

# Terrestrial Drivers of Coastal Plain Stream Water Quality in North Carolina

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*As gathered from various studies on two major types of streams:*

*\***urban/suburban tidal creeks**, and*

*\***rural/agricultural tributary streams**, some tidal and others not, some blackwater and others not.*

# Urban/suburban estuarine tidal creeks (some agricultural as well)

- ▶ Major pollution sources
  - ▶ Urbanization
  - ▶ Marinas
  - ▶ Golf courses
  - ▶ Agriculture



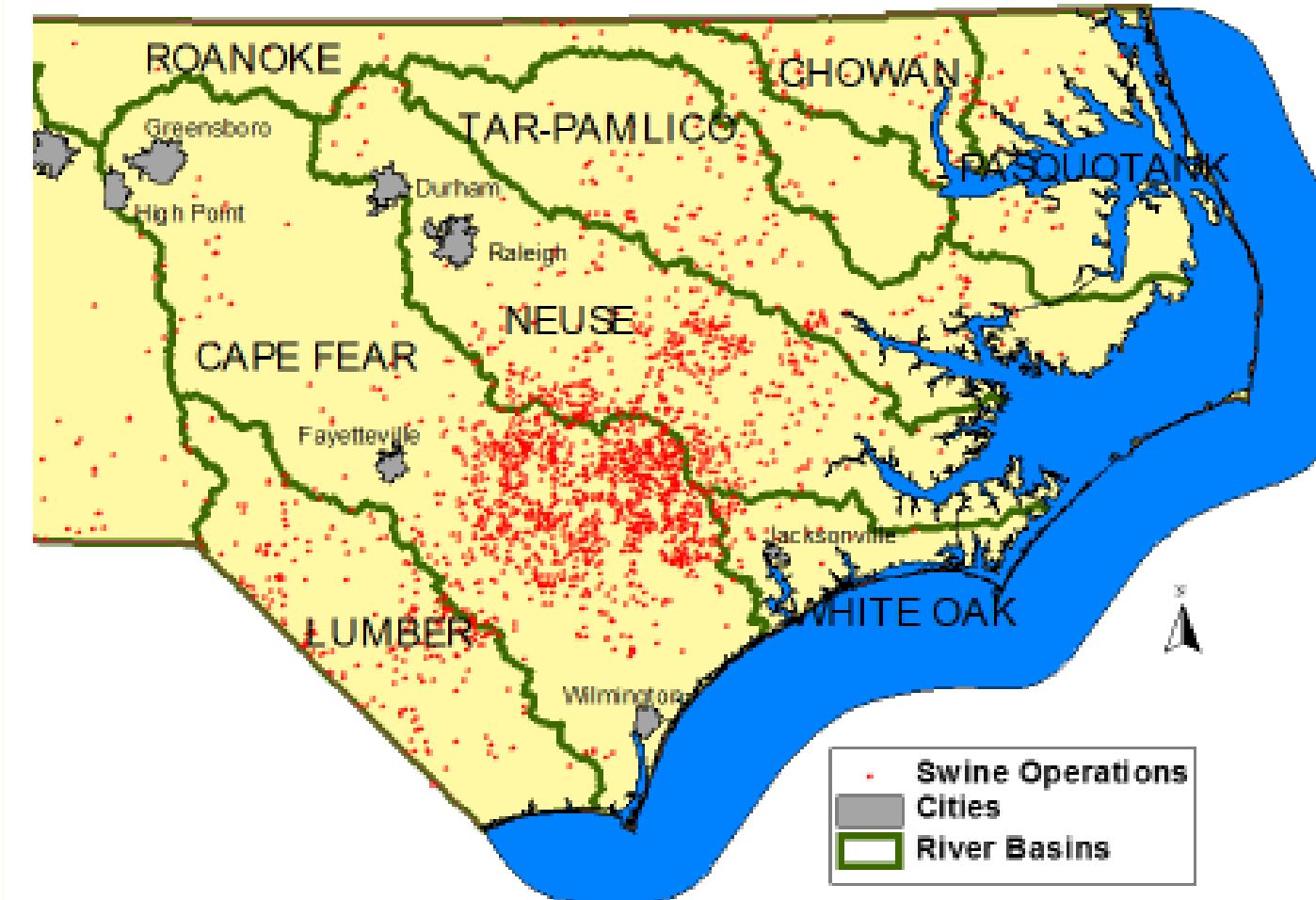


# Coastal Plain fresh and oligohaline streams (some tidal and some not) mainly 2<sup>nd</sup> to 5<sup>th</sup> order

- ▶ Major pollution sources
  - ▶ Swine and poultry CAFOs
  - ▶ Crop agriculture
  - ▶ Silviculture



## Swine Farms in Eastern North Carolina River Basins



Approximately 9,000,000 head of swine in confinement in NC

**Swine CAFOs eastern NC**



**Swine CAFO in Minnesota**



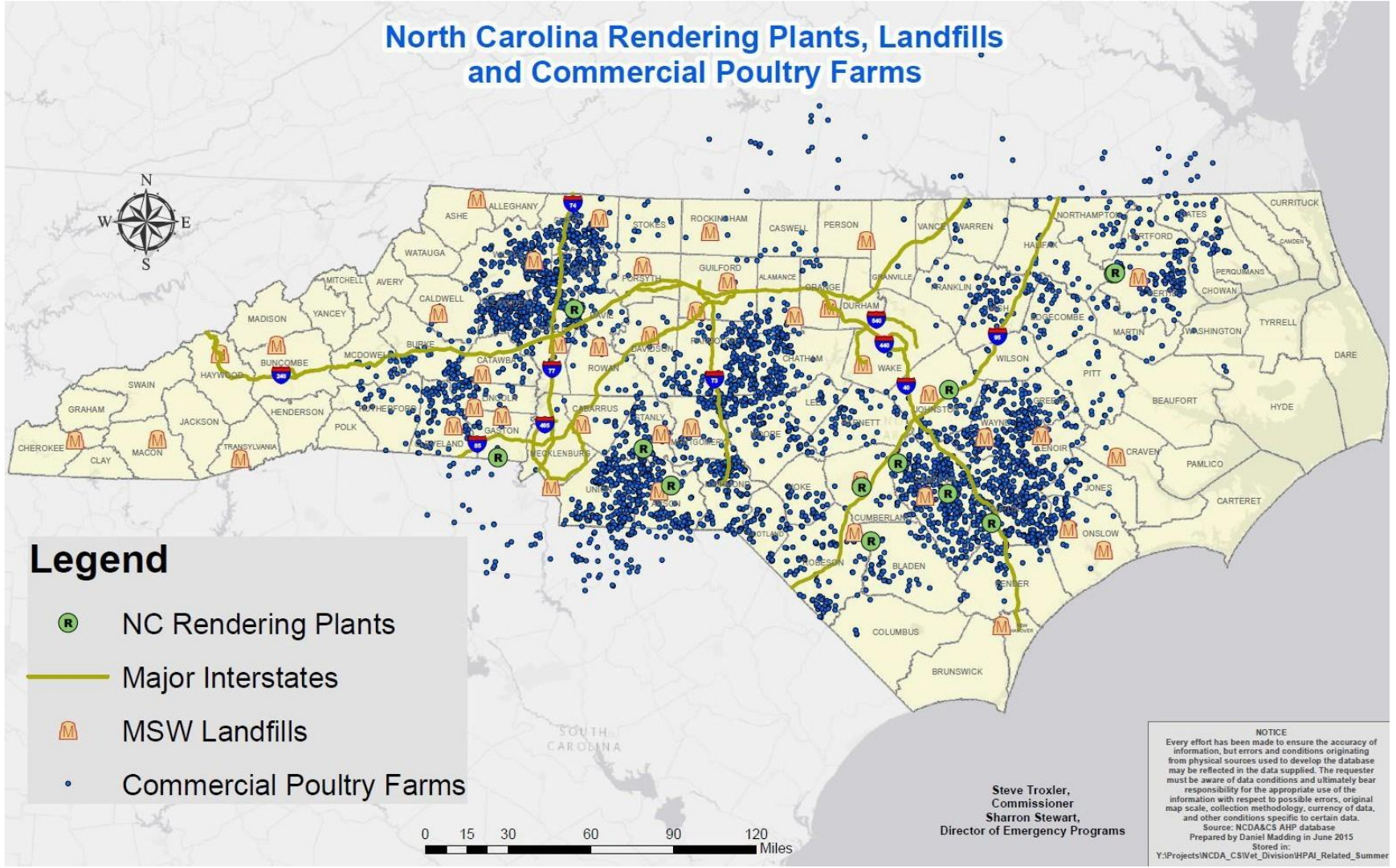
**Dr. Larry Cahoon, UNCW**

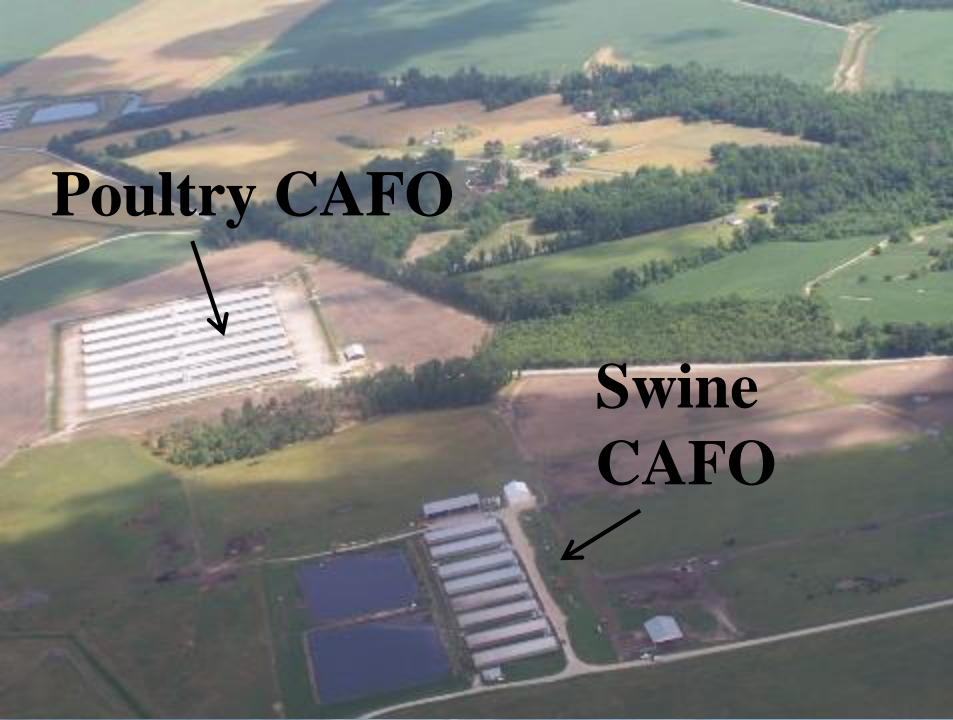
Swine CAFO waste disposal by spraying, top and bottom left; note saturated fields



Poultry CAFO dry waste in pile

# Poultry CAFO distribution in North Carolina (from Patt 2017)





**Drainage from poultry CAFO  
into public waters**

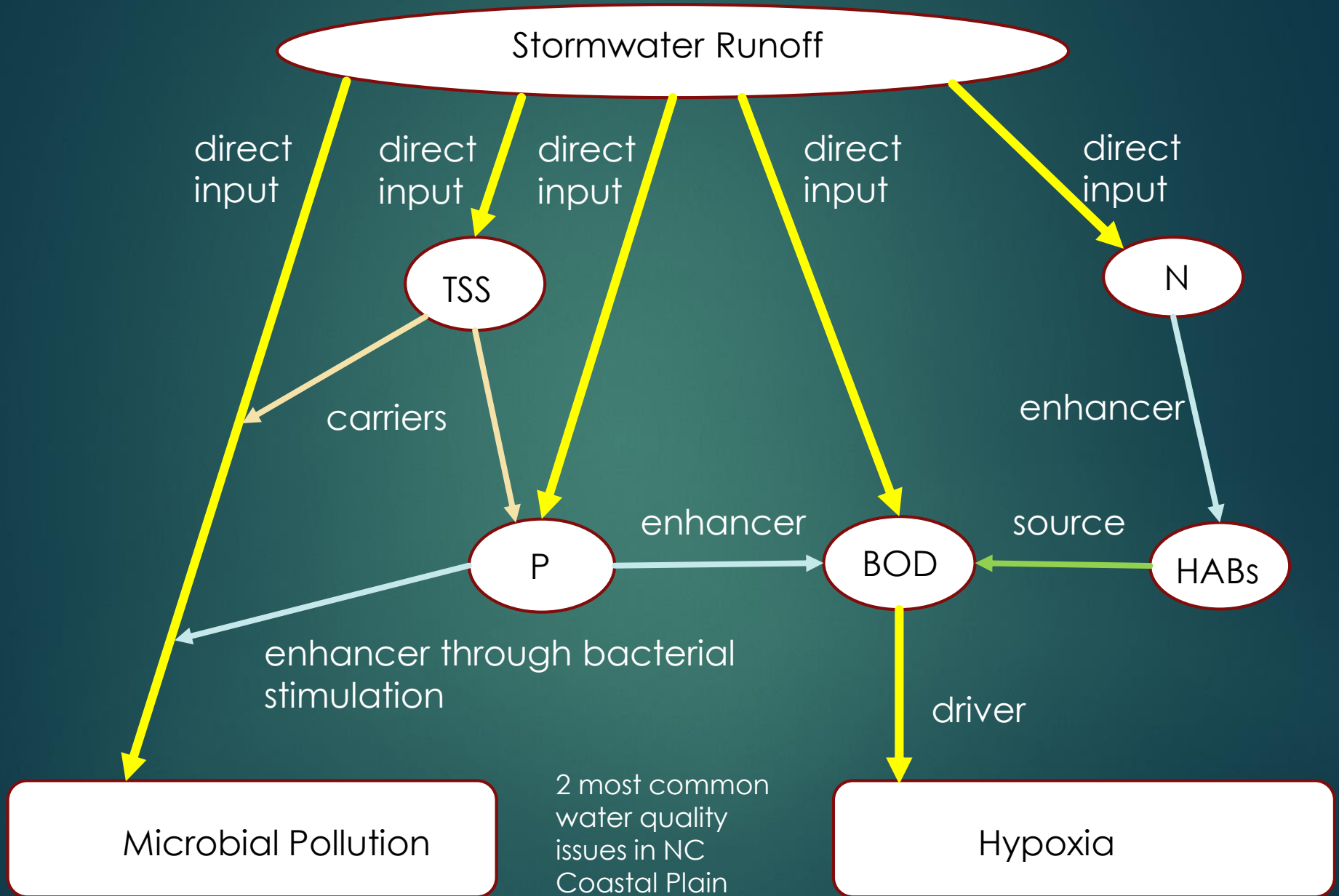


**Large poultry CAFO VA  
eastern shore**

**Poultry waste as dry litter**



# North Carolina Coastal Plain Streams: General Conceptual Pollution Model



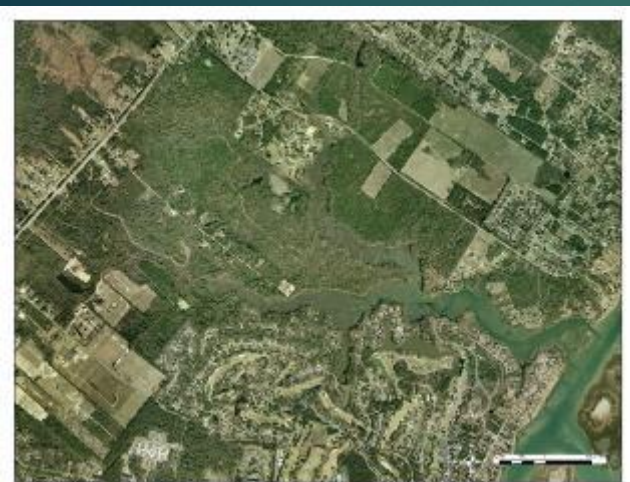
## The urban scene for tidal creeks: **Fecal microbial pollution**

Correlation analyses between geometric mean fecal coliform counts and **urbanization** factors, Wilmington NC tidal creeks

	Population	% Developed land	% Impervious surface
Fecal	0.922	0.945	0.975
Coliforms	0.026	0.015	0.005

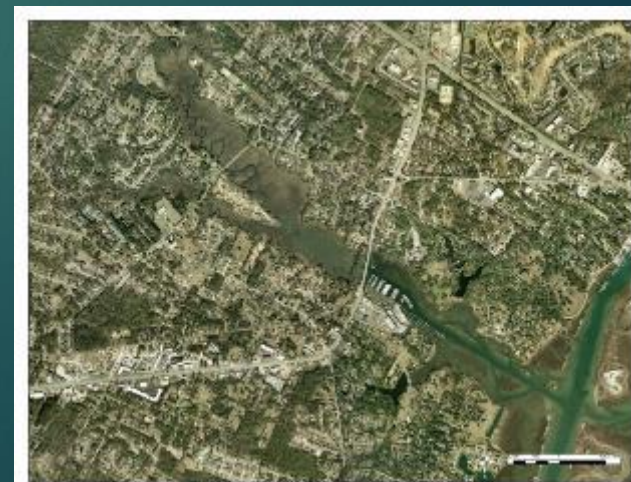
correlation coefficient (r) / probability (p), n = 700 fecal bacteria samples

Mallin et al. (2000) *Ecol. Appl.* 10: 1047-1056

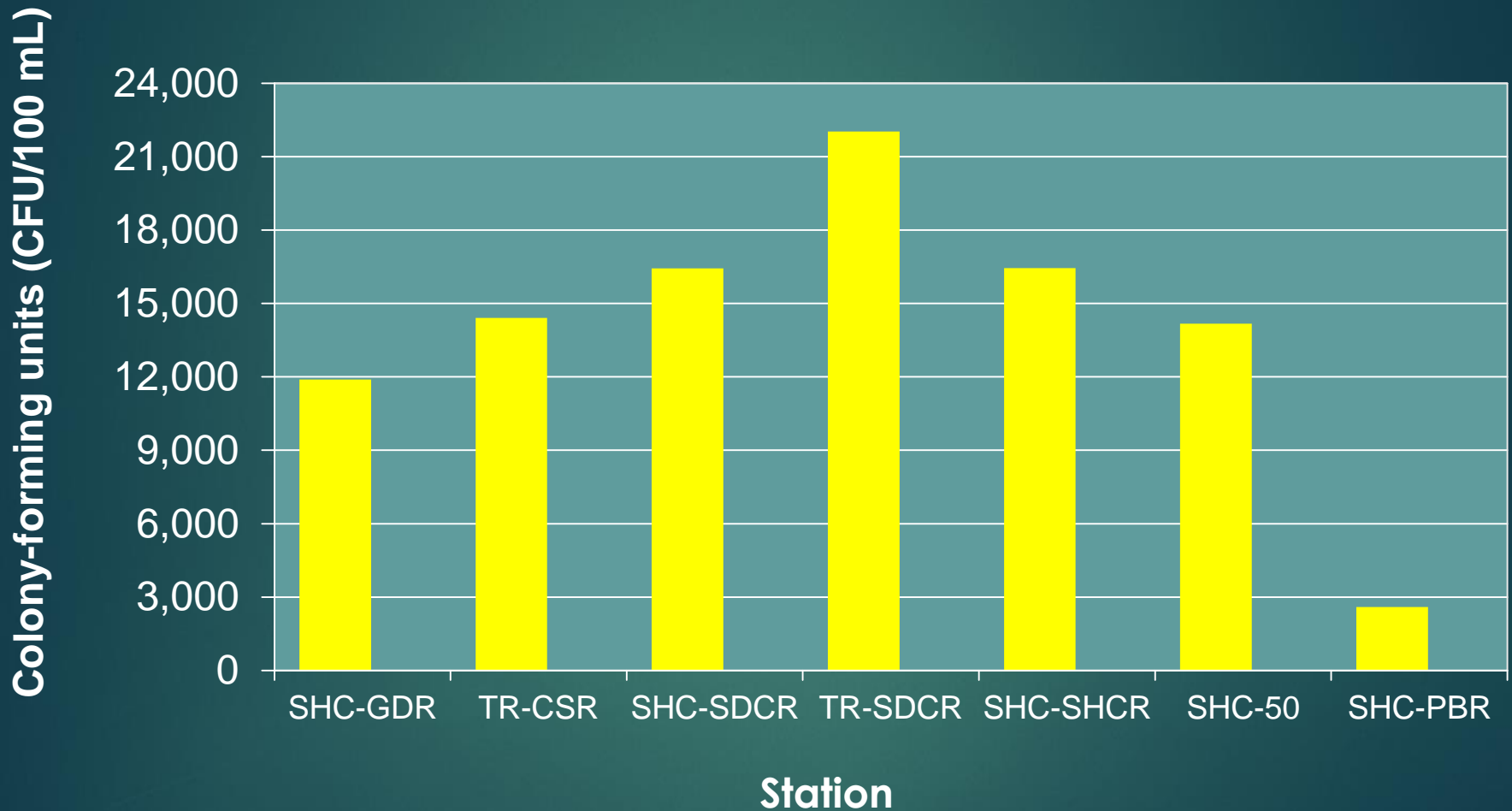


Left: Futch Creek, 12% impervious cover, open for shellfishing.

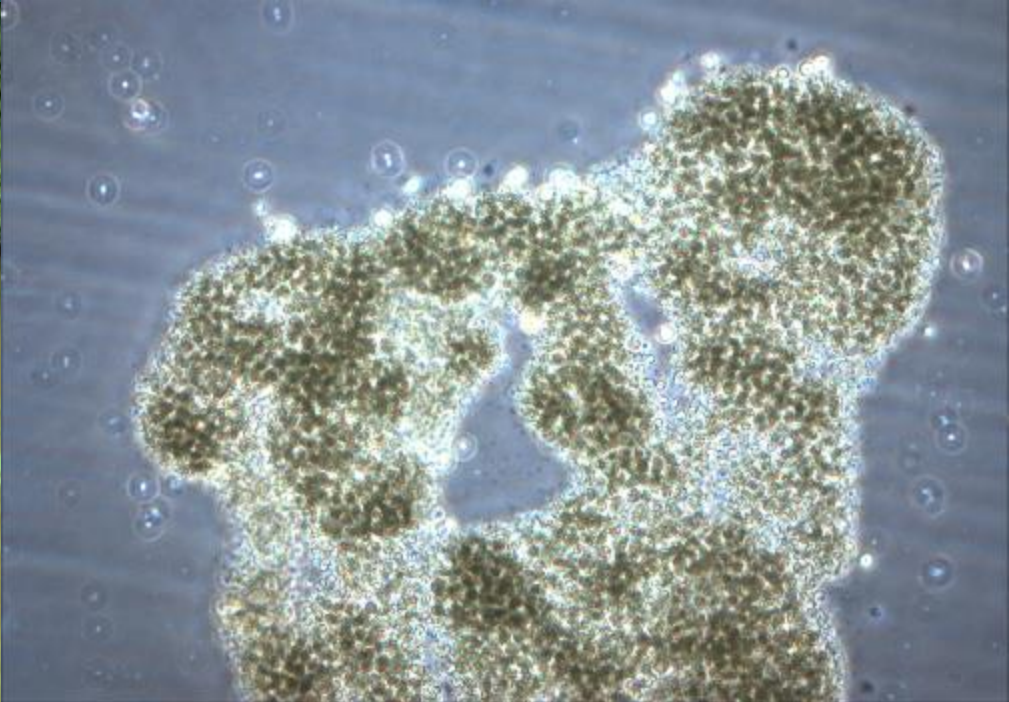
Right: Bradley Creek, 28% impervious cover, closed for shellfishing.



The *rural scene* in CAFO watersheds: **Fecal microbial pollution**  
Geometric mean fecal coliform counts by station August 2016 for  
Stocking Head Creek, Duplin Co., N.C. (n = 5 for each station)



100% of the samples (35/35) exceeded 200 CFU/100 mL and 97% of the samples (34/35) exceeded 400 CFU/100 mL within a 30-day period.

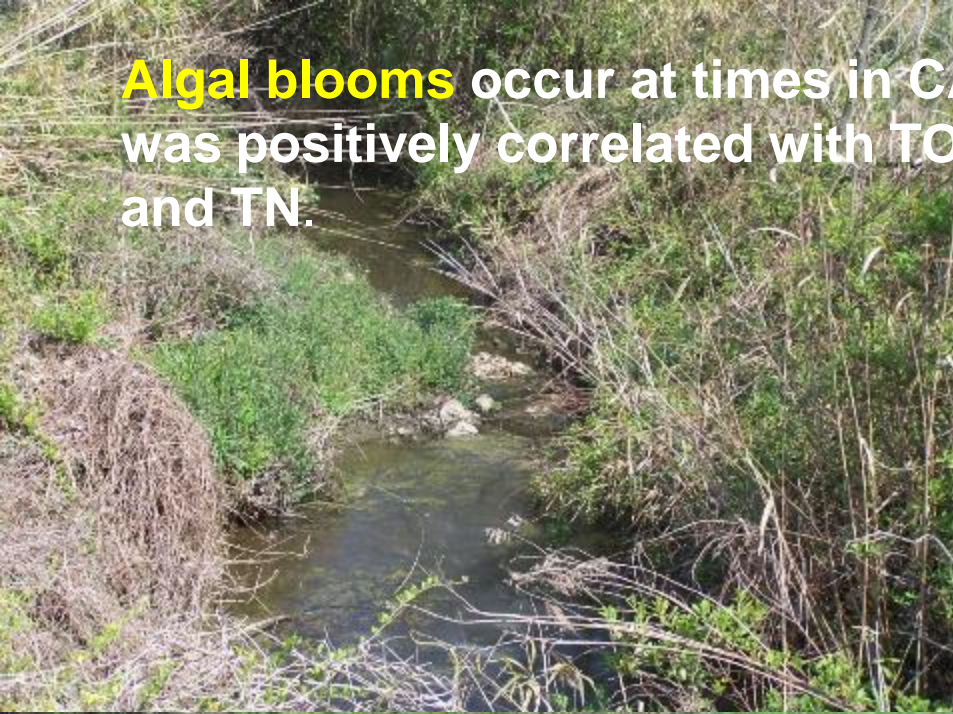


Occasional HABs occur in blackwater rivers:

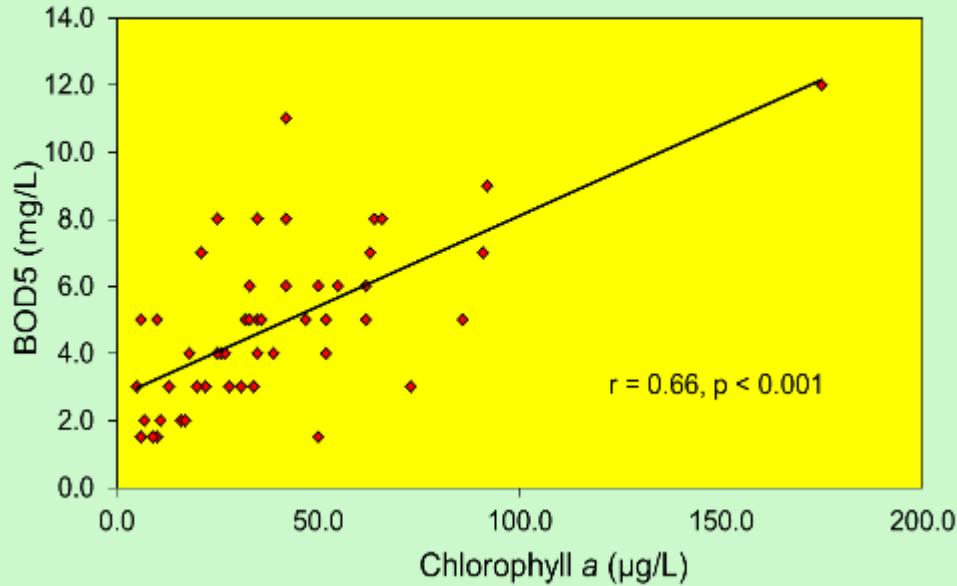
Above left and right, *Microcystis aeruginosa* blooms in the Cape Fear River, 2009-2012

Below left, *Anabaena planctonica* bloom in the Northeast Cape fear River, 2011 (led to DO crash).

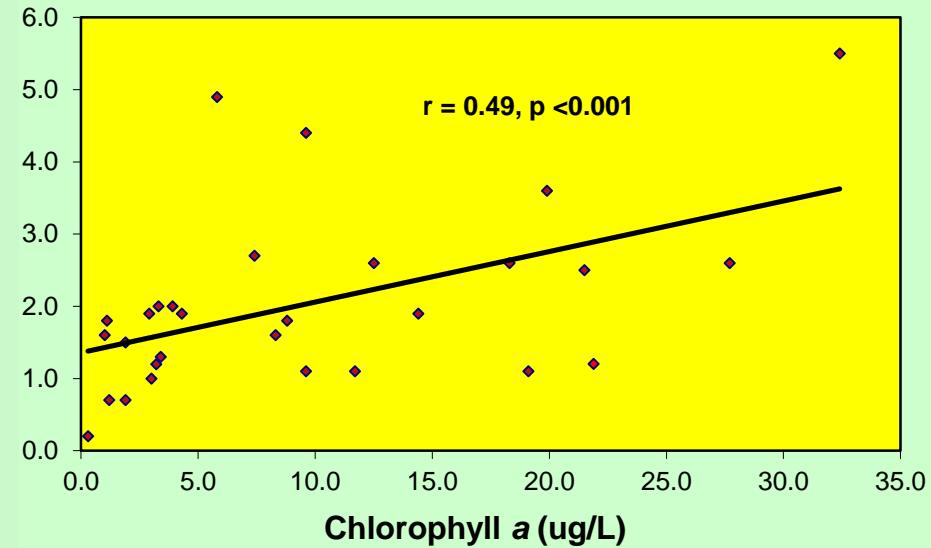
**Algal blooms** occur at times in CAFO-influenced streams. BOD was positively correlated with TOC, ammonium, TP, chlorophyll a, and TN.



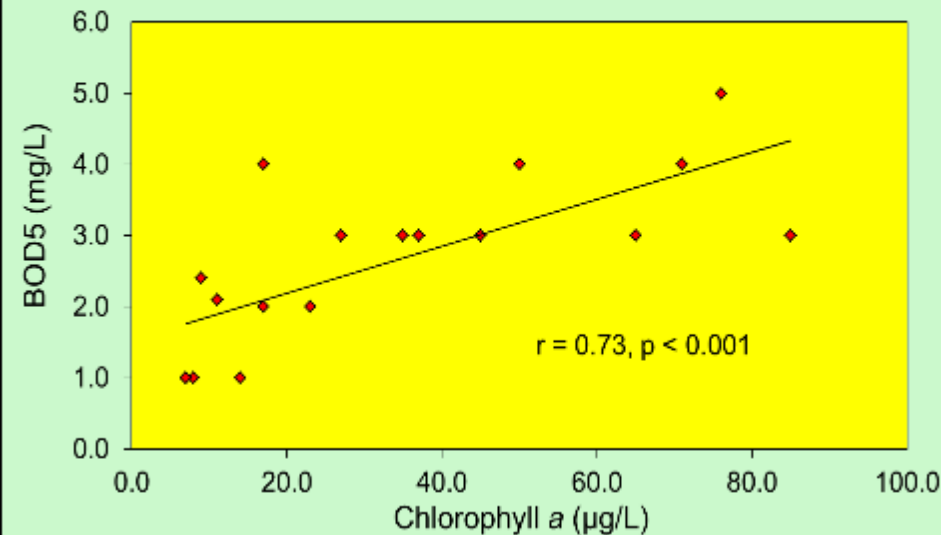
**BOD5 vs. Chlorophyll a, NC Outer Banks  
Creeks and Sloughs**



**BOD5 vs Chlorophyll a – Smith Creek  
(oligohaline tidal creek)**



**BOD5 vs. Chlorophyll a in Greenfield Lake,  
NC Coastal Plain**



A strong correlation exists in many NC Coastal Plain waterbodies between chlorophyll a and biochemical oxygen demand (BOD).

As many Coastal Plain streams are stressed for low DO in summer, algal blooms obviously contribute to this situation

Sedimentation to urban/suburban tidal creeks and streams, New Hanover Co., NC





Clearcut along Colly Creek, NC



Woody debris after clearcut



Clearcut over red clay near Horseshoe Bend Park, AL



Agricultural runoff, Duplin Co., NC

Suspended particles (measured as turbidity or TSS) are often associated with pollutants such as fecal bacteria and P in NC Coastal Plain streams

### Field data correlations (lower Cape Fear Watershed)

#### Turbidity and fecal coliforms

Cape Fear River	$r = 0.858, p = 0.001$
11 rural streams	$r = 0.764, p = 0.0001$
5 tidal creeks	$r = 0.346, p = 0.001$

#### Turbidity and orthophosphate

Silver Stream	$r = 0.788, p = 0.001$
Burnt Mill Creek	$r = 0.401, P = 0.035$
Echo Farms stream	$r = 0.788, p = 0.001$
11 rural streams	$r = 0.384, p = 0.001$

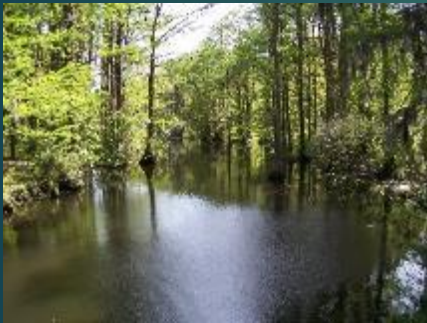
# Some P effects on ecosystems, are not algal-based

- ▶ **Essential nutrient for bacteria** (Kirchman 1994, *Microb. Ecol.* 28: 255-271).
- ▶ **P-limited conditions: bacteria out-compete phytoplankton for P**  
(Cotner et al. 2000, *Estuaries* 23: 61-620; Currie 1990, *L&O* 35: 1437-1455).



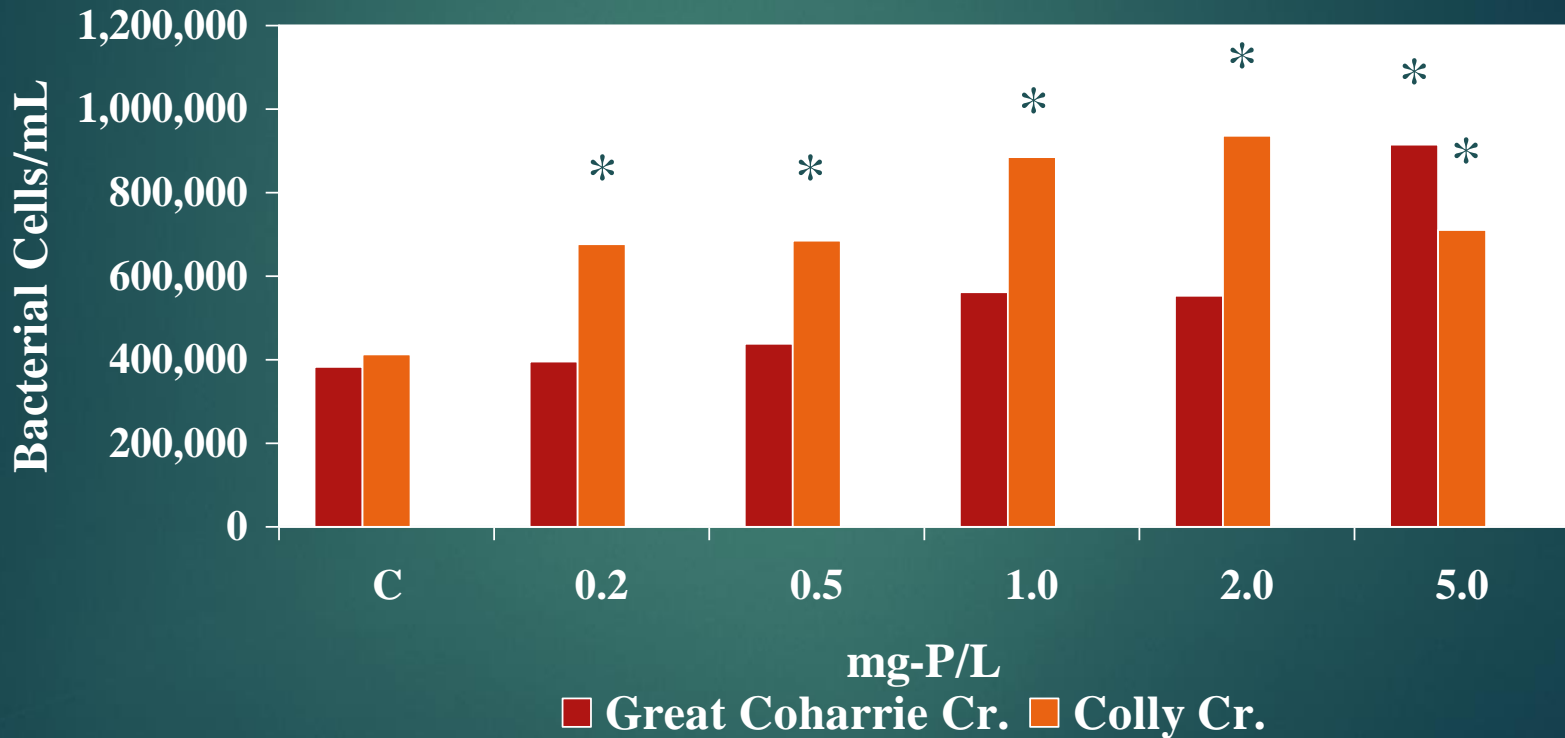
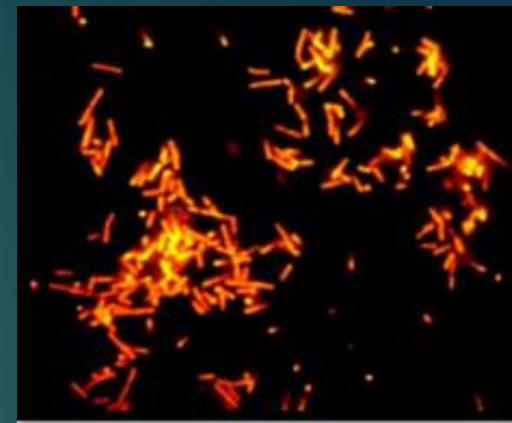
► **Field studies - Major P impacts on dissolved oxygen (DO), measured as BOD. TP strongly correlated with BOD<sub>5</sub> +/-or BOD<sub>20</sub>**

<b>TP x BOD</b>	<b>System</b>	<b>r</b>	<b>p value</b>
<b>BOD<sub>5</sub></b>	Greenfield Lake	0.53	0.0001
	NE Cape Fear River	0.34	0.008
	Hammond Creek	0.42	0.009
	Gr. Coharie Creek	0.66	0.0001
	Stockinghead Creek	0.63	0.0001
<b>BOD<sub>20</sub></b>	NE Cape Fear River	0.34	0.009
	Black River	0.33	0.010
	Hammond Creek	0.69	0.001
	Six Runs Creek	0.49	0.002
	Browns Creek	0.40	0.012
	Gr. Coharie Creek	0.78	0.0001
	Colly Creek	0.39	0.015



# Ambient bacterial Stimulation by Experimental P Additions

50% Pi, orthophosphate, + 50% Po, glycerophosphate;  
5-day incubations, acridine orange counts



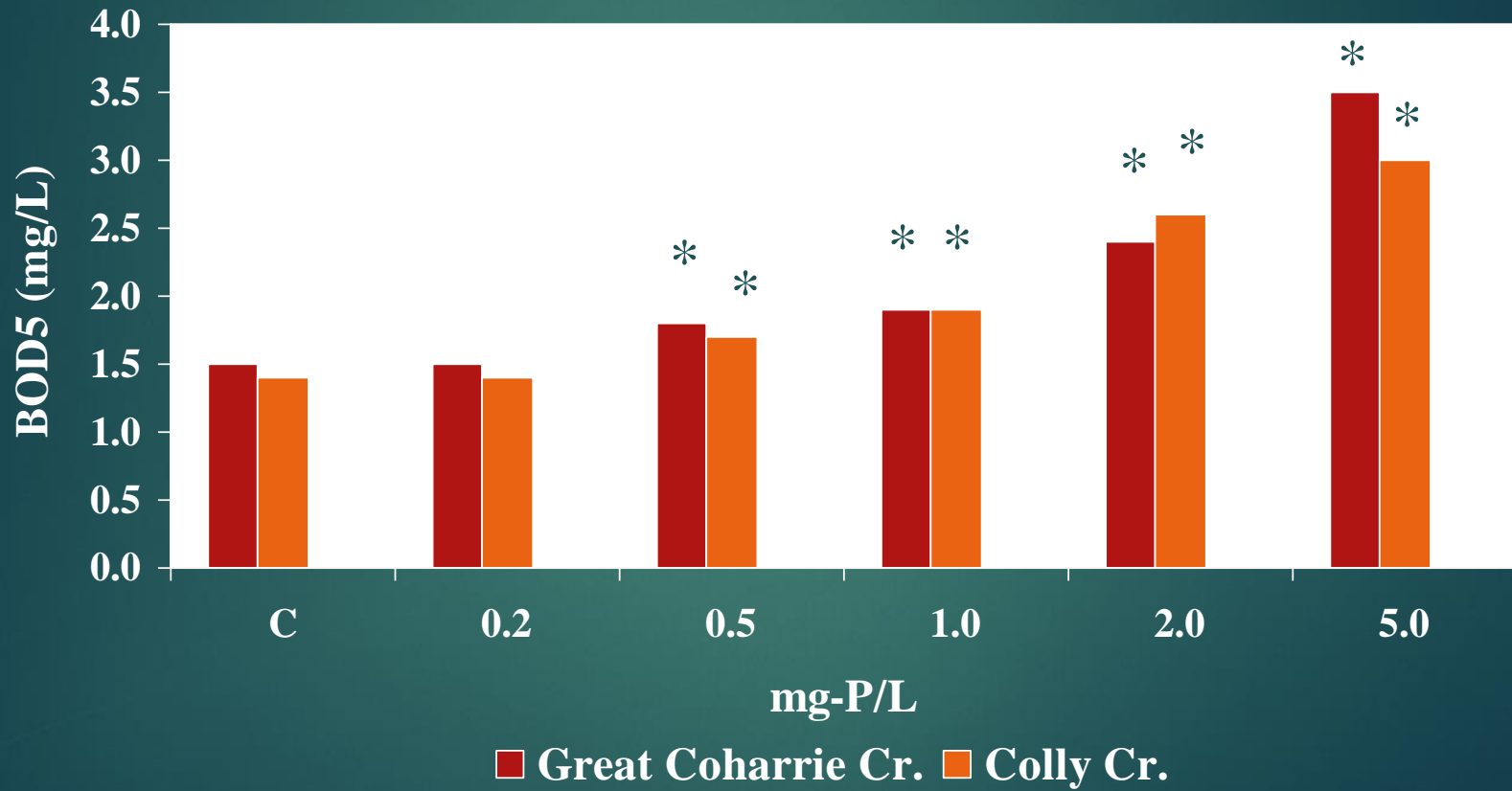
\*indicates significantly greater than control

Mallin et al. (2004) *Ecol. Appl.* 14: 823-838

# BOD Stimulation by Experimental P Additions



(50% orthophosphate + 50% glycerophosphate) – 5-day incubations

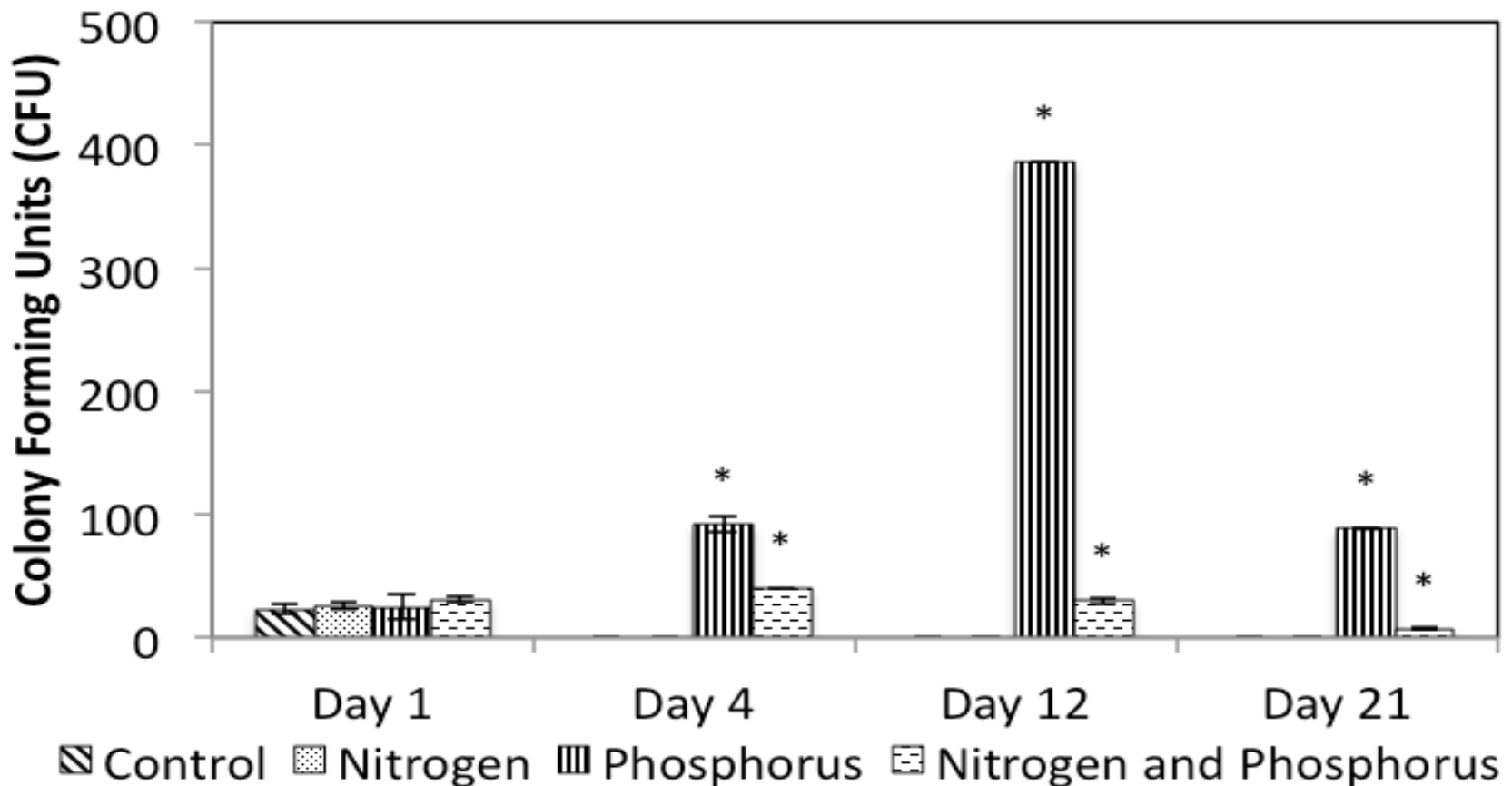


\*indicates significantly greater than control

**Fecal coliform bacteria** and nutrient addition assays; source water a constructed stormwater wetland in Wilmington, NC. September 2009; additions were 1.5 mg-P/L glycerophosphate

(Chudoba et al. 2013, *Water Research* 47:3455-3466)

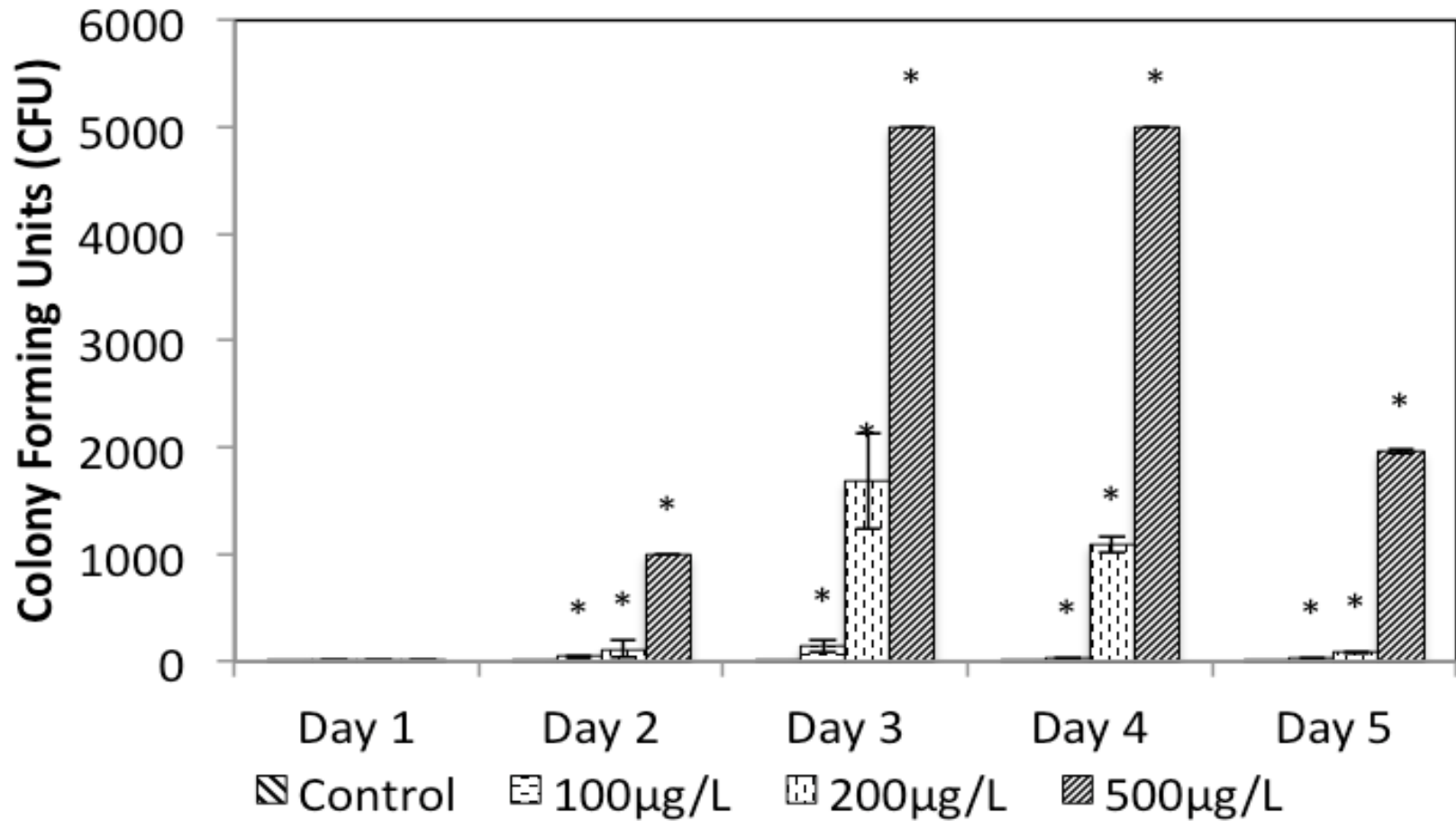
## P-stimulation of bacteria



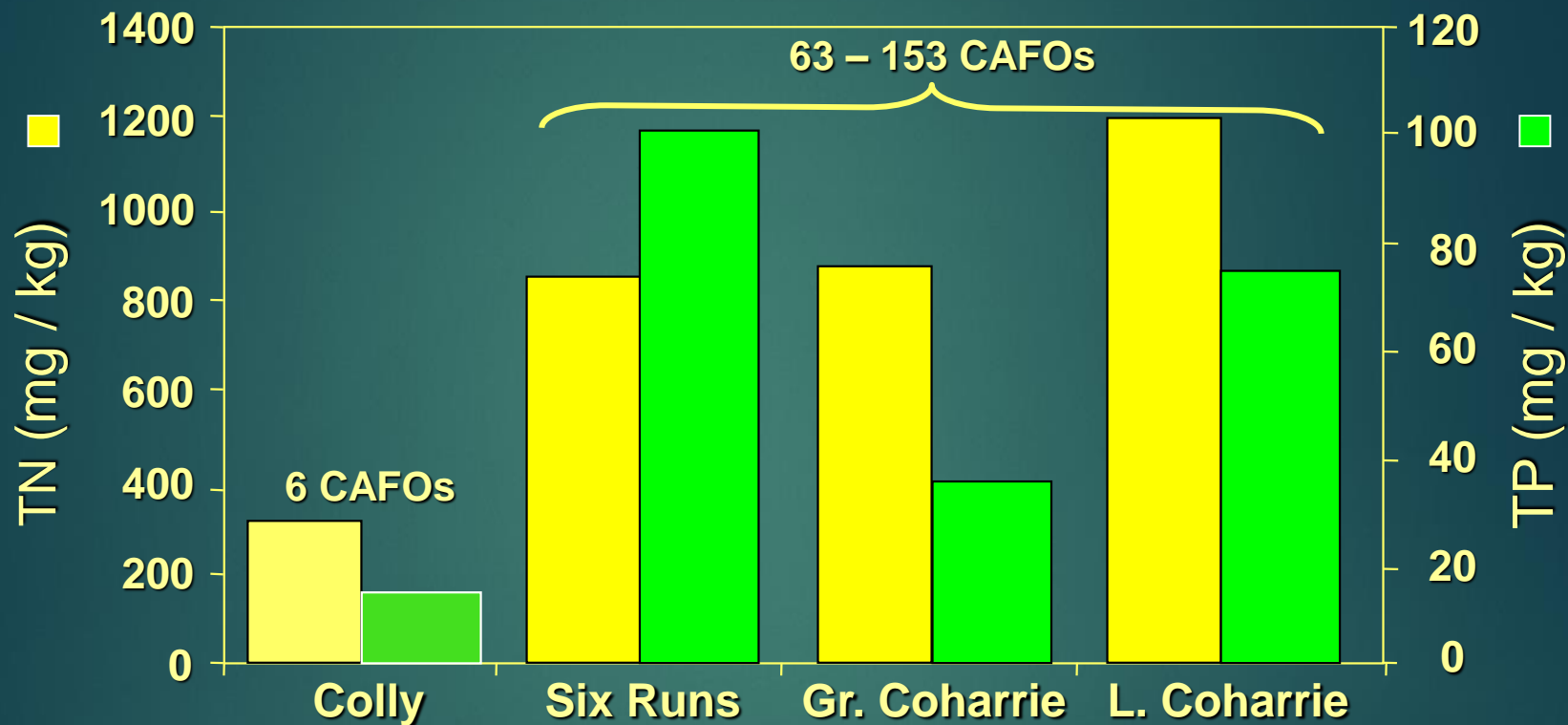
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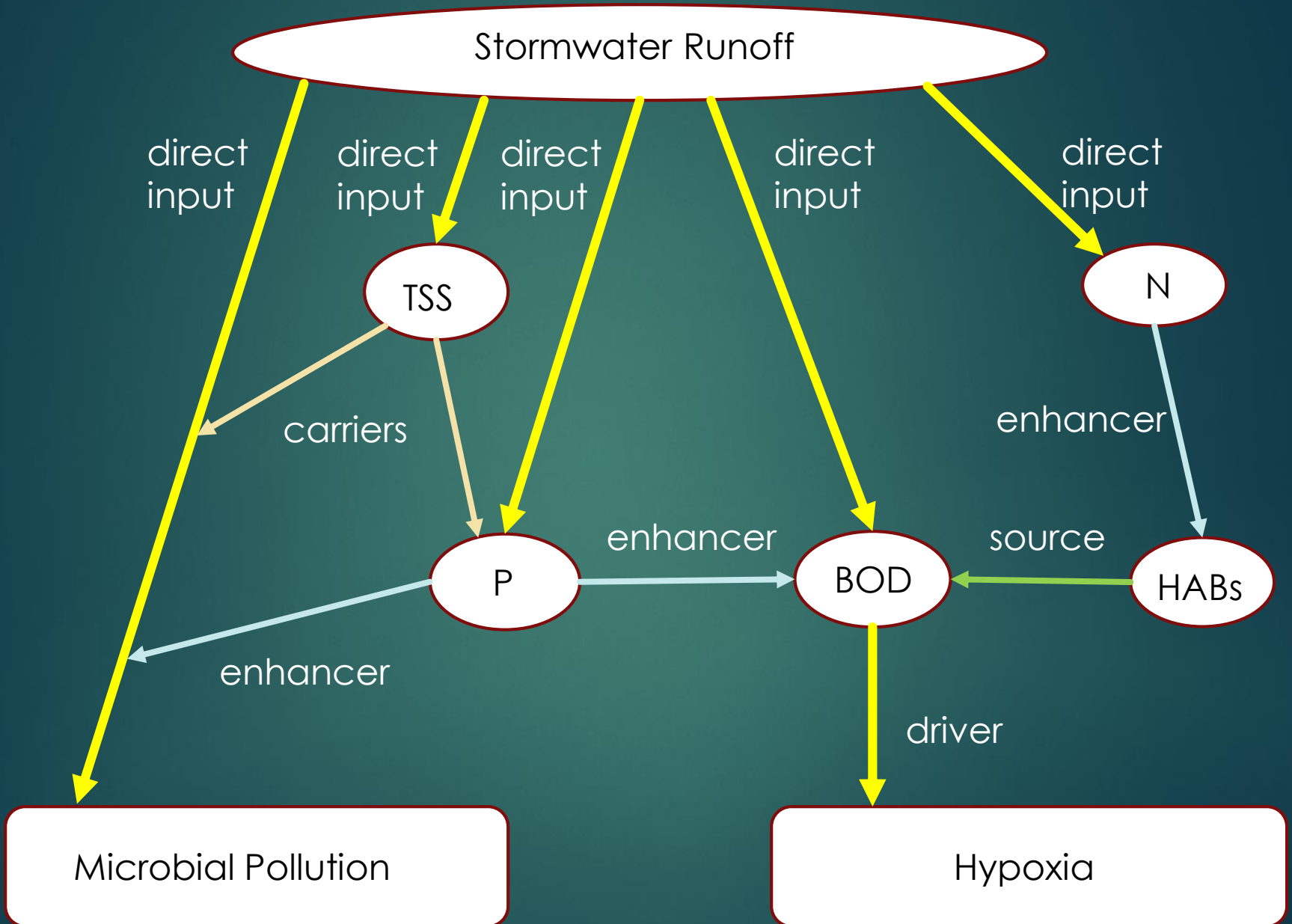


## Legacy P in Coastal Plain stream sediments? Sediment N, P in Black River tributaries



These stream sediment data are from non-point source watersheds; Colly Creek has only 6 swine CAFOs while the other three have many.

# North Carolina Coastal Plain Streams: General Conceptual Pollution Model



Back to stormwater runoff:  
Correlations between 72-hr rainfall preceding sampling and water quality for  
Burnt Mill, Smith, and Prince Georges Creeks combined (oligohaline tidal  
creeks)

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	TURBIDITY	TSS	FC	OP	BOD5	BOD20
RAINFALL	0.624	0.450	0.576	0.393	0.266	0.565
	0.001	0.001	0.001	0.001	0.003	0.001

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## Controlling runoff on the large scale:

Fecal coliform and turbidity response to 24-hr rainfall ( $n = 6$  months). Also shows % watershed wetlands coverage, and # swine CAFO's /watershed. For 11 Coastal Plain streams, 2<sup>nd</sup>-4<sup>th</sup> order. Mallin et al. 2001 *Hydrobiol.* 460: 185-193.

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Stream	CAFOs	% wetland	Rain v FC		Rain v Turbidity	
			<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
Colly Creek	6	55.2	-0.31	0.56	0.48	0.34
Angola Creek	13	27.4	0.46	0.36	0.20	0.69
Rockfish Creek	74	16.7	0.79	0.06	0.53	0.28
South River	16	14.5	0.99	<0.01	0.27	0.60
Goshen Swamp	119	13.8	0.61	0.20	-0.37	0.47
Brown's Creek	3	12.7	0.99	<0.01	0.99	<0.01
Little Coharie Cr	63	12.5	0.99	<0.01	0.99	<0.01
Great Coharie Cr	95	11.8	0.99	<0.01	0.99	<0.01
Six Runs Creek	153	8.5	0.99	<0.01	0.98	<0.01
Hammond Creek	6	6.1	0.99	<0.01	0.92	<0.01
Burgaw Creek	0	6.3	0.72	0.11	0.97	<0.01

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**\* The point of the above is that when wetlands coverage exceeds ~15%, stormwater runoff pollution problems greatly diminish**



**Natural fresh-to-oligohaline  
wetlands in NC and SC**





**Constructed stormwater treatment wetlands  
in Wilmington, NC**

