

SEA GRANT PROJECT SUMMARY FORM (90-2)

TITLE: Evaluating nutrient retention and removal associated with ditch management and restoration and exploring the role of biota

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EFFORT: 0.45 months

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KEYWORDS: Consumer-driven nutrient cycling, nutrient removal, emergent insects, aquatic processes, sediment

OBJECTIVES: The objective of this proposal is to:

- Evaluate the potential for ditch management or restoration (e.g. two-stage ditches) to reduce downstream nutrient fluxes by altering in-stream processes, measuring multiple pools and fluxes
- Determine the role of plants and animals in altering these nutrient fluxes, both directly and indirectly
- Help to address the goal “Improve the assimilative capacity and ecological functions of Lake Erie tributaries to help reduce nutrient loadings,” from the “Lake Erie Protection and Restoration Plan (2016): Strategic Objectives under Nutrient Pollution Reduction.”

We will achieve these objectives by measuring nitrogen and phosphorus content of sediment, the water column, aquatic animals, emergent insects, and plants, over time, in conventional ditches, two-stage ditches, and self-forming streams. We will pair these measurements with biomass estimates to calculate nutrient budgets for each management option.

METHODOLOGY: We will assess retention and removal of nitrogen (N) and phosphorus (P) in conventional agricultural ditches and within two key types of ditch restoration/management options—two-stage ditches and self-forming streams—utilizing an existing network of sampling locations in NW Ohio, where emergent insects have been collected (G. Metzner, MS Thesis). We will select four ditches within each category. At each location, we will measure pools and fluxes of N and P during low flow conditions. Specifically we will:

1. *Surface water:* Measure total N and P concentration and DRP (dissolved reactive phosphorus) and DIN (dissolved inorganic nitrogen) in surface water up and down stream in each location (1 sample upstream, 1 downstream, from each site, 3 times per growing season). We will also measure flow velocity and calculate discharge. This will allow us to estimate the addition or removal of N and P within a given length of ditch.
2. *Sediment:* Measure sediment total N and P content at beginning, middle, and end of the growing season (3 samples per site, 3 times per growing season). We will also place ion exchange resin bags within sediment and measure accumulation of nutrients over time (3 samples per site, 3 times per growing season). This will allow us to calculate bioavailability of nutrients in the sediment.
3. *Biofilm:* Measure biofilm total N and P content at beginning, middle, and end of growing season (3 samples per site, 3 times per growing season). We will also place ceramic tiles to measure biofilm growth (3 tiles per site, 3 times per growing season). This will allow us to quantify the pools of N and P within biofilms as well as the growth rate of biofilms, calculating the potential rate of uptake by biofilms.
4. *Aquatic animals:* Measure macroinvertebrate and fish biomass and total N and P content at beginning, middle, and end of growing season (when taxa are present; 3 samples per site, 3 times per growing season). We will also quantify nutrient content of excreted products by placing stream organisms in containers for a period of time and recording nutrient accumulation during that time, following methods of Vanni *et al.* [1] (3 samples per site, 3 times per growing season).

Additionally, we will measure growth rates of *Daphnia* and an appropriate species of fish in cages, *in situ* (1 per site, measured for multiple short periods of time each season). This will allow us to quantify the pools of N and P within animals, as well as the change in the size of these pools over time, assessing potential rate of uptake by animals, as well as rates of excretion.

5. *Emergent animals*: Measure emergent insect biomass and total N and P content at beginning, middle, and end of growing season (3 samples per site, 3 times per growing season). We will also determine biomass fluxes weekly for the duration of the growing season. This will allow us to quantify the amount of N and P being removed from the aquatic system by emergent insects.

6. *Plants*: When present, measure aboveground wetland plant biomass and total N and P content at beginning, middle, and end of growing season (3 samples per site, 3 times per growing season), plus measure growth rate of plants in patches cleared at the beginning of growing season. This will allow us to quantify the pools of N and P within plants, as well as the potential change in the size of these pools over time, assessing potential rate of uptake and retention by plants.

Nutrient content will be assessed using a Seal AQ2 Discrete Analyzer housed at BGSU, with persulfate digestion techniques refined for plants and animals (G. Metzner, MS Thesis), as well as standard digestion methods for sediments, when necessary.

Combined, these measurements will allow us to calculate the potential of conventional ditches, two-stage ditches, or self-forming streams for altering downstream nutrient fluxes. Specifically, we will scale-up nutrient fluxes at the reach level to scenarios with watersheds dominated by one of these three stream management options.

RATIONALE: Nitrogen and phosphorus are key nutrients that have been implicated in toxic algal blooms and the eutrophication of Lake Erie [2-5]. Research strongly points towards agricultural run-off as the major source of these nutrients [2-5]. However, the ability of in-stream processes to regulate the transport of nutrients from fields to the lake have not been adequately assessed. Some reports suggest that processes within water bodies in a watershed can alter downstream export of P by more than 30% [6, 7], which is close to the target amount of P reduction (40%) in Lake Erie watersheds [8]. Moreover, there are currently several ditch management approaches that may reduce downstream nutrient

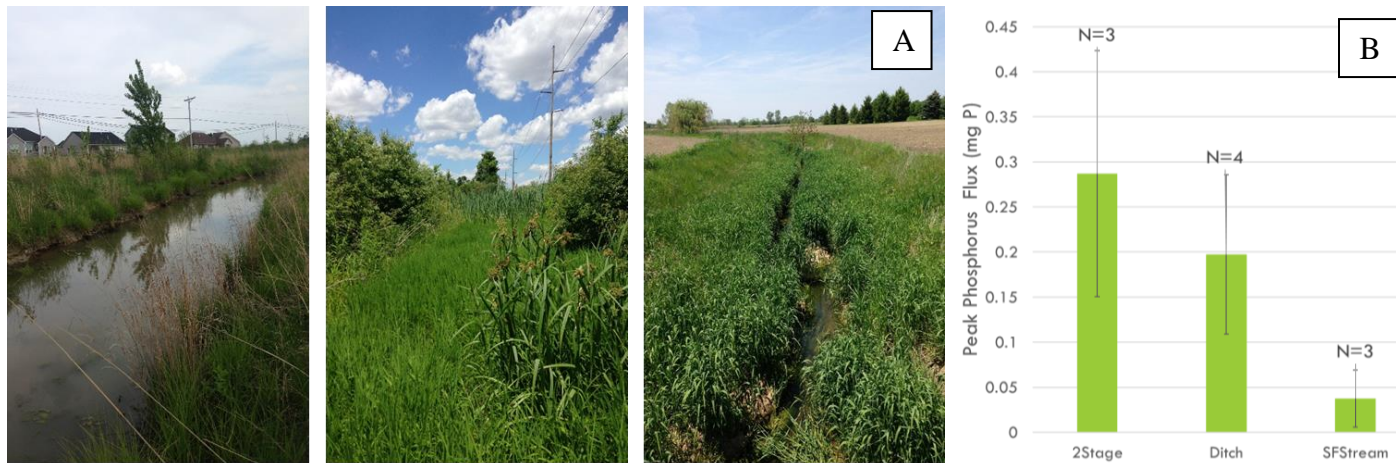


Figure 1. A) A conventional ditch, a self-forming stream, and a two-stage ditch. B) Differences in phosphorus flux via emergent insects between conventional ditches (Ditch), two-stage ditches (2Stage), and self-forming streams (SFStream). Photo and data: G. Metzner, MS Thesis.

transport (two-stage ditches and self-forming streams; Figure 1A)[9]. But these management options need further research, not only with respect to their overall effects on nutrient loading, but also with respect to how they might alter in-stream processes, including the role of plants and animal consumers in regulating nutrient cycling.

Animal consumers can directly remove nutrients from aquatic systems [10, 11], potentially reducing downstream fluxes, although these effects have not been measured. Likewise, plants may directly reduce downstream fluxes by retaining nutrients from sediment in their tissues. But plants and animals could also indirectly alter nutrient cycling through mechanical and physiological effects on the sediment, which could alter redox conditions [12], influencing nutrient uptake or release from sediment [13, 14]. For example, certain macroinvertebrates, like crayfish, may allow the escape of P

trapped in porewater, potentially altering sediment nutrients [12]. Importantly, changes to sediment nutrient content during low flow conditions [15], might influence nutrient release from these sediments during subsequent high-flow events [suggested by 6]. Thus, the effects of ditch restoration on plants and animals could play an important role in mediating downstream nutrient fluxes.

Overall, we hypothesize that nutrient cycling during low-flow conditions in these systems will be highly influenced by the effects of geomorphology and hydrology on stream biota (Figure 2). Specifically, we predict that nutrient cycling in conventional ditches will be driven by sediment, because there is little vegetation present and low to intermediate animal functional diversity, due to reduced area for vegetative growth and simplified habitat complexity (Figure 2). On the other hand, self-forming streams will allow for the greatest amount of vegetative development within the ditch, but the least flow-permanence (surface drying will be common), greatly reducing the functional diversity of stream animals [sensu 16, 17]. Lastly, we suspect that two-stage ditches will maximize nutrient retention and removal, by encouraging a balance between vegetative development and flow permanence (surface drying uncommon), thereby encouraging high functional diversity of animals. We have limited evidence for this idea from a preliminary study of the phosphorus flux via emergent insects at these site locations (Figure 1B).

Testing the hypotheses described here will aid calculations of the potential nutrient load reduction if two-stage ditches and self-forming streams were implemented more widely. It will also tell us how underlying factors, like hydrology, might influence the success of particular management options, via pathways involving the direct and indirect action of stream biota. Thus, it will assess our ability to “Improve the assimilative capacity and ecological functions of Lake Erie tributaries to help reduce nutrient loadings [18].”

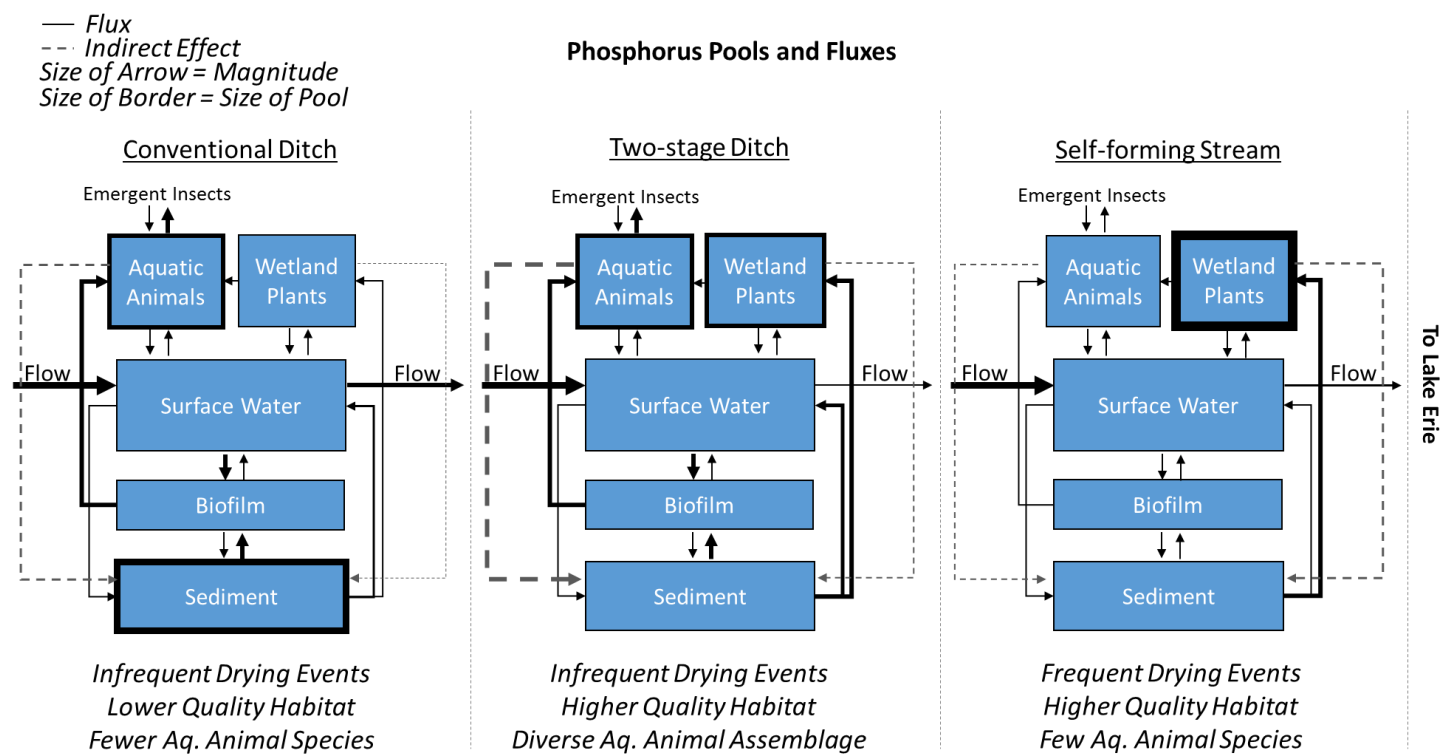


Figure 2. Conceptual diagram for hypothesized differences in nutrient pools and fluxes between conventional ditches, two-stage ditches, and self-forming streams.

References

- [1] Vanni MJ, Flecker AS, Hood JM, Headworth JL: **Stoichiometry of nutrient recycling by vertebrates in a tropical stream: linking species identity and ecosystem processes.** *Ecology Letters* 2002, **5**: 285-293.

- [2] Michalak AM, Anderson EJ, Beletsky D, Boland S, Bosch NS, Bridgeman TB, Chaffin JD, Cho K, Confesor R, Daloglu I, Depinto JV, Evans MA, Fahnenstiel GL, He L, Ho JC, Jenkins L, Johengen TH, Kuo KC, Laporte E, Liu X, McWilliams MR, Moore MR, Posselt DJ, Richards RP, Scavia D, Steiner AL, Verhamme E, Wright DM, Zagorski MA: **Record-setting algal bloom in Lake Erie caused by agricultural and meteorological trends consistent with expected future conditions.** *Proc Natl Acad Sci U S A* 2013, **110**: 6448-52.
- [3] Anderson DM, Cembella AD, Hallegraeff GM: **Progress in understanding harmful algal blooms: paradigm shifts and new technologies for research, monitoring, and management.** *Annual review of marine science* 2012, **4**: 143-176.
- [4] Baker DB, Confesor R, Ewing DE, Johnson LT, Kramer JW, Merryfield BJ: **Phosphorus loading to Lake Erie from the Maumee, Sandusky and Cuyahoga rivers: The importance of bioavailability.** *Journal of Great Lakes Research* 2014, **40**: 502-517.
- [5] Davis TW, Bullerjahn GS, Tuttle T, McKay RM, Watson SB: **Effects of increasing nitrogen and phosphorus concentrations on phytoplankton community growth and toxicity during Planktothrix blooms in Sandusky Bay, Lake Erie.** *Environmental science & technology* 2015, **49**: 7197-7207.
- [6] House WA: **Geochemical cycling of phosphorus in rivers.** *Applied Geochemistry* 2003, **18**: 739-748.
- [7] Pradhanang SM, Mukundan R, Zion MS, Schneiderman EM, Pierson D, Steenhuis TS: **Quantifying In-Stream Processes on Phosphorus Export Using an Empirical Approach.** *Journal of Water Resource and Protection* 2014, **06**: 120-131.
- [8] Agreement GLWQ, *Progress Report of the Parties.* 2016.
- [9] Mahl UH, Tank JL, Roley SS, Davis RT: **Two-Stage Ditch Floodplains Enhance N-Removal Capacity and Reduce Turbidity and Dissolved P in Agricultural Streams.** *JAWRA Journal of the American Water Resources Association* 2015, **51**: 923-940.
- [10] Sanzone DM, Meyer JL, Marti E, Gardiner EP, Tank JL, Grimm NB: **Carbon and nitrogen transfer from a desert stream to riparian predators.** *Oecologia* 2003, **134**: 238-250.
- [11] Vanni MJ: **Nutrient cycling by animals in freshwater ecosystems.** *Annual Review of Ecology and Systematics* 2002, 341-370.
- [12] Leslie AW: **The Diversity of Burrowing Benthic Invertebrates and their Impact on Phosphorus Dynamics in Agricultural Drainage Ditches.** 2014,
- [13] Baldwin DS, Mitchell AM: **The effects of drying and re-flooding on the sediment and soil nutrient dynamics of lowland river-floodplain systems: A synthesis.** *Regulated Rivers-Research & Management* 2000, **16**: 457-467.
- [14] Kinsman-Costello LE, O'Brien J, Hamilton SK: **Re-flooding a historically drained wetland leads to rapid sediment phosphorus release.** *Ecosystems* 2014, **17**: 641-656.
- [15] Nguyen L, Sukias J: **Phosphorus fractions and retention in drainage ditch sediments receiving surface runoff and subsurface drainage from agricultural catchments in the North Island, New Zealand.** *Agriculture, ecosystems & environment* 2002, **92**: 49-69.
- [16] Sabo JL, Finlay JC, Kennedy T, Post DM: **The Role of Discharge Variation in Scaling of Drainage Area and Food Chain Length in Rivers.** *Science* 2010, **330**: 965-967.
- [17] Schriever TA, Bogan MT, Boersma KS, Cañedo-Argüelles M, Jaeger KL, Olden JD, Lytle DA: **Hydrology shapes taxonomic and functional structure of desert stream invertebrate communities.** *Freshwater Science* 2015, **34**: 399-409.
- [18] Commission OLE: *Lake Erie protection & restoration plan.* Ohio Lake Erie Commission; 2000.