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

C. Bouget, H. Brustel, A. Brin, L. Valladares

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6   associated beetles: the effect of ethanol lure under contrasting environmental

7   conditions

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10 Running title: Baited window flight traps and saproxylic beetles

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13 Bouget, C.(1)*, Brustel, H.(2), Brin, A.(2), Valladares, L.(2)

14

15

16 (1) Institute for engineering in agriculture and environment (Cemagref) - Research

17 Unit "Forest ecosystems" - Domaine des Barres F-45290 Nogent-sur-Vernisson

18 christophe.bouget@cemagref.fr

19

20 (2) Ecole d'Ingénieurs de Purpan (EIP) - 75 Voie du TOEC F-31076 TOULOUSE

21 cedex 3 herve.brustel@esa-purpan.fr, antoine.brin@esa-purpan.fr,

22 lionel.valladares@esa-purpan.fr

23

24 * corresponding author

25

27

Abstract

28

29 1. Since the species-rich group of saproxylic beetles has been proposed to be used as

30 a factor in forest management, more explicit knowledge about the efficiency and

31 selective properties of beetle sampling methods is needed.

32 2. We compared saproxylic beetle assemblages caught by alcohol-baited or unbaited

33 window traps in different forest contexts. Considering that trap attractiveness

34 depends on kairomone concentrations, we appraised whether the trap efficiency was

35 influenced by trap environment (openness and local supply of fresh dead wood).

36 3. Saproxylic beetles were sampled using 48 cross-vane window flight traps,

37 arranged in paired designs (alcohol-baited/unbaited), in 8 ancient and 8 recent gaps

38 (open stands), and 8 closed-canopy control stands in an upland beech forest in the

39 French Pyrenees.

40 4. Baited traps were more efficient than unbaited devices in terms of abundance and

41 richness in our deciduous forests. The ethanol lure did not have any repellent effect

42 on the individual response of saproxylic taxa.

43 5. The influence of local environmental conditions on trap attractiveness was

44 observed. The effects of variations in openness were actually moderate, whereas trap

45 attractiveness appeared to be reduced in the alcohol-saturated environment of recent

46 gaps due to a disruption by local fresh dead-wood concentrations of the kairomonal

47 response of saproxylic beetles to baited traps ('alcohol disruption').

48 6. Since the ethanol lure globally enhances species detection probability (no repellent

49 effect, many individual attractive effects), it may be extensively used in programs of

50 early-warning surveillance, monitoring and control of wood borers. We recommend

51 to account for the slight influences of local conditions on baited trap efficiency while

52 using them for beetle biodiversity monitoring.

53   Introduction

54   Forest management practices currently include many nature conservation measures

55   in favour of fauna and flora. Nonetheless, in managed forest ecosystems, the dead

56   wood component has been severely reduced by intensive forestry and still is under-

57   represented (Siitonen, 2001).

58   Since considerable effort is devoted to preserving dead wood and the associated

59   fungi and fauna involved in the wood decaying process, we need an explicit

60   ecological assessment of the performance of forestry measures designed to increase

61   deadwood.

62   Saproxylic beetles have been widely studied over the past 20 years, especially in

63   northern and central Europe, and have been proposed as indicator species of forest

64   integrity (Speight, 1989 ; Nilsson et al., 2001) because they are highly dependent on

65   dead wood and have been particularly affected by forest management practices (e.g.

66   Siitonen, 2001 and references therein). They make up one of the largest groups of

67   red-listed species, and they represent many different functional groups (Siitonen,

68   2001).

69   As saproxylic beetles are diverse, and mainly small and cryptic, their study is very

70   challenging. If we want to use saproxylic beetles as a management tool in forestry

71   (evaluation of practices, biodiversity monitoring schemes), we need much more

72   explicit knowledge about the efficiency and selective properties of sampling

73   methods.

74

75   Several different methods are generally used to collect saproxylic beetles. These are

76   (i) direct active hand-collecting techniques, including peeling, sifting the bark of

77   dead trees and beating dead wood, (ii) rearing techniques (log emergence traps,

78   Owen traps, eclectors, extraction cylinders) and (iii) trapping methods such as

79   interception or attractive (coloured, silhouette, chemo-attractive) traps (Leather,

80   2005). Window-flight trapping (WFT), also called Flight-Intercept Trapping (FIT),

81   window/ barrier trapping or collision trapping), developed by Chapman & Kinghorn

82   Peck & Davies, 1980), is currently the most frequently used technique for catching

83   active flying saproxylic beetles (Økland, 1996 ; Wikars et al., 2005 ; Alinvi et al.,

84   2007). Window flight traps consist of a vertical barrier to insect flight that is

85   considered invisible to the insect. On hitting the barrier, most beetles drop down and

86   fall into a collection container with liquid preservatives.

87   Although interception traps do not give accurate information about the local habitat,

88   they have proved to be satisfactory in many respects. Compared with extraction

89   methods they offer reliable means of replication and standardization, and give a

90   representative picture of saproxylic beetle fauna (Siitonen, 1994).

91

92   From the original simple model of flight-interception trap, modifications have been

93   proposed concerning the dimensions, colour, shape, bait… For instance, window-

94   flight traps may be fitted with an attractant dispenser to increase catches of dead

95   wood associated beetles (Brustel, 2004).

96   Dead wood associated species have evolved behavioral responses to volatile host-

97   plant chemicals that indicate the presence of a suitable host (i.e. kairomones). It is

98   well known that ethanol, a volatile compound released by micro-organisms in

99   decaying woody tissue (mainly in fresh tissues ; Cade et al., 1970) and stressed

100   plants (Kimmerer & Kozlowski, 1982), acts as a foraging kairomone (used in the

101   context of food location ; Döring, 1955; Ruther et al., 2002). It is therefore attractive

102   to a wide variety of species of dead wood associated beetles (Montgomery & Wargo,

103   1983 ; Lindelöw et al., 1992), including early- (Nordlander et al., 1986 ; Byers,

104   1989) and late-successional saproxylic species (Jonsell et al., 2003), and beetles

105   associated with dead wood from deciduous (Roling & Kearby, 1975) or conifer trees

106   (Magema et al., 1982 ; Chénier & Philogène, 1989).

107   Previous studies have already demonstrated the general effects of ethanol as a lure in

108   attractive window flight traps (Berti & Flechtmann, 1986; Shibata et al., 1996). In

109   this study comparing two sampling techniques in paired designs, we first intended to

110   confirm and detail the differences in catches between alcohol-baited and unbaited

111   traps under field conditions.

112   Secondly, we wanted to assess whether the catches of dead wood associated beetles

113   in alcohol-baited or unbaited traps are influenced by local environmental conditions.

114   Indeed, we need standardized unbiased methods to study the effects of forest

115   management practices and compare open (e.g. felling areas) and closed-canopy

116   stands; ideally saproxylic beetle detectability should not change with habitat

117   structure. We thus asked the two following questions.

118   (i) Did the difference between the two methods (alcohol-baited and unbaited traps)

119   remain constant in open gaps or closed-canopy stands? From Schroeder and

120   Lindelöw (1989), release rates of chemicals are known to affect the attraction. We

121   may assume that kairomone volatility, and therefore trap attractiveness, increases

122   with stand openness. In this perspective, the difference between baited and unbaited

123   traps would be expected to be higher in open areas than in closed-canopy stands.

124   This bias variation between stands would call into question the between-stand

125   comparison using alcohol-baited traps.

126

127 (ii) Did the difference between the two methods remain constant whether or not the

128 close trap surroundings were poor or rich in naturally emitted ethanol from fresh or

129 decaying dead wood?

130 We may assume that trap attractiveness is influenced by the alcohol concentration in

131 the atmosphere surrounding the trap. In recent sun-exposed gaps, the high volumes

132 of fresh dead wood release a large amount of ethanol, which may lead to a saturated

133 olfactory landscape and therefore to a reduction in the capture efficiency of the trap

134 attractant. Due to an alcohol disruption, we hypothesize that the differences between

135 paired baited and unbaited traps would be lower in recent gaps than in both old gaps

136 and forest controls where the local atmosphere is not alcohol-saturated.

137

138 **Material and methods**

139 **Study areas and sampling designs**

140 Our investigations were carried out in an upland beech forest in the central French

141 Pyrenees, in the National Orlu Reserve, about 150 km south of Toulouse. Altitude

142 ranged from 1600 m to 1750 m. The selected plots were 100 to 140 year-old beech

143 stands, and had previously been exploited for charcoal by coppicing.

144 The balanced sampling design included three types of stands: 8 ancient gaps, 8 recent

145 gaps (open stands) and 8 forest controls (closed-canopy stands). The 16 gaps were

146 originally dedicated to the monitoring of conservation measures in favour of the

147 Western capercaillie (*Tetrao urogallus*, L. 1758). Ancient and recent gaps were

148 created in 1999 and 2004 respectively; they were circular in shape and ca 0.05 ha in

149 area. Distance between gaps varied from 80 m to 1000 m. Cut trees were left in all

150 gaps but only recent gaps had high amounts of recent (freshly-cut) dead wood. In

151 parallel, a transect of 8 forest control plots was set up in closed-canopy beech stands,

152   where the cover was quite dense (basal area = 23 m²/ha, stem density = 300 stems/ha,

153   mean dbh = 25cm, mean height=15m) and the understory very poor.

154   **Beetle sampling**

155   Beetles were sampled with a multidirectional Polytrap^{TM} (Brustel, 2004), a cross-

156   vane window flight trap with a cumulative panel area of 1 m² ((Fig. 1). For the

Fig. 1

157   preservation of insects, containers were half-filled with a salt mixture. A detergent

158   was added to reduce surface tension. Two traps were set in each plot, one baited with

159   an alcohol lure (1:10 ethanol released from a dispenser) and one unbaited trap.

160   Alcohol lure is known to attract hardwood-feeding species (Mongomery & Wargo,

161   1983).

162   Overall, 24 pairs of Polytraps^{TM} were set up in 2004, from May 15 to August 30 in

163   recent and ancient gaps and closed-canopy beech stands. The traps were emptied

164   every two weeks.

165   Collected specimens were stored in alcohol and we identified them to species level.

166   Several amateur entomologists helped with the identification on the following

167   families: Anobiidae, Curculionidae, Dasytidae, Melyridae, Mordellidae, Pselaphidae,

168   Scolytinae, Scraptiidae, Staphylinidae. The nomenclature follows the online

169   FaunaEuropaea database (www.faunaeur.org). We pooled the data for the entire

170   sampling period.

171

172   **Data processing**

173   The two sampling methods were compared in terms of total saproxylic beetle

174   abundance, cumulative species number per trap, family and species abundance per

175   trap (cumulated over the trapping periods).

176   Linear mixed-model ANOVA tests (Pinheiro & Bates, 2000) were carried out to

177   check for differences in abundance and species richness between the two trap types

178   in each paired comparison. The plot variable was classified as a spatial random effect

179   to take the pairing pattern of the sampling design into account. Some differences

180   were exceptionally tested by Wilcoxon signed-rank tests. Species and families

181   represented by fewer than 30 individuals were not tested.

182   The effects of the interaction between bait and two factors on total abundance and

183   abundance of alcohol-attracted taxa (in our data), species richness were assessed. The

184   three stand types of the study were clustered using two different grouping factors.

185   First, to study the influence of stand openness on trap attractiveness, we compared

186   the difference between paired baited and unbaited traps in open (recent and ancient

187   gaps) or closed-canopy stands. We analysed this difference through the interaction

188   effect in linear mixed-model ANOVAs (bait*openness). Second, to study the

189   influence of local fresh dead wood concentrations on trap attractiveness, we

190   examined the difference (baited - unbaited) in fresh dead-wood rich (recent gaps) or

191   poor (ancient gaps and forest controls) stands. The F-test of the interaction effect

192   (bait*stand type) in linear mixed-model ANOVAs was followed by a multiple

193   comparison post hoc Tukey test of the mean value of this difference.

194   Graphs include multipanel boxplots displaying the distribution of data according to

195   the two factors bait*environment, or simple boxplots showing the numerical

196   difference (baited-unbaited) for different environment types.

197   Non-Metric Multidimensional Scaling (NMDS) based on the Bray-Curtis

198   dissimilarity was used for pattern recognition in species composition and the

199   ANOSIM procedure was carried out to test for differences in assemblage

200   composition between trap types (Clarke, 1993). Before calculation of the Bray-Curtis

201   distance matrix, species represented by only 1 individual were discarded and

202   abundance data were (ln+1) transformed.

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

204

205   **RESULTS**

206   When baited with alcohol, window flight traps were more selective: the ratio

207   (number of saproxylic beetles/number of beetles) reached 85.8% in baited traps but

208   was only 69.4% in unbaited traps. A total of 12,211 saproxylic beetles were

209   identified during the study, including 196 species.

210

211   **Comparison of effectiveness between alcohol-baited and unbaited traps**

212   Alcohol-baited or unbaited traps significantly differed in effectiveness. The catches

213   of saproxylic beetles were significantly affected by the alcohol lure (mixed-model

214   ANOVA $F_{(1,23)}= 66.48$, $p<0.0001$; Table 1). Overall, more than twice as many

215   saproxylic beetle individuals were captured in alcohol-baited traps as in unbaited

216   traps (Table 1).

Tab. 1

    Similarly, significantly more saproxylic species were caught in alcohol-lured traps

218   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

Fig. 2

220   plot of the Bray-Curtis distance matrix between samples (Fig. 2), the species

221   composition of saproxylic beetle assemblages caught with or without an alcohol lure

222   clearly differed. Samples from baited or unbaited traps were obviously separated in

223   ordination space. This distinction was consistent with the results of the ANOSIM test

224   (10 000 permutations, $R=0.65$, $p<0.0001$). The average Bray-Curtis dissimilarity

225   between baited and unbaited traps reached a value of 44%.

226   In accordance with this global dissimilarity, important specific differences were

227   noticed. For several families and species (Cryptophagidae (*Cryptophagus* spp.),

228   Staphylinidae (*Paraphloeostiba gayndahensis, Aleochara sparsa*), Salpingidae

229   (*Rhinosimus ruficollis, R. planirostris, Rabocerus foveolatus*)), significantly more

230   individuals were caught in baited traps than in unbaited traps (mixed-model

231   ANOVA; Table 2). *Rhizophagus* spp. (Monotomidae) was more abundant in baited

232   traps compared with unbaited traps, whereas Cleridae were not affected by trap bait.

233   Amongst xylophagous taxa, Scolytidae (*Ernoporicus fagi*, *Xyloterus signatus, X.*

234   *domesticus, Xyleborus saxesenii*) and Lymexylidae (*Hylecoetus dermestoides*) were

235   more abundantly caught in baited traps, whereas Cerambycidae, Anobiidae,

236   Melyridae were not sensitive to alcohol bait.

Tab. 2 No species or family was significantly more abundant in unbaited traps.

238

239 **Comparison of effectiveness between alcohol-baited and unbaited traps in open**

240 **or closed-canopy stands**

241   The difference between alcohol-baited and unbaited traps in open (gaps) or closed-

242   canopy stands may be interpreted first in terms of abundance or species richness. As

Fig. 3 shown in figure 3, saproxylic beetle abundance in both baited and unbaited traps was

244   higher in open sites than in closed-canopy controls. The difference in abundance

245   between baited and unbaited devices was only slightly higher in open plots; in other

246   words, the bait-openness interaction effect was quite moderate (mixed-model

247   ANOVA test $F_{2,21}= 5.17$, p=0.015).

248   The difference in species richness between baited and unbaited traps was not

249   significantly influenced by the openness of trap environment (Fig. 3: mixed-model

250   ANOVA test of the bait-openness interaction effect: $F_{2,21}= 3.23$, p=0.060).

251

252 For several taxa noticed to be sensitive to the alcohol attractant (see above), i.e.

253 Monotomidae, Scolytidae and Lymexylidae as a whole, the difference baited-

254 unbaited was not affected by the environment closure. Two families

255 (Cryptophagidae, i.e. *Cryptophagus* spp., and Salpingidae), and 4 species (*Rabocerus*

256 *foveolatus, Rhinosimus ruficollis, Rhinosimus planirostris, Aleochara sparsa*)

Fig. 4

257 showed a significant difference baited-unbaited, but not in compliance with the

258 hypothesis of a bait-openness interaction. The difference was indeed lower in open

259 stands than in closed-canopy plots (fig. 4). Only the bark beetle species *Xyloterus*

260 *domesticus* showed a significant and higher difference baited-unbaited in open

261 stands.

262 In conclusion, the difference between alcohol-baited and unbaited traps was not

263 increased greatly by the openness of trap environment.

264

265 **Comparison of effectiveness between alcohol-baited and unbaited traps in fresh**

266 **dead wood poor or rich stands**

267 Regarding this potential bait-environment interaction effect, the difference between

268 alcohol-baited and unbaited traps was only slightly influenced by the local volume of

269 fresh woody debris releasing alcohol kairomones. The baited-unbaited difference in

270 fresh dead wood poor (ancient gaps and controls) or rich stands (recent gaps) was

271 examined in terms of total abundance, species richness, family and species

272 abundances.

273 In figure 5, the difference between baited and unbaited lures in terms of abundance

Fig. 5

274 and species richness seems to be slightly lower in gaps rich in recent fresh dead

275 wood. Nevertheless, this bait-environment interaction effect was only slightly

276   significant on saproxylic beetle abundance (mixed-model ANOVA, $F_{2,35} = 4.84$, p =

277   0.014). The only significant pairwise difference was observed between ancient and

278   recent gaps (Multiple comparison Tukey test), the difference being larger in ancient

279   gaps. This bait-environment interaction did not significantly affect species richness

280   in traps (mixed-model ANOVA, $F_{2,35} = 1.66$, p = 0.204).

Fig. 6

281   A bait-environment interaction effect was observed on the abundance of several

282   families and species known to be sensitive to the ethanol attractant (fig. 6). The

283   baited-unbaited differences were lower in recent gaps than in ancient gaps and forest

284   controls for the abundance of Salpingidae (and the species *Rhinosimus ruficollis* in

285   particular) (multiple comparison Tukey test). Similarly, we observed a smaller yet

286   still significant baited-unbaited difference for the abundance of Cryptophagidae and

287   *Rhinosimus planirostris* in recent gaps compared with closed-canopy stands. For

288   *Rabocerus foveolatus, Aleochara sparsa, Xyloterus signatus*, the difference was less

289   in recent gaps than in closed-canopy controls (but the difference between ancient or

290   recent gaps was not significant). No difference was measured for Scolytidae as a

291   whole (and *Xyloterus domesticus, Ernoporicus caucasicus, Xyleborus saxesenii* in

292   particular), Lymexylonidae, Staphylinidae (peculiarly *Paraphloeostiba gayndahense*)

293   and Monotomidae (*Rhizophagus* spp. in particular).

294

295   Discussion

296

297   Alcohol lure effect

298   The results from our study confirm that ethyl alcohol, acting as a kairomone released

299   from decaying woody tissues, strongly attracts some beetles associated with dead

300   hardwood (Montgomery & Wargo, 1983) and suggests that an ethanol lure

301   strengthens the effectiveness of window-flight traps in deciduous forests. Indeed,

302   more than twice as many saproxylic beetles, representing a 40% higher species

303   richness, were captured in alcohol-baited traps as in unbaited traps. Assemblages

304   were globally dissimilar between baited and unbaited devices, mainly because more

305   species were caught in baited traps. It is very important to stress that we did not

306   detect any species or family significantly more abundant in unbaited traps. We may

307   therefore infer that the ethanol lure did not have any inhibiting or repellent effect.

308

309   In our methodological approach in beech forests, the individual responses of dead-

310   wood taxa to alcohol lure were actually heterogeneous. As previously demonstrated

311   by Byers (1992), significantly more individuals of *Rhizophagus* spp. (Monotomidae)

312   were caught in baited traps than in unbaited traps. Host tree chemicals are known to

313   be important to *Rhizophagus* species in finding their habitat (scolytid galleries).

314   Conversely, natural enemies such as Cleridae were not affected by trap bait in our

315   study. Likewise, Schroeder (2003) pointed out that two *Thanasimus* clerid species

316   preying on several bark beetle species differ in their response to α-pinene and

317   ethanol. Our results showed that the abundance of ambrosia and bark beetles was

318   about 4 times as high in alcohol-baited traps, in agreement with previous findings

319   (Magema et al., 1982 ; Berti & Flechtmann, 1986 ; Poland et al. 2004). Amongst the

320   other wood-feeding taxa, Cerambycidae were not sensitive to alcohol bait, which had

321   been shown previously by Sweeney et al. (2004). Conversely, Döring (1955)

322   demonstrated that ethanol acts as a kairomone for the longhorned beetle *Cerambyx*

323   *cerdo*. Among the fungus feeders, unlike Tetratomidae, Melandryidae and Ciidae,

324   only Cryptophagidae were significantly attracted by the alcohol lure, as was the

325   tenebrionid studied by Jonsell et al. (2003).

326

327   Interaction effects between trap attractant and trap environment

328   Some results did not comply with the hypothesized bait-openness interaction. Five

329   species showed a significant lower baited-unbaited difference in open areas.

330   Moreover, the baited-unbaited difference in species richness and in abundance of the

331   other alcohol-attracted taxa was not significantly influenced by the openness of trap

332   environment. Only the total saproxylic beetle abundance and the abundance of the

333   bark beetle *Xyloterus domesticus* were in accordance with the hypothesis of an

334   increased baited-unbaited difference in open areas compared with closed-canopy

335   stands. In other words, trap attractiveness appeared to increase only slightly, but not

336   significantly, with stand openness, even though canopy cover may strongly influence

337   kairomone volatility. However, such an interaction effect was reported by Honek

338   (1988), between crop density and an attractant in pitfall traps, on catches of epigaeic

339   arthropods.

340

341   Apart from openness, another environmental factor separated the plots into groups.

342   Indeed, recent gaps, ancient gaps and forest controls differed in terms of local

343   volume of fresh dead wood. We hypothesized that the high volume of fresh dead

344   wood in recent sun-exposed gaps would release a large amount of ethanol, which

345   could saturate the beetle's olfactory landscape around the traps and therefore reduce

346   trap attractiveness. In accordance with this hypothesis, the baited-unbaited difference

347   was lower in recent and fresh dead wood rich gaps for some assemblage parameters.

348   Though this bait-environment interaction was slight, it significantly affected the total

349   abundance of saproxylic beetles, the abundance of several families and species

350   known to be sensitive to the ethanol attractant (Salpingidae, *Rhinosimus ruficollis*

351 and *Rhinosimus planirostris* in particular, Cryptophagidae). Conversely, the response

352 of species richness and abundance of the other families (such as Scolytidae) to traps

353 was not influenced by the local volume of fresh dead wood.

354 The alternative hypothesis of a "mass effect", i.e. a stronger attractiveness of baited

355 traps in the alcohol-rich atmosphere of recent gaps, was thus invalidated. These

356 results may be related to a phenomenon that could be called 'alcohol disruption' (in

357 the spirit of the 'mating disruption'; Ruther et al., 2002), i.e. the disruption by local

358 fresh dead-wood concentrations of the kairomonal response of saproxylic beetles to

359 baited traps. Nonetheless, even though trap attractiveness appeared to be reduced in

360 an alcohol-saturated environment, baited traps remain more efficient than unbaited

361 devices in terms of abundances and richness. They have the capacity to sample the

362 pool of saproxylic beetles in recent gaps.

363

364 **Conclusion - Implications for saproxylic beetle sampling**

365 Even though the extrapolation of our findings from upland forests to other climatic

366 contexts should be done with care, their interpretation may help with the

367 optimization of the two types of forest beetle monitoring.

368 The first type, i.e. monitoring and control of forest pest populations and early-

369 warning surveillance programs to detect invasive wood borers, aim at maximizing

370 detection probability. We demonstrated that the ethanol lure does not have any

371 repellent effect but significantly attracts several wood feeders. Like the New Zealand

372 monitoring programme for invasive wood-feeders (Brockerhoff et al., 2006),

373 effective sampling designs may use the large spectrum of ethanol attractiveness.

374 The second type, i.e. biodiversity surveys of saproxylic beetle diversity in monitoring

375 networks or evaluation studies of forest management practices, implies distinct

376 constraints. To compare the biodiversity between stands or to assess trends in

377 saproxylic beetle diversity over broader landscapes, ideally saproxylic beetle

378 detectability should not change with habitat structure. A variation in trap efficiency

379 as a function of any stand environmental parameter would call into question an inter-

380 site comparison. For instance, a relation between trap efficacy and stand openness

381 would prevent the comparison of open (e.g. felling areas) and closed-canopy stands

382 with alcohol-baited traps, or studies on the influence of shading for the attractiveness

383 of dead wood (Hjältèn et al., 2007). Our results show slight interaction effects

384 between trap attractant and trap environment. A very moderate bait-openness

385 interaction effect was measured, whereas trap attractiveness appeared to be reduced

386 in an alcohol-saturated environment, through a disruption by local fresh dead-wood

387 concentrations of the kairomonal response of saproxylic beetles to baited traps

388 ('alcohol disruption').

389 In accordance with these results and although alcohol-baited traps appeared to be

390 more efficient than unbaited devices, we recommend to take care to use baited

391 brine or glycol solution used as a preservative fluid does not vary with forest stands.

392 Beside the attractant, other trap parameters, such as colour and shape, should be

393 assessed for optimization and standardization and have been partly examined in

394 another study (Bouget et al., in press).

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510

511   Figure legends

512

513   Figure 1

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

515

516   Figure 2

517   NMDS ordination plot of the Bray-Curtis dissimilarity matrix of baited (AL) and

518   unbaited (NAL) samples. The two axes with highest correlation to bait factor are

519   represented. 4-dimension stress = 0.153. ANOSIM test (10 000 permutations)

520   confirmed the difference of assemblages (R=0.65, p<0.0001).

521

522   Figure 3

523   Mean abundance (a) and species richness (b) per trap of saproxylic beetles in baited

524   (AL) and unbaited (NAL) traps in open (MO) or closed-canopy (MF) stands. Linear

525   mixed-model ANOVA F-test significance of the interaction effect between bait and

526   openness: ** p<0.01, * 0.01<p<0.05, ns p>0.05.

527

528   Figure 4

529   Mean difference in abundance per trap of saproxylic beetle families (a) and species

530   (b) between baited (AL) and unbaited (NAL) traps in open (MO) or closed-canopy

531   (MF) stands. Mann-Whitney test significance: ** p<0.01, * 0.01<p<0.05, ns p>0.05.

532   Only species and families including more than 30 individuals were tested.

533

534   Figure 5

535   Mean species richness (a) and abundance (b) per trap of saproxylic beetles in baited

536   (AL) and unbaited (NAL) traps in fresh dead wood poor stands [forest controls (F)

537   and ancient gaps (TA)] and fresh dead wood rich stands [recent gaps (TR)]. Linear

538   mixed-model ANOVA test significance: ** $p < 0.01$, * $0.01 < p < 0.05$, ns $p > 0.05$.

539   Mean difference in richness (c) and abundance (d) between baited and unbaited traps

540   in fresh dead wood poor stands [F, TA] and fresh dead wood rich stands [TR].

541   Different letters indicate significant differences between means after a post-hoc

542   Tukey test ($p = 0.01$).

543

544   Figure 6

545   Mean difference in abundance per trap of saproxylic beetle families (a) and species

546   or genera (b) between baited and unbaited traps in fresh dead wood poor stands

547   [forest controls (F) and ancient gaps (TA)] and fresh dead wood rich stands [recent

548   gaps (TR)]. Linear mixed-model ANOVA test significance: ** $p < 0.01$, *

549     $0.01 < p < 0.05$, ns $p > 0.05$. Different letters indicate significant differences between

550   means after a post-hoc Tukey test ($p = 0.01$). Only species and families including

551   more than 30 individuals were tested.

552

553   Tables

554

555   Table 1

556

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

561

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	$F_{(1,23)}=68,649$ **

562

563 Table 2
564
565 Mean abundance per trap of saproxylic beetle species and families in baited (AL) and
566 unbaited (NAL) traps. Linear mixed-model ANOVA test significance: ** p<0.01, *
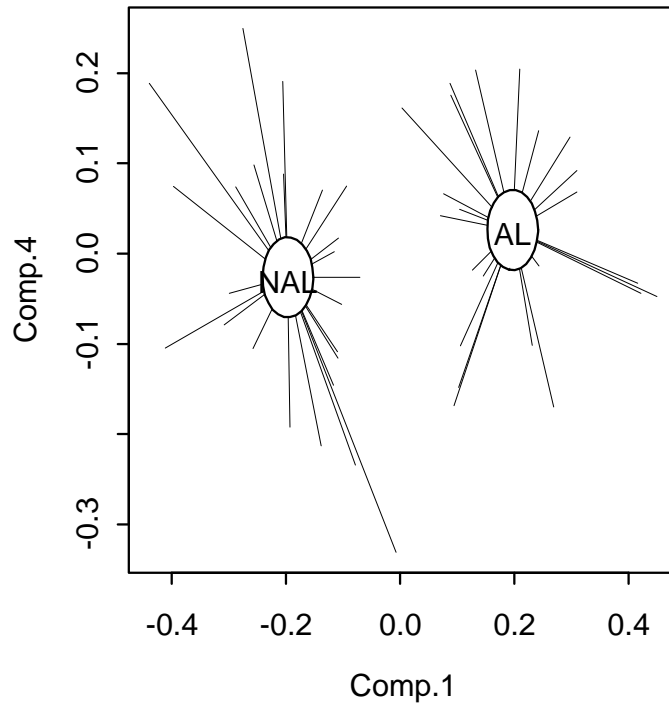567 0.01<p<0.05, ns p>0.05. Mean values are expressed +/- Standard Deviation.
568
569

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* **
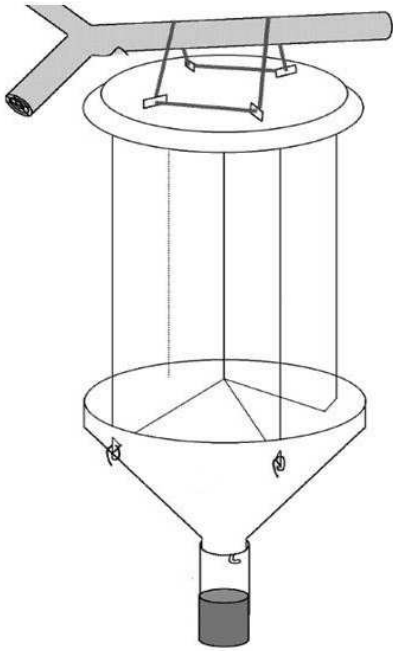
576   Figure 2
577

578   Figure 3

579

(a)   **(b)**

Mean abundance per trap
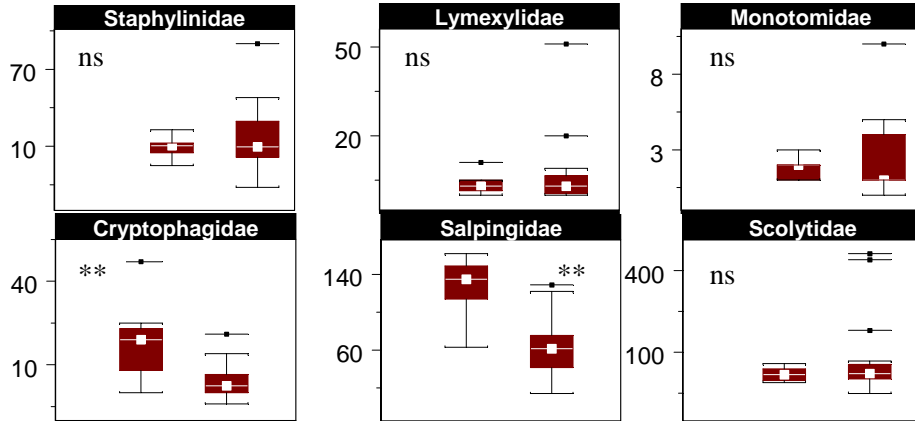
Mean species richness per trap
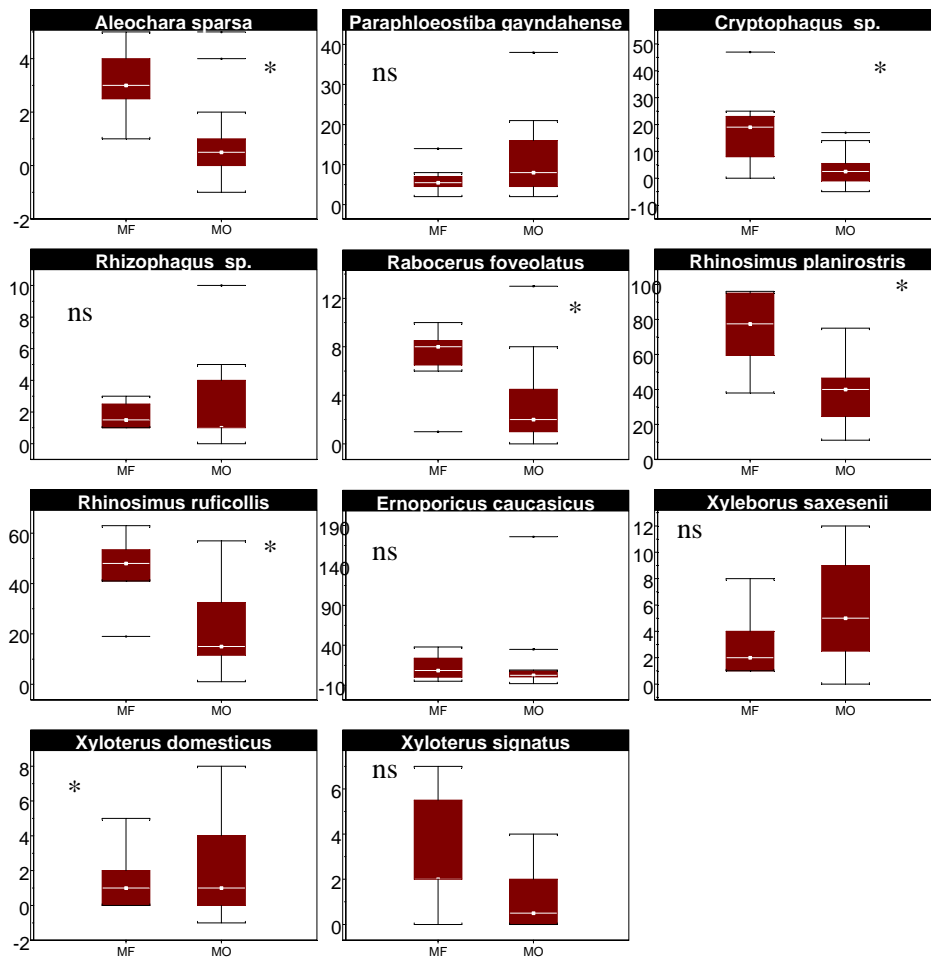
580
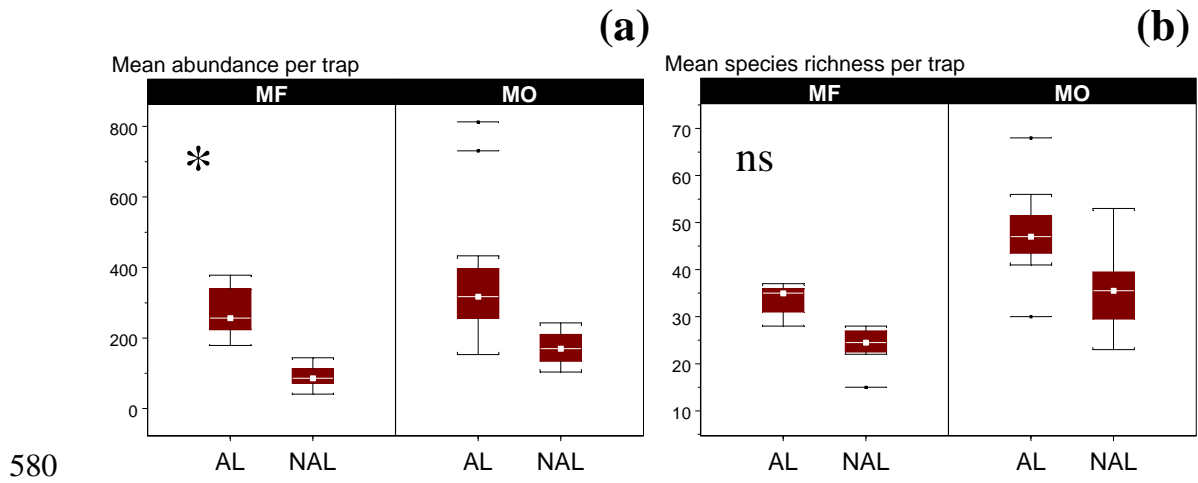
581   Figure 4
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(a) Families
Difference in abundance
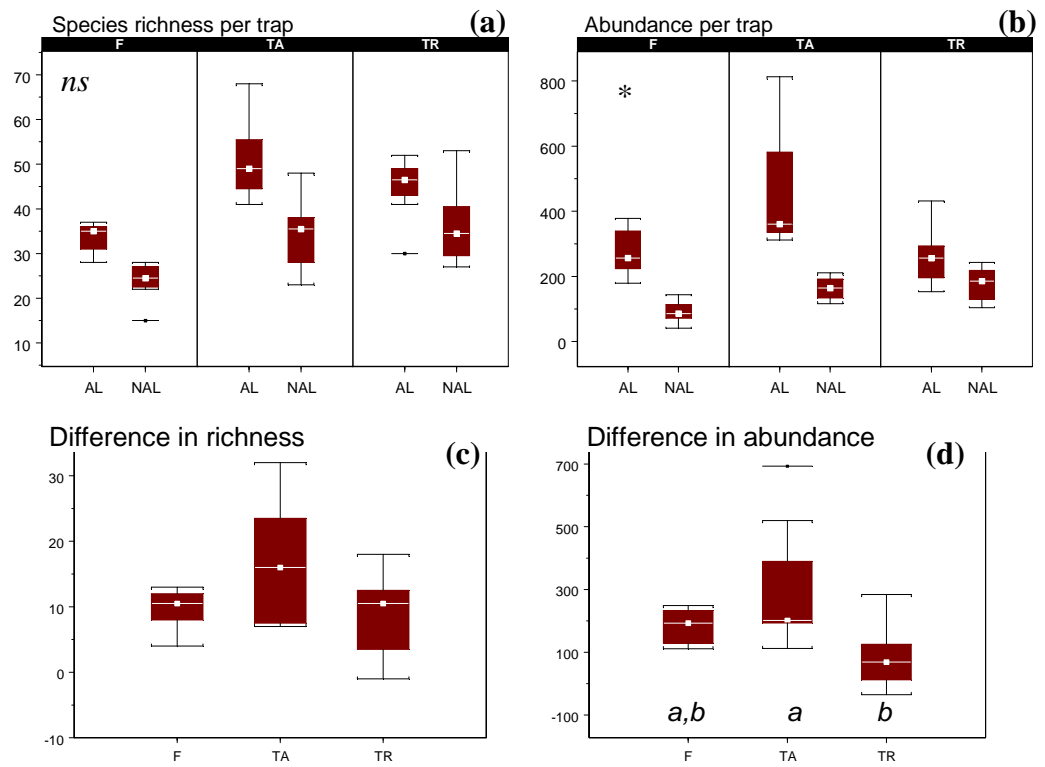

(b) Species
Difference in abundance
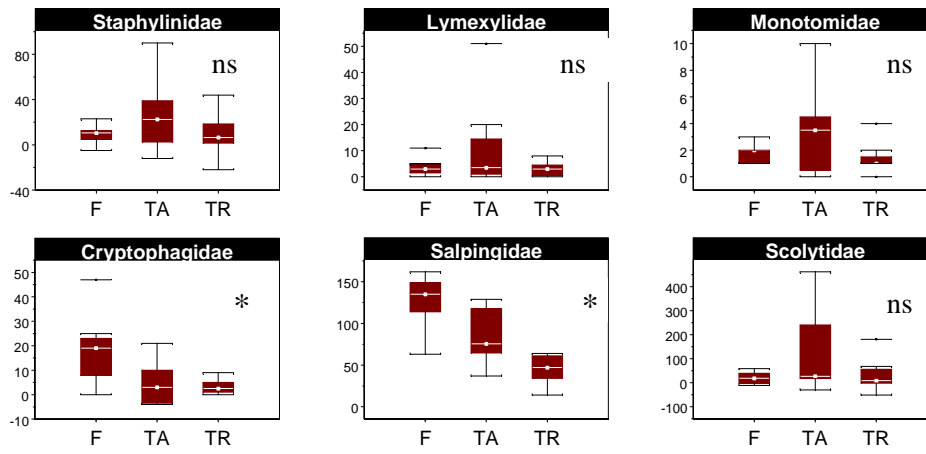

585
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587 Figure 5
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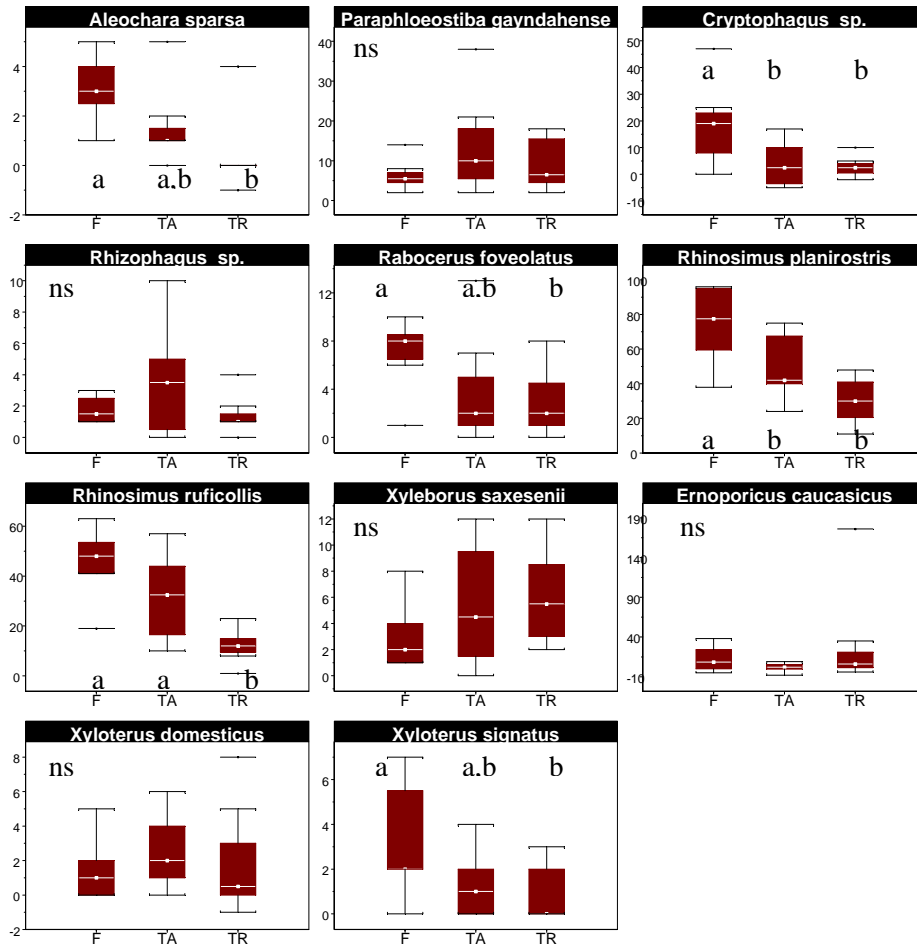590

591   Figure 6
592

(a) Families
Differences in abundance

(b) Species
Differences in abundance

593
594