NORTH-WESTERN JOURNAL OF ZOOLOGY 13 (1): 6-11
Article No.: e161102

http://biozoojournals.ro/nwjz/index.html

Effects of sampling design on the assessed structure of necrophilous terrestrial insect communities: evidence at order taxonomic level

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Received: 06. December 2015 / Accepted: 27. February 2016 / Available online: 19. September 2016 / Printed: June 2017

Abstract. Concerns about understanding the consequences of anthropic pressures on biodiversity and the goods and services it provides are still a priority in ecological research. Composition and structure of insect communities were frequently reported as major factors that modulate both the rates and patterns of ecological processes at different spatial and temporal scales. By decomposing animal detritus, necrophilous insects provide an important ecosystem service contributing to the release of nutrients needed for the development of primary producers and for food-web stability and soil fertility. The validity of the assessed insects diversity and functional relationship depend on the accuracy of measurements and ultimately on the design of field experiments. Nevertheless, the scientific literature is scarce in such results and unbalanced across biogeographic regions. The main objective of this study is to assess the effects of experimental design with respect to type of carrion-baited traps and position they were placed in the field on the assessed structure of terrestrial necrophilous insect communities. Although Coleoptera and Diptera share the core structure of the communities in both suspended and pitfall traps, the communities were differently structured in the two types of traps in both composition and structure. Lack of significant differences in the total number of larvae of Diptera recorded in the two types of traps suggests that besides position, the design of traps (open vs. closed) should be also considered when designing experiments directed to the characterization of biological diversity and comparison of processes across biogeographical regions. Biases in the assessed structure of communities due to experimental design affect the accuracy of estimates concerning their ecological state and the range of ecosystem services they provide to human communities, with serious consequences on the informed managerial decision for successful biodiversity conservation.

Key words: pitfall trap, suspended trap, carrion bait, terrestrial necrophilous insects.

Introduction

The fact that biodiversity significantly influences the functioning of ecological systems is certain (Srivastava & Vellend 2005, Zobel et al. 2006, Reiss et al. 2009), but the prediction of effects of identified anthropogenic pressures on biodiversity and the range of goods and services it provides remains one of the main concerns in current ecological research (Thebault & Loreau 2006, Reiss et al. 2009, Nagendra et al. 2013, Harrison et al. 2014). Identification and characterization of the structure of biotic communities represents a prerequisite in the attempt to fulfill this gap. Composition and structure of insect communities were frequently reported as major factors that, besides microorganisms, modulate both the rates and patterns of ecological processes at different spatial and temporal scales (Jonsson & Malmqvist 2000, Loreau et al. 2001, Parmenter & MacMahon 2009, Carter et al. 2007, Benbow et al. 2013). Necrophilous insects provide important ecosystem services by decomposing animal detritus, thus driving release of nutrients needed for development of primary producers, contributing to food-web stability and to soil fertility (DeVault et al. 2003, Moore et al. 2004, Carter et al. 2007, Barton et al. 2013). The great heterogeneity of species assemblages across biogeographic region (Brundage et al. 2011, Tomberlin et al. 2012), habitat type (Hwang & Turner 2005, Brundage et al. 2011) and site-specific conditions (Sharanowski et al. 2008, Matuszewski et al. 2013, Baz et al. 2014) resulted in a wide heterogeneity of results reported in the literature (Ermakov 2013), which underlines the need for further, context-based research for assessing ecosystem functioning and mapping of ecological services.

Species identity is very important when approaching ecological processes and function (Jonsson & Malmqvist 2005, McKie et al. 2008, Farwig et al. 2014). Nevertheless, the need to find a balance between the level of taxonomic identification and its relevance for characterizing large scale ecological processes remains of a very high concern as biodiversity assessment often requires much effort in terms of time, expertise and financial resources.

Taxa identification at higher taxonomic levels is frequently used as a "taxonomic surrogacy" (Bertrand et al. 2006) in studies that aim to characterize community diversity and accuracy of estimation methods of biological diversity. It is more time effective and reduces the costs of biodiversity surveys (Tanabe at al. 2008) while providing reliable results. Recently, Isaka and Sato (2015) reported correlation between species richness of sawfly and host plant association at higher taxonomic levels (family and subfamily), whereas Biaggini et al. (2007) revealed that use of the arthropod-order level allowed researchers to clearly distinguish among the main land uses within an agricultural landscape on the bases of their faunal composition and diversity. They proved that use of the arthropod-order level gave outcomes comparable to those obtained from analyzing at the level of carabid species.

Moreover, experimental design is highly influential on the accuracy of assessed composition and structure of terrestrial insect communities (Ermakov 2013, Farinha et al. 2014) and therefore on the validity of biodiversity measurements and on estimates of biodiversity – ecosystem functions relationship. Number of replicates (Brundage et al., 2011, Tomberlin et al. 2012), type of traps (Brundage et al. 2011, Devigne & De Biseau 2014), bait size and type (Nuorteva 1959, Ermakov 2013, Rîşnoveanu & Popescu 2015) were frequently reported as being responsible for the quality of experimental results. It is well documented that trap type and the position they were placed in habitats affect the detection probability of different taxa (Southwood & Henderson 2000, Muirhead – Thompson 2012, Skvarla et al. 2014). Nevertheless, the effect of these factors on the assessed structure of communities in different biogeographic and environmental conditions (Brundage et al. 2011, Tomberlin et al. 2012, Ermakov 2013) remains poorly understood, making it difficult to accurately assess the ecological state and role of biodiversity with consequences on informed managerial decision.

Our research aims to assess the extent to which experimental sampling design with respect to the type of carrion-baited traps and the position they were placed in the field influences the assessed structure and diversity of terrestrial necrophilous insect communities.

Material and methods

The present study is part of a broader field experiment which aimed to assess the decomposition rate of carrion in relation to necrophagous insect's diversity. The experiment was conducted in Harapu Island: 44º 59' 52"N, 27º 54' 31''E (Fig. 1), which formed early last century in the middle of the Danube River. It is part of the Little Island of Brăila that is Natural Park, Natura 2000 site (ROSCI0006, ROSPA0005), and RAMSAR site.

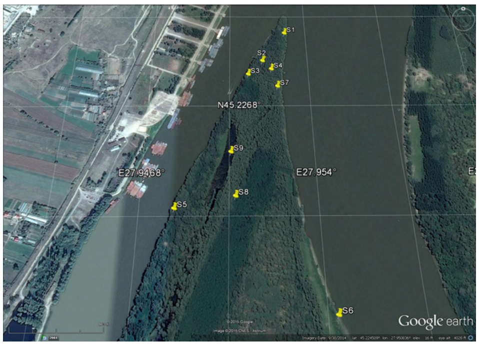

Figure 1. Position of the sampling stations (S1-S9) across Harapu Island.

The experiment was conducted for 13 days, in May 2012, in 9 randomly chosen sampling stations in the north part of the island, which includes all representative habitats and is relatively more accessible as compared to the south part, which is largely covered with wetlands. Two types of traps were used for terrestrial insects: pitfall and suspended traps (Fig. 2) baited with 5 grams of chicken meat. Small-bait carrion was preferred in order to enable more replicates for correct statistical analysis (Farinha et al. 2014).

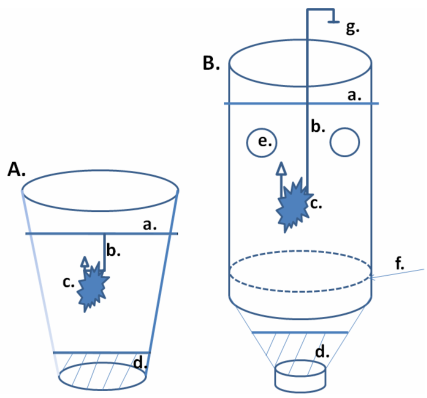

Figure 2. Pitfall trap (A.) and suspended trap (B.) used in the field experiment. a. = wire, b.= hook; c.= carrion bait; d.= water with detergent; e.= 1 cm holes ; f.= cut section of the wall to insert bait which was subsequently glued; g.= external hook for suspension on tree branch.

During the experiment, out of a total number of 176 traps (89 pitfall and 87 suspended) placed in field, 43 pitfalls were destroyed by wild animals. Besides, 23 suspended traps were not considered into analysis due to some experimental deficiencies (loss of immersing liquid, bait dropped into liquid). The pitfall traps were arranged in groups of five to six (4 to 5 displayed circularly on a 1.5 meters radius and one in the middle of the circle) whereas suspended traps were randomly placed in groups of three per tree. Between one and three nests of pitfall traps and between two and four groups of suspended traps were replicated in each sampling station.

The bait was suspended in the middle of the trap with a hook (Fig. 2). The roof of the pitfall trap was represented by plates, fixed at 1 cm above the soil. Two-liters plastic PET bottles fitted with 1-cm holes for enabling the access of insects were suspended in trees, about 2m above ground. All traps were supplied with water mixed with few detergent drops to reduce surface tension and to enable the immersion of insects.

The traps were emptied at 1, 2, 3, 6, 9 and 13 days after installation, except few sampling stations in the first day due to heavy rain. The specimens were collected, preserved in 70% ethanol and identified at order level using an Olympus stereomicroscope SZ30.

The structure of insect communities was analyzed based on the calculated values of taxa richness, frequency of occurrence, densities and relative abundances of terrestrial necrophilous insects in the two types of traps, as well as Shannon diversity (H') and evenness (J') (Rîşnoveanu & Popescu 2011). According to their occurrence frequencies, taxa were considered constant (F% ≥ 50 %), accessories (50 % > F % ≥ 25 %) and accidentals (F% < 25 %). Taxa having relative abundances over 10% of the total number of insects were considered dominant. Sørensen and Renkönen indices were used to assess similarity in the composition and structure of insect communities (Popescu 2011).

One-way ANOVA (STATISTICA 10) was used to identify significant differences between insect densities depending on the position the traps were placed in the field. Mann-Whitney U nonparametric test was used to compare densities of insects belonging to the same order in different traps.

Results

In both types of traps, arthropods were represented by the following classes: Insecta (81%), Malacostraca (10%), Arachnida (7%), Diplopoda (1%), Entognatha (0.03%), Chilopoda (0.05%). The density of insects caught per trap was significantly (p=0.002) higher in pitfall traps (17.30 ind/trap*day) than in suspended traps (10.06 ind/trap*day) (Fig. 3). Instead, higher relative abundance of insects was recorded in suspended (96%) as compared to pitfall (76%) traps.

The total number of 21813 adult insects cached in traps belongs to ten orders: Coleoptera, Diptera, Neuroptera, Mecoptera, Trichoptera, Lepidoptera, Hymenoptera, Hemiptera, Orthoptera, Dermaptera. The arthropod-order richness was unequal in the two types of traps, with Orthoptera being absent in suspended traps, and Neuroptera and Lepidoptera in pitfall traps.

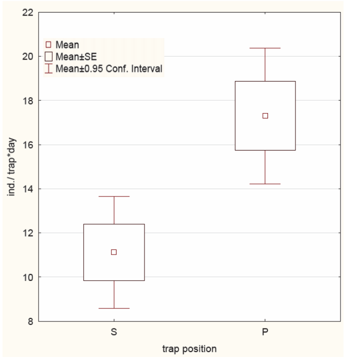

Figure 3. Insects density (number of individuals/ trap*day) in the suspended (S) and pitfall (P) traps.

The occurrence frequency of insect orders (only adults) in samples depends on the type of trap (Fig. 4). In pitfall traps Coleoptera (F% > 90%) and Diptera (F > 60 %) were constant; instead, in suspended traps Diptera had the highest frequency (F% > 90 %), followed by Mecoptera (F% > 60%; in pitfall traps this order was accidental) and Coleoptera (F% > 50%). Order Hymenoptera was accessory in both traps; other orders were all accidentals (Fig. 4).

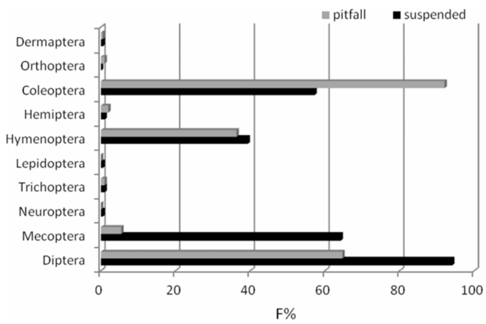

Figure 4. Occurrence frequency (%) of insect orders in pitfall vs. suspended traps.

Coleoptera density was significantly higher in pitfall traps than in suspended traps (p < 0.0001). On the contrary, densities of adults from Diptera and Mecoptera orders were significantly higher in suspended traps (p < 0.0001) (Fig. 5). However, the density of Diptera larvae was similar for both types of traps (p=0.79). Hymenoptera density did not differ significantly between the two types of traps (p = 0.83) (Fig. 5).

In pitfall traps, Coleoptera represented 62% of all insects, followed by Hymenoptera (20%) and Diptera (18%). Instead, in suspended traps, Diptera had higher relative abundance (51%), followed by Hymenoptera (28%), Coleoptera (11%) and Mecoptera (10%, which recorded only 0.23% in pitfall traps) (Fig. 6).

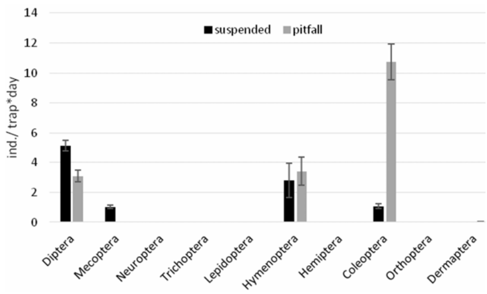

Figure 5. Density of Insecta' orders in different type of traps ± SE.

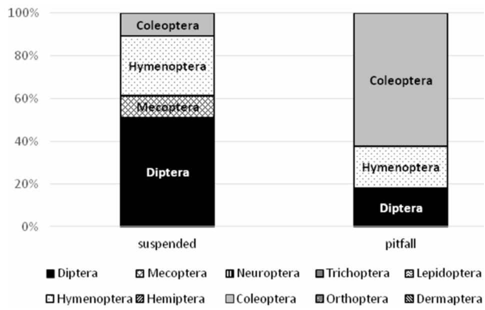

Figure 6. Relative abundances (%) of insect orders in different type of traps.

Shannon' diversity and evenness were higher in suspended (H'=1.72, J'=0.54) than in pitfall (H'=1.37, J' = 0.46) traps. The similarity of the taxonomic composition assessed by the two types of traps was 82% (Sørensen index). Nevertheless, from quantitative point of view, similarity was only 49 % (Renkönen index).

Discussion

As in most studies dedicated to the assessment of the necrophilous communities' structure (Payne 1965, Hanski 1987, Kočárek 2003), insects were the dominant arthropods in our samples.

Coleoptera and Diptera, which each have major roles in decomposition of animal detritus (Payne 1965, Campobasso et al. 2001), were the constant and dominant orders ("the core of necrophilous community", Ermakov 2013) in both type of traps, but their densities and relative abundances differ according to type of traps. Significantly higher number of insects combined with higher relative abundance of coleopterans in pitfall traps resulted in significantly higher density of beetles in this trap type as compared to the suspended traps. Pitfall traps catch ground beetles, and therefore they are frequently used for this goal (Greenslade 1964, Southwood & Henderson 2000, Skvarla et al. 2014). Equally, the unintended presence of beetles in pitfall traps cannot be excluded given the design of the traps, which are opened at ground level so that individuals can fall unintended into them.

It is also the position and design of the trap that seem to explain significantly higher densities of adult Diptera in suspended traps. As flies are best for flying and use trees as shelters, they can easily reach suspended traps (Muirhead-Thompson 2012). On the other hand, preponderant colonization of suspended baits could be a mechanism through which the flies, having a choice, avoid their consumption by some species of beetles which are known to feed on adult and larvae of flies (Bajerlein et al. 2011). However, no significant differences recorded between Diptera larvae cached in the two types of traps, suggesting that roughly equal numbers of adults visited the traps, but that the suspended trap design prevents adults from escaping, enabling adults to be caught in larger numbers as compared to the open design of the pitfall traps. So, both the design and position of suspended traps could be responsible for differences recorded in densities of Diptera adults, overall suspended traps being more effective in catching flies (Muirhead-Thompson 2012). The higher values of occurrence frequency, the greater density and relative abundance of Mecoptera in the suspended traps unlike pitfall traps, could be also explained by the closed design of the former. Devigne and De Biseau (2014) reported also large differences in the effectiveness of five traps commonly used in catching flying insects.

The structure of insect communities in both pitfall and suspended traps was dominated by Coleoptera, Diptera and Hymenoptera. Mecoptera makes a difference, being dominant only in suspended traps. Besides, Orthoptera were absent in suspended traps, and Neuroptera and Lepidoptera in pitfall traps. This could be particularly relevant for ecosystem function (i.e. decomposition rate of carrion), which according to Farwig et al. (2014), depends on composition and not abundance of insect assemblages.

Sørensen and Renkönen indices revealed a high degree of similarity in the qualitative structure of the insect communities assessed by the two types of traps (82 %). Nevertheless, the higher values of Shannon diversity and evenness in the distribution of orders in the suspended traps reduce the similarity in quantitative structure of the necrophilous insect community assessed for the two types of traps (only 49 %). This value reflects an important bias that the experimental design introduced in the assessed quantitative structure of the necrophilous insect community and highlights the complementarities of the two designs in the attempt to correctly characterize the biological diversity and the structure of this type of communities.

Based on the recorded results, we may conclude that the necrophilous insect communities were differently structured in suspended traps as compared to the pitfall traps. Significant differences were recorded in the community composition. Neither the pitfall nor the suspended traps was able to capture the entire diversity of insects' community. Out of 10 orders of insects identified in the study, only eight were caught by pitfall traps and nine by suspended traps. Moreover, the core structure of communities recorded in the two types of traps is significantly different: Coleoptera and Diptera, which share the core of the communities in both the suspended and pitfall traps, switch on the first position, with Coleoptera having the highest frequencies, densities and relative abundances in pitfall traps and Diptera in suspended traps. Even the similarity in taxonomic composition assessed by the two types of traps is over 80%, it decreases under 50% when the quantitative structure is considered. These results support the hypothesis that trap position can influence the assessed structure of terrestrial insect communities involved, directly or indirectly, in animal detritus decomposition.

Significant differences in total number of adults and no significant differences in the total number of larvae of Diptera recorded in the two types of traps suggest that besides position, the design of traps (open vs. closed) should be also considered when designing experiments directed at characterizing biological diversity, its functional role as well as comparison of processes across biogeographical regions.

The recorded biases in the assessed structure of communities due to the experimental design affect the accuracy of the estimates concerning their ecological state and the range of ecosystem services they provide to human communities, with serious consequences on the informed managerial decisions for successful biodiversity conservation. Further research, including insect identification at species level, may provide understanding about biological diversity across ecosystems and allow better assessment of biodiversity and ecological systems functionality.

Acknowledgements. We thank our technicians Aglaia Pârvu, Costel Amărioarei, Aristide Dimache, Anişoara Bobeică, Săndica Vişinescu, Carlos Mihai Tunea, who helped in the field experiment and to Geta Niculae for sorting individuals from samples. This work was supported by the strategic grant POSDRU/159/1.5/S/133391, Project "Doctoral and Postdoctoral programs of excellence for highly qualified human resources training for research in the field of Life sciences, Environment and Earth Science" cofinanced by the European Social Found within the Sectorial Operational Program Human Resources Development 2007 – 2013.

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