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River Mun Restoration at Northrepps

Final report of pre- and post-restoration monitoring

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River Mun Restoration at Northrepps:
Final report of pre- and post-restoration monitoring

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Contents

1. Summary 1
2. Methods 2
   2.1. Biotic characterisation 2
   2.2. Statistical methods 2
3. Monitoring Results 3
4. Comments and Recommendations 8
5. References 9
6. Supplementary information 10

List of Tables

Table 1 Species list and total count. 10

List of Figures

Figure 1. The River Mun monitoring design uses a control on Foxes Beck (above), a local adjacent catchment which was not restored, and an impact site close to the headwater of the Mun (below). Contains OS data © Crown copyright [and database right] (2015) 1

Figure 2. Plan view of the replicated reach-scale sampling design. Habitat measures were recorded and invertebrate samples taken randomly from the three habitats (where present) across all reaches before and after restoration. 2

Figure 3. Psychodidae (Diptera) larvae *Tonnoiriella (pulchra).* 3

Figure 4. PCA of the Mun habitat data 4

Figure 5. NMDS of invertebrate community composition: 5

Figure 6 Results from general linear mixed effects models, error bars represent 95% confidence intervals: 6

Figure 7. Comparison of Mun data to other restored sites: data were combined across restorations to demonstrate the relative effectiveness of the Mun project using general linear mixed effects models for density estimates and rarefaction and extrapolation for diversity [13], error bars represent 95% confidence intervals. 7

1. Summary

Before-After-Control-Impact habitat and invertebrate assessment has been undertaken across a control and restored site along Foxes Beck and the River Mun, respectively (Figure 1). This approach has enabled the assessment of water quality, habitat and ecological restoration following the diversion of sewage effluent and the installation of large woody debris (Lwd). We have combined data from multiple stream Lwd restorations in order to assess how the project on the Mun is performing. Relative to other streams in the database, the Mun had the second lowest invertebrate species richness (39) after Foxes Beck (29), likely due to their nature as headwaters which are depauperate relative to lower reaches[1]. There was a significant restoration effect causing invertebrate density and biomass to increase across all habitats within the Mun.

Figure 1. The River Mun monitoring design uses a control on Foxes Beck (above), a local adjacent catchment which was not restored, and an impact site close to the headwater of the Mun (below). Contains OS data © Crown copyright [and database right] (2015)

2. Methods

Annual sampling took place during July 2014 and 2015, once before and once following restoration. Substrate proportions (i.e. %silt relative to other substrate), coarse (<10cm) and large (>10cm) wood and plant percentage volume infested (PVI) were estimated at each invertebrate survey point (Figure 2).

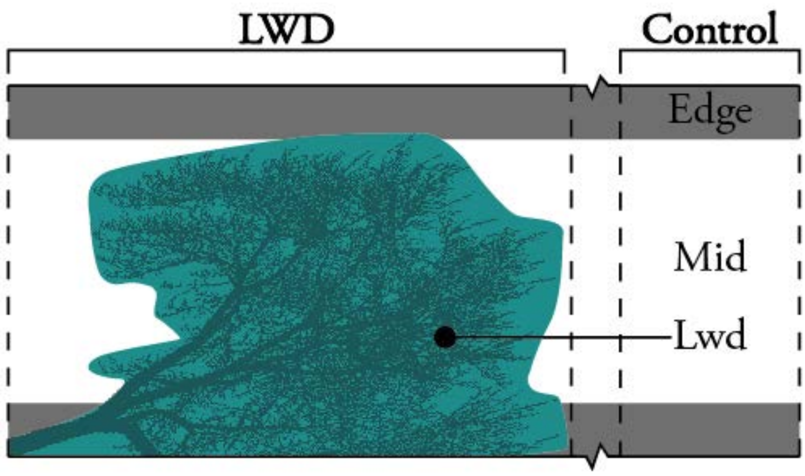

Figure 2. Plan view of the replicated reach-scale sampling design. Habitat measures were recorded and invertebrate samples taken randomly from the three habitats (where present) across all reaches before and after restoration.

2.1. Biotic characterisation

A bespoke 152.4mm diameter Hess sampler with 335 microns mesh was used to collect invertebrates. Unlike a kick net survey, Hess samples are quantitative meaning population densities can be estimated. A row of teeth at the base of the Hess and robust handles enabled it to cut through branches when used within woody structures. Samples were immersed immediately in 70% IMS to preserve contents for identification in the laboratory. Invertebrates were identified to species in most cases using a dissecting microscope with 40-100x magnification and counted to give the density per sample.

Estimates of species mean body size (dry mass [mg]) were made using at least five individuals of each taxon per sample, selected at random. Individuals were measured with regard to the body dimension required for existing length-mass regression equations using an eye-piece graticule with a scale bar containing 100 units scaled to 10mm at 40x magnification. Regression equations were obtained from Baumgäertner & Rothhaupt [2], Benke *et al.* [3], Burgherr and Meyer [4], Calow [5], Edwards *et al.* [6], Hildrew and Townsend [7], Johnston and Cunjak [8], Meyer [9], Sabo *et al.* [10], Smock [11] and Towers [12].

2.2. Statistical methods

Spatial and temporal variation (i.e. besides the treatment effect) was not of primary interest in this study, but rather, the amount of variation explained by the restoration after the differences caused by site characteristics had been estimated. Therefore, the statistical techniques used here have been designed to focus on the effect of Lwd restoration after accounting for temporal and spatial variation as confounding factors. We assess restored (i.e. those with treatment trees; TT) sites vs controls (i.e. those with no trees; N) which encompass all pre-restoration sites and post-restoration control sites. This grouping has enabled us to demonstrate whether invertebrates increased in density, for instance, in restored sites relative to unrestored sites. We also assess local within-site differences between Lwd habitat and adjacent mid and edge habitat. This combination of analyses provides critical information on the scale of the restoration effect.

We use principal components analysis (PCA) and non-metric multidimensional scaling (NMDS) with the Bray–Curtis dissimilarity index to assess changes in environmental parameters and invertebrate composition, respectively. Estimates of species richness were made using recently developed methodology published as the R package iNEXT [13]. This approach provides information on the sampling efficiency (i.e. estimates what percentage of the community we are capturing) and provides a robust means of comparing samples where different sample sizes occur. “Treatment” and “habitat” were fixed terms and “stream” a random term in general linear mixed effects models (GLMM) in assessments of differences in invertebrate density and biomass.

3. Monitoring Results

In total we made 27 habitat recordings and processed 27 corresponding invertebrate samples which contained a total of 6749 individuals and 47 unique taxa (e.g. Fig X), of which 1846 individuals were measured for biomass estimates. Sampling efficiency was high with an estimated >98% coverage of invertebrate species sampled in the target communities within each sampling location each year. Chironomids, Annelids, *Pisidium* and *Hydracarina* were not identified to species and so were removed from analyses of species diversity.

Figure 3. Psychodidae (Diptera) larvae *Tonnoiriella (pulchra).*

PCA of environmental data revealed no significant differences between the Mun or Foxes Beck and no statistical difference between years at Foxes Beck (Figure 4a, b). This indicated that there was no evidence of confounding temporal habitat change unrelated to the restoration. The habitat restoration was successful at increasing wood demonstrated by the significant difference between pre- and post-impact conditions (Figure 4c). Edge and Lwd habitat were significantly different to mid-stream, the latter having higher proportions of gravel substrate and relatively low variation in the other measured parameters (Figure 4d).

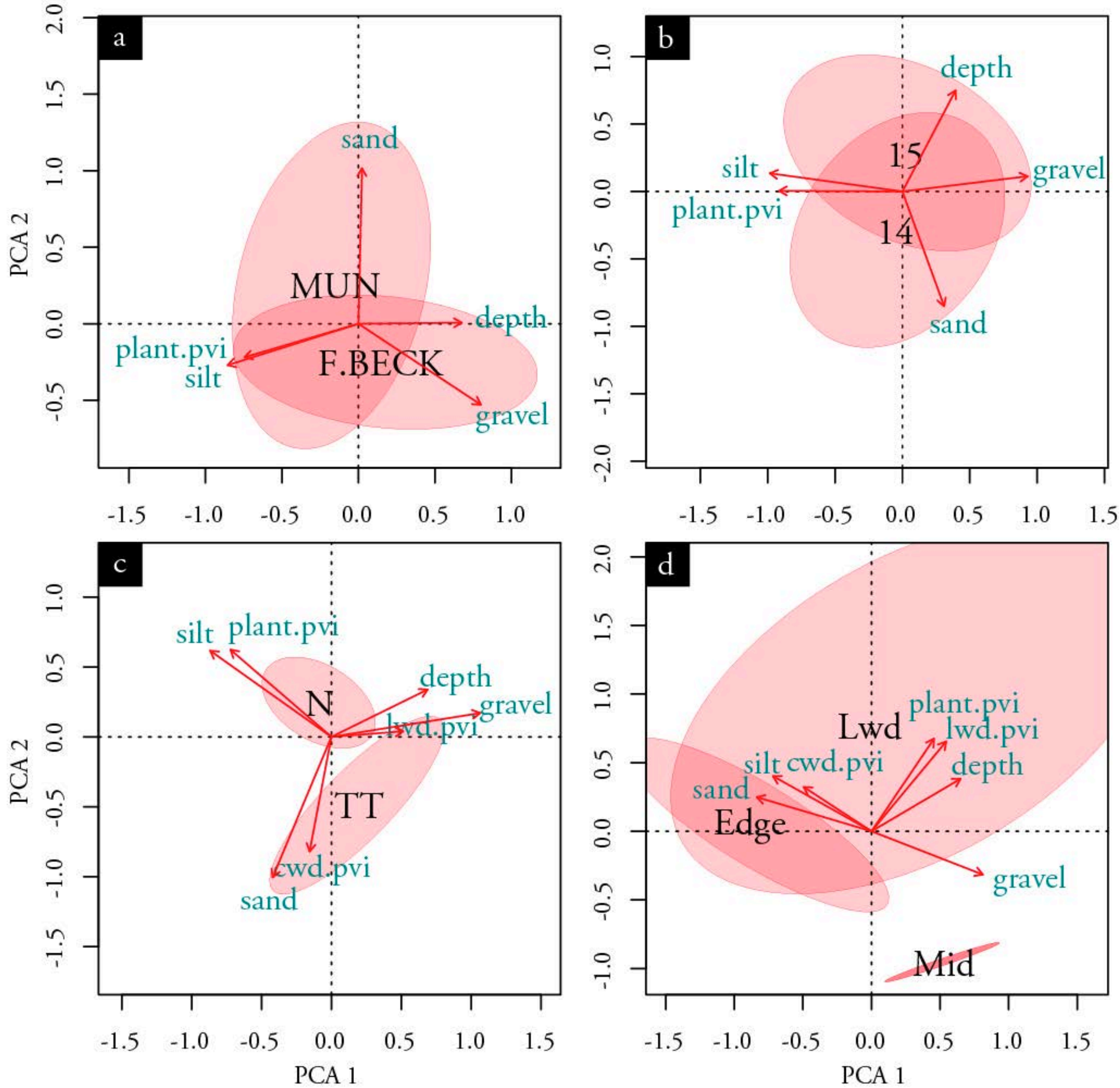

Figure 4. PCA of the Mun habitat data

Ellipses in Fig. 4 represent standard error: a) there were no statistical stream habitat differences in 2014; b) there was no significant difference between years 2014 and 2015 within the control stream demonstrating that there was no confounding temporal habitat change unrelated to the restoration; c) there was a significant treatment effect within the restored stream (i.e. with treatment trees; TT) relative to reaches with no trees (N) caused by increasing large and coarse woody debris PVI (lwd.pvi and cwd.pvi respectively); d) Lwd habitat generally had higher plant and large woody debris PVI but large variation between samples demonstrates the variability of this habitat relative to stream-edge and mid-stream.

Invertebrate community composition was not significantly different between streams but there was a significant difference between years within the control stream (Figure

5a, b), indicating that there was evidence of confounding temporal effects unrelated to the restoration. Invertebrate composition also changed within the post-impact reach relative to the pre-impact reach (Fig 5c). Invertebrate composition within Lwd was significantly different from mid-stream but not stream-edge (Fig 5d).

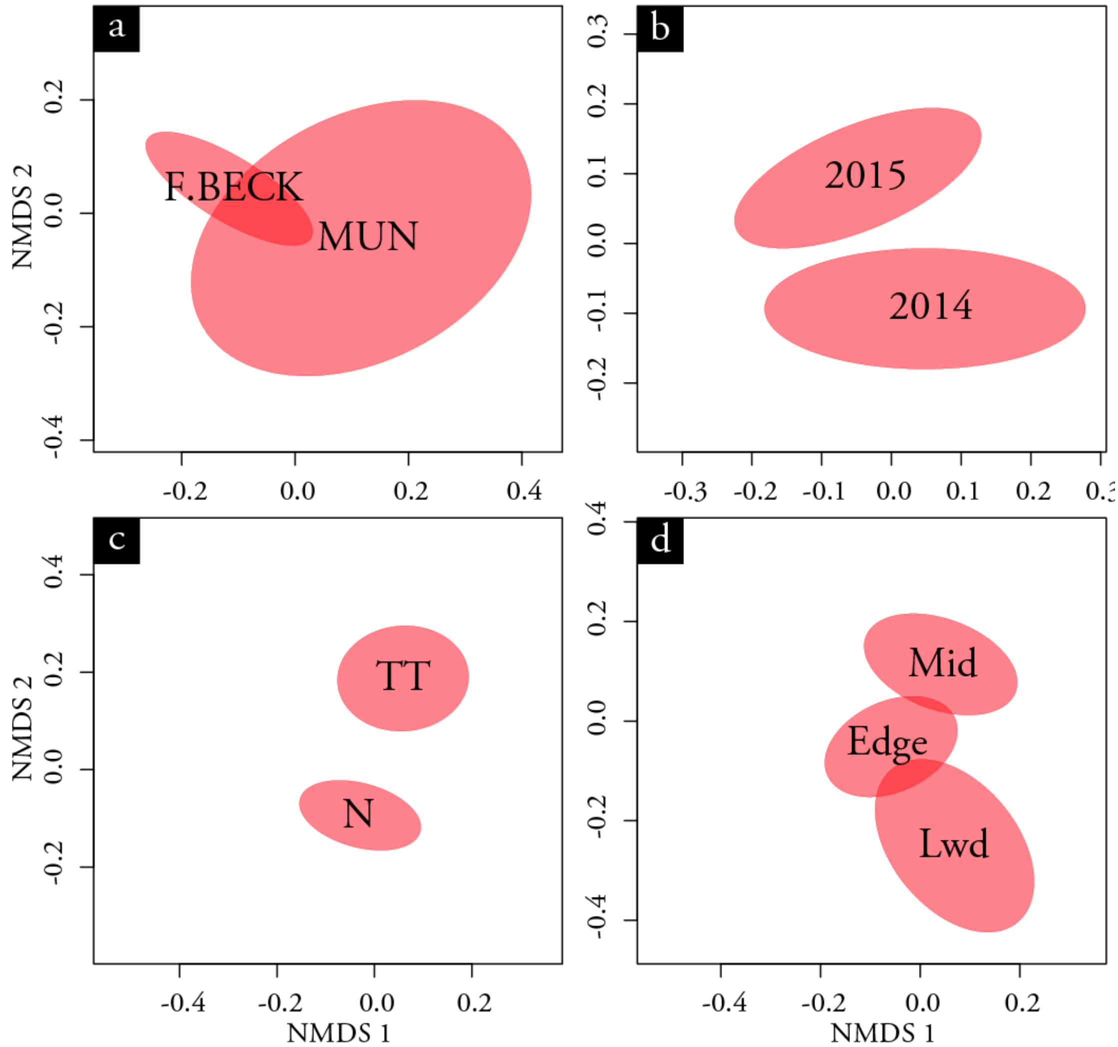

Figure 5. NMDS of invertebrate community composition:

In Figure 5, a) there was no significant difference between stream invertebrate communities in 2014; b) control site communities were significantly different between 2014 and 2015; c) and within the post-impact (i.e. with treatment trees; TT) relative to the pre-impact reach with no trees (N); d) and there were significant differences in composition between mid-stream and Lwd communities.

There was a clear treatment level response in invertebrate density and biomass, particularly within Lwd (Figure 6a-d) but diversity decreased across both streams in 2015 relative to 2014 (Figure 6e-f). This suggests that the restoration was successful at increasing populations of some species but overall change in species diversity was not responding to the restoration.

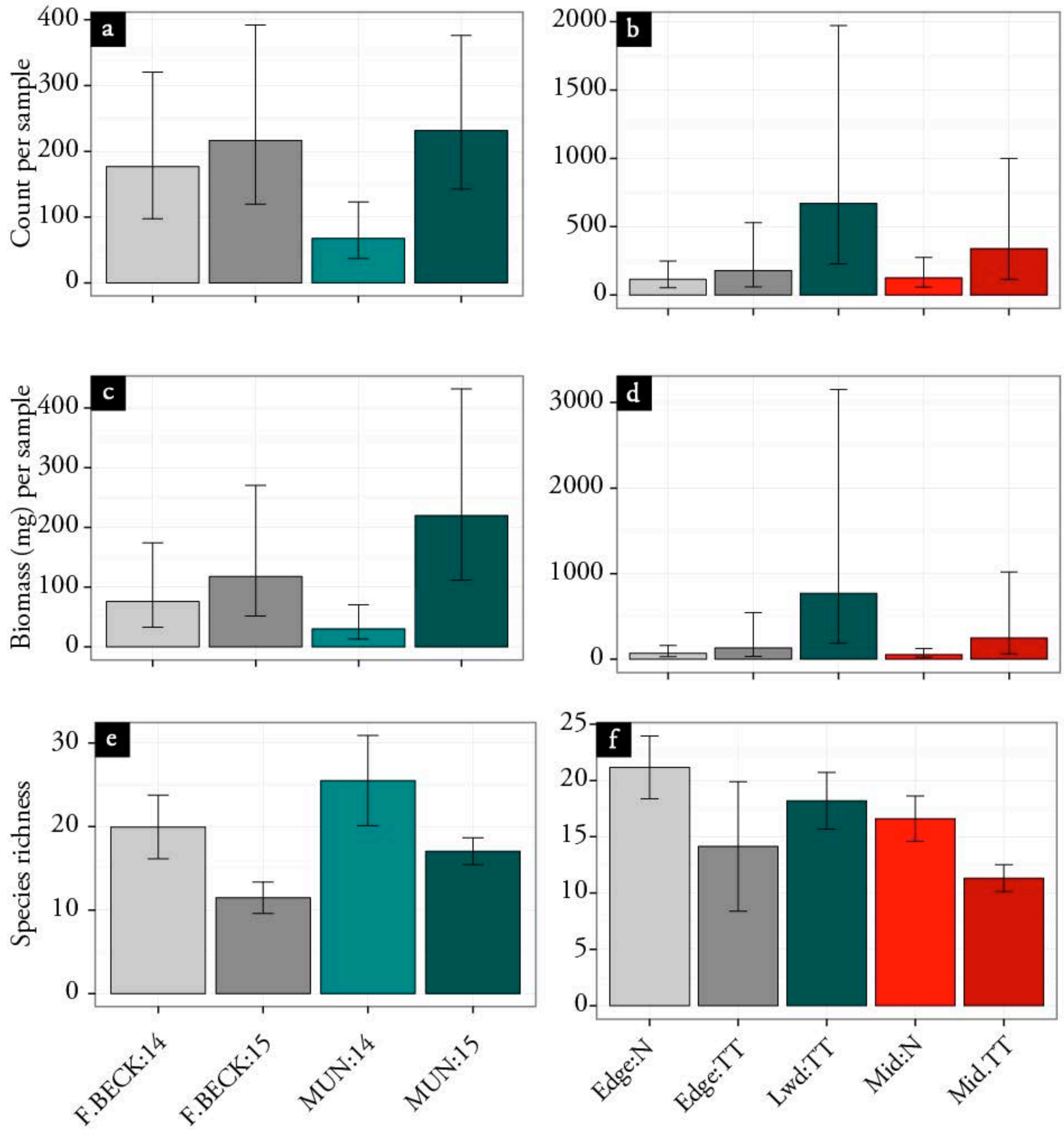

Figure 6 Results from general linear mixed effects models, error bars represent 95% confidence intervals:

In Figure 6, a) invertebrate density significantly increased in the restored reach (MUN:15) relative to the pre-impact (MUN:14) and matched control densities (F.BECK:14, F.BECK:15) which did not change during the study; b) invertebrate density was not significantly different between habitats when compared to adjacent samples collected from restored reaches (i.e. with treatment trees; TT) relative to reaches with no trees (N); c) invertebrate biomass significantly increased in the restored relative to the pre-impact reach, whereas control biomass did not change significantly during the study; d) but there was no statistical difference between habitats; e) there was a significant decrease in invertebrate species richness across both streams; e) and Lwd habitat had a higher species richness relative only to restored mid-stream habitat.

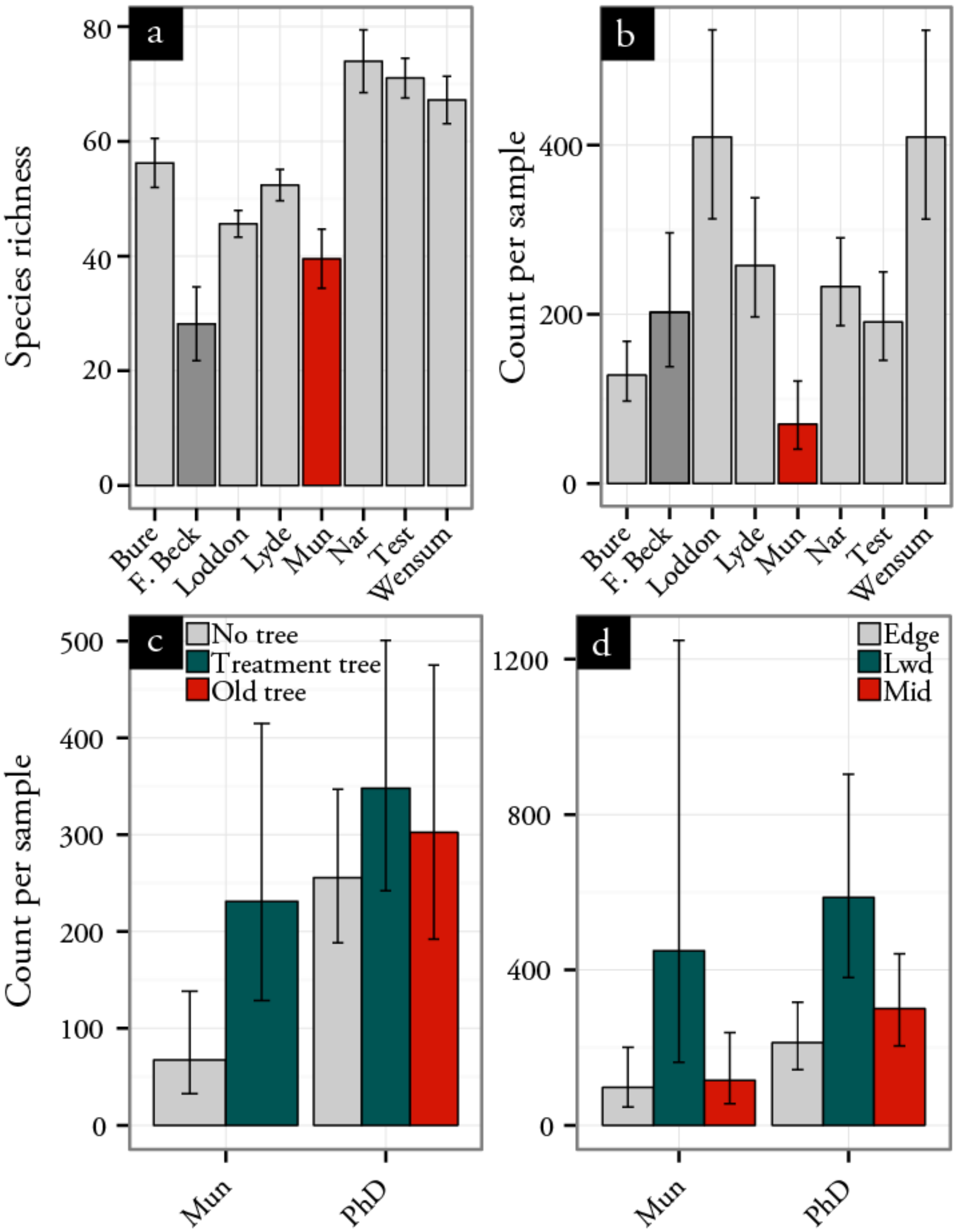

Figure 7. Comparison of Mun data to other restored sites: data were combined across restorations to demonstrate the relative effectiveness of the Mun project using general linear mixed effects models for density estimates and rarefaction and extrapolation for diversity [13], error bars represent 95% confidence intervals.

The data presented in Figure 7 show: a) species richness was relatively low in the Mun and Foxes Beck compared to other streams on the database; b) invertebrate density was also relatively low in 2014; c) however, invertebrate density significantly increased in the Mun following restoration so that densities were comparable to other streams; d) Lwd habitat had the highest densities but there was large variation between samples.

4. Comments and Recommendations

The response of the invertebrate community to the restoration on the Mun clearly demonstrates success (Figure 6a-d; Figure 7a). However, likely large-scale factors (e.g. climatic) or large annual fluctuation in species composition in these headwaters was impacting diversity in both study systems. Longer-term monitoring and increased within site repeat measures alongside water chemistry data collected by Norfolk Rivers Trust will be key to help understand the causes of this.

We therefore recommend that invertebrate populations are explored in the longer-term and the additional samples collected are processed - a further two samples were collected from each habitat during each sampling visit. If additional funds were available ENSIS could collaborate with Norfolk Rivers Trust and Jonathan Lewis (UCL PhD student studying the restoration) to process the additional samples and combine these data with water chemistry data to further strengthen the results presented here.

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6. Supplementary information

Table 1 Species list and total count.

Taxa	F.BECK	MUN
Agapetus fuscipes	21	1
Asselus aquaticus	2	61
Asselus meridian	1	0
Baetis rhodani	53	46
Beraea maurus	2	2
Beraea pullata	0	1
Bezzia solstitalis	14	12
Chaetopteryx villosa	0	1
Chironomid	59	279
Clinocera sp1	0	1
Coleoptera sp1	0	8
Dendrocoelum lacteum	0	4
Dicranota bimaculata	14	36
Dixa sp	3	1
Dugesia lugubris	1	22
Elmis aenea	2	54
Eloeophila	6	4
Erpobdella octoculata	1	22
Gammarus pulex	593	1830
Glossiphonia complanata	14	20
Helobdella stagnalis	0	1
Hydracarina	30	7
Leuctra hippopus	1	0
Limnephilus fuscicornis	0	2
Lype reducta	0	1
Micropterna lateralis	1	0
Micropterna sequax	0	3
Muscidae sp	0	1
Nemouridae sp	0	2
Oligochaeta	105	187
Pisidium	141	55
Planaria torva	0	6
Planorbis contortus	0	2
Polycelis tenuis	18	1082
Potamopyrgus jenkinsi	1519	245
Psychoda cinerea	0	1
Ptychoptera lacustris	8	0
Radix peregra	1	5
Scirtes sp	1	16
Silo nigricornis	0	17
Simulium equinum	0	2
Simulium lundstromi	17	2
Simulium ornatum	13	0
Stictotarsus sp	0	1
Tanypod	28	19
Tonnoiriella pulchra	0	6
Velia caprai	2	2
x.Baetis indet	0	1
x.Diptera indet	1	0
x.Hydropsyche indet	0	1
x.Limnephilidae indet	1	0
x.Springtail indet	0	3
x.Trichoptera indet	0	1
TOTAL	**2673**	**4076**

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