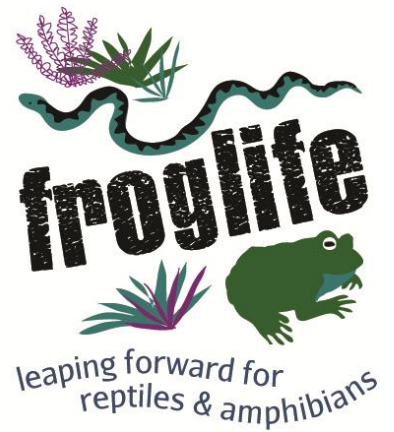


# Ponds and carbon capture

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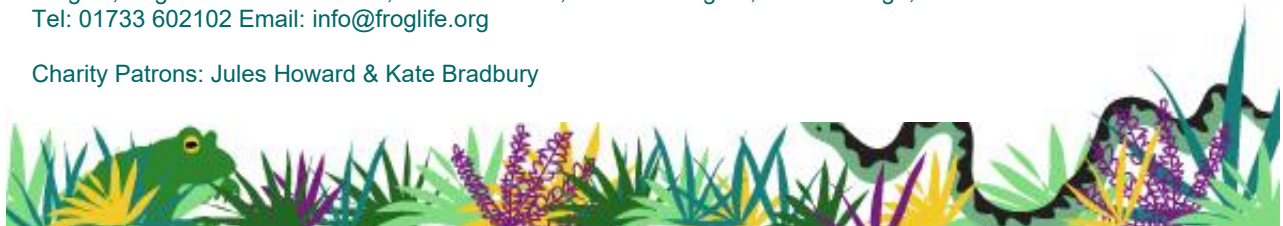


The UK Government Department for Energy Security and Net Zero update on Climate Change in June 2023 (UK Government, 2024) includes a series of stark and direct statements regarding climate change. We must consider the action needed to capture carbon and remove it from the atmosphere. Natural ponds, and other small freshwater bodies in the UK can increase the capture of organic carbon. Lakes (Kastowski *et al.*, 2011, Mendonça 2017, Anderson *et al.*, 2013) and rivers (Ho *et al.*, 2020) have been known to have a role in carbon capture but only recently has the role of small waterbodies ponds been considered. Downing *et al.* (2008) found that ponds bury significantly more carbon than was previously believed to be the case. Small ponds (generally with a maximum depth of 5 m and surface area of < 5 ha) have a carbon capture role (Holgerson, 2024, Cereghino *et al.* 2014). Gilbert *et al.* (2014) found carbon density was highest in sediments of ponds that dried out every year and in ponds with a diverse wetland flora. Permanent, naturally vegetated ponds accumulated the highest percentage of organic carbon and were least affected by climatic variation (Gilbert *et al.*, 2014). Taylor *et al.* (2019) calculated organic carbon burial rates for small ponds at a rate of 142 g m<sup>-2</sup> yr<sup>-1</sup> but this varied depending on the pond's vegetation. Jefferies *et al.* (2023) reviewed information relating to organic carbon in pond sediments and estimated a general measure of 9.38 kg organic carbon stored in a 1m<sup>2</sup> x 20 cm block of surface sediment, which could be extrapolated to a figure for the UK of approximately 2.625 million metric tonnes of organic carbon 'stored' in ponds. This burial rate is 20 to 30 times higher than woodlands and grasslands and higher than those of other natural wetlands.

However ponds have the potential to act both as carbon sinks and sources with CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O greenhouse gas (GHG) emissions taking place (Cambroner *et al.* (2022, Holgerson and Raymond, 2016, Rosentreter *et al.*, 2021, Davidson *et al.*, 2018, Ljung and Lin, 2023 and Peacock, 2021). Taylor *et al.*'s (2019) results suggested methane fluxes measured in ponds in the UK were equivalent to only 1.7% of the organic carbon burial rate and, although CO<sub>2</sub> flux rates in ponds can switch rapidly from 'sink' to 'source' as they dry (Gilbert *et al.* 2017), over their successional cycle ponds act as carbon 'sinks'. Soued *et al.* (2016) suggested that N<sub>2</sub>O pond emissions were negligible when compared to those

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from lakes and rivers, an argument supported by studies by Mander *et al.* (2014), Sovik *et al.* (2006) and Webb (2019).

Taylor *et al.* (2019) found carbon burial rates varied over time, with young ponds sequestering carbon at a lower rate than mature ponds. At 19 to 25 years of age, sediment burial rates decrease but ponds still provide an ecosystem service by trapping sediments and elements (Rogers *et al.*, 2022). Rogers *et al.* (2022) found that pond type and substrate type have an influence on carbon sequestration; as ponds become shallower in the latter stages of the succession, the exposure of sediment increases GHG emissions but, as they dry, ponds gain more vegetation that mitigates methane emissions (Davidson *et al.*, 2018). Ponds with denser vegetation cover and emergent vegetation were found to emit smaller amounts of CO<sub>2</sub> as they dried and capture more carbon (Gilbert *et al.* 2021, More & Hunt 2012) and littoral zones and shelves to enable vegetation growth and increase carbon uptake are important in pond design (Merriman *et al.*, 2017). Taylor *et al.*'s (2019) results show that the diversity of pond communities is important when characterising differences in the carbon capture function of different ponds. Vegetation type and quantity and stratification during the summer months are believed to influence the release of CO<sub>2</sub> and CH<sub>4</sub> over time (Rabaey & Cotner, 2024; S<sup>ó</sup> *et al.* (2024) and measured quantities suggest many ponds are 'sources' rather than 'sinks' (Audet *et al.*, 2020, Herrero Ortega, 2019, Kosten and Bodmer, 2024; Ray *et al.* 2023; Ray and Holgerson, 2023; Ribaudó *et al.*, 2024 and Rosentreter *et al.*, 2021). Gilbert *et al.* (2021) argued high carbon burial can be attributed to high nutrient concentrations driving primary productivity, high levels of soil particulate transfer from adjacent land, and continuous sediment anoxia.

Other ponds such as beaver ponds are now found to also operate as 'sinks', (Gatti *et al.* (2018), Puttock *et al.* (2018) and Mitsch *et al.* (2013) studied carbon fluxes from constructed wetlands and argued that when balanced over time, carbon sequestration exceeds methane emissions, and they can also be net sinks. Aquaculture ponds bury carbon at a lesser rate (70%) than large water bodies and agricultural water bodies because of a low input of external material but still act as 'sinks' (Boyd *et al.*, 2010, Annikuttan *et al.*, 2016).

Small ponds have a significant role in the conservation of biodiversity (Batrons, 2024; Lewis-Phillips 2019 & 2020) and flood management (Cambronero *et al.*, 2022). Taylor *et al.* (2019) argued that late succession, drying or newly dry ponds are often considered as species-poor, and as such are often targeted for restoration to enhance biodiversity. Taylor *et al.* (2019) proposed a more effective strategy; to build new ponds near to existing pond sites, retaining the older habitats and creating pond clusters, part of a 'pondscape', which would support greater biodiversity (Williams *et al.*, 2010) and increase the potential for carbon burial. The construction of pond networks or 'pondscapes' are significant for amphibians which move between ponds and may breed successfully in different ponds in different environmental conditions.

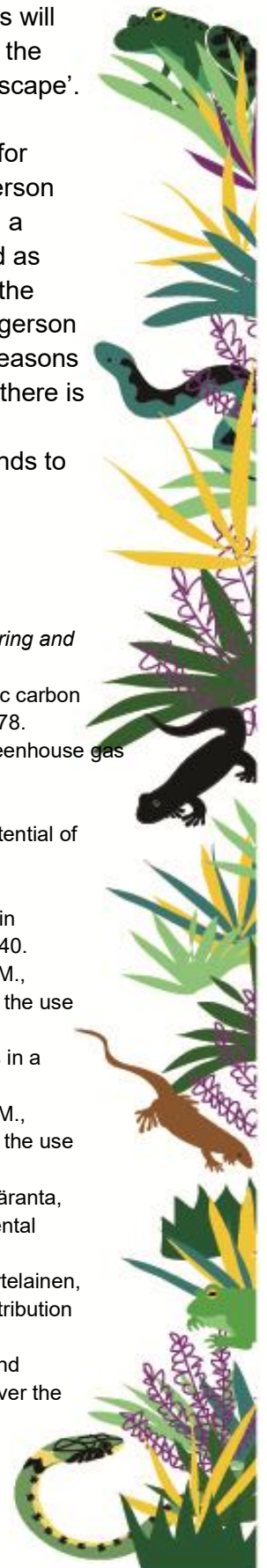
If we consider 500,000 ponds lost from the UK 'pondscape' in the last 100 years (Wildlife Trusts, 2024), and use the value of carbon storage estimated by Jefferies *et al.* (2023) of



9.38 kg m<sup>-2</sup>, we can estimate that 2.73 million tonnes additional carbon per year could be retained should those 500,000 'lost ponds' be replaced. Admittedly many lost ponds will have become vegetated and be continuing to store carbon, but this figure supports the case for pond restoration and the creation of 'pond clusters' within a national 'pondscape'. The value of ponds as carbon sinks, (Mitsch *et al.*, 2013, Hamback *et al.*, 2023) strengthens the arguments for pond creation as a practical and beneficial strategy for managing climate change although work by Ljung and Lin (2023), Ray and Holgerson (2023) and (Ray *et al.* 2023) argue strongly that ponds should not be considered in a 'global' context because of the wide variation in measurements and estimates used as proxies for actual measures of CO<sub>2</sub> and CH<sub>4</sub> release and research on two ponds in the USA found that carbon emissions were similar to carbon sequestration leading Holgerson *et al.* (2026) to suggest that some ponds act as 'sinks' rather than 'sources'. The reasons why some ponds have different roles in carbon budgets remains to be clarified but there is no doubt that as well as resolving water storage issues, improving biodiversity and supporting amphibians and reptiles, future research will guide us towards using ponds to sequester carbon.

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