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Evaluation of window flight traps for effectiveness at monitoring dead wood associated beetles: the effect of ethanol lure under contrasting environmental conditions

Running title: Baited window flight traps and saproxylic beetles

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Abstract

1. Since the species-rich group of saproxylic beetles has been proposed to be used as a factor in forest management, more explicit knowledge about the efficiency and selective properties of beetle sampling methods is needed.

2. We compared saproxylic beetle assemblages caught by alcohol-baited or unbaited window traps in different forest contexts. Considering that trap attractiveness depends on kairomone concentrations, we appraised whether the trap efficiency was influenced by trap environment (openness and local supply of fresh dead wood).

3. Saproxylic beetles were sampled using 48 cross-vane window flight traps, arranged in paired designs (alcohol-baited/unbaited), in 8 ancient and 8 recent gaps (open stands), and 8 closed-canopy control stands in an upland beech forest in the French Pyrenees.

4. Baited traps were more efficient than unbaited devices in terms of abundance and richness in our deciduous forests. The ethanol lure did not have any repellent effect on the individual response of saproxylic taxa.

5. The influence of local environmental conditions on trap attractiveness was observed. The effects of variations in openness were actually moderate, whereas trap attractiveness appeared to be reduced in the alcohol-saturated environment of recent gaps due to a disruption by local fresh dead-wood concentrations of the kairomonal response of saproxylic beetles to baited traps ('alcohol disruption').

6. Since the ethanol lure globally enhances species detection probability (no repellent effect, many individual attractive effects), it may be extensively used in programs of early-warning surveillance, monitoring and control of wood borers. We recommend to account for the slight influences of local conditions on baited trap efficiency while using them for beetle biodiversity monitoring.

Introduction

Forest management practices currently include many nature conservation measures in favour of fauna and flora. Nonetheless, in managed forest ecosystems, the dead wood component has been severely reduced by intensive forestry and still is under-represented (Siitonen, 2001).

Since considerable effort is devoted to preserving dead wood and the associated fungi and fauna involved in the wood decaying process, we need an explicit ecological assessment of the performance of forestry measures designed to increase deadwood.

Saproxylic beetles have been widely studied over the past 20 years, especially in northern and central Europe, and have been proposed as indicator species of forest integrity (Speight, 1989 ; Nilsson et al., 2001) because they are highly dependent on dead wood and have been particularly affected by forest management practices (e.g. Siitonen, 2001 and references therein). They make up one of the largest groups of red-listed species, and they represent many different functional groups (Siitonen, 2001).

As saproxylic beetles are diverse, and mainly small and cryptic, their study is very challenging. If we want to use saproxylic beetles as a management tool in forestry (evaluation of practices, biodiversity monitoring schemes), we need much more explicit knowledge about the efficiency and selective properties of sampling methods.

Several different methods are generally used to collect saproxylic beetles. These are (i) direct active hand-collecting techniques, including peeling, sifting the bark of dead trees and beating dead wood, (ii) rearing techniques (log emergence traps, Owen traps, eclectors, extraction cylinders) and (iii) trapping methods such as interception or attractive (coloured, silhouette, chemo-attractive) traps (Leather, 2005). Window-flight trapping (WFT), also called Flight-Intercept Trapping (FIT), window/ barrier trapping or collision trapping), developed by Chapman & Kinghorn Peck & Davies, 1980), is currently the most frequently used technique for catching active flying saproxylic beetles (Økland, 1996 ; Wikars et al., 2005 ; Alinvi et al., 2007). Window flight traps consist of a vertical barrier to insect flight that is considered invisible to the insect. On hitting the barrier, most beetles drop down and fall into a collection container with liquid preservatives.

Although interception traps do not give accurate information about the local habitat, they have proved to be satisfactory in many respects. Compared with extraction methods they offer reliable means of replication and standardization, and give a representative picture of saproxylic beetle fauna (Siitonen, 1994*)*.

From the original simple model of flight-interception trap, modifications have been proposed concerning the dimensions, colour, shape, bait… For instance, window-flight traps may be fitted with an attractant dispenser to increase catches of dead wood associated beetles (Brustel, 2004).

Dead wood associated species have evolved behavioral responses to volatile host-plant chemicals that indicate the presence of a suitable host (i.e. kairomones). It is well known that ethanol, a volatile compound released by micro-organisms in decaying woody tissue (mainly in fresh tissues ; Cade et al., 1970) and stressed plants (Kimmerer & Kozlowski, 1982), acts as a foraging kairomone (used in the context of food location ; Döring, 1955; Ruther et al., 2002). It is therefore attractive to a wide variety of species of dead wood associated beetles (Montgomery & Wargo, 1983 ; Lindelöw et al., 1992), including early- (Nordlander et al., 1986 ; Byers, 1989) and late-successional saproxylic species (Jonsell et al., 2003), and beetles associated with dead wood from deciduous (Roling & Kearby, 1975) or conifer trees (Magema et al., 1982 ; Chénier & Philogène, 1989).

Previous studies have already demonstrated the general effects of ethanol as a lure in attractive window flight traps (Berti & Flechtmann, 1986; Shibata et al., 1996). In this study comparing two sampling techniques in paired designs, we first intended to confirm and detail the differences in catches between alcohol-baited and unbaited traps under field conditions.

Secondly, we wanted to assess whether the catches of dead wood associated beetles in alcohol-baited or unbaited traps are influenced by local environmental conditions. Indeed, we need standardized unbiased methods to study the effects of forest management practices and compare open (e.g. felling areas) and closed-canopy stands; ideally saproxylic beetle detectability should not change with habitat structure. We thus asked the two following questions.

(i) Did the difference between the two methods (alcohol-baited and unbaited traps) remain constant in open gaps or closed-canopy stands? From Schroeder and Lindelöw (1989), release rates of chemicals are known to affect the attraction. We may assume that kairomone volatility, and therefore trap attractiveness, increases with stand openness. In this perspective, the difference between baited and unbaited traps would be expected to be higher in open areas than in closed-canopy stands. This bias variation between stands would call into question the between-stand comparison using alcohol-baited traps.

(ii) Did the difference between the two methods remain constant whether or not the close trap surroundings were poor or rich in naturally emitted ethanol from fresh or decaying dead wood?

We may assume that trap attractiveness is influenced by the alcohol concentration in the atmosphere surrounding the trap. In recent sun-exposed gaps, the high volumes of fresh dead wood release a large amount of ethanol, which may lead to a saturated olfactory landscape and therefore to a reduction in the capture efficiency of the trap attractant. Due to an alcohol disruption, we hypothesize that the differences between paired baited and unbaited traps would be lower in recent gaps than in both old gaps and forest controls where the local atmosphere is not alcohol-saturated.

Material and methods

Study areas and sampling designs

Our investigations were carried out in an upland beech forest in the central French Pyrenees, in the National Orlu Reserve, about 150 km south of Toulouse. Altitude ranged from 1600 m to 1750 m. The selected plots were 100 to 140 year-old beech stands, and had previously been exploited for charcoal by coppicing.

The balanced sampling design included three types of stands: 8 ancient gaps, 8 recent gaps (open stands) and 8 forest controls (closed-canopy stands). The 16 gaps were originally dedicated to the monitoring of conservation measures in favour of the Western capercaillie (*Tetrao urogallus*, L. 1758). Ancient and recent gaps were created in 1999 and 2004 respectively; they were circular in shape and ca 0.05 ha in area. Distance between gaps varied from 80 m to 1000 m. Cut trees were left in all gaps but only recent gaps had high amounts of recent (freshly-cut) dead wood. In parallel, a transect of 8 forest control plots was set up in closed-canopy beech stands, where the cover was quite dense (basal area = 23 m²/ha, stem density = 300 stems/ha, mean dbh = 25cm, mean height=15m) and the understory very poor.

Beetle sampling

Beetles were sampled with a multidirectional Polytrap^{TM} (Brustel, 2004), a cross-vane window flight trap with a cumulative panel area of 1 m² ((Fig. 1). For the preservation of insects, containers were half-filled with a salt mixture. A detergent was added to reduce surface tension. Two traps were set in each plot, one baited with an alcohol lure (1:10 ethanol released from a dispenser) and one unbaited trap. Alcohol lure is known to attract hardwood-feeding species (Mongomery & Wargo, 1983).

Fig. 1

Overall, 24 pairs of Polytraps^{TM} were set up in 2004, from May 15 to August 30 in recent and ancient gaps and closed-canopy beech stands. The traps were emptied every two weeks.

Collected specimens were stored in alcohol and we identified them to species level. Several amateur entomologists helped with the identification on the following families: Anobiidae, Curculionidae, Dasytidae, Melyridae, Mordellidae, Pselaphidae, Scolytinae, Scraptiidae, Staphylinidae. The nomenclature follows the online FaunaEuropaea database (www.faunaeur.org). We pooled the data for the entire sampling period.

Data processing

The two sampling methods were compared in terms of total saproxylic beetle abundance, cumulative species number per trap, family and species abundance per trap (cumulated over the trapping periods).

Linear mixed-model ANOVA tests (Pinheiro & Bates, 2000) were carried out to check for differences in abundance and species richness between the two trap types in each paired comparison. The plot variable was classified as a spatial random effect to take the pairing pattern of the sampling design into account. Some differences were exceptionally tested by Wilcoxon signed-rank tests. Species and families represented by fewer than 30 individuals were not tested.

The effects of the interaction between bait and two factors on total abundance and abundance of alcohol-attracted taxa (in our data), species richness were assessed. The three stand types of the study were clustered using two different grouping factors. First, to study the influence of stand openness on trap attractiveness, we compared the difference between paired baited and unbaited traps in open (recent and ancient gaps) or closed-canopy stands. We analysed this difference through the interaction effect in linear mixed-model ANOVAs (bait*openness). Second, to study the influence of local fresh dead wood concentrations on trap attractiveness, we examined the difference (baited - unbaited) in fresh dead-wood rich (recent gaps) or poor (ancient gaps and forest controls) stands. The F-test of the interaction effect (bait*stand type) in linear mixed-model ANOVAs was followed by a multiple comparison post hoc Tukey test of the mean value of this difference.

Graphs include multipanel boxplots displaying the distribution of data according to the two factors bait*environment, or simple boxplots showing the numerical difference (baited-unbaited) for different environment types.

Non-Metric Multidimensional Scaling (NMDS) based on the Bray-Curtis dissimilarity was used for pattern recognition in species composition and the ANOSIM procedure was carried out to test for differences in assemblage composition between trap types (Clarke, 1993). Before calculation of the Bray-Curtis distance matrix, species represented by only 1 individual were discarded and abundance data were (ln+1) transformed.

ANOVA, NMDS and ANOSIM were performed using S.Plus 7.0.

RESULTS

When baited with alcohol, window flight traps were more selective: the ratio (number of saproxylic beetles/number of beetles) reached 85.8% in baited traps but was only 69.4% in unbaited traps. A total of 12,211 saproxylic beetles were identified during the study, including 196 species.

Comparison of effectiveness between alcohol-baited and unbaited traps

Alcohol-baited or unbaited traps significantly differed in effectiveness. The catches of saproxylic beetles were significantly affected by the alcohol lure (mixed-model ANOVA $F_{(1,23)}$= 66.48, p<0.0001; Table 1). Overall, more than twice as many saproxylic beetle individuals were captured in alcohol-baited traps as in unbaited traps (Table 1).

Tab. 1

Similarly, significantly more saproxylic species were caught in alcohol-lured traps than in unbaited (ANOVA $F_{(1,23)}$= 68.65, p<.0001 ; Table 1). The richness per trap was 40% higher in baited traps than in unbaited traps (Table 1). From the ordination plot of the Bray-Curtis distance matrix between samples (Fig. 2), the species composition of saproxylic beetle assemblages caught with or without an alcohol lure clearly differed. Samples from baited or unbaited traps were obviously separated in ordination space. This distinction was consistent with the results of the ANOSIM test (10 000 permutations, R=0.65, p<0.0001). The average Bray-Curtis dissimilarity between baited and unbaited traps reached a value of 44%.

Fig. 2

In accordance with this global dissimilarity, important specific differences were noticed. For several families and species (Cryptophagidae (*Cryptophagus* spp.), Staphylinidae (*Paraphloeostiba gayndahensis, Aleochara sparsa*), Salpingidae (*Rhinosimus ruficollis, R. planirostris, Rabocerus foveolatus*)), significantly more individuals were caught in baited traps than in unbaited traps (mixed-model ANOVA; Table 2). *Rhizophagus* spp. (Monotomidae) was more abundant in baited traps compared with unbaited traps, whereas Cleridae were not affected by trap bait. Amongst xylophagous taxa, Scolytidae (*Ernoporicus fagi*, *Xyloterus signatus, X. domesticus, Xyleborus saxesenii*) and Lymexylidae (*Hylecoetus dermestoides*) were more abundantly caught in baited traps, whereas Cerambycidae, Anobiidae, Melyridae were not sensitive to alcohol bait.

No species or family was significantly more abundant in unbaited traps.

Tab. 2

Comparison of effectiveness between alcohol-baited and unbaited traps in open or closed-canopy stands

The difference between alcohol-baited and unbaited traps in open (gaps) or closed-canopy stands may be interpreted first in terms of abundance or species richness. As shown in figure 3, saproxylic beetle abundance in both baited and unbaited traps was higher in open sites than in closed-canopy controls. The difference in abundance between baited and unbaited devices was only slightly higher in open plots; in other words, the bait-openness interaction effect was quite moderate (mixed-model ANOVA test $F_{2,21}$= 5.17, p=0.015).

Fig. 3

The difference in species richness between baited and unbaited traps was not significantly influenced by the openness of trap environment (Fig. 3: mixed-model ANOVA test of the bait-openness interaction effect: $F_{2,21}$= 3.23, p=0.060).

For several taxa noticed to be sensitive to the alcohol attractant (see above), i.e. Monotomidae, Scolytidae and Lymexylidae as a whole, the difference baited-unbaited was not affected by the environment closure. Two families (Cryptophagidae, i.e. *Cryptophagus* spp., and Salpingidae), and 4 species (*Rabocerus foveolatus, Rhinosimus ruficollis, Rhinosimus planirostris, Aleochara sparsa*) showed a significant difference baited-unbaited, but not in compliance with the hypothesis of a bait-openness interaction. The difference was indeed lower in open stands than in closed-canopy plots (fig. 4). Only the bark beetle species *Xyloterus domesticus* showed a significant and higher difference baited-unbaited in open stands.

Fig. 4

In conclusion, the difference between alcohol-baited and unbaited traps was not increased greatly by the openness of trap environment.

Comparison of effectiveness between alcohol-baited and unbaited traps in fresh dead wood poor or rich stands

Regarding this potential bait-environment interaction effect, the difference between alcohol-baited and unbaited traps was only slightly influenced by the local volume of fresh woody debris releasing alcohol kairomones. The baited-unbaited difference in fresh dead wood poor (ancient gaps and controls) or rich stands (recent gaps) was examined in terms of total abundance, species richness, family and species abundances.

Fig. 5

In figure 5, the difference between baited and unbaited lures in terms of abundance and species richness seems to be slightly lower in gaps rich in recent fresh dead wood. Nevertheless, this bait-environment interaction effect was only slightly significant on saproxylic beetle abundance (mixed-model ANOVA, $F_{2,35} = 4.84$, $p = 0.014$). The only significant pairwise difference was observed between ancient and recent gaps (Multiple comparison Tukey test), the difference being larger in ancient gaps. This bait-environment interaction did not significantly affect species richness in traps (mixed-model ANOVA, $F_{2,35} = 1.66$, $p = 0.204$).

Fig. 6

A bait-environment interaction effect was observed on the abundance of several families and species known to be sensitive to the ethanol attractant (fig. 6). The baited-unbaited differences were lower in recent gaps than in ancient gaps and forest controls for the abundance of Salpingidae (and the species *Rhinosimus ruficollis* in particular) (multiple comparison Tukey test). Similarly, we observed a smaller yet still significant baited-unbaited difference for the abundance of Cryptophagidae and *Rhinosimus planirostris* in recent gaps compared with closed-canopy stands. For *Rabocerus foveolatus, Aleochara sparsa, Xyloterus signatus*, the difference was less in recent gaps than in closed-canopy controls (but the difference between ancient or recent gaps was not significant). No difference was measured for Scolytidae as a whole (and *Xyloterus domesticus, Ernoporicus caucasicus, Xyleborus saxesenii* in particular), Lymexylonidae, Staphylinidae (peculiarly *Paraphloeostiba gayndahense*) and Monotomidae (*Rhizophagus* spp. in particular).

Discussion

Alcohol lure effect

The results from our study confirm that ethyl alcohol, acting as a kairomone released from decaying woody tissues, strongly attracts some beetles associated with dead hardwood (Montgomery & Wargo, 1983) and suggests that an ethanol lure strengthens the effectiveness of window-flight traps in deciduous forests. Indeed, more than twice as many saproxylic beetles, representing a 40% higher species richness, were captured in alcohol-baited traps as in unbaited traps. Assemblages were globally dissimilar between baited and unbaited devices, mainly because more species were caught in baited traps. It is very important to stress that we did not detect any species or family significantly more abundant in unbaited traps. We may therefore infer that the ethanol lure did not have any inhibiting or repellent effect.

In our methodological approach in beech forests, the individual responses of dead-wood taxa to alcohol lure were actually heterogeneous. As previously demonstrated by Byers (1992), significantly more individuals of *Rhizophagus* spp. (Monotomidae) were caught in baited traps than in unbaited traps. Host tree chemicals are known to be important to *Rhizophagus* species in finding their habitat (scolytid galleries). Conversely, natural enemies such as Cleridae were not affected by trap bait in our study. Likewise, Schroeder (2003) pointed out that two *Thanasimus* clerid species preying on several bark beetle species differ in their response to α-pinene and ethanol. Our results showed that the abundance of ambrosia and bark beetles was about 4 times as high in alcohol-baited traps, in agreement with previous findings (Magema et al., 1982 ; Berti & Flechtmann, 1986 ; Poland et al. 2004). Amongst the other wood-feeding taxa, Cerambycidae were not sensitive to alcohol bait, which had been shown previously by Sweeney et al. (2004). Conversely, Döring (1955) demonstrated that ethanol acts as a kairomone for the longhorned beetle *Cerambyx cerdo*. Among the fungus feeders, unlike Tetratomidae, Melandryidae and Ciidae, only Cryptophagidae were significantly attracted by the alcohol lure, as was the tenebrionid studied by Jonsell et al. (2003).

Interaction effects between trap attractant and trap environment

Some results did not comply with the hypothesized bait-openness interaction. Five species showed a significant lower baited-unbaited difference in open areas. Moreover, the baited-unbaited difference in species richness and in abundance of the other alcohol-attracted taxa was not significantly influenced by the openness of trap environment. Only the total saproxylic beetle abundance and the abundance of the bark beetle *Xyloterus domesticus* were in accordance with the hypothesis of an increased baited-unbaited difference in open areas compared with closed-canopy stands. In other words, trap attractiveness appeared to increase only slightly, but not significantly, with stand openness, even though canopy cover may strongly influence kairomone volatility. However, such an interaction effect was reported by Honek (1988), between crop density and an attractant in pitfall traps, on catches of epigaeic arthropods.

Apart from openness, another environmental factor separated the plots into groups. Indeed, recent gaps, ancient gaps and forest controls differed in terms of local volume of fresh dead wood. We hypothesized that the high volume of fresh dead wood in recent sun-exposed gaps would release a large amount of ethanol, which could saturate the beetle's olfactory landscape around the traps and therefore reduce trap attractiveness. In accordance with this hypothesis, the baited-unbaited difference was lower in recent and fresh dead wood rich gaps for some assemblage parameters. Though this bait-environment interaction was slight, it significantly affected the total abundance of saproxylic beetles, the abundance of several families and species known to be sensitive to the ethanol attractant (Salpingidae, *Rhinosimus ruficollis* and *Rhinosimus planirostris* in particular, Cryptophagidae). Conversely, the response of species richness and abundance of the other families (such as Scolytidae) to traps was not influenced by the local volume of fresh dead wood.

The alternative hypothesis of a “mass effect”, i.e. a stronger attractiveness of baited traps in the alcohol-rich atmosphere of recent gaps, was thus invalidated. These results may be related to a phenomenon that could be called ‘alcohol disruption’ (in the spirit of the ‘mating disruption’; Ruther et al., 2002), i.e. the disruption by local fresh dead-wood concentrations of the kairomonal response of saproxylic beetles to baited traps. Nonetheless, even though trap attractiveness appeared to be reduced in an alcohol-saturated environment, baited traps remain more efficient than unbaited devices in terms of abundances and richness. They have the capacity to sample the pool of saproxylic beetles in recent gaps.

Conclusion - Implications for saproxylic beetle sampling

Even though the extrapolation of our findings from upland forests to other climatic contexts should be done with care, their interpretation may help with the optimization of the two types of forest beetle monitoring.

The first type, i.e. monitoring and control of forest pest populations and early-warning surveillance programs to detect invasive wood borers, aim at maximizing detection probability. We demonstrated that the ethanol lure does not have any repellent effect but significantly attracts several wood feeders. Like the New Zealand monitoring programme for invasive wood-feeders (Brockerhoff et al., 2006), effective sampling designs may use the large spectrum of ethanol attractiveness.

The second type, i.e. biodiversity surveys of saproxylic beetle diversity in monitoring networks or evaluation studies of forest management practices, implies distinct constraints. To compare the biodiversity between stands or to assess trends in saproxylic beetle diversity over broader landscapes, ideally saproxylic beetle detectability should not change with habitat structure. A variation in trap efficiency as a function of any stand environmental parameter would call into question an inter-site comparison. For instance, a relation between trap efficacy and stand openness would prevent the comparison of open (e.g. felling areas) and closed-canopy stands with alcohol-baited traps, or studies on the influence of shading for the attractiveness of dead wood (Hjältèn et al., 2007). Our results show slight interaction effects between trap attractant and trap environment. A very moderate bait-openness interaction effect was measured, whereas trap attractiveness appeared to be reduced in an alcohol-saturated environment, through a disruption by local fresh dead-wood concentrations of the kairomonal response of saproxylic beetles to baited traps ('alcohol disruption').

In accordance with these results and although alcohol-baited traps appeared to be more efficient than unbaited devices, we recommend to take care to use baited brine or glycol solution used as a preservative fluid does not vary with forest stands.

Beside the attractant, other trap parameters, such as colour and shape, should be assessed for optimization and standardization and have been partly examined in another study (Bouget et al., in press).

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Figure legends

Figure 1

Design of the cross-vane window flight trap used during the study

Figure 2

NMDS ordination plot of the Bray-Curtis dissimilarity matrix of baited (AL) and unbaited (NAL) samples. The two axes with highest correlation to bait factor are represented. 4-dimension stress = 0.153. ANOSIM test (10 000 permutations) confirmed the difference of assemblages ($R=0.65$, $p<0.0001$).

Figure 3

Mean abundance (a) and species richness (b) per trap of saproxylic beetles in baited (AL) and unbaited (NAL) traps in open (MO) or closed-canopy (MF) stands. Linear mixed-model ANOVA F-test significance of the interaction effect between bait and openness: ** $p<0.01$, * $0.01<p<0.05$, ns $p>0.05$.

Figure 4

Mean difference in abundance per trap of saproxylic beetle families (a) and species (b) between baited (AL) and unbaited (NAL) traps in open (MO) or closed-canopy (MF) stands. Mann-Whitney test significance: ** $p<0.01$, * $0.01<p<0.05$, ns $p>0.05$. Only species and families including more than 30 individuals were tested.

Figure 5

Mean species richness (a) and abundance (b) per trap of saproxylic beetles in baited (AL) and unbaited (NAL) traps in fresh dead wood poor stands [forest controls (F) and ancient gaps (TA)] and fresh dead wood rich stands [recent gaps (TR)]. Linear mixed-model ANOVA test significance: ** $p<0.01$, * $0.01<p<0.05$, ns $p>0.05$. Mean difference in richness (c) and abundance (d) between baited and unbaited traps in fresh dead wood poor stands [F, TA] and fresh dead wood rich stands [TR]. Different letters indicate significant differences between means after a post-hoc Tukey test ($p=0.01$).

Figure 6

Mean difference in abundance per trap of saproxylic beetle families (a) and species or genera (b) between baited and unbaited traps in fresh dead wood poor stands [forest controls (F) and ancient gaps (TA)] and fresh dead wood rich stands [recent gaps (TR)]. Linear mixed-model ANOVA test significance: ** $p<0.01$, * $0.01<p<0.05$, ns $p>0.05$. Different letters indicate significant differences between means after a post-hoc Tukey test ($p=0.01$). Only species and families including more than 30 individuals were tested.

Tables

Table 1

Differences between baited (AL) and unbaited (NAL) traps, in terms of saproxylic beetle abundance, species richness. Test significance: ** p<0.01, * 0.01<p<0.05, ns p>0.05. Differences were tested by linear mixed-model ANOVA F-tests. Mean values are expressed +/- Standard Deviation.

Taxa	Alcohol-baited traps	Unbaited traps	
Abundance	*331,417 +/- 156,330*	*143,750 +/- 55,155*	$F_{(1,23)}$=66,482 **
Species richness	*43,125 +/- 9,768*	*31,458 +/- 8,827*	$F_{(1,23)}$=68,649 **

Table 2

Mean abundance per trap of saproxylic beetle species and families in baited (AL) and unbaited (NAL) traps. Linear mixed-model ANOVA test significance: ** p<0.01, * 0.01<p<0.05, ns p>0.05. Mean values are expressed +/- Standard Deviation.

Taxa	Alcohol-baited traps	Unbaited traps	$F_{(1,23)}$ ^{p}
LEIODIDAE	1,125 +/- 1,424	1,625 +/- 2,123	F=1,274 ^{ns}
STAPHYLINIDAE	*49,458 +/- 28,290*	*34,667 +/- 19,325*	*F=15,243* **
Aleochara sparsa	*1,833 +/- 1,711*	*0,167 +/- 0,637*	*F=27,688* **
Eusphalerum angustum	29,542 +/- 26,132	30,500 +/- 19,638	F=1,908 ^{ns}
Paraphloeostiba gayndahense	*9,958 +/- 8,175*	*0,375 +/- 0,576*	*F=198,854* **
Leptusa pulchella	0,958 +/- 1,301	0,500 +/- 0,780	F=1,929 ^{ns}
LUCANIDAE	0,625 +/- 0,824	0,833 +/- 1,007	F=0,512 ^{ns}
Sinodendron cylindricum	0,542 +/- 0,658	0,750 +/- 0,847	F=0,682 ^{ns}
EUCNEMIDAE	1,250 +/- 2,345	0,667 +/- 1,049	F=0,414 ^{ns}
Melasis buprestoides	1,250 +/- 2,345	0,667 +/- 1,049	F=0,467 ^{ns}
ELATERIDAE	1,667 +/- 1,903	2,292 +/- 1,944	F=1,422 ^{ns}
Idolus picipennis	0,917 +/- 1,501	1,375 +/- 1,610	F=2,293 ^{ns}
ANOBIIDAE	26,500 +/- 22,043	24,042 +/- 22,160	F=0,141 ^{ns}
Grynobius planus	0,917 +/- 1,558	1,167 +/- 2,160	F=0,012 ^{ns}
Hemicoelus costatus	7,292 +/- 8,961	7,250 +/- 7,731	F=0,000 ^{ns}
Ptilinus pectinicornis	16,500 +/- 20,061	12,458 +/- 15,704	F=0,280 ^{ns}
Ptinomorphus imperialis	0,458 +/- 0,932	0,958 +/- 3,458	F=0,043 ^{ns}
Xestobium plumbeum	1,333 +/- 1,494	2,083 +/- 5,579	F=0,209 ^{ns}
LYMEXYLIDAE	*6,333 +/- 10,639*	*0,375 +/- 1,279*	*F=38,526* **
Hylecoetus dermestoides	*6,333 +/- 10,639*	*0,375 +/- 1,279*	*F=41,528* **
CLERIDAE	0,917 +/- 1,283	1,042 +/- 1,459	F=0,053 ^{ns}
Tillus elongatus	0,917 +/- 1,283	1,042 +/- 1,459	F=0,125 ^{ns}
MELYRIDAE	12,792 +/- 12,646	8,875 +/- 8,295	F=0,617 ^{ns}
MALACHIIDAE	2,000 +/- 2,537	3,292 +/- 3,196	F=3,651 ^{ns}
MONOTOMIDAE	*2,417 +/- 2,263*	*0,250 +/- 0,442*	*F=60,460* **
Rhizophagus spp.	*2,375 +/- 2,281*	*0,167 +/- 0,381*	*F=57,873* **
CRYPTOPHAGIDAE	*14,625 +/- 14,984*	*5,917 +/- 5,823*	*F=17,544* **
Cryptophagus spp.	*14,125 +/- 15,103*	*5,833 +/- 5,880*	*F=14,091* **
LATRIDIIDAE	8,625 +/- 6,851	6,000 +/- 5,703	F=3,009 ^{ns}
MYCETOPHAGIDAE	1,750 +/- 1,539	1,042 +/- 1,083	F=2,757 ^{ns}
CIIDAE	5,667 +/- 5,346	5,208 +/- 5,073	F=0,143 ^{ns}
TETRATOMIDAE	3,583 +/- 3,202	2,625 +/- 3,609	F=4,037 ^{ns}
Tetratoma ancora	3,583 +/- 3,202	2,625 +/- 3,609	F=4,037 ^{ns}
MELANDRYIDAE	2,250 +/- 2,592	1,542 +/- 1,615	F=1,850 ^{ns}
Melandrya caraboides	0,958 +/- 1,398	0,792 +/- 1,285	F=0,456 ^{ns}
MORDELLIDAE	1,333 +/- 3,199	1,083 +/- 1,909	F=0,337 ^{ns}
Tomoxia bucephala	0,917 +/- 2,586	0,917 +/- 1,886	F=0,316 ^{ns}
SALPINGIDAE	*89,417 +/- 44,071*	*3,417 +/- 2,165*	*F=162,552* **
Rabocerus foveolatus	*4,750 +/- 3,650*	*0,208 +/- 0,588*	*F=82,129* **
Rhinosimus planirostris	*53,167 +/- 25,426*	*1,583 +/- 1,248*	*F=486,084* **
Rhinosimus ruficollis	*31,458 +/- 18,967*	*1,583 +/- 1,472*	*F=201,812* **
SCRAPTIIDAE	2,292 +/- 2,510	2,458 +/- 1,719	F=1,540 ^{ns}
Anaspis rufilabris	1,417 +/- 1,213	1,792 +/- 1,587	F=0,428 ^{ns}
CERAMBYCIDAE	10,375 +/- 7,471	9,792 +/- 7,396	F=0,042 ^{ns}
Clytus arietis	1,625 +/- 2,143	1,042 +/- 1,654	F=2,878 ^{ns}
Oxymirus cursor	1,625 +/- 2,018	1,542 +/- 1,250	F=0,065 ^{ns}
Rhagium bifasciatum	3,542 +/- 3,176	3,958 +/- 3,862	F=0,007 ^{ns}
Rhagium mordax	1,417 +/- 1,349	1,667 +/- 2,160	F=0,005 ^{ns}
SCOLYTIDAE	*81,417 +/- 127,180*	*22,583 +/- 21,040*	*F=23,698* **
Ernoporicus caucasicus	*18,667 +/- 37,632*	*4,417 +/- 4,452*	*F=10,469* **
Taphrorychus bicolor	53,083 +/- 125,971	17,208 +/- 20,121	F=0,586 ^{ns}
Xyleborus saxesenii	*4,792 +/- 3,683*	*0,042 +/- 0,204*	*F=107,812* **
Xyloterus domesticus	*2,000 +/- 2,284*	*0,125 +/- 0,448*	*F=22,674* **
Xyloterus signatus	*1,792 +/- 2,021*	*0,000 +/- 0,000*	*F=32,427* **

Figures

Figure 1

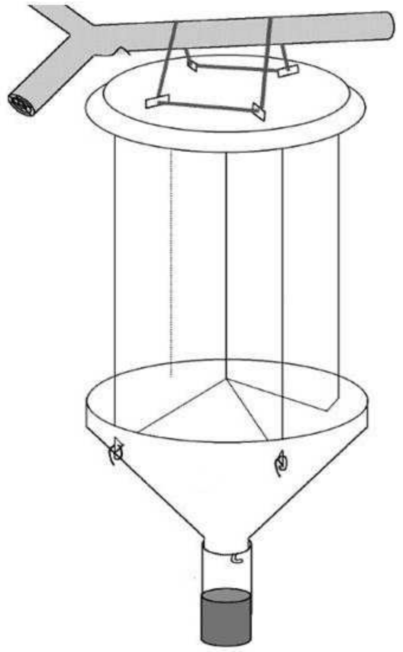


Figure 2

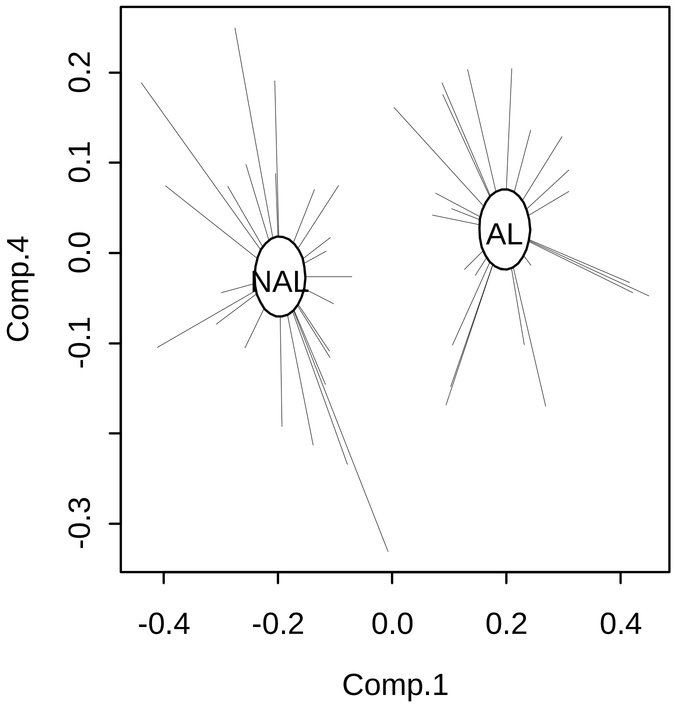


Figure 3

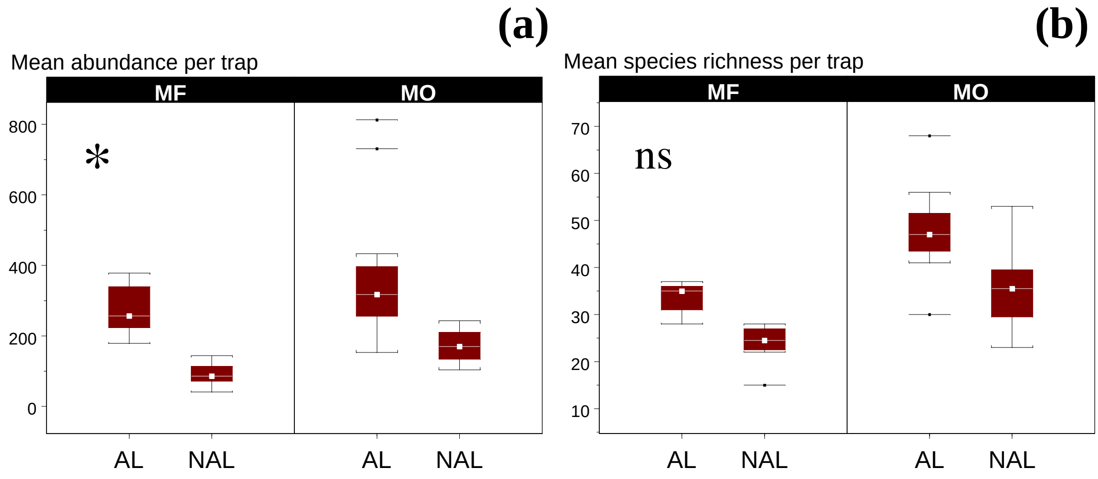
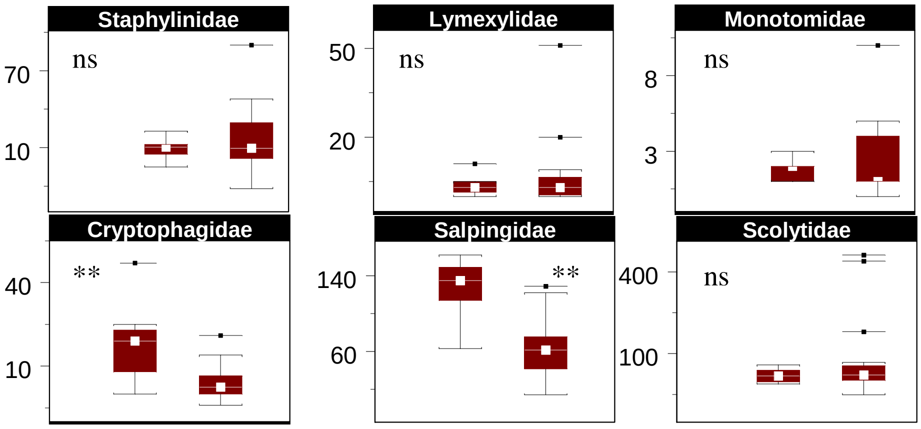

(a)
Mean abundance per trap
MF
MO
800
600
400
200
0
*
AL
NAL
AL
NAL
(b)
Mean species richness per trap
MF
MO
70
60
50
40
30
20
10
ns
AL
NAL
AL
NAL

Figure 4

(a) Families

Difference in abundance



(b) Species

Difference in abundance

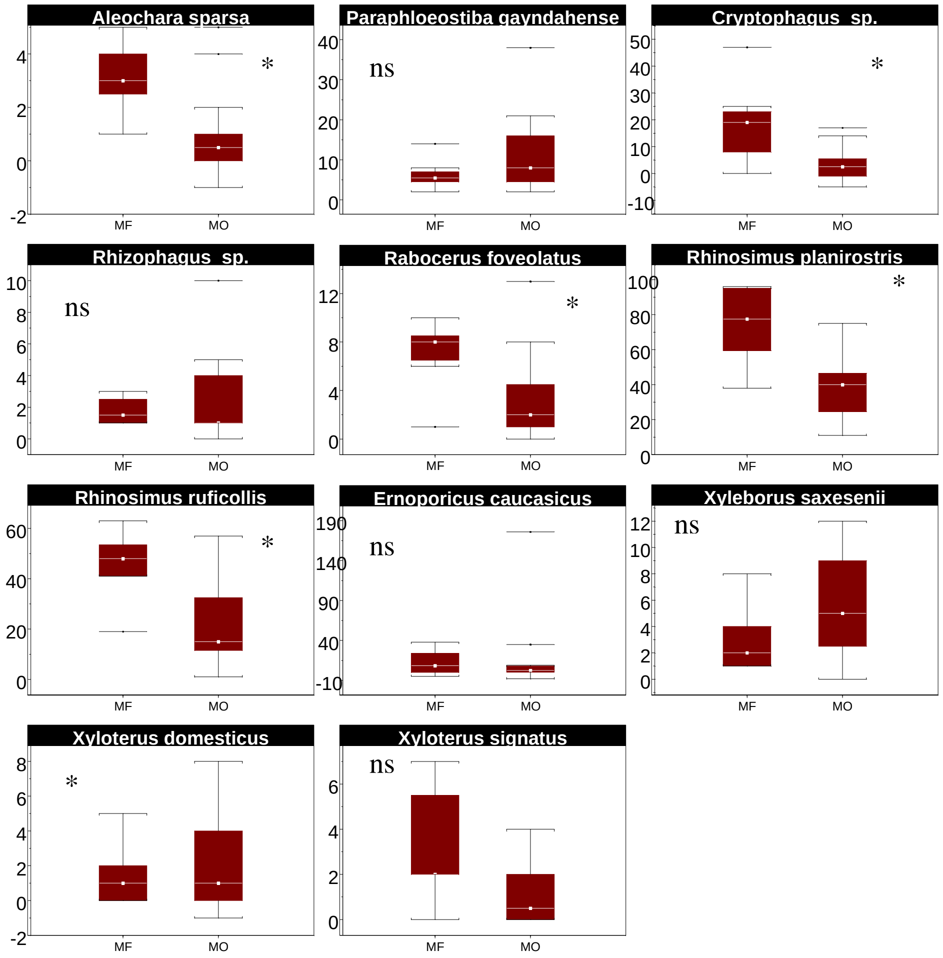


Figure 5

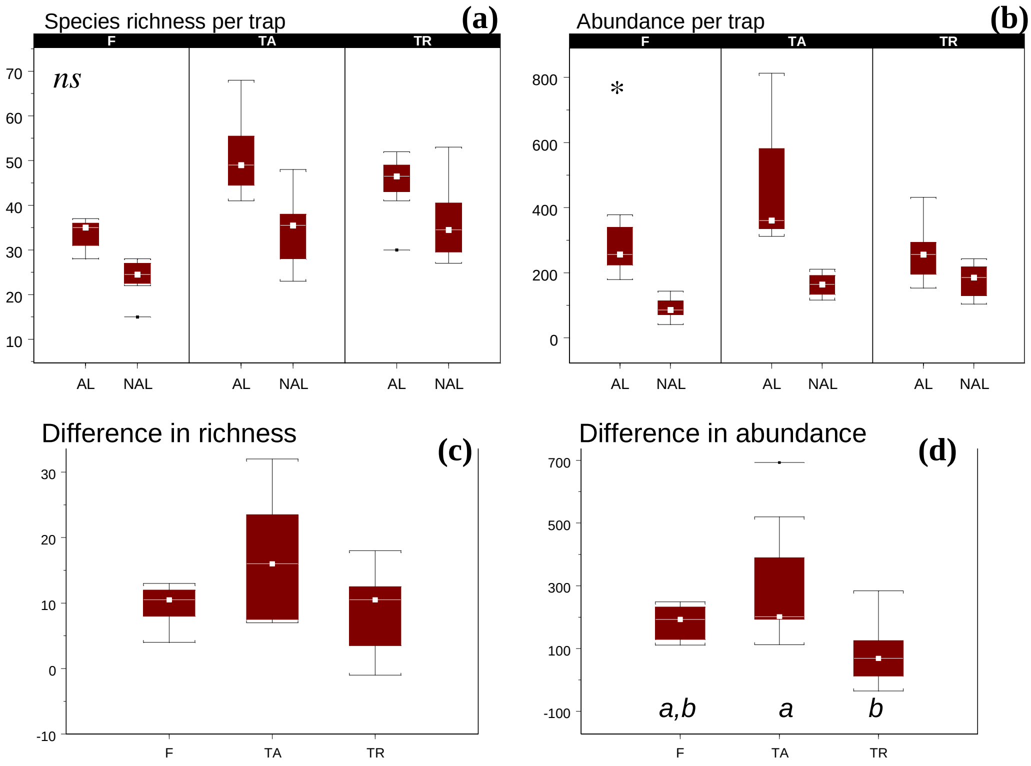
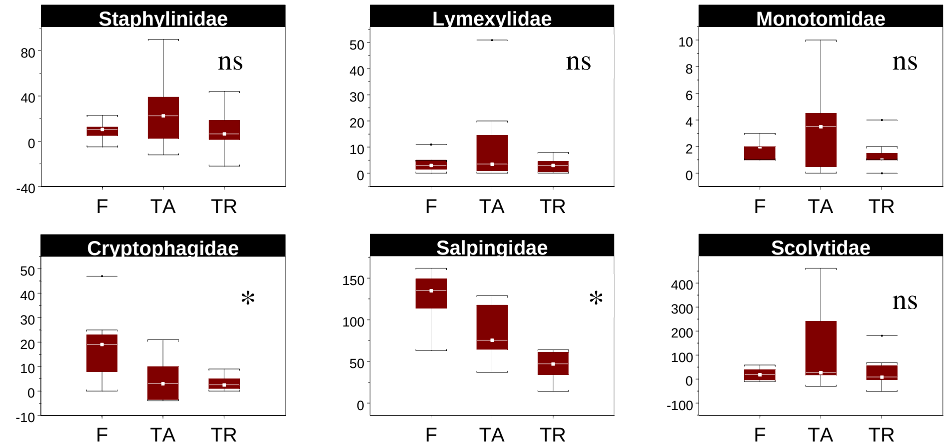

Species richness per trap
(a)
F
TA
TR
ns
70
60
50
40
30
20
10
AL
NAL
AL
NAL
AL
NAL
Abundance per trap
(b)
F
TA
TR
*
800
600
400
200
0
AL
NAL
AL
NAL
AL
NAL
Difference in richness
(c)
30
20
10
0
-10
F
TA
TR
Difference in abundance
(d)
700
500
300
100
-100
a,b
a
b
F
TA
TR

Figure 6

(a) Families
Differences in abundance



(b) Species
Differences in abundance