprestidae	*Dicerca alni* (Fischer, 1824)*	0	2	2
Cerambycidae	*Cerambyx cerdo* Linnaeus, 1758*	NT	2	3
Cerophytidae	*Cerophytum elateroides* (Latreille, 1804)	VU	0	3
Cetoniidae	*Protaetia speciosissima* (Scopoli, 1786)*	NT	0	3
Cucujidae	*Pediacus dermestoides* (Fabricius, 1792)	DD	2	2
Curculionidae	*Kissophagus novaki* Reitter, 1894	0	0	3
Curculionidae	*Scolytus koenigi* Schevyrew, 1890	0	0	4
Elateridae	*Brachygonus campadellii* Platia & Gudenzi, 2000	DD	0	3
Elateridae	*Drapetes mordelloides* Host, 1789	0	0	3
Erotylidae	*Triplax lacordairii* Crotch, 1870	EN	0	2
Eucnemidae	*Dromaeolus barnabita* (Villa, 1837)	LC	0	3
Eucnemidae	*Microrhagus emyi* (Rouget, 1856)	LC	0	3
Eucnemidae	*Nematodes filum* (Fabricius, 1801)	DD	1	4
Eucnemidae	*Rhacopus sahlbergi* (Mannerheim, 1823)	LC	0	4
Latridiidae	*Corticaria polypori* Sahlberg, 1900	0	0	3
Lucanidae	*Lucanus cervus* (Linnaeus, 1758)	NT	0	1
Tenebrionidae	*Prionychus ater* (Fabricius, 1775)*	0	0	3

Saproxylic Fungi Inventories

The survey of saproxylic fungi indicated 107 species. The total number of species reached 130 when all the surveys carried out at the Table-Ronde Island and Millery were pooled.

From our investigations, we described two species new for science: *Antrodiella pirumspora* Rivoire & Gannaz, 2012 and *Phlebia rhodana* Duhem & Rivoire, 2013. This follows the description of *Ceriporia alba* M. Pieri & B. Rivoire (1997) whose type specimen was found at the Table-Ronde Island.

Among the 130 species listed, 17 can be considered as rare for the country. Four match the IUCN criteria for the near threatened status at the national level: *Catinella olivacea* (Batsch) Boud., *Dendrothele griseocana* (Bres.) Bourdot & Galzin, *Fibricium subceraceum* (Hallenb.) Bernicchia, and *Phellinus igniarius* (L.) Quél. One species, *Phlebia rhodana* B. Duhem & B. Rivoire, is locally threatened because its host tree (*Salix* spp.), is disappearing from the forest, along with the regular flooding.

The correlation between deadwood volume and the diversity of saproxylic fungi was not significant (linear correlation $r=0.024113$; $p=0.9693$). The sites 2014-1 & 2 (Millery) were species-rich although the amounts of deadwood were very low. The sites 2014-1 & 2014-2 are densely populated by *Acer negundo* which hosts 24 species of saproxylic fungi, slightly more than *Salix* spp. (23 species). In the sites 2011 and 2012, the most colonized host is *Populus nigra* with 30 fungal species.

DISCUSSION

The deadwood inventories revealed a heterogeneity between studied stands. Differences concerned tree species composition, stand maturity and its recent history. In mature stands, large collapses of big poplars some years ago have created major stocks of deadwood, that are by now strongly decayed. But after those events, not

Tab. 7. SIMPER results for saproxylic beetles. Only species that contribute to the first 50% of cumulative variation are listed. Overall average dissimilarity is 88.65%.

Species	**Cumulative variation**	**Mean relative abundance**			
		Site 2012	**Site 2011-3A & 3B**	**Site 2011-1 & 2**	**Site 2014**
Xyleborus dispar (Fabricius, 1792)	8.13%	0.633	0.011	0	0.024
Enicmus rugosus (Herbst, 1793)	16.12%	0.121	0.314	0.574	0.025
Anobium hederae Ihssen, 1949	23.13%	0.051	0.191	0.228	0.28
Mycetochara linearis (Illiger, 1794)	30.09%	0.157	0.098	0	0.394
Dasytes plumbeus (Müller, 1776)	34.24%	0	0.04	0	0.329
Xyleborinus saxesenii (Ratzeburg, 1837)	37.74%	0	0.081	0.195	0.102
Anaspis rufilabris (Gyllenhall, 1827)	40.56%	0.057	0.114	0.13	0.006
Melanotus villosus (Fourcroy, 1785)	43.30%	0.05	0.152	0.111	0.013
Biphyllus lunatus (Fabricius, 1787)	45.39%	0	0.088	0.112	0
Dasytes niger (Linnaeus, 1767)	47.37%	0	0.045	0.151	0
Cortinicara gibbosa (Herbst, 1793)	49.23%	0.071	0.066	0	0.066
Ptilinus pectinicornis (Linnaeus, 1758)	50.94%	0.075	0.079	0.016	0.044

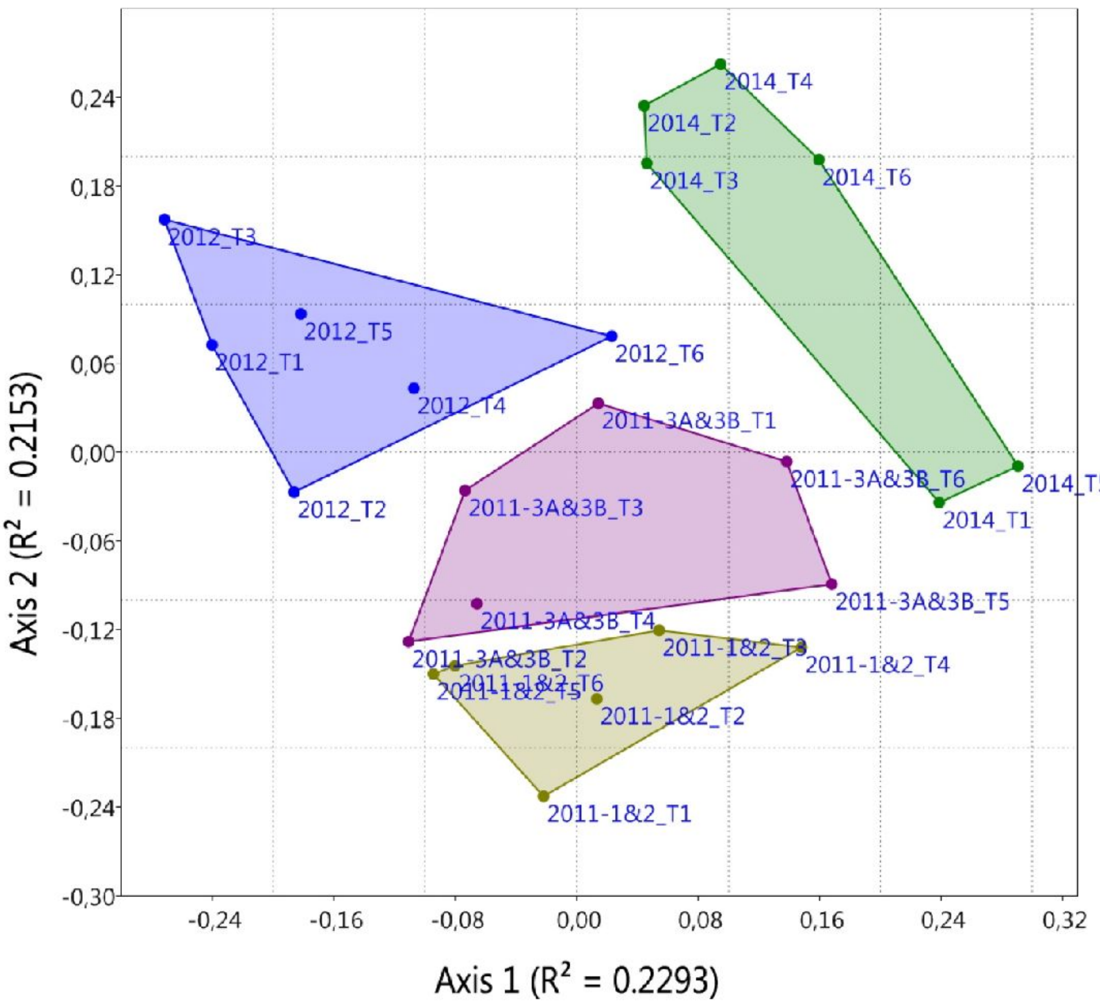

Fig. 4 (left). Non-metric multidimensional scaling of saproxylic beetles. Total stress: 0.2569.

enough large living trees were left standing to continue to supply the coarse woody debris stock, creating a recent gap for large trees. The other situation, observed in the youngest stands and in stands rich in *Acer negundo*, was the creation of small woody debris, tree by tree, at the individual scale. Those sites showed a weak continuity for large dead wood.

We found an interesting diversity of saproxylic beetles (133 species) and fungi (107 species), including rare and red listed species. Those diversities correspond to our other observations with similar techniques in alluvial forests of the Rhône river. The total diversity of fungi (130 species) represents half of the known diversity for polyporous fungi in the Rhône-Alpes region (total of 260, see Rivoire 2010). Because of the relative homogeneity of the studied sites, we consider those 130 species as a high diversity. However, when we compare this situation with diversities we encounter in other alluvial forests of the Rhône river (Îles des Noyés, Molottes), we can expect the Corticiaceae s.l. group to be twice as diverse. This arises from the important number of species in the Corticiaceae, the most important in our studied fungi group with around 950 species in France. In addition, the Corticiaceae are often small, insignificant, hidden and demand a long systematic research that takes time and a large number of days of field work, especially on such a vast territory.

There was a weak correspondence between the measured deadwood volumes and the diversity of saproxylic communities. The factors that affect the saproxylic communities are to be sought in the quality of the deadwood and in the site history and its spatial connection with other forests (Lassauce *et al.* 2011; Heilmann-Clausen & Christensen 2004). The spatial connection among study sites may need more investigations. As we found that the similarity between saproxylic beetle communities decreased when the distance between sites increased, one can question the dispersal efficiency of those species. It seems as if the communities had very little exchange of species between them.

Some new questions need to be examined, such as the presence of thermophilic species. This raises the question of the relationship between the islands and the adjacent dry hillsides; especially about the exchange of species between these two forest types. We also detected species whose distribution was only known from much further south (e.g. *Scolytus koenigi, Synchita mediolanensis*). Can it be the consequence of the local climate warming? There are also signs of a gradual transition of the alluvial forest towards a drier forest with the arrival of oak 20 years ago. Our data do not actually reflect this change, which would require regular monitoring.

ACKNOWLEDGMENTS

The SMIRIL funded all of our studies. We would like to thank all those who were involved in this research program: P. Athanaze, S. Tabarand, O. Kristo, R. Saurat, la Brigade verte de Rhône Insertion Environnement, D. Bouteille, M. Kireeff, J. Trannoy, J. Cavet, E. Bidaud, J. André, F. Dämmrich, G. Trichies, N. Van Vooren. Thanks to the two referees and to S. Barbalat for her careful proofreading.

RESUME

Sept peuplements de la forêt alluviale du Rhône ont été étudiés pour évaluer les stocks de bois mort et la diversité des coléoptères et champignons saproxyliques. Les volumes de bois mort relevés vont de 22 à 184 m^3/ha. Les arbres les plus représentés en volume, sont les peupliers. Le bois mort est principalement recruté par de grands effondrements de peuplements matures provoqués par des épisodes de vents forts. Mais dans les peuplements plus jeunes, cela intervient arbre par arbre. 133 espèces de coléoptères et 107 espèces de champignons saproxyliques ont été trouvées dans les sites étudiés et, respectivement, 200 et 130 espèces saproxyliques en tenant compte de toutes les données disponibles pour la forêt. Chez les coléoptères, 20 espèces sont rares au niveau national ou placées sur la liste rouge européenne. L'analyse indique une différence entre communautés de coléoptères saproxyliques d'autant plus grande que les sites sont éloignés. Pour les champignons, deux nouvelles espèces pour la science ont été décrites à partir du matériel collecté tandis que 17 espèces sont considérées comme rares au niveau national. Nous n'avons trouvé qu'une faible correspondance entre la diversité des espèces saproxyliques et le volume de bois mort. Cela pourrait provenir d'un effet d'échantillonnage mais aussi de l'importance de la qualité plutôt que la quantité de bois mort.

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(received January 31, 2015; accepted March 24, 2015; published June 30, 2015)