Pond creation for Natural Flood Management and biodiversity: a Scottish case study

Julie Fahy

SSHL Webinar

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Introduction

- **Flood frequency** has increased globally over the last 30 years (Kundzewicz et al., 2014) and the risk of great floods is also expected to heighten with climate change (Milly et al., 2002).

- Freshwater ecosystems are particularly vulnerable to **biodiversity loss** (Dudgeon et al. 2006).

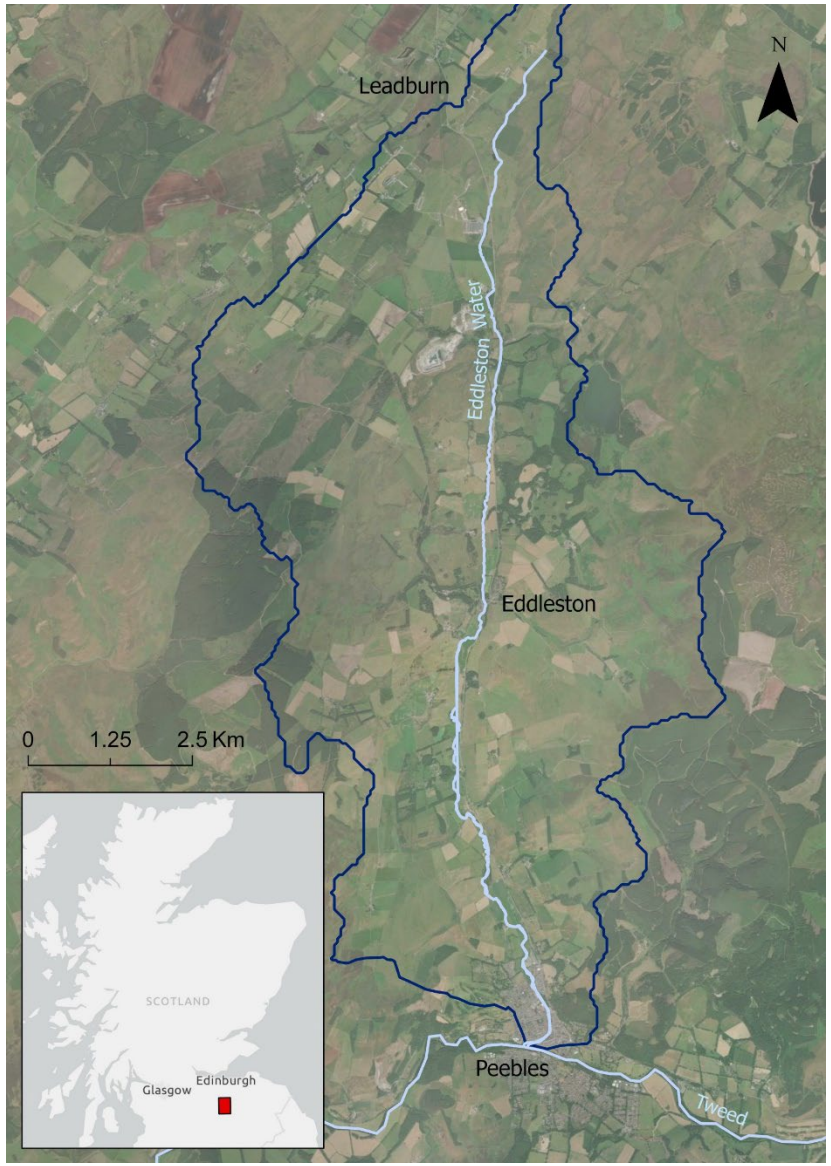
→ These challenges call for **integrated solutions** to sustainably reduce flood risk as well as safeguard freshwater biodiversity.

Introduction

- Nature-based Solutions (NbS): “actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, **simultaneously providing human well-being and biodiversity benefits**” (WCC, 2016).
- NbS targeting floods: **Natural Flood Management (NFM)**
- NFM uses the potential of ecosystems and “natural features” to **slow and retain water in the landscape**, to reduce flood risk and provide habitats for biodiversity.
- NFM implementation: creation and/or restoration of ecosystems, construction of natural features (e.g. leaky woody dams)
- **Catchment scale**

Context: the Eddleston Water Project

- NFM implementation project in the Eddleston Water catchment, in the Scottish Borders, since 2009
- Funded by the Scottish Environment Protection Agency and led by Tweed Forum
- Primary motivation: reduce the impact of floods



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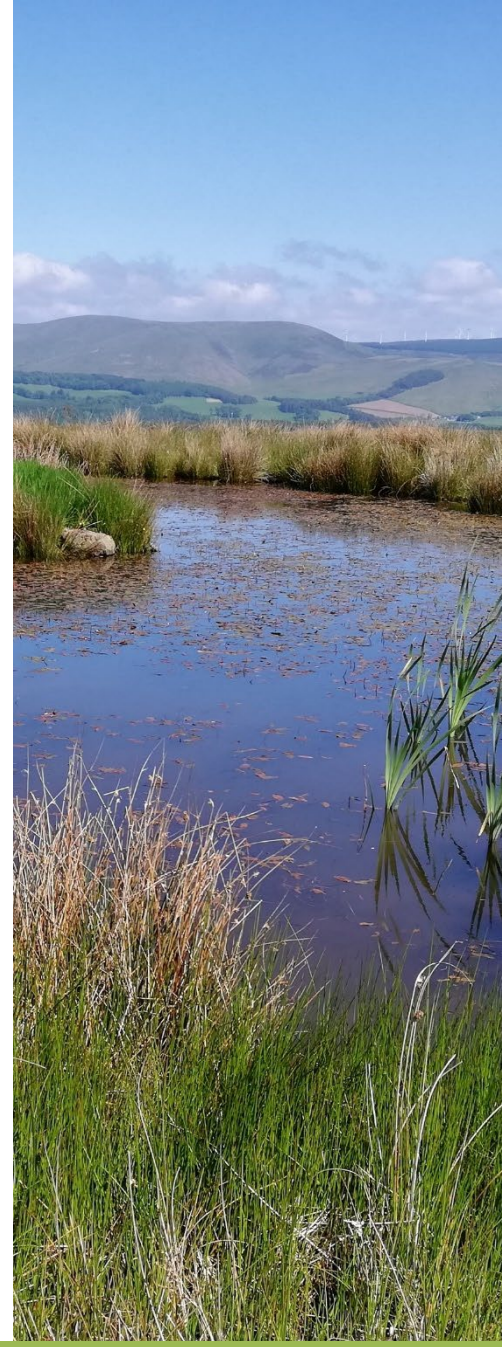
Context: the Eddleston Water Project

- ~600 properties at risk in and around Peebles
- Long history of flooding, with Annual Average Damages (AAD) estimated at £1,200,000

Flooding events in Peebles

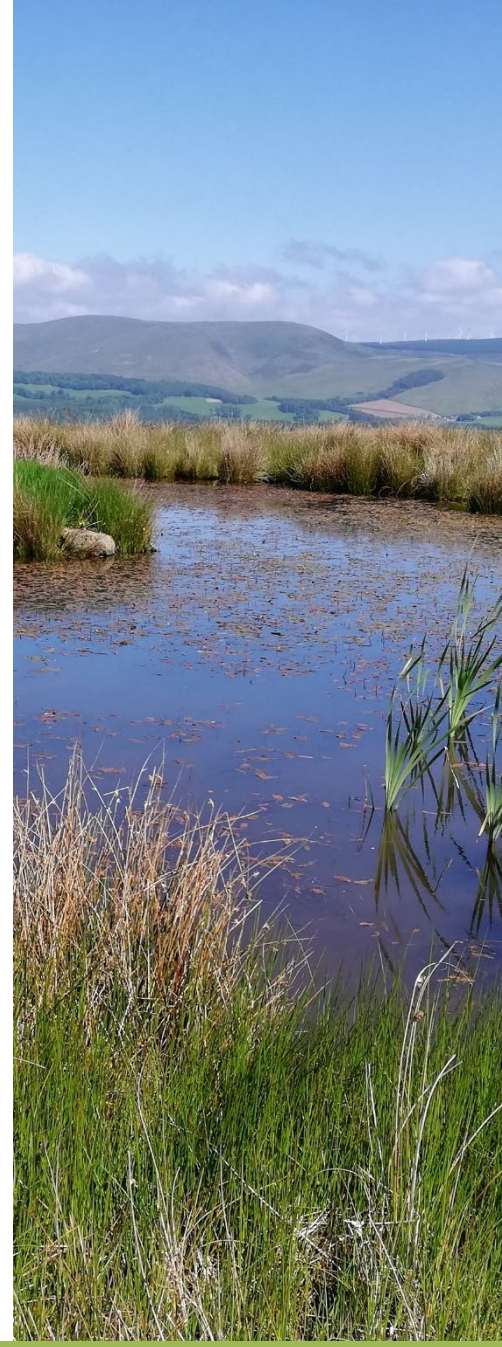


Context: the Eddleston Water Project

Various measures implemented across the catchment since 2011:

- re-meandering over 2.9 km of river length

Photo: Tweed Forum



Context: the Eddleston Water Project

Various measures implemented across the catchment since 2011:

- Riparian tree planting (330’000 trees, 207 ha)
- Construction of 116 leaky woody dams to act as high-flow restrictors

Photos: Tweed Forum

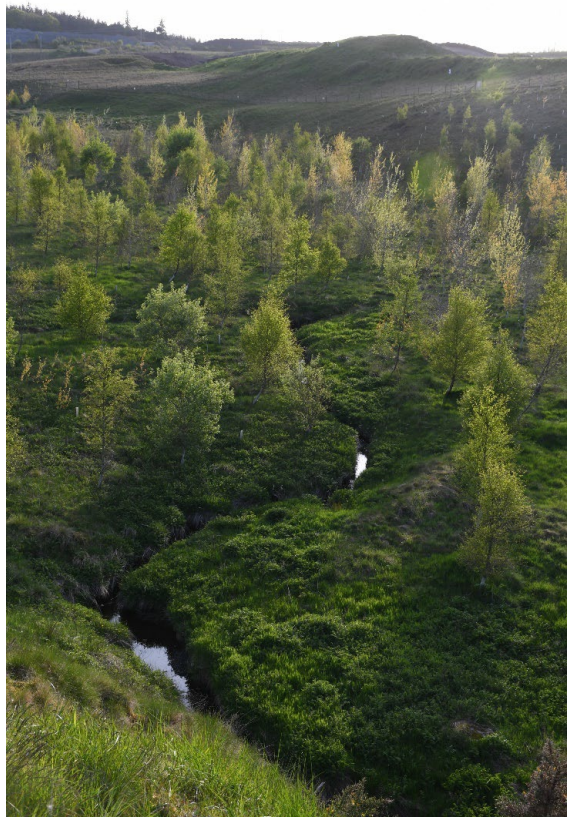


Photo: J. Fahy

Context: the Eddleston Water Project

Various measures implemented across the catchment since 2011:

- 38 flood storage ponds, created between 2015 and 2018

Small flow-attenuation ponds located in the headwaters and tributaries

One of the larger ponds in the lower floodplain

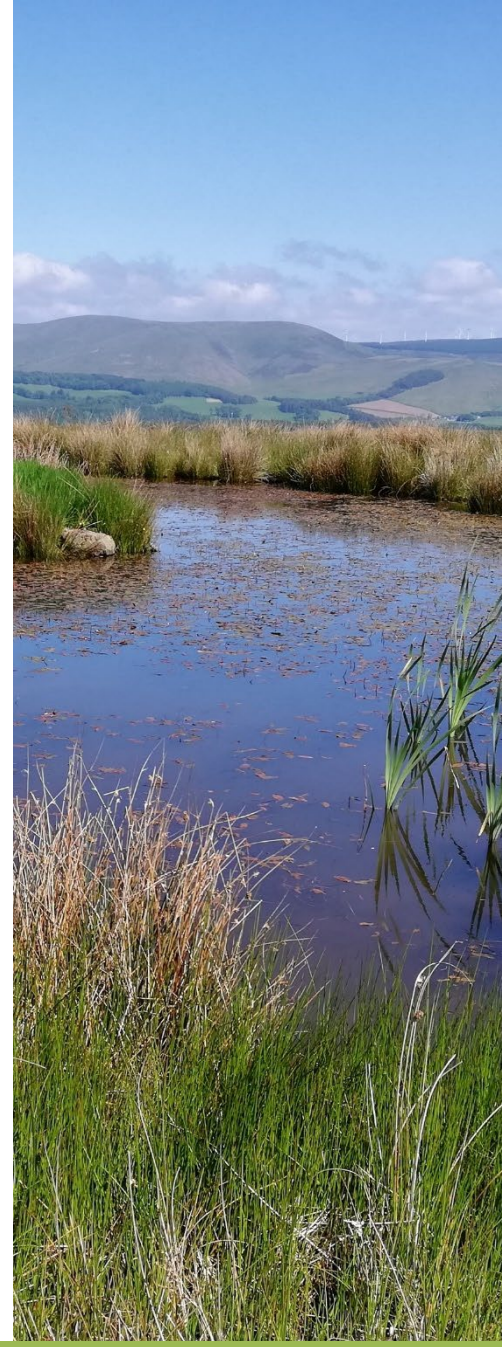
Photos: Hamish Robertson

Context: the Eddleston Water Project

Comparison between normal and flooded states:

Photos: Tweed Forum

Estimation that £1 million in flood damages avoided over 100 years thanks to the measures already implemented (Spray et al. 2021)



Context: the Eddleston Water Project

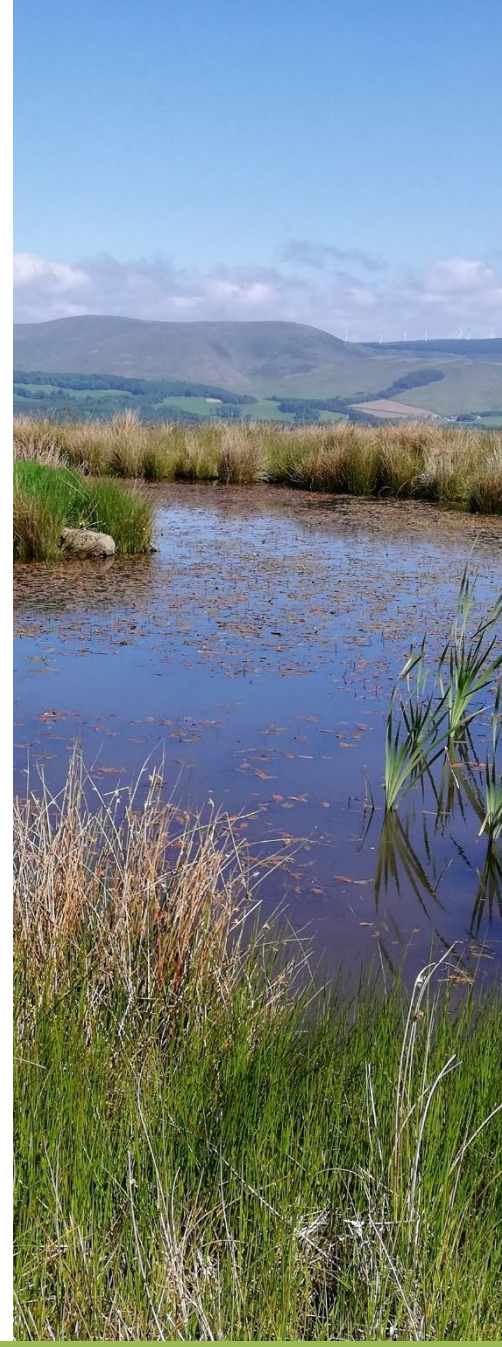
- Ongoing monitoring by the Eddleston Water Project to measure the effectiveness of NFM implementation on flood risk reduction, but very little monitoring of impacts on biodiversity

- NbS are supposed to address both human/societal issues and biodiversity loss, therefore we need to also measure the effectiveness of these measures for freshwater biodiversity

Main objective of the study and research questions

Investigate the contribution of NFM ponds to the Eddleston pondscape freshwater biodiversity, using dragonflies (Insecta: Odonata) as indicators

- How do dragonfly communities differ between NFM and reference ponds?
  - In terms of species **richness** / alpha diversity
    (e.g. Do NFM ponds host as many species as reference ponds?)
  - In terms of species **composition**
    (e.g. Do we find the same species in both types of ponds?)



Why dragonflies?

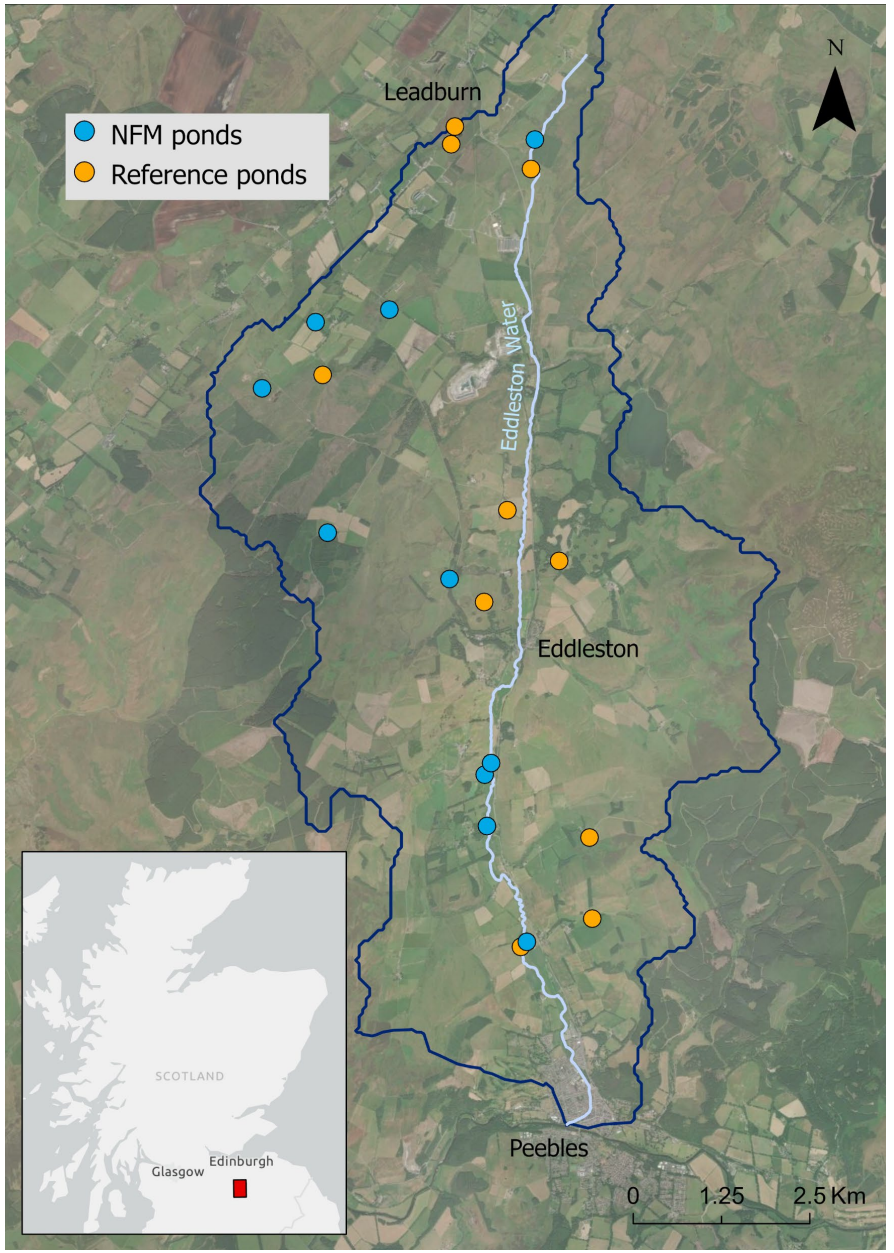
Odonata as tools for environmental assessment

Odonata are often used as indicators, for several reasons (see Oertli, 2008; Golfieri et al. 2016; Corbet, 2004):

- Their taxonomy is well established and they are relatively easy to identify to the species level (esp. adults).
- They are widespread and their distribution is well known.
- Their ecological preferences are varied and also well known.
- They react quickly to alterations to their habitats and rapidly colonise new sites.
- Their diversity is often closely related to that of other freshwater taxa (Chovanec et al. 2015) (e.g. wetland plants (Simaika and Samways, 2009), aquatic macroinvertebrates (Smith et al. 2007))

Methods: study sites

- Adult dragonfly surveys carried out in summer 2023 on **20 ponds**:
  - 10 NFM ponds created by Tweed Forum
  - 10 reference ponds, representative of the pondscape prior to NFM implementation
- Larval sampling in 6 ponds (3 NFM, 3 reference ponds)



Methods: study sites

NFM ponds

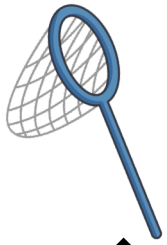



Reference ponds




Methods: field surveys

- Adult dragonfly surveys carried out following the IBEM protocol (Pond Biodiversity Index, Indermuehle et al. 2010):
  - 2 visits per pond (1) late May – early June; 2) mid-July – mid-August)
  - Investigation of 3 to 5 plots per pond for 10 minutes each (1 plot = 10*30 m)



- Collection of exuviae

- Qualitative larval sampling in early June following the PONDERFUL protocol:
  - 20 sweeps of 1 m (net mesh size: 500 µm, 25*18 cm frame size)
  - Close to the shore, near the land-water interface

- Collection of environmental variables

Results: pondscape richness

- 9 species observed in the pondscape in summer 2023
- All common, but representative of the **typical assemblage** that could be expected in those habitats and that area of Scotland

Pyrrhosoma nymphula

Lestes sponsa

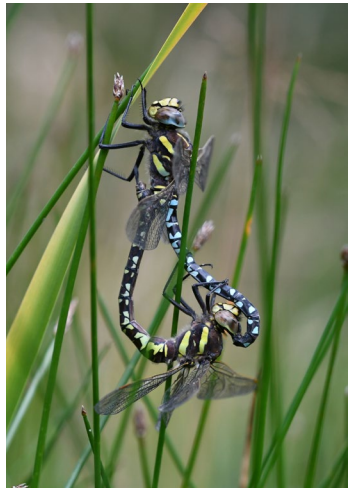
Coenagrion puella

Enallagma cyathigerum

Ischnura elegans

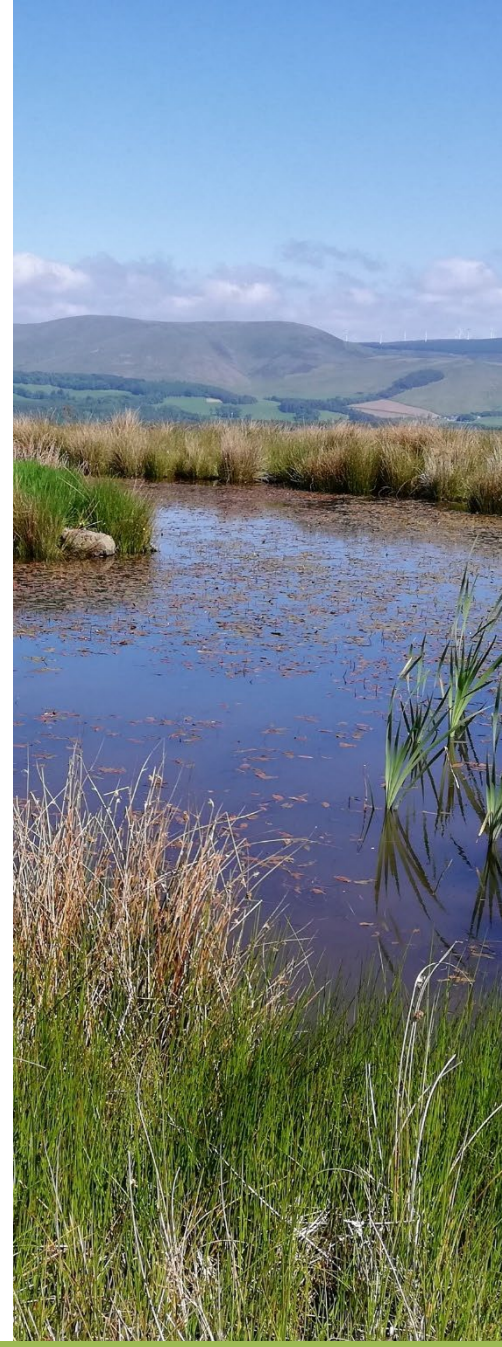
Libellula quadrimaculata

Sympetrum danae



Aeshna juncea

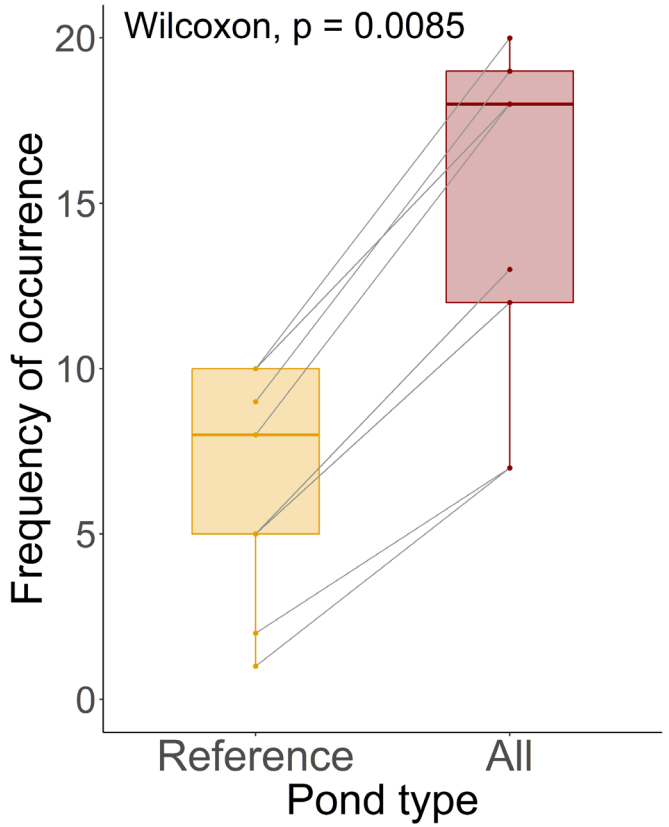
Sympetrum striolatum



Results: contribution of NFM ponds

Pond creation for NFM has **strengthened the pondscape's dragonfly populations**.

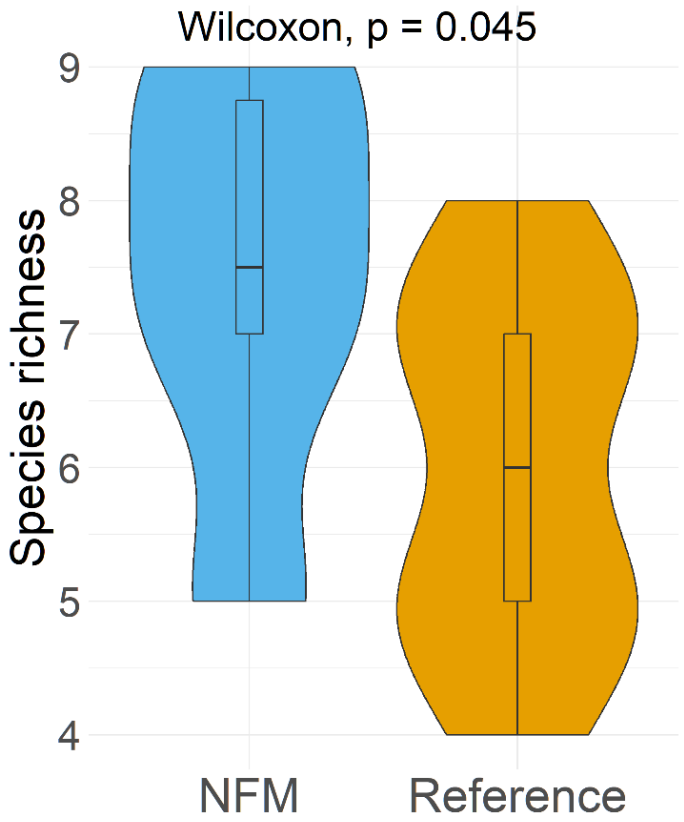
Pond creation has increased **habitat availability** and all recorded species of dragonflies are now found at more sites.



Frequency of occurrence of each species in reference ponds only and with new NFM ponds added.

Results: contribution of NFM ponds

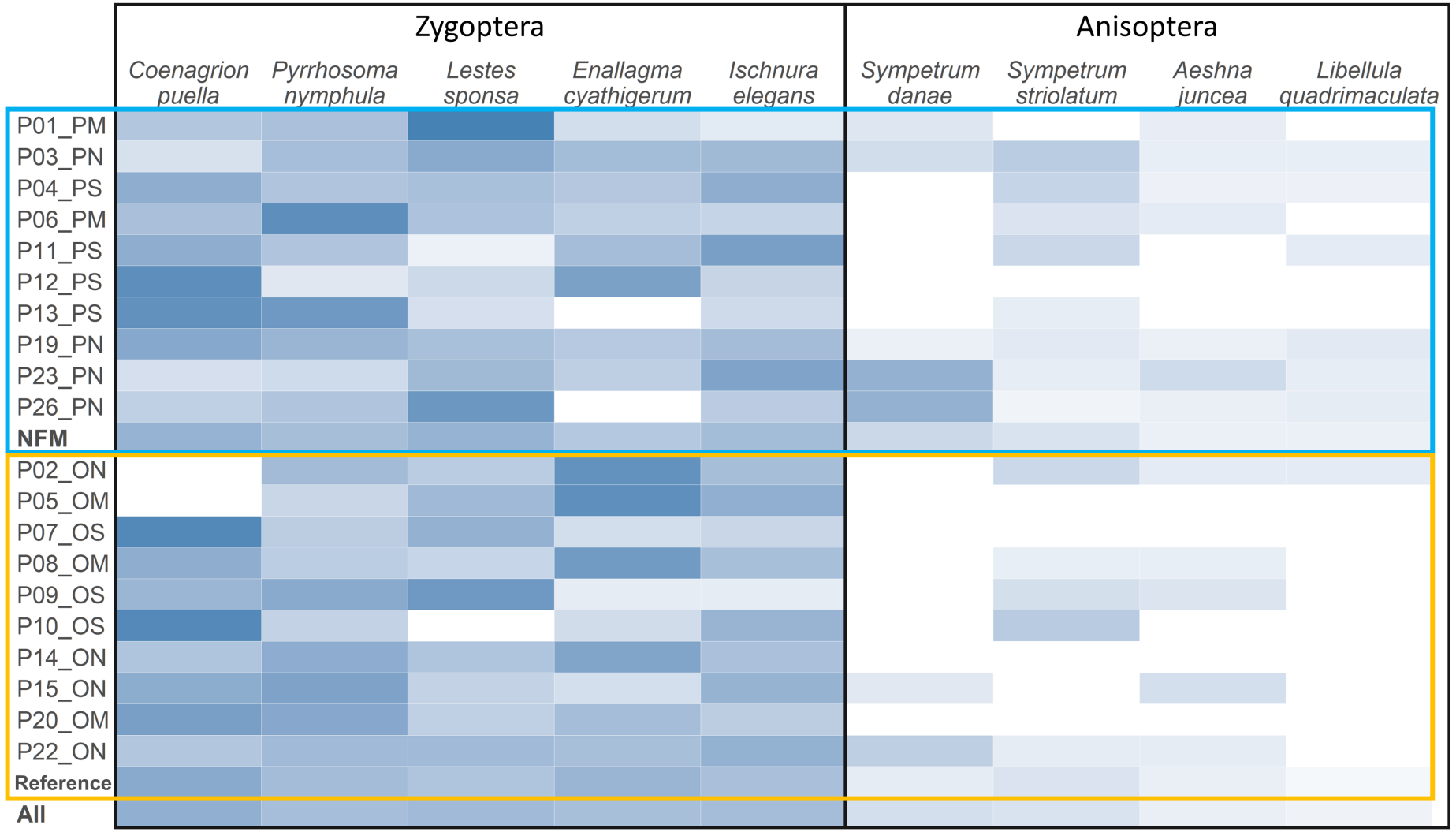
The ponds created for NFM even display a **slightly higher Odonata richness**.



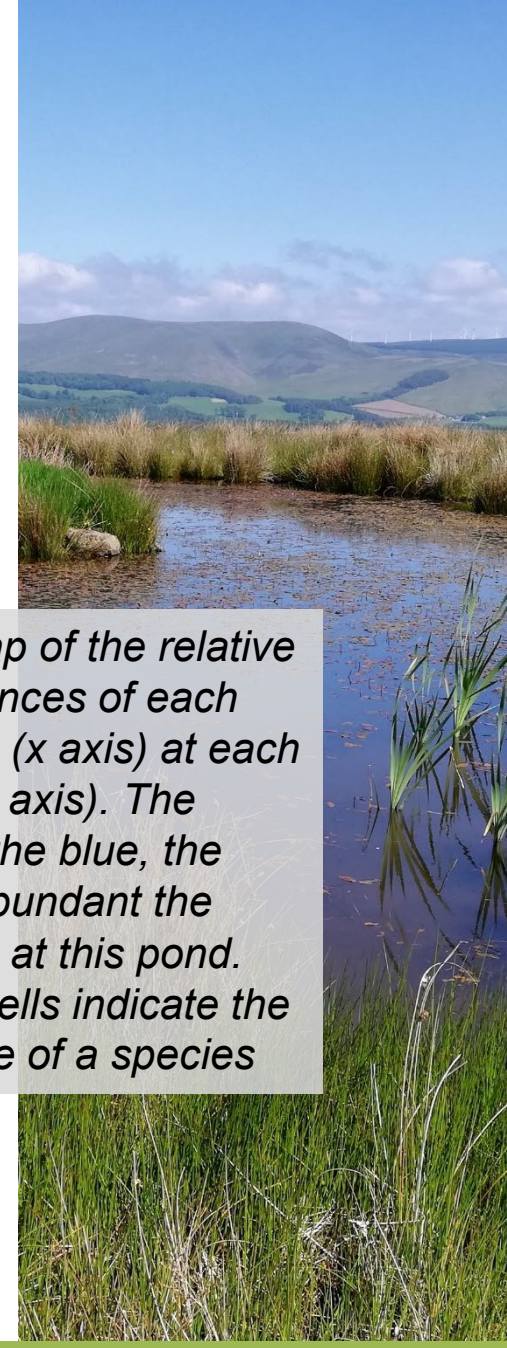
Dragonfly richness in NFM vs. reference ponds

Results: community composition

Reference and NFM ponds hosted **similar dragonfly communities**.

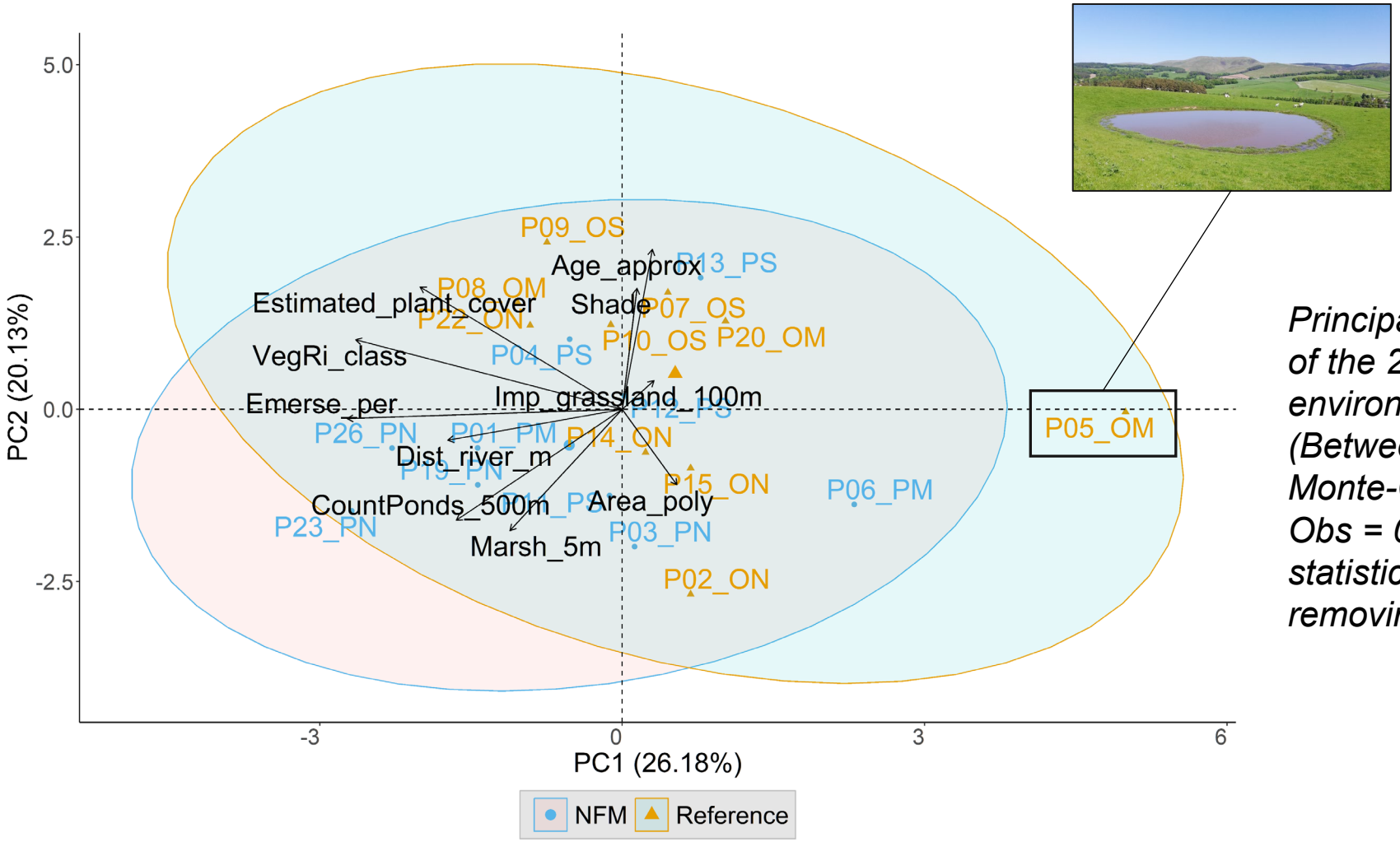


Heatmap of the relative abundances of each species (x axis) at each pond (y axis). The darker the blue, the more abundant the species at this pond. White cells indicate the absence of a species

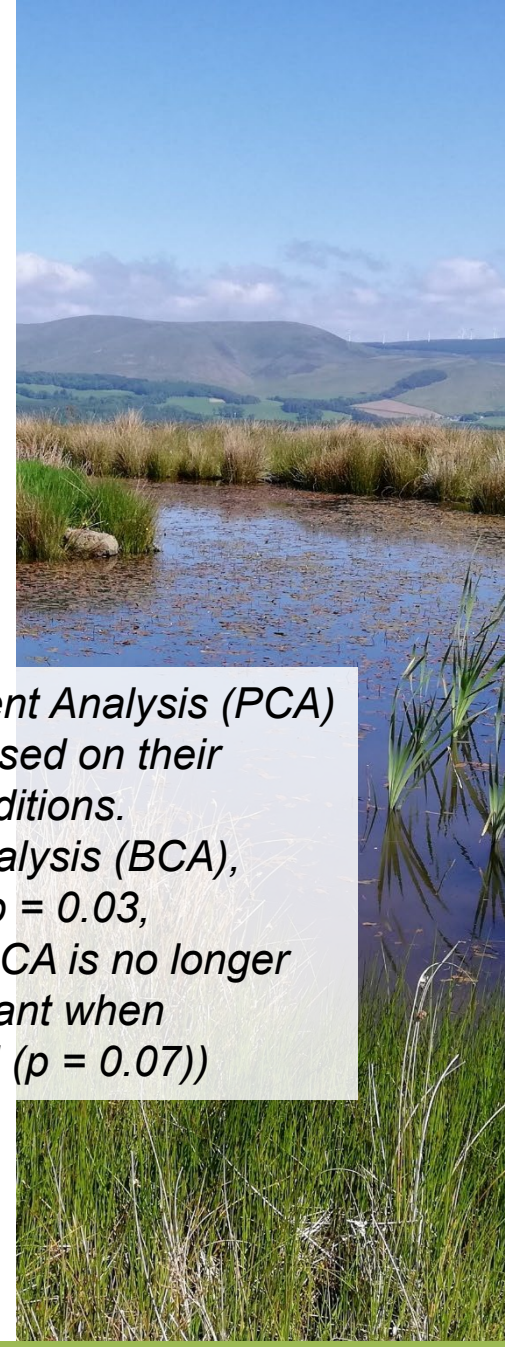


Results: environmental variables

This similarity in composition is not surprising given the similar environmental conditions



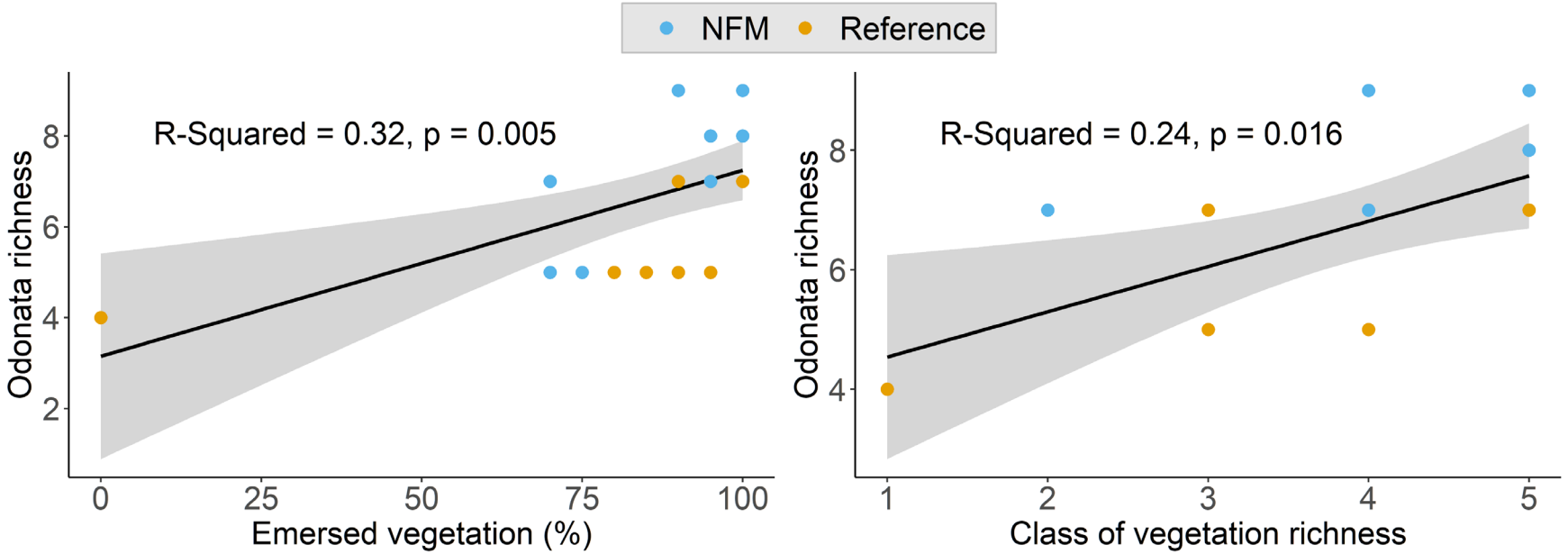
Principal Component Analysis (PCA) of the 20 ponds based on their environmental conditions. (Between-class analysis (BCA), Monte-Carlo test, p = 0.03, Obs = 0.10. This BCA is no longer statistically significant when removing P05_OM (p = 0.07))



Results: relationships with environmental variables

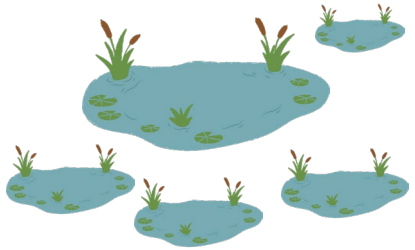
Positive relationships between dragonfly richness and

- the % of pond perimeter with emersed vegetation
- macrophyte richness
- the % of land use “bog, fen or marsh” within 5 m of a pond’s edge

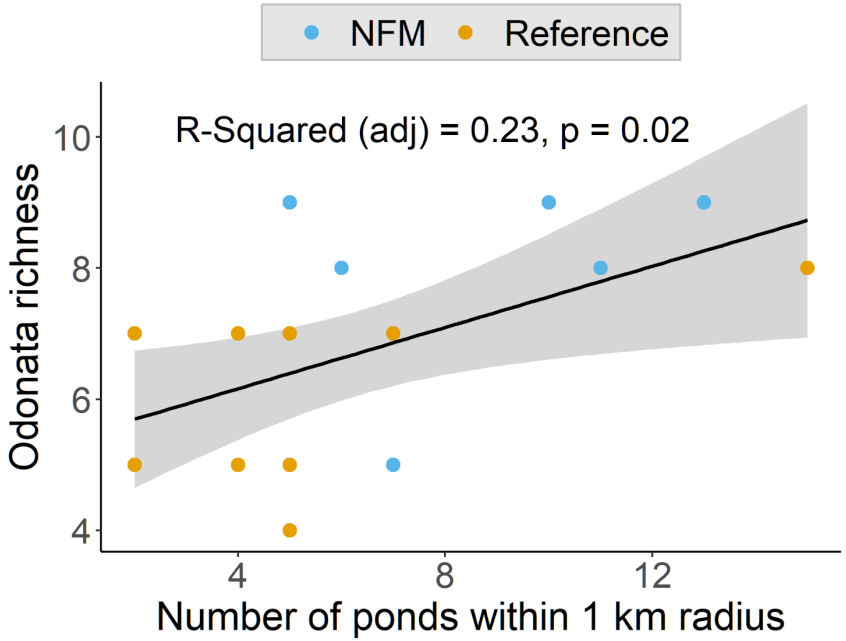


Odonata richness in relation to i) the percentage of the pond perimeter covered by emersed vegetation (left); and ii) the class of vegetation richness (right) (GLMs).

Results: relationships with environmental variables



Positive relationship between dragonfly richness and **pond density**.

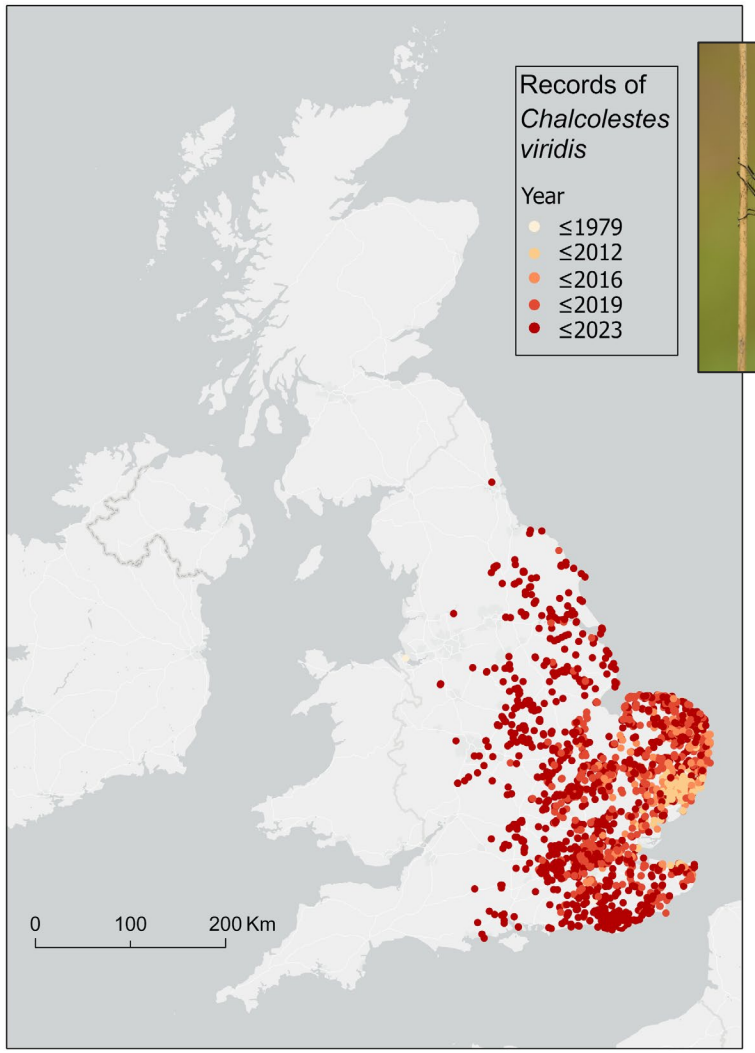


Odonata richness in relation to pond density within a 1 km radius (GLM).

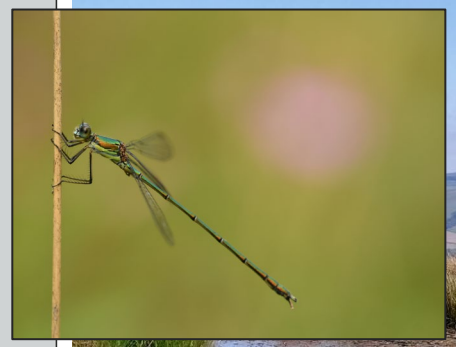
Several small ponds dug close to one another: a typical situation in Eddleston (Photo: Hamish Robertson)

Discussion & Conclusions

- Ponds created primarily for flood management can host **dragonfly communities as diverse as other ponds**.
- Importance of vegetation, buffer zones and pond density for dragonflies (Raebel et al. 2015; Simaika et al. 2016)
- Area previously under-recorded. This study represents a first **baseline** of dragonfly diversity in the Eddleston Water catchment.
- Expectation that Odonata richness will increase in Scotland with climate change, as species migrate northwards (Hassall et al. 2010; Hickling et al. 2005; Olsen et al. 2022).



Records of C. viridis *from the NBN Atlas. Basemap from ESRI.*



Discussion & Conclusions

- The Eddleston Water Project is a **good example of effective Nature-based Solution implementation**, which helps tackle both the biodiversity crisis and human-related issues such as flood risk.
  - However, the created ponds could have more diversity in size, depth, etc. A greater **heterogeneity of habitats** could be promoted across the pondscape.
  - Monitoring of pond biodiversity not included in the main project.
  - Context of the new European Nature Restoration Law: we need **measurable objectives for biodiversity**. As with NbS, we need to monitor and assess the effectiveness of measures.

Illustration: Arup

Thank you to the funding institutions which supported this project and to all people who contributed to the study!

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Haute école du paysage, d'ingénierie et d'architecture de Genève

SSHL SGHL

Swiss Zoological Society

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Hes·so

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Edinburgh Napier UNIVERSITY

Thank you for your attention!

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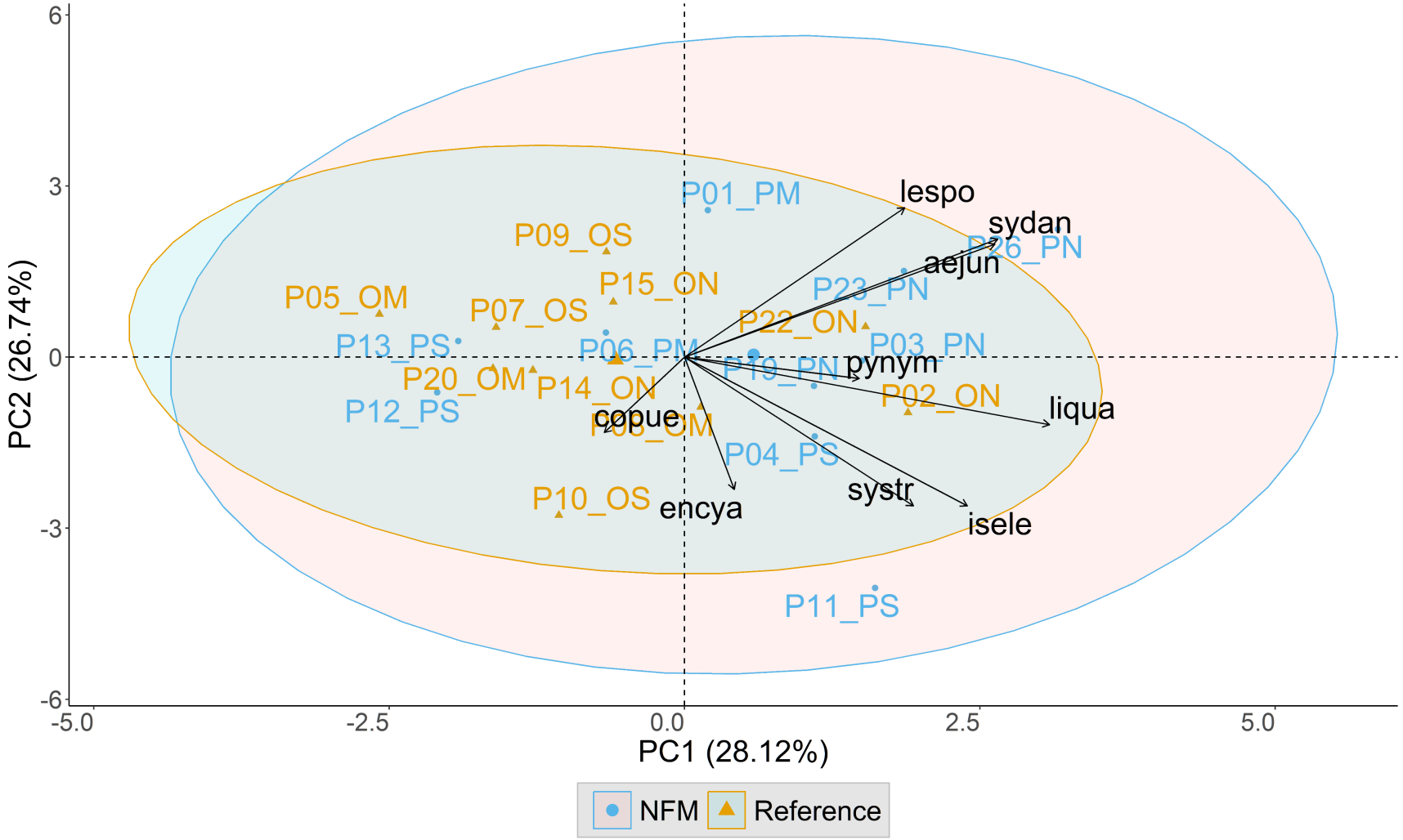
Results – community composition

Also visible with a Principal Component Analysis



Principal Component Analysis (PCA) based on log-transformed Odonata abundances from 20 ponds. No significant differences in community composition were found between types of ponds (NFM vs. Reference, p = 0.42).

Results – beta diversity

Lower species turnover (and overall beta diversity) between NFM ponds than among reference ponds