

**SHORT COMMUNICATION**

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# Physicochemical drivers of managed river and agricultural drainage channel macroinvertebrate communities

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Email: kieran.getthing2015@my.ntu.ac.uk**Abstract**

Artificial channels are common features in lowland agricultural catchments, and are a potentially significant habitat for aquatic species. Recent studies have suggested communities in managed rivers and artificial channels are broadly similar, but with some compositional differences. However, because relatively few studies have considered how artificial channels may contribute to supporting aquatic communities, their physicochemical condition and suitability for aquatic fauna remain poorly characterised. Therefore, this study explores the role of physicochemical variables in driving macroinvertebrate community differences between intensively managed rivers and artificial channels in a highly arable catchment. Aquatic macroinvertebrates were sampled in intensively managed rivers and artificial channels. Physicochemical water quality variables were also recorded, and used to identify macroinvertebrate community responses. Both intensively managed rivers and artificial channels had spatiotemporally stable communities, with no significant differences in richness, abundance, effective diversity or Berger–Parker dominance detected between sampling months or channel types. Macroinvertebrate composition in intensively managed rivers and artificial channels was significantly different, and driven by the relative abundance of taxa present, not the number of taxa unique to each channel type. Compositional differences between intensively managed rivers and artificial channels were partially driven by conductivity, dissolved oxygen and temperature. Identifying remaining sources of compositional variance may support tailored management strategies that accentuate compositional differences between rivers and artificial channels, increasing overall diversity in intensively farmed arable catchments.

**KEYWORDS**

chemical, ditches, drains, environmental drivers, invertebrate composition, physical

## 1 | INTRODUCTION

Land drainage is vital to sustaining agriculture in lowland catchments (Buisson et al., 2008), which is increasingly threatened by sea level rise (Chen, McCarl, & Chang, 2012; Oppenheimer et al., 2019). In addition

to sustaining agriculture, lowland drainage networks provide an expanded habitat for aquatic species and can support high biodiversity (Hill, Chadd, Morris, Swaine, & Wood, 2016; Rhoads & Massey, 2012). The backbone of most drainage networks are rivers that were historically straightened, and have since been intensively

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managed by dredging, embankment and vegetation cutting (Buisson et al., 2008; Mayer et al., 2017). Artificial channels of varying sizes intersect rivers and other artificial channels forming a dense network of aquatic habitats that broadly resemble the slow flowing, heavily sedimented freshwater marshes lost during land reclamation (Shaw, Johnson, Macdonald, & Feber, 2015).

Rivers and artificial channels in agricultural catchments support high diversity in their own right (Herzon & Helenius, 2008; Hill et al., 2016; Williams et al., 2004). When compared, macroinvertebrate communities in intensively managed rivers and larger artificial channels ( $\geq 4$  m wide) can have a similar taxonomic richness (Gething & Little, 2020), but smaller artificial ditches typically contain fewer species (Davies, Biggs, Williams, Lee, & Thompson, 2008; Williams et al., 2004). Thus, in catchments with a continuum of small to large artificial channels, the role of differing channels in sustaining aquatic communities remains unclear. Compositionally, artificial channels of varying sizes contain unique species (Armitage, Szoszkiewicz, Blackburn, & Nesbitt, 2003; Gething & Little, 2020), suggesting the presence of artificial channels allows an overall greater number of species to survive in a catchment. However, because relatively few studies have considered how these highly connected components of agricultural drainage networks may collectively contrast and/or complement each other to support aquatic communities their physicochemical condition and suitability for aquatic fauna remain poorly characterised.

In rivers, macroinvertebrate community composition is driven by a range of factors, including dissolved oxygen, water temperature and conductivity. In artificial channels, macroinvertebrate composition is reportedly driven by pH, shading and dredging (Shaw et al., 2015), but factors that are key in rivers, such as water temperature and dissolved oxygen, appear to have a weak influence (Leslie et al., 2012; Rolke, Jaenike, Pfaender, & Rothe, 2018). Armitage et al. (2003) suggest that the distinct physicochemical environment provided by smaller ditches aids in increasing overall catchment biodiversity, but the study's focus on one ditch limits what can be learned from its community comparison with the nearby river. Thus, despite what is known of physicochemical drivers of composition in rivers and artificial channels in isolation, the specific variables driving compositional differences between rivers and artificial channels remain unidentified.

This study aims to explore macroinvertebrate community differences between intensively managed rivers and artificial channels in a highly arable agricultural landscape, and determine how physicochemical variables influence any observed differences. This research is a key step towards identifying the nature and driver(s) of differences between intensively managed rivers and artificial channels in agricultural catchments, which may be used to guide understanding of the role and potential importance of artificial channels in maintaining aquatic macroinvertebrate diversity.

## 2 | METHODS

### 2.1 | Study area

This study was conducted in lower reaches of the Steeping catchment, on channels surrounding Wainfleet All Saints, Lincolnshire,

UK. Approximately 6 km east of Wainfleet All Saints, the River Steeping enters Gibraltar Point National Nature Reserve before terminating in The Wash estuary (Lincolnshire Wildlife Trust, 2020). The 170 km<sup>2</sup> Steeping catchment is dominated by intensive arable agriculture and has an extensive network of artificial drainage channels (Environment Agency, 2020). All of the channels in this study (rivers and artificial channels) are subject to long-term, and on-going intensive management due to their active role in supporting irrigation and flood risk mitigation within the catchment. Specifically, Wainfleet Relief Channel is the largest artificial channel, sharing similar dimensions to the River Steeping (c. 17 m wide and 2.7 m deep). As such, the River Steeping and Wainfleet Relief Channel are subject to similar management in the form of embankments, bank and channel vegetation removal, and dredging. Three smaller channels were also studied, the Little River Lymn, Good Dike and an unnamed agricultural ditch adjacent to the A52 Wainfleet All Saints bypass. These smaller channels were 0.5–3 m wide, 0.2–1 m deep and periodically managed by vegetation removal.

### 2.2 | Data collection

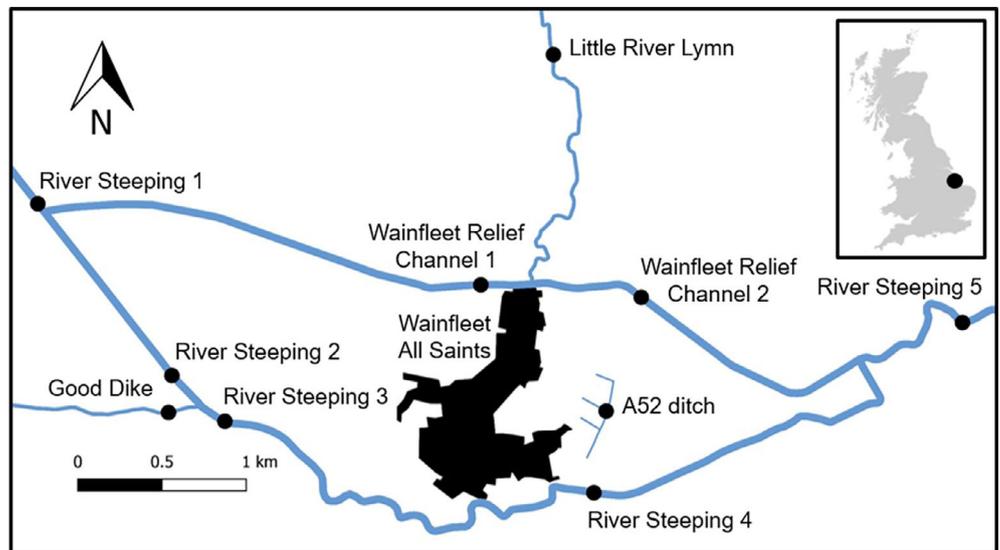
Aquatic macroinvertebrates were sampled three times at 10 sites in the lower Steeping catchment between July and September 2017 ( $n = 30$ : Figure 1). Samples were collected by a 3-min kick/sweep methodology (Murray-Bligh, 1999) using a 500  $\mu\text{m}$  mesh net. In the field, the samples were preserved in 70% isopropanol. In the laboratory, macroinvertebrates were identified to family level (except Hydrachnidia Oligochaeta and Turbellaria, which were identified as such).

At all 10 sites, pH, conductivity (mS/cm), dissolved oxygen (DO: mg/L and % saturation) and water temperature ( $^{\circ}\text{C}$ ) were recorded immediately prior to macroinvertebrate sampling using a Hanna pHep<sup>®</sup>4 (HI 98127), a Hanna DiST<sup>®</sup>6 (HI 98312) and a Hach HQ30d flexi. On each occasion, three readings were taken and a mean calculated for use in analysis.

### 2.3 | Statistical analyses

All analyses were conducted in the R environment (R Core Team, 2020). Sample sites were assigned to a channel type depending on their origin: intensively managed river (River Steeping 1–5, and the Little River Lymn) or artificial channel (Wainfleet Relief Channel 1–2, Good Dike and the A52 ditch). Macroinvertebrate richness (`vegan::specnumber`: Oksanen et al., 2019), abundance (`biomonitor::abundance`: Laini et al., 2020), effective diversity (Hill's N2: `analogue::n2`: Simpson & Oksanen, 2020) and Berger–Parker dominance (BPD: `biomonitor::berpar`) were calculated for each sample. The influence of month (categorical—three levels) and channel type (categorical—two levels) on sample richness, abundance, effective diversity and BPD was tested using linear mixed effect models (`lme4::lmer`: Bates, Maechler, Bolker, & Walker, 2015: eight models total: Table 1). All eight models included site as a random intercept to

**FIGURE 1** Sampling locations in the Steeping catchment [Color figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]



**TABLE 1** Models testing the influence of month and channel type on macroinvertebrate richness, abundance, effective diversity (Hill's N2) and Berger–Parker dominance (BPD)

Model no.	Model
1	Richness ~ month + ( 1   site)
2	Abundance ~ month + ( 1   site)
3	Effective diversity ~ month + ( 1   site)
4	BPD ~ month + ( 1   site)
5	Richness ~ channel type + ( 1   site) + ( 1   month)
6	Abundance ~ channel type + ( 1   site) + ( 1   month)
7	Effective diversity ~ channel type + ( 1   site) + ( 1   month)
8	BPD ~ channel type + ( 1   site) + ( 1   month)

account for spatial dependency. The four models testing the influence of channel type also included month as a random intercept. All model assumptions were tested using DHARMA (Hartig, 2020). The influence of month and channel type on community dispersion and composition was tested using PERMDISP2 (`vegan::betadisper`) and permutational multivariate analysis of variance (PERMANOVA: `vegan::adonis2`). PERMANOVA included a restricted permutation scheme for site to meet the assumption of exchangeability under the null hypothesis. Taxa contributions to dissimilarity between channel types were identified using similarity percentages (SIMPER: `vegan::simper`).

Principle component analysis (PCA) was applied to the macroinvertebrate community, and the first two principle components were extracted. Stepwise variance inflation factor analysis (VIF: `usdm::vifstep`; Naimi, Hamm, Groen, Skidmore, & Toxopeus, 2014) was used to highlight collinearity between pH, conductivity, DO (mg/L), DO (% saturation) and temperature. Variables with a VIF score > 3 were considered collinear (Zuur, Ieno, & Elphick, 2010), and excluded from further analysis. The relationship between principle components 1 and 2 and the

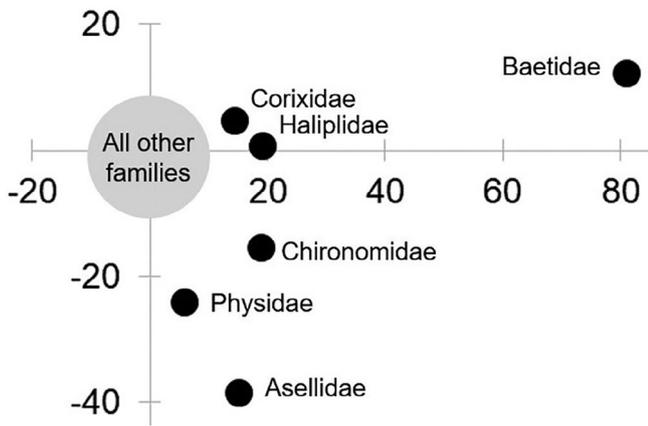
physicochemical variables was tested using a Pearson product-moment correlation.

### 3 | RESULTS

A total of 5,828 individuals were recorded from 48 macroinvertebrate families. Intensively managed rivers contained 44 families (91.7% of total), and artificial channels contained 40 families (83.3% of total). Gyrinidae, Hydrophilidae, Hydroptilidae, Lestidae, Psychomyiidae, Scirtidae and Tubellaria were exclusive to managed rivers, and Dryopidae, Mesoveliidae and Planariidae were exclusive to artificial channels. The compositional overlap between intensively managed rivers and artificial channels was 37 families (77.1% of total).

None of the models highlighted significant differences in richness, abundance, effective diversity or BPD between sampling months, or channel types (see Supporting Information S1). Sampling month had no influence on community dispersion or composition (betadisper:  $F(2) = .129, p = .879$ , PERMANOVA:  $F(2) = 1.123, R^2 = .08, p = .296$ ). Channel type had no influence on dispersion, but was responsible for compositional variances between samples (betadisper:  $F(1) = .058, p = .822$ , PERMANOVA:  $F(1) = 2.441, R^2 = .08, p = .010$ ).

Principle components 1 and 2 accounted for 59.0% and 19.8% (total: 78.8%) of the compositional variance, respectively. Most families clustered around the centroid, except Baetidae, which was driven by principle component 1, and Asellidae, Chironomidae and Physidae, which were driven by principle component 2 (Figure 2). Asellidae (SIMPER: 16.5%,  $p = .980$ ), Bithyniidae (14.0%,  $p = .020$ ), Baetidae (8.8%,  $p = .350$ ), Chironomidae (8.5%,  $p = .050$ ) and Physidae (9.6%,  $p = .010$ ) contributed the most to dissimilarity between channel types (total: 57.4%), but not all were statistically significant. The 10 taxa that were unique to one channel type contributed <1.0% to the dissimilarity between managed rivers and artificial channels. VIF highlighted collinearity between the five physicochemical variables, so pH and DO (mg/L) were excluded from further analyses. Principle



**FIGURE 2** Principle components 1 and 2 for macroinvertebrate families in the Steeping catchment, Lincolnshire

component 1 was not significantly correlated with any recorded physicochemical variables (Supporting Information S1). Principle component 2 was significantly correlated with conductivity (Pearson  $r(28) = -.560, p = .001$ ), DO (% saturation: Pearson  $r(28) = .494, p = .005$ ) and water temperature (Pearson  $r(28) = .417, p = .022$ ).

## 4 | DISCUSSION

The catchment community remained similar between July and September 2017, and is, therefore, unlikely to confound the following spatial assessment of managed rivers and artificial channels. Richness, abundance, effective diversity and BPD were comparable between intensively managed rivers and artificial channels, likely reflecting the homogenous agricultural land use, which increases the availability of limiting nutrients (Jarvie et al., 2018). Additionally, high connectivity between the channels and similar management practices that are applied to all channel types (e.g., dredging and vegetation cutting) likely also contribute to the observed similarities (Buisson et al., 2008; Gallardo et al., 2008; Mayer et al., 2017). Despite the similarities, it is unclear whether differences in richness, abundance and diversity/dominance between intensively managed rivers and artificial channels are obscured by the taxonomic level of identification used. The macroinvertebrates in this study were resolved predominantly to family level, which is typically sufficient to highlight inter-site differences (Heino & Soininen, 2007; Marshall, Steward, & Harch, 2006), but further studies are required to determine whether the observed similarities are consistent at higher taxonomic resolutions.

Significant differences in macroinvertebrate community composition between intensively managed rivers and artificial channels mirror the findings of Gething and Little (2020), who suggest physicochemical conditions are a potential source of variance. Despite these differences, the high compositional overlap between channel types adds to evidence that a common core of tolerant taxa exist in lowland catchments. A common core implies that compositional differences between channel types are caused by a minority of taxa that are

unique to each site (Williams et al., 2004). Similar observations have been made at smaller spatial scales, with a small number of species contributing most to differences between microhabitats within artificial channels (Verdonschot, Didderen, & Verdonschot, 2012). However, the PCA demonstrates that some core families, which are present at every site, are at the extremes of principle coordinates 1 and 2. This suggests that although all the same core taxa are ubiquitous, their relative abundance is more important than the number of unique species in characterising the distinct communities of intensively managed rivers and artificial channels. General trends in macroinvertebrate composition between intensively managed rivers and artificial channels are consistent between channel types and catchments (Gething & Little, 2020), suggesting the role of abundance in driving compositional differences is likely to be observed in agricultural catchments more broadly. However, further studies are required to determine the role of sample size ( $n = 30$ ) and the close proximity of the sampling locations (max separation = 5.5 km) in this study.

SIMPER and the PCA show that the taxa unique to one channel type cluster around the centroid, suggesting a limited response to the recorded physicochemical conditions. These unique taxa may be responding to patch scale variances in habitat type and/or structure (Gething, Ripley, Mathers, Chadd, & Wood, 2020; Verdonschot et al., 2012), or be filling the altered range of niches that become available when a different element of the ubiquitous core community is dominant. The relative importance of core taxa abundance implies taxa unique to one channel type may be of limited value. However, by filling open niches, taxa that are not present at all locations may still play a key role in supporting the functioning of aquatic ecosystems in lowland agricultural catchments, and thus warrant further investigation.

Conductivity, DO and water temperature are known to influence aquatic riverine communities, and this also appears true in artificial channels. In previous studies, dissolved oxygen and temperature had a limited effect on macroinvertebrate composition in artificial channels (Leslie et al., 2012; Rolke et al., 2018). This likely reflects that conditions are relatively stable within channel types, but differences between intensively managed rivers and artificial channels are sufficient to cause compositional differences (as proposed by Armitage et al., 2003). This is also supported by the significant compositional differences observed in this study and the correlation between compositional and physicochemical gradients, which suggest a distinct habitat provision in intensively managed rivers and artificial channels. Although responses to the recorded variables were observed, little of the principle component 1 variance was accounted for suggesting more influential variables remain unidentified. At present, most water bodies (including rivers) in lowland catchments are managed to fulfil an agricultural purpose (e.g., land drainage), but the identification of key compositional drivers may facilitate tailored management for rivers and artificial channels. A tailored management strategy that differentiates between rivers and artificial channels is likely to promote greater overall diversity, and improve resilience to natural stressors (e.g., climate change) in systems that are already pressured by intensive agricultural practices (Mantyka-Pringle, Martin, Moffatt, Linke, & Rhodes, 2014).

## 5 | CONCLUSION

Intensively managed rivers and artificial channels support high diversity in their own right, but the nature and driver(s) of compositional differences between these highly connected habitats are poorly characterised. Intensively managed rivers and artificial channels had a similar richness, abundance, effective diversity and BPD, but a significantly different composition. The relative abundance of taxa present at every sampling site was more important in driving compositional differences between managed rivers and artificial channels than taxa that were unique to each site. However, taxa unique to each site may still play a role in maintaining ecosystem functions by filling niches that are only available when a differing element of the ubiquitous core community is dominant. Compositional differences between intensively managed rivers and artificial channels were partially driven by conductivity, DO and temperature, but further research is required to identify remaining sources of compositional variance. Identifying outstanding drivers of macroinvertebrate composition in rivers and artificial channels offers opportunities to shape management practices that promote diversity and increase resilience to natural and anthropogenic pressures.

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### CONFLICT OF INTEREST

The author declares that there are no conflicts of interest.

### DATA AVAILABILITY STATEMENT

The data presented here is available in supplementary information.

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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