An Introduction to Stormwater Ponds and Their Ecology

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“Lake” or “Pond”

= “Wet Detention Basin”

= Engineered and built structure to control stormwater runoff and prevent flooding
Coastal zone development in South Carolina

Coastal development = Stormwater management
- Flat topography (low-lying coastal plain)
- Shallow water table
- Precipitation dominated by storm events

Stormwater management = Wet detention basins
- Primarily necessary for flood control
- Important source of fill dirt
- (Increasingly) enhance adjacent property values
Forest Water Budget

Lots of infiltration and transpiration
Little surface runoff
Suburban/Urban Water Budget

Lots of runoff (from lots of impervious surfaces)
Little infiltration and transpiration

Developments must contain and control their runoff

- Evaporation
- Surface runoff
- Roof runoff
- Plant uptake & transpiration
- Infiltration and groundwater recharge
Suburban/Urban Water Budget

Lots of runoff (from lots of impervious surfaces)
Little infiltration and transpiration

Stormwater Ponds:
Currently most common means of controlling stormwater runoff
Stormwater ponds are artificial structures

But, nature abhors a vacuum…

- If you dig a hole in the ground and fill it with water, biology will come and it will grow.
- The more you “feed” it, the more biology will grow.
- This is often when the water quality problems begin…
What is “water quality”?  

- Many technical definitions for water quality.  
- Based on many different measurements.  
  - Nutrients  
  - Algae  
  - Dissolved oxygen  
  - Suspended sediments  
  - pH and alkalinity  
  - Heavy metals  
  - Organic toxins (pesticides, etc)  
  - Pathogens (e.g., *E. coli*)  

- Currently, no regulatory standards exist for any WQ measurements in stormwater ponds.  
- Consequently, ponds are largely managed for water quality based on homeowner aesthetics.
POOR Water Quality: Mostly we know it when we see it.

Symptoms:

- Looks like pea-green soup
- Scum on surface
- Can smell bad
- No fish or bottom life
- Soft, mucky bottom
Pea-green soup = excessive growth of algae

Algae: Microscopic, single-celled “plants”

- Most algae, although unsightly in high concentrations, are harmless.
- Some algae can produce toxins that are potentially harmful to human health.
What causes algal growth?

- Algae (like all plants) require nutrients (plus sunlight) to grow.
  → without nutrients there would be no algae

- Plants (algae) are the base of the food chain.
  → without algae, ponds cannot support fish, wildlife, etc…

- Problem becomes “too much of a good thing.”
  - Excessive and/or toxic algal growth
  - Decomposition of algae causes oxygen depletion, leading to fish kills
  - Can leads to potential water quality problems for receiving waters

The Goldilocks dilemma:

No nutrients = no life in pond.

“Right” amount of nutrients = healthy, balanced pond ecosystem.

Too much nutrients = unbalanced, dysfunctional pond ecosystem.
**Typical sources of nutrients to ponds:**

Most nutrients enter into ponds when carried from land by stormwater runoff

- **Fertilizers** (nitrogen & phosphorus)
- **Soaps and detergents** (phosphorus)
- **Animal waste** (human, pet, waterfowl, wildlife, etc.)
  (both, but very high in phosphorus relative to nitrogen)
- **Fossil fuel combustion** (mostly nitrogen)
- **Rainfall** (mostly nitrogen)
- **Decaying plant matter** (nitrogen & phosphorus)
- **Weathering of soil / rock** (mostly phosphorus)

Mostly due to humans

Mostly Natural
How do nutrient concentrations vary among ponds? How do ponds respond to varying nutrient concentrations?

A study of 26 residential ponds with varying development density:

- 2 Undeveloped
- 7 Low residential development
- 10 Medium residential development
- 7 High residential development

Pond size:
- Median = 2.2 acres
- Range: 0.2 – 18.5 acres

Pond depth:
- Median = 5 ft
- Range: 3 – 14 ft

Sampled 8 times from May – Sept.

All ponds are freshwater.
How do nutrient concentrations vary among ponds?

Total Nitrogen ($\mu$g L$^{-1}$)

Total Phosphorus ($\mu$g L$^{-1}$)
How do nutrient concentrations vary among ponds?

Total Phosphorus ($\mu$g L$^{-1}$)

Pond 24
six times higher in TP than pond 23
Total Phosphorus is a strong predictor of algal abundance

Relationship for ponds not subject to routine algaecide treatments

Amount of algae in pond vs. Total Phosphorus (µg L⁻¹)

\[ y = 0.4x^{1.02} \]

\[ r^2 = 0.65 \]
Total Phosphorus is a strong predictor of algal abundance

Relationship does not significantly change for ponds treated with algaecide

\[ y = 0.4x^{1.02} \]
\[ r^2 = 0.65 \]

\[ y = 0.52x^{0.85} \]
\[ r^2 = 0.53 \]
Submerged and floating aquatic vegetation:
(Often considered the other pond plant problem)
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Negatives associated with rooted plants:
- Can take over and “choke-out” the pond.
- Can look visually unappealing (aesthetic judgment).
- In large quantities can reduce ability of pond to hold necessary stormwater volume.

Positives associated with rooted plants
- Provides critical habitat/forage for fish, wildlife
- Can help stabilize pond shoreline.
- Will reduce sediment resuspension
- Can often outcompete algae for nutrients.
- Often produce natural chemicals that can inhibit algal growth.
Can submerged plants help control the growth of algae?

Can allelopathically active submerged macrophytes stabilise clear-water states in shallow lakes?

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Submerged and floating aquatic vegetation: (Often considered the other pond plant problem)

Can submerged plants help control the growth of algae?
→ Yes, very often! (depending on the species of algae)

Fig. 3: Frequency of studies indicating inhibition (or lack thereof) exerted by submerged plants on different types of algae.

Common allelopathic plants:
• *Myriophyllum* (watermilfoil)
• *Ceratophyllum* (hornworts)
• *Elodea* (waterweed)
• *Najas* (waternymph)
Linking nutrients, algae and dissolved oxygen dynamics:

Nutrients + sunlight make algae grow

Algae produce organic matter that ‘fuels’ growth of natural bacteria

\[
\text{nutrients} + \text{sunlight} \Rightarrow \text{algae growth} \Rightarrow \text{organic matter}
\]

\[
\text{algae} \Rightarrow \text{organic matter} \Rightarrow \text{growth of natural bacteria}
\]

\[
\text{CO}_2 \text{ consumption} = O_2 \text{ production}
\]

\[
\text{CO}_2 \text{ production} = O_2 \text{ consumption}
\]
Example of effects of pond stratification on oxygen:

**Water Temperature**

- **Surface**
- **Bottom**

**Dissolved Oxygen**

Dissolved Oxygen (mg O₂ L⁻¹)

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Linking nutrients, algae and dissolved oxygen dynamics:

Low nutrients $\rightarrow$ high light conditions
(a healthy, balanced pond ecosystem)

Light penetration is a function of concentration of algae (and suspended sediments)
Linking nutrients, algae and dissolved oxygen dynamics:

Increased Nutrients

Loss of Plants

High nutrients $\rightarrow$ low light conditions
(Loss of bottom water oxygen & animal life)

Light penetration is a function of concentration of algae (and suspended sediments)
Almost all stormwater ponds have an outlet:

What happens in the pond does not entirely stay in the pond

- Increased Nutrients
- Loss of Plants

Build up of organic muck on bottom

Discharge to downstream waters

To what effect?
What is the effect of the dissolved material in pond water when it is discharge to coastal waters?

**Experiment:**  Mix: 20 % pond water with 80 % coastal marine water

**Measure:** Changes in growth rate of algae
Changes in growth rate of natural bacterial
Over 3 days of incubation under natural sunlight

Each day measure:
1. Algal growth rate
2. Bacterial growth rate
Results:

→ Pond discharges have the potential to exacerbate oxygen conditions in coastal waters by stimulating bacterial growth.
Key Points:

- Ponds are created structures intended to control stormwater runoff.  
  - But they readily develop a thriving ecosystem when provided nutrients.

- Ponds exhibit a large range in their nutrient concentrations.  
  - Residential development increases phosphorus more than nitrogen.  
  - Homeowner practices can affect the amount of phosphorus entering ponds (fertilizers, feeding wildlife, types of vegetation in/around ponds).

- Algal growth is strongly linked to nutrients (especially phosphorus).

- There will always be conditions that require intensive (ie, chemical) pond management practices.  
  - But the more one can promote (or accept) a natural pond ecosystem, the less effort (= $$) must be spent on artificial treatment practices.

- What goes into, and occurs within, ponds can have consequences for downstream receiving waters.
Primary Purpose:

- Develop an integrated, sustainable, economic and natural resource strategy for the construction, use, and maintenance of stormwater ponds to meet the needs of local communities and businesses.

Key Research Questions:

- What constitutes proper pond management? What impact does management and maintenance, including dredging, have on pond function, pollutant accumulation, and potential impacts to adjacent waters and people?
- How have ponds changed coastal hydrology, impacting ecological processes and the functioning of coastal and marine ecosystems?
- How do ponds interact with groundwater, and what effect does this have on their performance and role in coastal hydrology and ecology?
- Do ponds function as designed and engineered with respect to hydrologic and pollutant removal performance, and does the functioning change with pond age?
- Is the land activity surrounding ponds linked with the occurrence of harmful algae? How are harmful algae in ponds linked to the occurrence of harmful algae in receiving waters?