



Hemiptera community and species responses to grassland sward islets

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Abstract: Sward islet is a term that has been used to describe a patch of longer vegetation in a pasture produced by a reduction in cattle grazing around their dung. They are known to affect the abundance and distribution of grassland arthropods. Hemiptera, like other groups, are found in higher densities within islets than the surrounding sward. Does this modify the community composition or is there just a density effect? Evidence from a paired (islets, non-islets) study at an Irish cattle-grazed site, would suggest that although a change in the density of species explains much of the patterns observed, some species respond to islets in different ways. Grassland Auchenorrhyncha were dominated by two genera, *Javesella* (mostly *J. obscurella* and to a lesser extent *J. pellucida*) and *Macrosteles* (mostly *M. viridigriseus* with some *M. laevis* and *M. sexnotatus*). The nymphs and to a lesser extent the adults, showed contrasting distribution patterns in relation to islets. *Javesella* were more common in the islets, whereas *Macrosteles* showed little difference between the two sub-habitats. Possible reasons for the difference in sub-habitat choice between these two Auchenorrhyncha taxa are discussed.

Key words: *Javesella*, *Macrosteles*, Auchenorrhyncha, microhabitat choice, grassland Auchenorrhyncha communities

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Introduction

Pasture is a widespread land use in Ireland, covering approximately 50 % of agricultural land (DEPARTMENT OF AGRICULTURE, FISHERIES AND FOOD, IRELAND 2013), and much of this is intensively managed. Biodiversity conservation is of course not the primary aim of pasture management and these grasslands are generally associated with low levels of plant and invertebrate species richness and diversity (CURRY 1987a, 1987b, MORRIS 2000). However the total area covered means that this habitat has the potential to contribute to landscape biodiversity at national level. Indeed the decline of traditional grassland management and consequent disappearance of flower rich meadows has been recognised as a major factor in the decline of biodiversity in many European countries, including the UK and Ireland (VICKERY et al. 2001, BENTON et al. 2001, SCHUCH et al. 2012). Given this, it is perhaps surprising that much of ecological interest could be found today's intensive agricultural grasslands. However as we show in this study, it is possible to discover interesting patterns that give insight into ecological processes. It could even

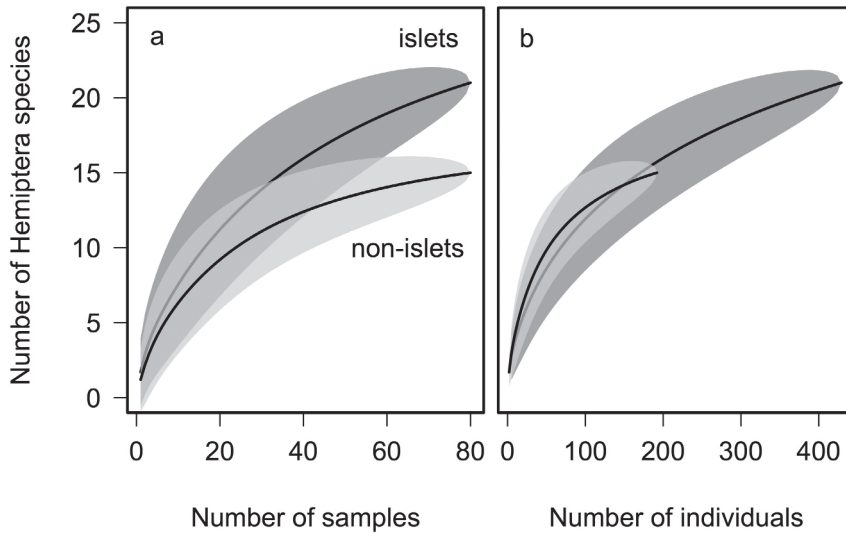


Fig. 1: Species accumulation curves for islet and non-islet sub-habitat: a) Number of Hemiptera species plotted against number of samples; b) Number of Hemiptera species plotted against number of individuals.

be argued that the relatively low species richness makes the study of ecological patterns simpler to interpret than in more complex communities.

Grassland sward islets are created through the grazing behaviour of cattle, which they tend to avoid grazing around their dung (NORMAN & GREEN 1958, MARSH & CAMPLING 1970). Consequently the sward immediately around the dung is taller than the more heavily grazed area surrounding it (MACDIARMID & WATKIN 1972). They have been recognised by agriculturalists for many years with most research into their establishment and persistence being done from an agronomic perspective, given that they have been considered to represent wastage of part of the pasture (NORMAN & GREEN 1958, MARTEN & DONKER 1964, BOSKER et al. 2002). However more recently they have begun to be recognised as having ecological interest (DESENDER 1982, HELDEN et al. 2010, DITTRICH & HELDEN 2012, D'HULSTER & DESENDER 1982). The presence of islets results in a substantial proportion of grassland invertebrates being concentrated into a relatively small area of pastures, although this effect is moderated by the length of the sward (HELDEN et al. 2010). The islets represents a sub-habitat that differs from the surrounding sward not only in physical structure but in plant biomass, microclimate and nutrient status, and it is this contrast which is likely to give rise to the relative distribution of invertebrates.

In Irish agricultural grasslands, the Hemiptera form a major part of the invertebrate fauna. The other major groups being the Araneae, Coleoptera, Collembola, Diptera and Hymenoptera. HELDEN et al. (2008) found that within the Hemiptera, the most common groups were the Aphidoidea (aphids) and the Auchenorrhyncha (leafhoppers, planthoppers and relatives). Although the concentrative effect of islets on Hemiptera abundance has now been shown, what is not known is whether there is any difference in the community composition between islets and the surrounding, non-islet sward. In this study we investigated potential community effects by comparing the Hemiptera communities in these

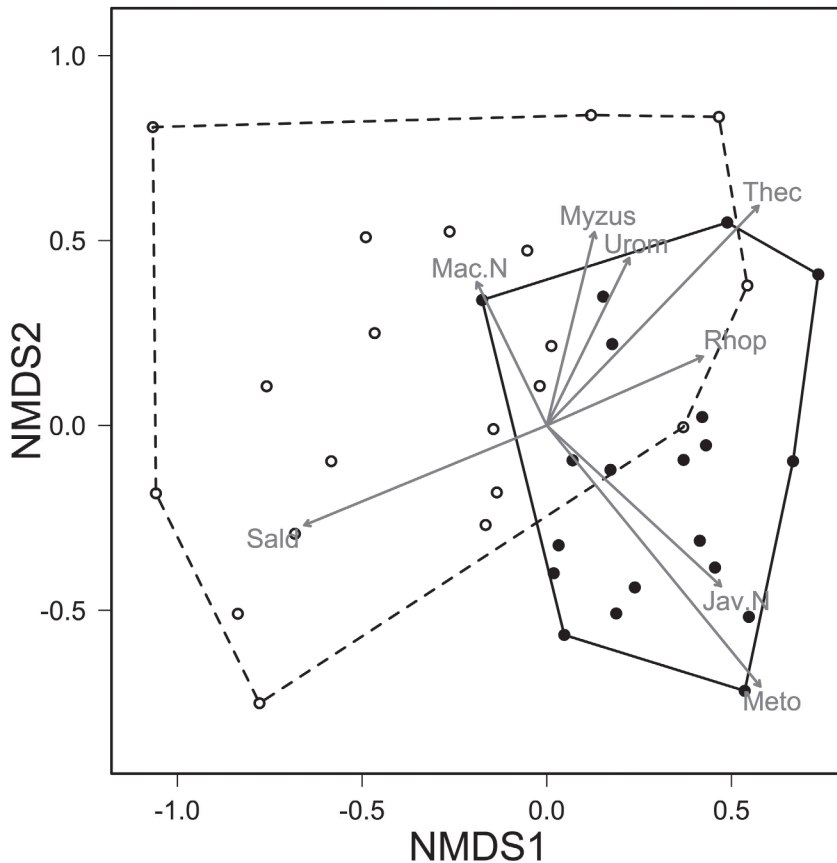


Fig. 2: Non-metric dimensional scaling (NMDS) ordination plot, showing islet (filled circles and solid lines) and non-islet (open circles and dashed lines) sub-habitat communities. The NMDS solution had two dimensions with a final stress was 0.213. The fit of sub-habitat to the ordination gave $r^2 = 0.269$, $p < 0.001$. Individual species fitted to the ordination are indicated in grey arrows as follows: Jav.N *Javesella* nymphs, Mac.N *Macrosteles* nymphs, Meto *Metopolophium* sp., Myzus *Myzus* sp., Rhop *Rhopalosiphum* sp., Sald *Saldula orthochila*, Thec *Thecabius affinis*, Urom *Uromelan*.

two sub-habitats. We used species accumulation curves, ordination and species-based generalised linear mixed models to compare communities, given a null hypothesis that there was purely a density effect and no species differences.

Material and methods

Site details and insect collection

The study was carried out at Teagasc Grange Research Centre, County Meath, Ireland, longitude E 6°40'4", latitude N 53°31'14", (Irish grid reference N884530). The sample site was part of a suckler beef experimental production system, with two levels of management intensity: 1.5 livestock units (LU) per hectare and 225 kg ha⁻¹ yr⁻¹ of inorganic nitrogen; and 1.2 LU ha⁻¹ and 88 kg ha⁻¹ yr⁻¹. Individual paddocks were grazed between April and November, rotationally on an approximate 21 to 28-day cycle.

The grassland was a typical intensive pasture, dominated by the grasses *Lolium perenne* and *Agrostis stolonifera*, with *Ranunculus repens* and *Trifolium repens* the most common broadleaved plants. The Hemiptera community was limited to 41 observed species, with 88 % of individuals being aphids of six species, most notably members of the genus *Rhopalosiphum*. The most common Auchenorrhyncha were *Javesella obscurella* (BOHEMAN, 1847) and *Macrosteles viridigriseus* (EDWARDS, 1922). There were smaller numbers of *Javesella pellucida* (FABRICIUS, 1794), *Macrosteles laevis* (RIBAUT, 1927) and *Macrosteles sexnotatus* (FALLÉN, 1806).

Hemiptera were sampled using a Vortis suction sampler (Burkard Manufacturing Co Ltd, Rickmansworth, Hertfordshire, UK) (ARNOLD 1994) on 13 May, 10 August and 1 September 2004. On the second date, two and on the first and third dates, three recently grazed paddocks were chosen. Within each paddock 10 islets were randomly selected. A pair of separate samples was taken from the sward inside and the outside each islet. Each sample consisted of four sucks of 10 second duration, giving a total area per sample of 0.08 m². The four sucks for the outside, i.e. non-islet, samples were arranged in an approximately north, south, east and west arrangement. In addition to suction sampling, and with the same spatial arrangement, four measurements of sward height were made within and outside each tussock, using a Filips Folding Plate Pasture Meter manufactured by Jenquip (www.jenquip.co.nz).

Hemiptera collected were stored in 70 % ethanol prior to identification. Adult specimens were identified to species (or genus for female *Macrosteles*), except for some of the Aphidoidea, which were identified to morphospecies. Nymphs were identified to genus or family level. The literature used for identification is listed in HELDEN et al. (2008).

Statistical methods

Analyses were carried out using R version 3.2.2 (R CORE TEAM 2015). Species accumulation curves were created using the `specaccum` function and non-metric multidimensional scaling (NMDS) using the `metaMDS` function, both from the `vegan` package (OKSANEN et al. 2015). For generalised linear mixed models the `lme4` package was used (BATES et al. 2015).

To remove the effect of seasonal differences on the community structure, species counts from the three dates were combined to give 20 islet and 20 non-islet communities for the NMDS. Only taxa with 10 or more individuals in total were used in the ordinations. Islets communities were compared with non-islets, and these categories were fitted to the ordination using the `envfit` function, which determined a goodness of fit statistic based on 1000 random permutations of the data. Similarly `envfit` was used to assess whether specific taxa fitted to the ordination showed a significant pattern.

For those taxa showing significant patterns with NMDS, generalized linear mixed models were used to compare the number of individuals in islets and non-islets. Each pair (islet and non-islet) of samples were paired in the statistical models using a random effect. The response variable was number of individuals, the explanatory variables, sub-habitat (islet or non-islet), sward height and the sub-habitat: sward height interaction, and the random effects pair nested within date. The maximal model was fitted first, followed by the se-

Table 1. Minimal adequate models and parameter estimates from generalized linear mixed models (GLMM) of the abundance of individual species, or genera, in relation to sub-habitat type (islets or non-islets). Explanatory variables were sub-habitat, sward height and their interaction (ab = abundance, with significance indicated by * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

Genus	Model	Model parameter estimates
<i>Metopolophium</i>	ab = intercept (islets) + ab (non-islets)	$y = -0.54 - 1.17^{***}$
<i>Myzus</i>	ab = intercept (islets) + ab (non-islets) + sward ht + non-islets sward ht	$y = -1.68 - 7.02^* - 0.41 + 0.94^*$
<i>Rhopalosiphum</i>	ab = intercept (islets) + ab (non-islets) + sward ht + non-islet:sward ht	$y = -2.25^* - 0.67 - 0.24^{***} + 0.26^{***}$
<i>Javesella</i> nymphs	ab = intercept (islets) + ab (non-islets)	$y = -0.19 - 1.79^{***}$
<i>Macrosteles</i> nymphs	ab = intercept (islets) + ab (non-islets) + sward ht + non-islet:sward ht	$y = -1.48 + 1.33^{**} + 0.15^{**} - 0.13^*$

quential removal of non-significant terms until the minimal adequate model was identified (CRAWLEY 2007). Model parameters were considered significant at the $\alpha = 0.05$ level.

Results

Species accumulation curves plotted against the number of samples showed that islets clearly had more species of Hemiptera (21) than non-islets (15) (Fig. 1a). The 95 % confidence intervals of the curves indicated that the difference was significant. However when plotted against abundance, the two curves completely overlapped (Fig. 1b). For 192 individuals (the total number in non-islet samples) there were 15 species in non-islets and 15.5 species in islets. The 95 % confidence limits indicated that at the 192 individuals point, there was no significant difference in the species richness.

When sub-habitat type was fitted to the NMDS ordination there was a partial separation and a significant difference ($r^2 = 0.270$, $p < 0.001$) between islet and non-islet communities (Fig. 2). At the species or genus level, the aphids of the genus *Metopolophium* ($p < 0.001$), *Myzus* sp. ($p = 0.015$), *Thecabius affinis* (KALTENBACH, 1843) ($p < 0.001$) and *Uromelan* sp. ($p = 0.027$); the heteropteran, *Saldula orthochila* (FIEBER, 1859) ($p < 0.001$); and nymphs of the delphacid genus *Javesella* ($p = 0.005$), showed a significant pattern within the ordination. The aphid genus *Rhopalosiphum* ($p = 0.051$) and nymphs of the cicadellid genus *Macrosteles* ($p = 0.066$) were just outside the 0.05 significance level. For most of the aphids with a significant result, there was no obvious pattern in relation to islet and non-islet habitat (Fig. 2), with the genus *Metopolophium* being the exception, which was associated more with islets. Similarly *Javesella* nymphs were strongly orientated to islets on the ordination. The apparent association of *Macrosteles* nymphs was towards non-islets, although this was non-significant, but *S. orthochila* did show a clear pattern in this direction.

When tested with generalised linear mixed models there were no significant effects for *T. affinis*, genus *Uromelan* or *S. orthochila*. The models for *Metopolophium* and *Javesella* nymphs indicated that these two genera were significantly more abundant in islets ($z = 6.60$, $p < 0.001$ and $z = 17.82$, $p < 0.001$, respectively)(Table 1, Fig. 1). The significant interaction for *Myzus* sp. ($z = 1.98$, $p = 0.048$) indicated that they had a significant

positive relationship with sward height outside islets but not within them. In addition *Myzus* sp. were more abundant within islets ($z = 2.31$, $p = 0.021$). For the genus *Rhopalosiphum* there was no significant sub-habitat effect ($z = 1.52$, $p = 0.130$) but the significant interaction ($z = 4.62$, $p < 0.001$) indicated the positive relationship with sward height was stronger outside of islets (Table 1). The *Macrosteles* nymph abundance model also had a significant interaction ($z = 2.14$, $p = 0.032$), indicating that there was a significant sward height effect within islets ($z = 2.71$, $p = 0.007$) but no effect outside them ($z = 0.28$, $p = 0.780$) (Table 1). There was also a significant sub-habitat difference, with greater numbers outside islets ($z = 1.33$, $p = 0.003$) (Fig. 3).

Discussion

The two sub-habitats did not differ in their species richness. Although a simple species accumulation curve indicated a clear difference between them, when corrected for abundance there was near total overlap between the curves, indicating any difference in richness was a density effect. As the density of Hemiptera is higher within islets than outside them (HELDEN et al. 2010), taking the same number of samples within each sub-habitat would inevitably result in finding more species in islets.

Species accumulation curves of course only give the number of species observed, regardless of their identity. Two communities could have the same number of species and identical shaped curves, yet contain a different set of species. Therefore the apparent density effect found for islets could conceal a dissimilarity between the sub-habitat communities. This was indeed the case with the NMDS indicating a significant difference between the communities, involving six Hemiptera species. However generalized linear mixed modelling suggested that the significant differences were limited to three genera: the aphid *Metopolophium*, and nymphs of the delphacid *Javesella*, which were more abundant within islets and the cicadellid *Macrosteles*, which was more abundant outside islets. *Metopolophium* is a genus of grass feeding aphids containing several common species (BLACKMAN 2010). With their high reproductive capacity, aphids can respond rapidly to improved environmental conditions, such as greater nitrogen availability in their food plants (DIXON 1973). It is probable that due to the formation of islets around cattle dung, the sward within this sub-habitat may be relatively rich in nitrogen and could explain why this genus was more abundant there (HELDEN et al. 2010). Improved microclimatic conditions within the longer sward of the islets may have also had a positive effect. The lack of sub-habitat differences for other aphid species may be largely due to the relatively small numbers of most genera but this cannot explain the lack of effect for the most abundant aphid genus, *Rhopalosiphum*. It may be that this aphid is more tolerant of the intensive management of the grassland and can be found well distributed across the site, where it appears to respond strongly to sward height. The stronger response outside islets may reflect the relatively greater improvement of conditions that results from sward growth after heavily grazing than the comparatively small change in islets that are much less heavily grazed.

The contrasting pattern between *Javesella* and *Macrosteles* is interesting given these genera represent the two main groups of Auchenorrhyncha (Delphacidae and Cicadellidae) to be found in northern European grasslands (WALOFF 1980, NICKEL 2003). Given that the

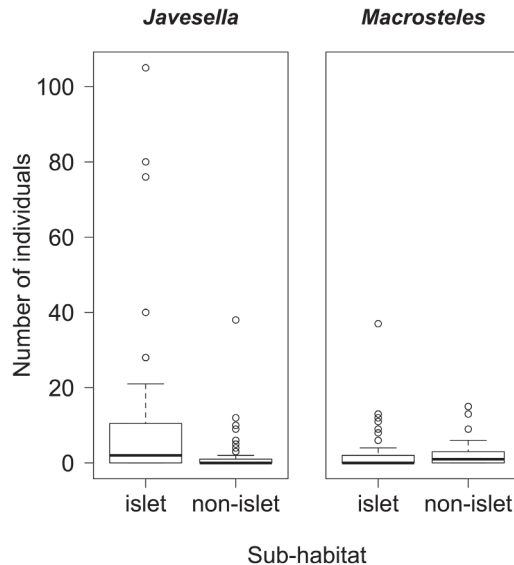


Fig. 3: Boxplots showing the number of *Javesella* nymphs, and *Macrosteles* nymphs found in islet and non-islet samples. Dark horizontal lines show the median, with the upper and lower boxes the 25th and 75th percentiles respectively. The dashed lines indicate either 1.5 times the interquartile range or the maximum and minimum values if there are no outliers (small circles).

species representing these genera in our study are all generalist feeders and are thought to feed in the same way on a range of grass species (NICKEL 2003), it is interesting to consider how the results presented here contribute to the understanding of how the genera co-exist. Cicadellids and delphacids have been shown to alternate in adult abundance, with delphacids reaching an earlier peak in numbers in the spring, facilitated by their overwintering as nymphs (WALOFF & SOLOMON 1973, WALOFF 1980). The cicadellids, which overwinter as eggs, peak later as adult delphacid numbers decline. Therefore there appears to be some temporal niche differentiation. However our results indicate that there may also be some spatial niche differentiation, with *Javesella* more abundant within islets and *Macrosteles* outside islets.

The reasons for a difference in sub-habitat choice between delphacids and cicadellids were not investigated here and must remain a matter of conjecture. One possibility is a difference micro-climate. Islets retain longer swards where humidity may be higher and less variable and temperature variation reduced. An alternative possibility is differences in the availability or composition of nutrients. Indeed in an experiment using artificially created islets DITTRICH & HELDEN (2012) found a contrasting response to different forms of nutrient input, with delphacids more abundant in tall plots that had been treated with artificial fertiliser, and more cicadellids in the islets created around dung. Similarly, PRESTIDGE (1982) found that delphacids were more abundant on fertilised areas and cicadellids on unfertilised. In addition he suggested that cicadellids move with their habitat to locate an optimal plant nitrogen level. In our study it may be that the sward of islets, being in close proximity to dung, is likely to have a higher nitrogen content, which would explain why

Javesella were more abundant in this sub-habitat. While *Macrosteles* may have located more outside the islets due to a more optimal nitrogen level, it does not exclude the possibility that in other grasslands they may find their preferred feeding location in islets.

So as we have shown both in this paper and previous work (HELDEN et al. 2010, DITTRICH & HELDEN 2012) the characteristics of islets and surrounding non-islet sward provide some spatial variation within agricultural grasslands. These habitats tend to be considered as species poor and rather uniform in nature and therefore of little interest for biodiversity. This may be true when compared to species rich natural or semi-natural grasslands but that does not mean that interesting biological phenomena cannot be found there. Indeed it could be argued that there is an advantage in studying ecological phenomena in relatively simple systems, as the reduced complexity means it may be easier to decipher patterns. The differences we found in sub-habitat choice between the two main groups of grassland Auchenorrhyncha are one such an interesting pattern that contributes to our understanding of how they can co-exist despite apparently having such similar requirements.

Zusammenfassung

“Sward islets” oder “Hochgrasinselchen” sind in einer Rinderweide jene kleinen Bereiche um einen Kuhfladen, die höherwüchsigeres Gras aufweisen, weil dieses von Rindern weniger intensiv beweidet wird als der Rest der Fläche. Sie haben eine wesentliche Bedeutung für die Häufigkeit und Verbreitung von Arthropoden im Weideland. Auch Zikaden, Wanzen und Pflanzenläuse sind in diesen Inselchen häufiger als im umgebenden Grasland. Beeinflusst dies nun die Zusammensetzung der Artengemeinschaft oder ist dies nur ein Dichteeffekt? Die Ergebnisse einer Paarvergleichs-Studie (Inseln mit Nicht-Inseln) auf einer Rinderweide in Irland zeigen, dass zwar die Dichteunterschiede den Großteil der Unterschiede der Artengemeinschaften erklären, einige Arten jedoch auf die Präsenz der Inselchen in anderer Weise reagieren. Die beiden Gattungen *Javesella* (v. a. *J. obscurella*, zudem auch *J. pellucida*) und *Macrosteles* (v. a. *M. viridigriseus*, aber auch *M. laevis* und *M. sexnotatus*) dominieren die Zikadenfauna im Wirtschaftsgrünland. Larven und – in geringerem Ausmaß – Adulti zeigen unterschiedliche Verteilungen in Bezug auf die Hochgrasinselchen. *Javesella* ist wesentlich häufiger auf den Inselchen, während die Verteilung von *Macrosteles* auf den Inseln und ihrer Umgebung fast gleich ist. Möglicher Gründe für diese Unterschiede zwischen den Gattungen werden diskutiert.

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