A Review of the Role of Agricultural Ponds in England

Climate change and biodiversity risks and opportunities

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Supplement 2 – Paper Summary

NATURAL ENGLAND

Natural England Agricultural Ponds

Literature Review

Summaries of Journal Articles

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Paper 2.

Ruggiero, A. et al. (2008) 'Farm ponds make a contribution to the biodiversity of aquatic insects in a French agricultural landscape', Comptes Rendus Biologies, 331(4), pp. 298–308. Available at: https://doi.org/10.1016/j.crvi.2008.01.009.
Location: France
Take home message: In a landscape without many natural water features, manmade farm ponds had 40% of regional aquatic insect species pool present. Species composition not correlated with use, but with area. Duck presence could also reduce aquatic insect diversity. Larger pond – Species Area relationship – greater number of ecological niches.
Biodiversity: In a landscape without many natural water features, manmade farm ponds had 40% of regional aquatic insect species pool present
Method: Assessed 37 farm ponds of Odonata (SW France). Landscape lacked natural wetlands. Area had lots of ponds dug for rainwater capture. Ponds described with 6 surrounding land variables - % bare area, % herbaceous plants, % fields, % bushes, % forest in 800 m radius. Pond described with 7 habitat variables – surface area, max depth, water transparency, % submerged veg, % floating leaf veg, % emergent veg, % shading and presence of ducks/fishes. Ponds sampled for insect larvae, exuvia and adults.

Paper 7.

Holgerson, M.A. (2015) 'Drivers of carbon dioxide and methane supersaturation in small, temporary ponds', Biogeochemistry, 124(1), pp. 305–318. Available at: https://doi.org/10.1007/s10533-015-0099-y.
Location: Connecticut, USA
Take home message: Shallow waters and high carbon input = potential for anaerobic and CO_2/CH_4 saturation. Need for regular input of water to reduce CO_2. Depth to surface ratio is key.
Threats: Small ponds, which are the majority of pond types, are very difficult to identify on maps and satellite imagery.
Carbon/climate: Within the global carbon cycle, inland waters play a significant role. Respiration from microbes within the sediment of the pond produces CO_2. Methane production increases with temperature (Borrel, et al., 2011; van Hulzen et al., 1999). Greater rainfall volumes decreased concentrations of CH_4. However, a study by Natchimuthu et al., 2014 showed that CH_4 concentrations increased with precipitation.
Management: Pond's ability to get deeper with rainfall rather than grow in area. Deeper = dilution, area = more contact with sediments. Shallow ponds have more mixing within the water column and therefore more of the water has contact with the sediment. This can increase CH_4 production due to the increased contact with anoxic sediments (methanogenesis).

Specific figures: The majority of ponds across the globe are small (it is believed that 90% are less than 10,000m^2), which makes them very difficult to map (Downing et al. 2006; Lehner and Doell 2004; Verpoorter et al. 2014). It is possible that ponds under 1000m^2 could cover 0.8 million km^2 and number as many as 3.2 billion ponds (Downing, 2010). The carbon dioxide equivalent of CO_2 and CH_4 was similar (4.43g CO_2 per m^2 per day vs. 4.26g CO_2e per m^2 per day).
Method: Study of six ponds in Connecticut, USA. Temporary, forested, under 1000m^2. On average, ponds were 19-fold supersaturated in CO_2 and 504-fold supersaturated in CH_4 relative to the atmosphere (level of supersaturation is among the highest reported for still freshwaters).

Paper 9.

Taylor, S. (2017) Exploring factors driving organic carbon burial and storage in small constructed ponds: An experimental approach. Doctoral. Northumbria University. Available at: https://nrl.northumbria.ac.uk/id/eprint/36143/
Location: UK
Take home message: Ponds can store carbon (67-212 g OC m2 year-1) This seems to be heavily dependent on quick establishment of vascular plant communities. Microbial diversity greater in ponds storing more carbon.
Specific figures: Ponds can store 1413-4459 g OC m2 (cores gave similar value to exhumation within a 0-15% range). 67-212 g OC m2 year-1.
Method: Whole thesis. Carbon stocks surveyed in 12 mature (20 years) ponds in Northumbria. Sediments cores vs whole pond exhumation.

Paper 10.

Downing, J. (2008) 'Emerging global role of small lakes and ponds: Little things mean a lot', Limnetica, 29, pp. 9–24. Available at: https://doi.org/10.23818/limn.29.02.
Location: Global
Take home message: Small ponds are important in the global carbon cycle but have been historically overlooked. More research into their carbon role required.
Threats: Ponds overlooked. Assumed that because they were small, they were unimportant.
Carbon/climate: Smaller waterbodies tend to have a greater contribution to carbon sequestration but also in emitting greenhouse gases (Downing, J., 2010). This is due to the fact that smaller waterbodies tend to have lower oxygen concentrations (Crisman et al., 1998) and their surface water carbon dioxide levels are also higher (Kelly et al, 2001). Smaller ponds bury more organic carbon per year than larger waterbodies. Burial rates of 40 studied waterbodies of various sizes concluded that there was a vast range of between 17 kg C/m2/y to 148 g C/m2/y (Downing, J., et al 2008 & Downing, J., 2010). Global inland waters may bury as much as four-times the amount of carbon as the world's oceans. Small waterbodies can have high nutrient levels and therefore, emissions of methane and nitrous oxide could be high (Knowles et al. 1981; Michmerhuizen et al. 1996; Bastviken et al. 2004), adding to further emissions of greenhouse gases.
Specific figures: It is possible that ponds and other inland waterbodies process more carbon than was originally thought, by 1Pg/yr (petagram - 1,000,000,000,000,000 grams, 1015 grams). Data from 2009 (see Tranvik et al., 2009) suggests that the value could be even higher than 1.9Pg, estimating 2.9Pg/yr. 20% (0.6Pg/yr) of Carbon may be buried in sediment.

Paper 12.

Webb, J.R. et al. (2019) 'Regulation of carbon dioxide and methane in small agricultural reservoirs: optimizing potential for greenhouse gas uptake', Biogeosciences, 16(21), pp. 4211–4227. Available at: https://doi.org/10.5194/bg-16-4211-2019.
Location: Canada
Take home message: CO2 concentration driven by internal pond metabolism and groundwater alkalinity (Carbonates can saturate water with CO_2). CH_4 production driven by eutrophication. Higher N = greater algal and denitrification leading to CO_2 and CH_4 emissions. 8% of farm reservoirs found to be carbon sinks.
Management: Make reservoirs deeper, reduce nutrient loading
Specific figures: Fluxes range between -21 to 466 mmol m-2 day-1 for CO_2 and 0.14-92 mmol m-2 day-1.
Method: Regional study (235,000 km2) measured CO_2 and CH_4 flux for 101 farm reservoirs in Canada. Assessed other landscape features, abiotic and biotic characteristics for each pond. 2m average depth. Drier than average year.

Paper 15.

Gilbert, P.J. et al. (2014) ‘Variations in sediment organic carbon among different types of small natural ponds along Druridge Bay, Northumberland, UK’, Inland Waters, 4(1), pp. 57–64. Available at: https://doi.org/10.5268/IW-4.1.618.
Location: UK
Take home message: Agricultural ponds are an overlooked source of CO_2 and CH_4.
Carbon/climate: Agricultural ponds are an overlooked source of CO_2 and CH_4. Important carbon sinks. Surrounding land use of pond, presence of natural vegetation, and compaction level of sediment all play an important role in determining to what extent the waterbody is effective in sequestering carbon (Gilbert et al., 2013). A study by Gilbert et al., (2013) showed that shallow ponds with little vegetation, which dried out exposing bare substrate had the lowest amount of stored organic carbon. These types of ponds tend to be relatively common across the agricultural landscape. The study showed that ponds within 30m of each other, of a similar size, age and soil type, had variable levels of organic carbon, with the deciding factor being the presence of vegetation, especially moss swards that covered the sediment when the ponds dried out. This indicates that it is very problematic to determine the carbon sequestration rate of ponds as a whole, as this figure can vary (1% - 19% sediment OC) depending on the ecology of the individual pond.
Specific figures: Permanent ponds with natural vegetation tended to have uncompacted sediments, and organic carbon was highest in this pond type (7.68 and 12.86%) whereas ponds that had compacted sediments or were located within agricultural land (pasture or arable) had decreased levels of carbon (3.72% and 3.44% respectively).
Method: Six ponds. 2 x pasture, 2 x arable, 2 x field-adjacent. 4 ponds dried out with no rain. 10 1m^2 ponds constructed 1994 on nature reserve in other location. 4cm corer driven into sediment as far as possible. Single sample for small ponds, transect for larger ponds

Paper 16.

Fiener, P., Auerswald, K. and Weigand, S. (2005) ‘Managing erosion and water quality in agricultural watersheds by small detention ponds’, Agriculture, Ecosystems & Environment, 110(3), pp. 132–142. Available at: https://doi.org/10.1016/j.agee.2005.03.012.
Location: Germany
Take home message: Ponds trapped 54-85% of incoming sediment, temporarily stored 250-500 m^2 stormwater. Runoff reduced by 10% for large rainfall events. Nutrient enrichment of trapped sediments. Decrease in peak agrochemical runoff volumes.
Method: Small terrace style detention ponds with tile drainage outlets studied. Ponds had volume of 30-260 m^3.

Paper 18.

Alderton, E. et al. (2017) 'Buried alive: Aquatic plants survive in "ghost ponds" under agricultural fields', Biological Conservation, 212, pp. 105–110. Available at: https://doi.org/10.1016/j.biocon.2017.06.004.
Location: Norfolk, UK
Take home message: Seeds from macrophytes can be dormant for up to 50-150 years following filling of pond of pond. Upon exposure following pond excavation up to 8 aquatic macrophytes germinated from seed and oospores. Historic ponds excavation much better for rapid plant colonisation. Good photographs of post-restoration.
Management: Ghost ponds provide good opportunity for restoration i.e. plant species already present.
Specific figures: In Norfolk – 5371 km^2, around 8400 ponds lost since 1950's.
Method: Resurrected 3 x ghost ponds (50-150 years). Onsite mesocosm experiments with pond sediment (sterile or historic), sealed microcosms looking at germination from sterile vs historic sediment. Multiple lost ponds nearby study area. Ponds location defined by tithe maps. Ponds excavated with central trench. Dig down until dark historic pond sediments are exposed.

Paper 23.

Tranvik, L.J. et al. (2009) 'Lakes and reservoirs as regulators of carbon cycling and climate', Limnology and Oceanography, 54(6part2), pp. 2298–2314. Available at: https://doi.org/10.4319/lo.2009.54.6_part_2.2298.
Location: Global
Take home message: More research on impact of global carbon cycle needed. Burial could increase but emissions could also increase.
Carbon/climate: Microorganisms consume and produce carbon dioxide, methane, and nitrous oxide, which has an impact on the levels of these greenhouse gases in the atmosphere. Research on methane emissions from lakes and ponds is approximately 50 times less than that of research on emissions of carbon dioxide. Interactions between pond organisms and nutrients can be the determining factor on whether a pond is a carbon dioxide sink or source, especially with consideration between the interactions of phytoplankton and zookplankton. It is predicted that temperate lakes in 2050 will experience more drought occurrences and increased eutrophication, resulting in increased methane emissions. It is possible that burial of organic carbon could be increased, therefore offsetting a potential increase in carbon dioxide emissions.

Paper 28.

Bullock, J.M. et al. (2021) 'Does agri-environmental management enhance biodiversity and multiple ecosystem services?: A farm-scale experiment', Agriculture, Ecosystems & Environment, 320, p. 107582. Available at: https://doi.org/10.1016/j.agee.2021.107582.
Location: UK
Take home message: Implementing a range of agri-schemes across a farm is the best course of action, rather than assuming one action will be a "silver bullet". Include wildflower margins around pond to benefit insects.
Specific figures: Block 1 (32 m2) a total of 211.4 kg of sediment and 231.3 g of P. Block 2 (31 m2) a total of 342.9 kg of sediment and 604.6 g of P. Block 3 (53 m2) a total of 1035.3 kg of sediment and 1861.2 g of P.
Method: Ponds dug at the end of field ditches

Paper 38.

Passy, P. et al. (2012) 'Restoration of ponds in rural landscapes: Modelling the effect on nitrate contamination of surface water (the Seine River Basin, France)', Science of The Total Environment, 430, pp. 280–290. Available at: https://doi.org/10.1016/j.scitotenv.2012.04.035.
Location: France
Take home message: 30% reduction in N by use of small pond taking Ag drainage water. Total N organic matter reduced. Sediment storage. Restoring ponds at 5% of ag area = reduced riverine N export by 25% on annual basis.
Method: Measured inflow and outflow of small pond receiving Ag drainage for 3 years. Catchment studied is 1200 km2. Pond is 3700 m2, depth 2m,, storage volume of 8000m3 with catchment of 35 ha of arable land. Plot Nitrate leching is 3700 kg N km-2 year-1. Macrophyte coverage of less than 10%. Translated these numbers across whole catchment with restoration of 18th C ponds.

Paper 41.

Ockenden, M.C. et al. (2014) 'Keeping agricultural soil out of rivers: Evidence of sediment and nutrient accumulation within field wetlands in the UK', Journal of Environmental Management, 135, pp. 54–62. Available at: https://doi.org/10.1016/j.jenvman.2014.01.015.
Location: UK
Take home message: Small field wetlands constructed along flow pathways can slow and store runoff. Sediment trapped by wetlands. Sandy site = more sediment trapping than silt and clay sites. Timing of rainfall more important than annual rainfall for sediment accumulation. Most sediment transported in a few intense rainfall events., especially when correlated with bare soil or poor crop cover. Nutrient composition of sediment similar to surrounding fields. Can be used to return to field.

Paper 48.

Sayer, C.D. (2014) 'Conservation of aquatic landscapes: ponds, lakes, and rivers as integrated systems', WIREs Water, 1(6), pp. 573–585. Available at: https://doi.org/10.1002/wat2.1045.
Location: River Glaven, UK
Take home message: Need integrated catchment (whole landscape) led approach to conservation of ponds and wetland systems. Ponds are good for headwater management – flood water, holding back pollution and connecting aquatic habitats. Need to consider ponds as part of much larger system when restoring. Ponds very important for biodiversity due to high between site variability.
Threats: Small water bodies excluded from WFD. And many agri-environment schemes focus on streams and larger water bodies. One reason ponds are being lost is due to arable land reclamation (Sayer, C., 2014; Hassall, C., 2014). No legislation preventing pond infilling – ponds could still be being filled in and lost. Lack of pond management means many have become terrestrialised.
Biodiversity: Pond networks important for amphibians and aquatic invertebrates – local metapopulation. Could act as stepping stones for species that would need to migrate due to the impacts of climate change.
Specific figures: 61% of ponds disappeared in Cheshire 1870 – 1990s.
Method: Looked at Glaven Catchment- lots of small farmland ponds excavated in 18-19th C. Example of otter and eel in catchment, using multiple types of freshwater habitat.

Paper 52.

Jeffries, M.J. (2016) 'Flood, drought and the inter-annual variation to the number and size of ponds and small wetlands in an English lowland landscape over three years of weather extremes', Hydrobiologia, 768(1), pp. 255–272. Available at: https://doi.org/10.1007/s10750-015-2554-0.
Location: UK
Take home message: Extremes of weather can have both positive and negative effects on pond hydrology and biodiversity. Intensification of surrounding landuse is an important factor deciding factor in pond plant communities.
Biodiversity: Biodiversity hotspots. It is often not accurate to use pond area to predict invertebrate diversity. Temporary ponds that stay wet "too" long can have negative impacts on its biodiversity.
Specific figures: In one area of Northumberland, the number of ponds over 4m2 had increased in the 150 years from 1860 to 2010, but of the 222 original ponds, only 24 of these remained, meaning 198 ponds had been lost, with a similar amount created. Pond number may depend on whether temporary ponds are counted. For example, during 2011 and 2012, a survey by Jeffries, M. J., (2016) counted 105 ponds in an area following heavy rainfall, with only 12 of these ponds being present during the time of a drought.

Paper 58.

Dadson, S. et al. (2017) 'A restatement of the natural science evidence concerning catchment-based "natural" flood management in the UK', Proceedings of the Royal Society A: Mathematical, Physical and Engineering Science, 473, p. 20160706. Available at: https://doi.org/10.1098/rspa.2016.0706.
Location: UK
Take home message: Evidence summary of catchment level NFM for lay audience. Small amount of specific mention of ag ponds. Example from Belford Catchment in Northumbria. 800-1000m3 pond next to river. During storm (96 mm in 36 hours) the pond increased time to peak by 5 mins. Multiple features would be needed to make larger catchment level improvement.

Paper 65.

Grillas, P. et al. (2021) 'Foreseen impact of climate change on temporary ponds located along a latitudinal gradient in Morocco', Inland Waters, 11(4), pp. 492–507. Available at: https://doi.org/10.1080/20442041.2021.1962688.
Location: Morocco
Take home message: 18 temporary ponds in 6 areas across a 4o/750 km latitude (and climate) gradient in Morocco. Simulated future evolution of water balance. Deficit of water expected to increase, which would lead to reduction in species richness of 8-15 species due to extended wet/dry periods. Area of pond is factor i.e. larger = takes longer to dry out, and thickness of permeable soil layer.

Paper 66.

Rosset, V., Lehmann, A. and Oertli, B. (2010) 'Warmer and richer? Predicting the impact of climate warming on species richness in small temperate waterbodies', Global Change Biology, 16(8), pp. 2376–2387. Available at: https://doi.org/10.1111/j.1365-2486.2010.02206.x.
Location: Switzerland
Take home message: Ponds are crucial for freshwater biodiversity.
Threats: Pollution/nutrient loading in ponds could reduce gains in biodiversity.
Biodiversity: Species richness could increase for a range of pond species (plants, snails, beetles, dragonflies, amphibians) as temperatures increase (refs in paper).
Specific figures: Increase of species richness of 83% in lowland ponds. 277 million ponds across globe (Downing et al, 2006).
Method: 113 ponds, lowland to high altitude.

Paper 70.

Robotham, J. et al. (2021) 'Sediment and Nutrient Retention in Ponds on an Agricultural Stream: Evaluating Effectiveness for Diffuse Pollution Mitigation', Water, 13(12), p. 1640. Available at: https://doi.org/10.3390/w13121640.
Location: UK
Take home message: Ponds and wetlands have potential to alleviate stream pollution in catchments affected by diffuse agricultural pollution. Ponds retained dissolved nitrate, soluble phosphorus and suspended solids during base flows. During moderate storm events ponds could reduce peak concentrations of suspended solids and P. However, during major storm events, solids were resuspended and then then lost from pond. 3 x ponds accumulated 7.6 % of suspended sediment, 6.1% silt and clay and 3.2% P leaving 340 ha catchment. Despite only covering >0.02%
Method: Assessed 3 x ponds online ponds in lowland headwater stream Pond 1 = 145m2, 70m3 Pond 2 = 126m2, 90m3 Pond 3 = 156m2, 95m3

Paper 89.

Bilton, D. t. et al. (2009) 'Ecology and conservation status of temporary and fluctuating ponds in two areas of southern England', Aquatic Conservation: Marine and Freshwater Ecosystems, 19(2), pp. 134–146. Available at: https://doi.org/10.1002/aqc.973.
Location: Southern England, UK
Take home message: Ponds are very good at supporting rare and common species. Need a variety of pond types to support large range of species. Management practices should be on regional scale to ensure that a wide range of pond types are created. Large variability of species distribution. Ponds are good at supporting different species due to differing micro-climates, stochastic events associated with species dispersal. But taxa can be found at relatively few sites. This means that a regional management approach is needed i.e. need to know what is present in different ponds.
Biodiversity: Ponds supported 119 plants and 165 macro invertebrates. Most species found were locally rare, with over 50% occurring in less than 10% of ponds. More than 50% ponds supported at least one nationally rare plant and 75% at least one nationally rare macroinvertebrate.
Method: Plant and macro invertebrate76 temporary/fluctuating ponds in southern England studied. Relatively high conductivity of ponds (1113 uS cm-3)

Paper 95.

Oertli, B. et al. (2002) 'Does size matter? The relationship between pond area and biodiversity', Biological Conservation, 104(1), pp. 59–70. Available at: https://doi.org/10.1016/S0006-3207(01)00154-9.
Location: Switzerland
Take home message: Pond size important for Odonata (flying insects) and explained 31% of species richness (number of species). Pond size not really correlate with richness of aquatic plants, molluscs, coleopetra. Multiple small ponds have greater conversation value than single large pond of same area. But larger ponds can harbour species not found in smaller ponds (ie critical size for these species?) Therefore, a range of pond sizes is needed.
Method: 8000 ponds baseline survey to then look at 80 ponds, lowland to high altitude (210-2757 masl). Mean area of 8817m2 and depth of 1.66 m. 21 natural. 49 artificial.

Paper 96.

Hassall, C., Hollinshead, J. and Hull, A. (2012) 'Temporal dynamics of aquatic communities and implications for pond conservation', Biodiversity and Conservation, 21(3), pp. 829–852. Available at: https://doi.org/10.1007/s10531-011-0223-9.
Location: NW England, UK
Take home message: Increase in diversity over time, but community composition suggests ponds are undergoing terrestrialisation. E.g. loss of charophytes and increase in grass. Can't expect pond to stay in same state for a long period of time. Need a range of early and mid-successional ponds. Succession affects invertebrates and macrophytes at different timelines.
Method: Surveyed 51 ponds in 1995/9 and again in 2006. Surveyed macrophytes and invertebrates.

Paper 98.

Raebel, E.M. et al. (2012) 'Multi-scale effects of farmland management on dragonfly and damselfly assemblages of farmland ponds', Agriculture, Ecosystems & Environment, 161, pp. 80–87. Available at: https://doi.org/10.1016/j.agee.2012.07.015.
Location: England, UK
Take home message: Surrounding land use can affect dragon and damselfly population. Therefore, need landscape level integrated management schemes. Dragonflies – more mobile and therefore more affected by wider landscape changes (1600 m). Damselflies – less mobile and therefore local landscape (100-400 m radius) more important.
Threats: Agricultural intensification has led to declines in odonate (dragon and damselfly) populations as they require healthy water bodies for larval stages.
Biodiversity: Looked at exuvial evidence – greater presence/richness when 2 m wide cross

compliance buffer strips are around ponds, amount of water in local landscape (but not number of ponds). Negative relationship between entry level schemes and exuvial richness, i.e. other types of buffer are better. And ELS do not positively affect odonate richness.
Management: Polices need multiple farms in same landscape to take up conversations schemes to have continuously managed landscapes.

Paper 105.

Clarke, S. (2010) 'Adapting to Climate Change: Implications for Freshwater Biodiversity and Management in the UK', Freshwater Reviews, 2, pp. 51–64. Available at: https://doi.org/10.1608/FRJ-2.1.3.
Location: UK
Take home message: Difficult to predict future impacts on waterbodies. Likely to have negative impacts due to increasing temperatures and changes in hydrological system.
Biodiversity: Many freshwater species are sensitive to variations in water temperature as they are unable to regulate their body heat.
Carbon/climate: Most research on impacts of climate change are focussed on terrestrial environments. Between now and 2050, we will experience a range of changing weather patterns (King, D., 2005; IPCC, 2007). The complexity of the earth's climate system means that predicting future impacts on natural systems is difficult. The water temperature in ponds is closely related to air temperature. Increased temperature could result in undesired increase in algal growth. The water cycle could be impacted due to changes in timings of rainfall, along with quantity and duration, combined with increased evapo-transpiration due to increased temperatures (Clarke, S. J., 2009).

Paper 123.

Newman, J.R. et al. (2015) Do on-farm natural, restored, managed and constructed wetlands mitigate agricultural pollution in Great Britain and Ireland?, A Systematic Review. Report Reference No. WT0989. London, UK.: Department for Environment, Food and Rural Affairs (Defra). Available at: http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=2&ProjectID=18374
Location: England, UK
Take home message: Centre for Ecology and Hydrology Review, Definition of wetlands quite broad, but can include ponds (usually with good vegetation coverage. Wetlands very good at removing/reducing Total N, nitrate, nitrite, Total and Soluble Reactive Phosphorus (mean of 78-97%), COD (mean of 90%), BOD (mean of 91%) and Suspended Solids (mean of 83%). Older and larger wetlands remove more nutrients. Linked open pond systems less effective than constructed wetland systems. Removal of nitrate may require additional treatment by passage of water though overland buffer strips.

Method: Systematic review of effect of wetlands of agricultural runoff studies

Paper 129.

Walton, R.E. (2019) “The pond pollinator pantry”: Assessing how pond management influences pollinators in the UK farmland landscape, Doctoral thesis, UCL (University College London). Doctoral. UCL (University College London). Available at: https://discovery.ucl.ac.uk/id/eprint/10081473/
Location: England, UK
Take home message: Investigated drivers of pollinator utilisation of farmland ponds. In general, pond woody plant management is beneficial for pollinators due to increases flowering plants richness and abundance. Subfossil analysis showed that pond wood management has historically occurred.
Threats: Overgrown and undermanaged farmland ponds = problem for pollinating insects.

Paper 133.

Downing, J.A. et al. (2008) ‘Sediment organic carbon burial in agriculturally eutrophic impoundments over the last century’, Global Biogeochemical Cycles, 22(1). Available at: https://doi.org/10.1029/2006GB002854.
Location: Iowa, USA
Take home message: Most information gathered from Downing, J., 2010

Paper 136.

Malerba, M.E. et al. (2022) ‘Methane emissions from agricultural ponds are underestimated in national greenhouse gas inventories’, Communications Earth & Environment, 3(1), pp. 1–7. Available at: https://doi.org/10.1038/s43247-022-00638-9.
Location: USA and Australia
Take home message: Ag ponds emits a lot of CH_4. Often underestimated in models. Due to high concentrations of manure, fertiliser runoff. High amount of organic accumulation and therefore anaerobic respiration to lead to CH_4. Shallow systems which warm quickly leading to fast bacterial build up and methanogeneis. Reduce organic matter build up to reduce CH_4 – exclude livestock using fences, improves water quality. Vegetation buffers around ponds.
Carbon/climate: Ag ponds have some of the highest CH_4 emissions per area for freshwater habiats.
Specific figures: USA 2.56 million ag ponds (420.9kha) emit 95.8 kt year ch4 Australia 1.76 million Ag ponds (291.2 kha) and emit 75.1kt year ch4

Paper 138.

Peacock, M. et al. (2021) 'Small artificial waterbodies are widespread and persistent emitters of methane and carbon dioxide', Global Change Biology, 27(20), pp. 5109–5123. Available at: https://doi.org/10.1111/gcb.15762.
Location: Sweden
Take home message: Constructed waterbodies are emitters of CO_2 and CH_4.
Carbon/climate: Large volumes of carbon dioxide and methane are released from inland waters. Intergovernmental Panel on Climate Change guidelines state that the emissions from natural waterbodies do not need to be included in national emissions reporting but constructed waterbodies do as these form part of "anthropogenic emissions". Ponds that have a human influence may have more emissions than natural, undisturbed ponds due to biogeochemical cycling being altered by water inflows/outflows and surrounding use, e.g. agriculture (Blaszczak et al., 2018). Ponds that have a low level of disturbance are likely to have a greater vegetation cover including emergent plants: this can increase the transport of methane from the sediment to the atmosphere (Oliveira-Junior et al., 2018; Peacock, M., et al., 2021). The emissions of methane from ditches could be enough to offset the carbon sequestered by terrestrial ecosystems (Evans et al., 2016; Peacock et al., 2021). Small ponds emit more GHGs than larger ponds. Concentrations of CO_2 and CH_4 decrease with (constructed) pond size. Warmer water temperatures increase CH_4 emissions. Ebullition (bubbles) in water is positively correlated with warmer water temperature, contributing to raised emissions in the warmer summer months (Aben et al., 2017) and emissions are even more likely in nutrient-rich, eutrophic waterbodies (Davidson et al., 2018). CO_2 concentrations may be even higher in ditches than ponds, although CH_4 is reported to be similar (Peacock, M., et al., 2021). When methane is converted to CO_2e (equivalent), 93% of waterbodies including ponds and ditches were a source of greenhouse gases (Peacock, M., et al., 2021). The IPCC estimate, with 95% confidence interval, that methane emissions of ponds are 12–23 g CH_4 per m^2 per year.
Management: Protecting ponds from nutrient enrichment is beneficial as methane emissions from waterbodies are linked with levels of eutrophication (Peacock, M., et al., 2021; Bastviken et al., 2004; Beaulieu et al., 2019; Juutinen et al., 2009). Per square metre, artificial ponds may release more carbon dioxide and methane than constructed ponds.

Ponds that were more alkaline (pH over 8) had reduced concentrations and fluxes of CO_2. Carbonates buffer CO_2 (Stets et al., 2017).
Method: Seven ditches, nine ponds. Fluxes were measured using a floating chamber. Pond area estimated on Google Earth.

Paper 149.

Cole, J.J. et al. (2007) 'Plumbing the Global Carbon Cycle: Integrating Inland Waters into the Terrestrial Carbon Budget', Ecosystems, 10(1), pp. 172–185. Available at: https://doi.org/10.1007/s10021-006-9013-8.
Location: Global
Take home message: Gas exchange of carbon occurs in inland waters. More research required on farmland ponds.
Carbon/climate: 0.2Pg carbon buried in aquatic sediments per year, out of 1.9Pg that the waters receive.

Paper 151.

Fromin, N. et al. (2010) 'Impact of seasonal sediment desiccation and rewetting on microbial processes involved in greenhouse gas emissions', Ecohydrology, 3(3), pp. 339–348. Available at: https://doi.org/10.1002/eco.115.
Location: SE France
Take home message: Drying cycle promotes CO_2 release as microbial community starts to mineralise carbon. As sediment dries out fully CO_2 emission decline. But these then rapidly increase once wetted up again. This process is more pronounced at edge of pond in areas used to wet/dry cycles as microbial community is better able to bounce back from dry spell.
Management: Try to limit dry down spell for max of 2 weeks to prevent excessive CO_2 release when pond wets up again
Method: Measured CO_2 flux in number of soil cores taken from ponds experiencing dry down cycles

Paper 156.

Malyan, S.K. et al. (2022) 'Greenhouse Gases Trade-Off from Ponds: An Overview of Emission Process and Their Driving Factors', Water, 14(6), p. 970. Available at: https://doi.org/10.3390/w14060970.
Review
Take home message: Ponds can contribute CO_2, CH_4 and NO_2. Emission rate influenced by nutrients, temp, DO, depth, sediments, plankton. Mechanisms of GHG emissions 1. Methane emission, diffusion, ebullition and plant mediate transport three main pathways from anaerobic sediment zone. 2. CO_2 emission – degradation of dissolved OC and soil respiration 3. NO_2 emission – due to N rich fertiliser runoff. Generally N_2O moves downwards and therefore ponds considered a weak source of N_2O

Factors which affect GHG emissions. - Water pH – general negative relationship with CO_2, and low effect on CH_4 and N_2O - Temperature – CH_4 emission higher in summer due to temp. but less effect for CO_2 - Nutrients – generally increases CH_4 (P and dissolved C have big effect), increase of N increases CO_2

Paper 157.

Davidson, T.A. et al. (2018) 'Synergy between nutrients and warming enhances methane ebullition from experimental lakes', Nature Climate Change, 8(2), pp. 156–160. Available at: https://doi.org/10.1038/s41558-017-0063-z.
Review
Take home message: Increased nutrition increase CH_4 emission from 51% to 75%. When increased temperature (2-5oc) was added to increased nutrients, significantly increased emissions.
Method: Long running mesocosm experiment in Denmark. 24 fully heated. Mixed, outdoor flow through mesocosms.