Proof of Management Success in an Agriculturally-Impacted Delaware Estuary

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Tidal Wetlands

"Tidal wetlands are one of the most productive ecosystems on earth. They perform many valuable **functions**: filtering impurities from storm water runoff, minimizing the damage of storm surges, **providing shelter and food** for migrating birds, and serving as **spawning and breeding grounds** for fish and wildlife– in essence, they serve as the base of the food web."

http://www.pseg.com/info/environment/estuary.jsp

Riparian Buffers

- Maintain integrity of the stream channel
- Enhance water quality by trapping and filtering pollutants (sediments, N, P)
- Moderate water temperature
- Reduce flood and storm water effects
- Provide habitat and corridors for terrestrial and aquatic biota

Blackbird Creek a Tidal Creek!

- Blackbird Creek (BBC), 31 square miles of largely forested watershed located in northern Delaware.
- 1 of 29 protected areas as National Estuarine Research Reserve System established by partnerships between NOAA and coastal states.
- Characterized by extensive salt marshes and large native populations of saltmarsh cord grass (*Spartina alterniflora*).
- Provides many recreational activities and is exposed to varying degrees of anthropogenic effects which disturb the ecosystem.

Aerial photo of Blackbird Creek taken by Andrew Augustine. (picture copied from Roeske 2014).

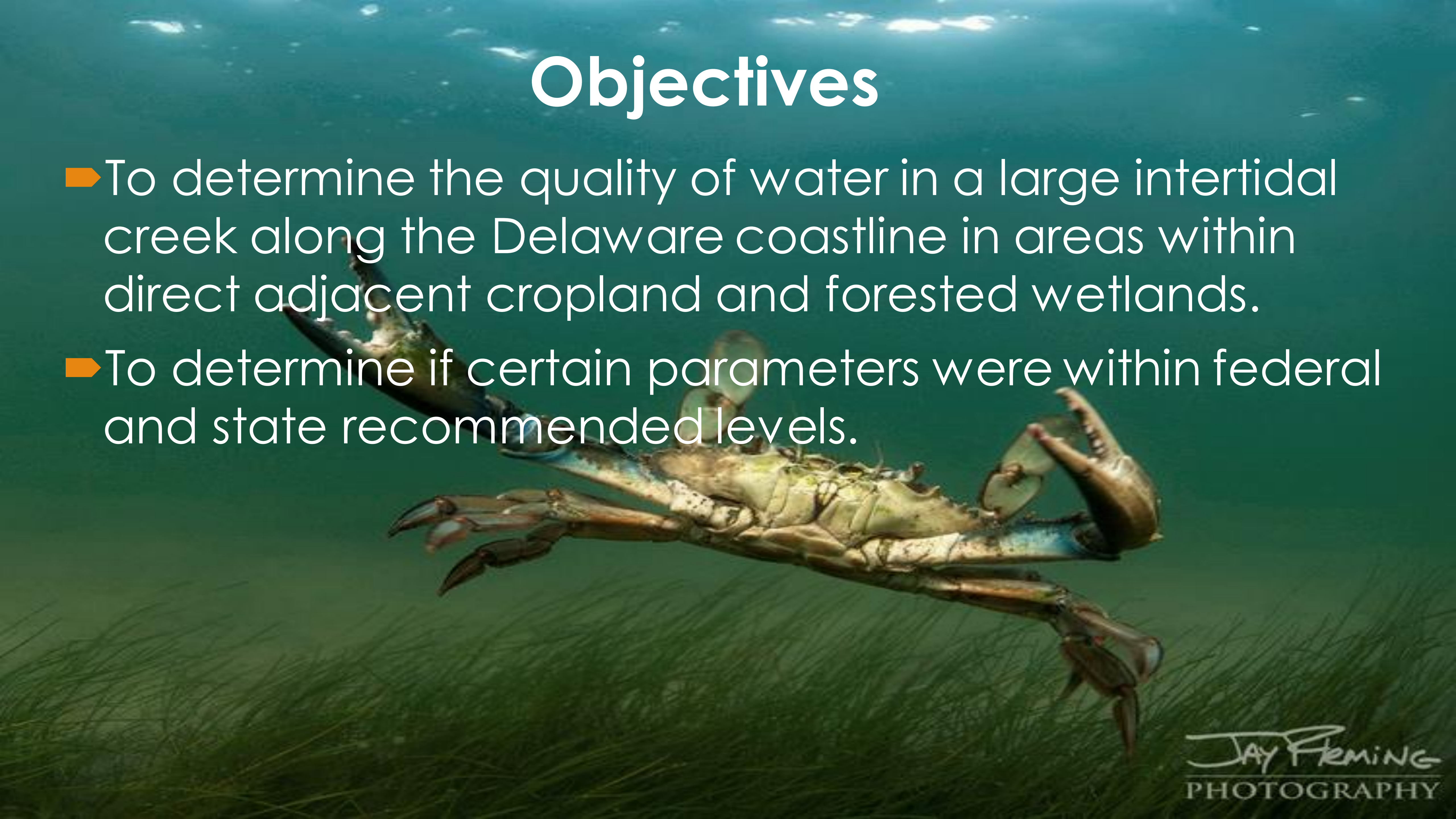
Why Delaware Blackbird Creek?

- Productive ecosystem that supports a large biomass
- Nutrient and chemical storage
- Nursery area for fish, birds, reptiles, crustaceans, insects
- Foraging ground
- Water storage along flood plain
- Minimizes impacts inland by large storms

- 1 of 29 protected areas as National Estuarine Research Reserve System
- Comprised about 51% agriculture, 48% forested land, and 1% urban development

Objectives

- To determine the quality of water in a large intertidal creek along the Delaware coastline in areas within direct adjacent cropland and forested wetlands.
- To determine if certain parameters were within federal and state recommended levels.



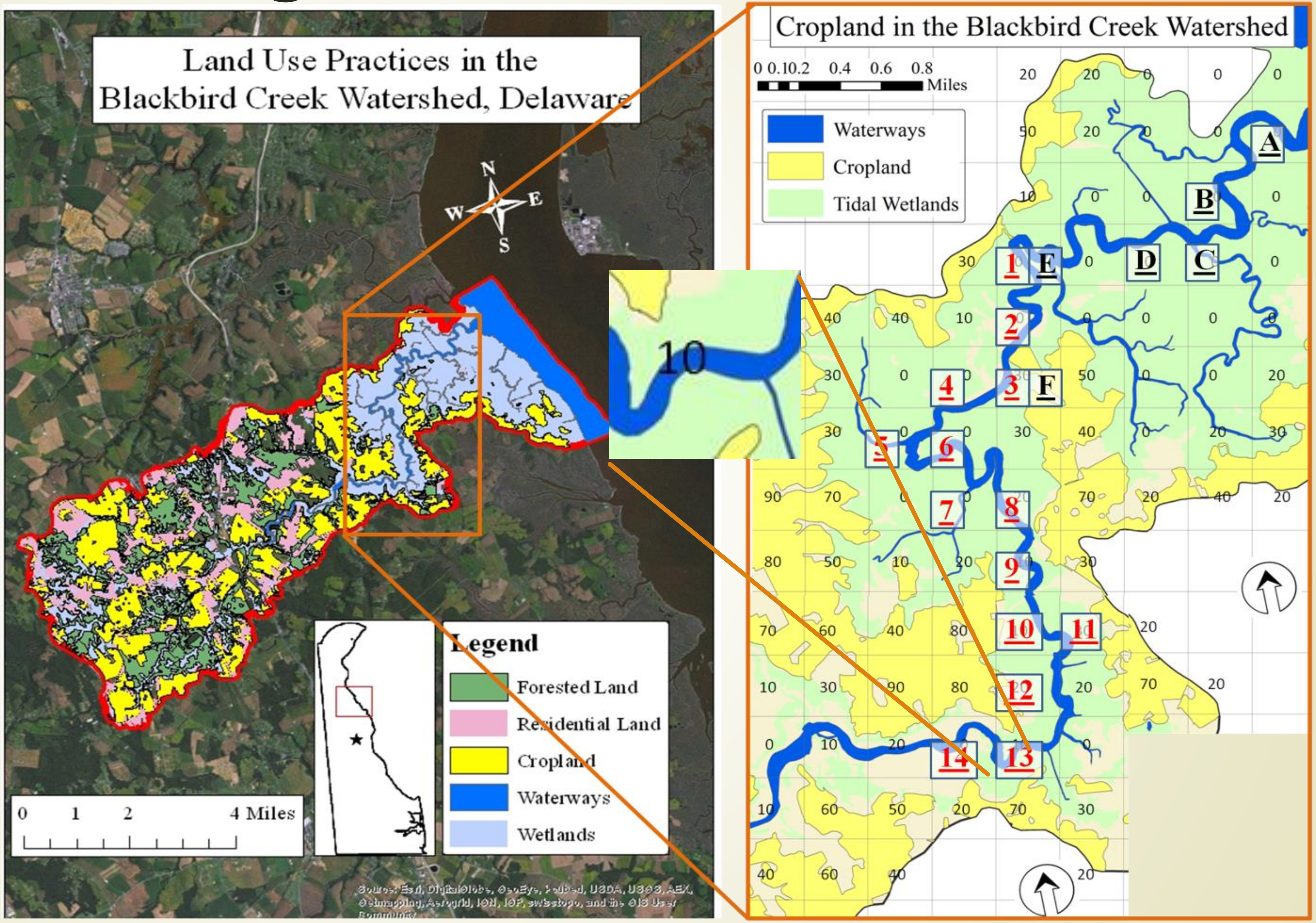
Hypothesis

- The land cover in the Blackbird Creek watershed includes over 36% designated as cropland.
- A large portion of BBC is fertilized on at least a semi-annual basis.
- It was hypothesized that the nutrient levels throughout the creek would be elevated, especially immediately after fertilization in early spring (planting season) and following harvest in the fall (harvesting season).

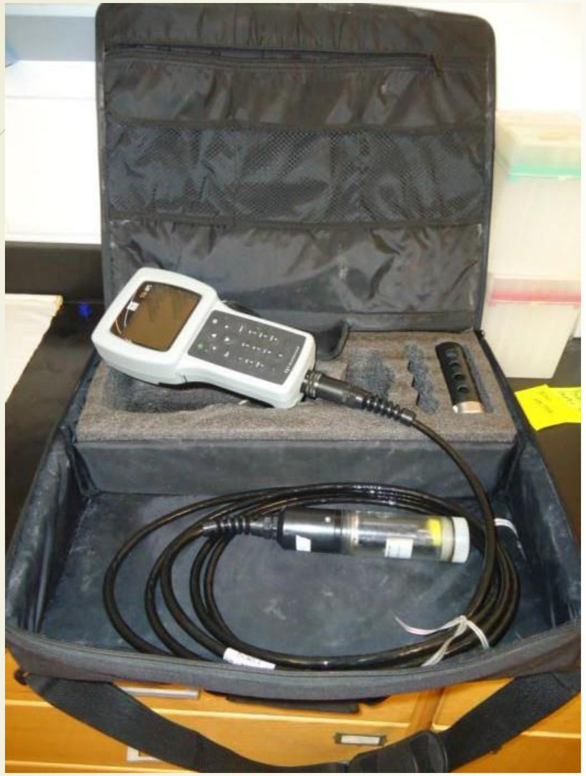
Experimental Designs

- Land use practices (left) and site locations (right) for WQ measurements in Blackbird Creek.
- Each site is 500m×500m. Sites labeled alphabetically in red identify those in which water quality measurements were taken in 2012-2014.
- Sites labeled numerically in black identify those in which measurements were taken in 2015.

Figure 1. Study Sites.



Collection and Measurement



Temperature
Dissolved
Oxygen Salinity
pH

Turbidity
Alkalinity

Nitrate
Nitrite Ammonia
Orthophosphate

Statistical Analyses

Generalized Linear Models

Factors	Interactions
Year	Year × Season
Season	Year × Treatment
Treatment	Season × Treatment
	Year × Season × Treatment

Factors	Interaction
Season	Season × Treatment
Treatment	

(SPSS 23 for Windows, IBM Corp., Armonk, NY)

Followed by principal component analysis (PCA) *(PRIMER 6 version 6.1.16 - PRIMER-E, Plymouth, UK).*

1 2014/2015 Combined
"Ag" vs. "Non-Ag"

2 2015 Alone Differences along the "Percent Ag" gradient

Results

Table 1. Mean±std for water quality parameters according to seasons and habitats.

	Agriculture Season			Habitat	
	Planting	Growth	Harvesting	Non-Agriculture	Agriculture
NH_3 (mg L^{-1})	0.136±0.0058	0.110±0.0050	0.088±0.0043	0.108±0.0039	0.113±0.0052
NO_3 (mg L^{-1})	0.203±0.0293	0.229±0.0243	0.353±0.0330	0.274±0.0243	0.248±0.0226
NO_2 (mg L^{-1})	0.012±0.0020	0.027±0.0015	0.014±0.0011	0.019±0.0016	0.016±0.0012
PO_4^{3-} (mg L^{-1})	0.557±0.0226	0.596±0.0204	0.510±0.0173	0.584±0.0162	0.526±0.0176
Alkalinity (mg $CaCO_3$ L^{-1})	77.9±2.13	84.3±1.70	92.0±1.77	83.7±1.50	86.7±1.62
Turbidity (FTU)	63.5±3.70	43.4±1.77	49.0±2.94	48.6±2.16	51.4±2.18
Temperature (°C)	24.15±0.189	26.48±0.108	19.54±0.397	24.01±0.268	23.8±0.327
Salinity (ppt)	3.545±0.1115	5.539±0.1806	8.412±0.197	5.999±0.18525	5.585±0.2271
Dissolved Oxygen (mg L^{-1})	6.384±0.1569	5.137±0.0949	5.850±0.1997	5.882±0.1013	5.313±0.1473
pH	7.217±0.1569	7.217±0.0253	7.172±0.0599	7.215±0.032	7.192±0.0348

Results

Table 2. Statistical output of generalized linear models with F-statistics and p-values for each dependent variable within each main effect and the interaction term.

Factor →	Season		Habitat		Season x Habitat	
	F-statistic	**p-value**	**F-statistic**	**p-value**	**F-statistic**	**p-value**
NH_3	34.807	0.000	0.954	0.329	2.464	0.292
NO_3	14.046	0.001	10.242	**0.001**	2.988	0.225
NO_2	54.91	0.000	2.205	0.138	0.508	0.776
PO_4^{3-}	0.597	**0.742**	0.024	0.877	1.036	0.378
Alkalinity	26.73	0.000	0.107	0.744	1.948	0.378
Turbidity	6.165	0.046	1.067	0.302	0.300	0.861
Temperature	400.816	0.000	0.065	0.798	1.079	0.583
Salinity	369.761	0.000	9.431	**0.002**	0.216	0.897
Dissolved Oxygen	69.015	0.000	22.086	**0.000**	3.608	0.165
pH	105.632	**0.328**	1.119	0.290	0.492	0.782

Results

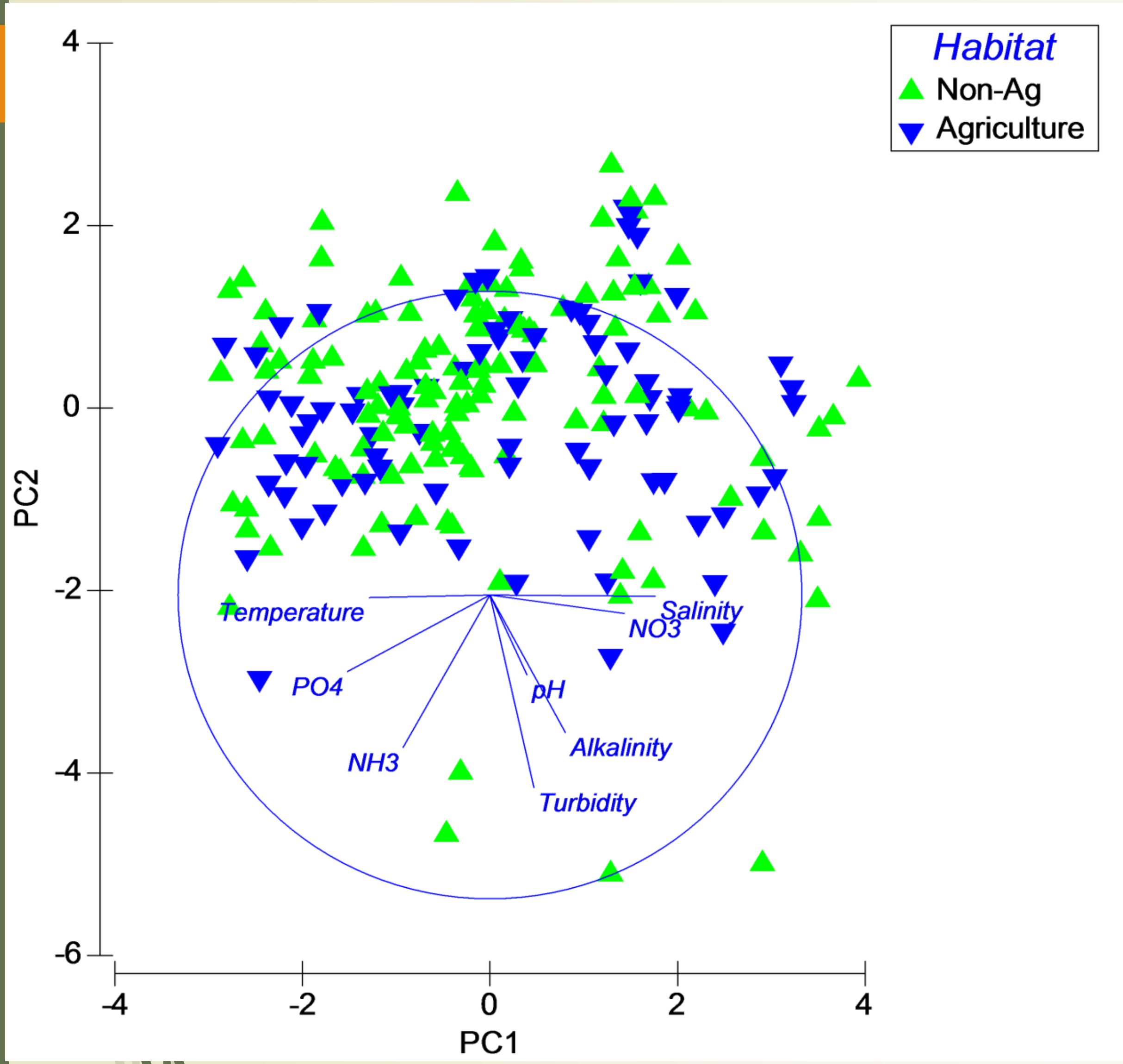


Figure 2. Principal component analysis between habitat types in 2012-2014.

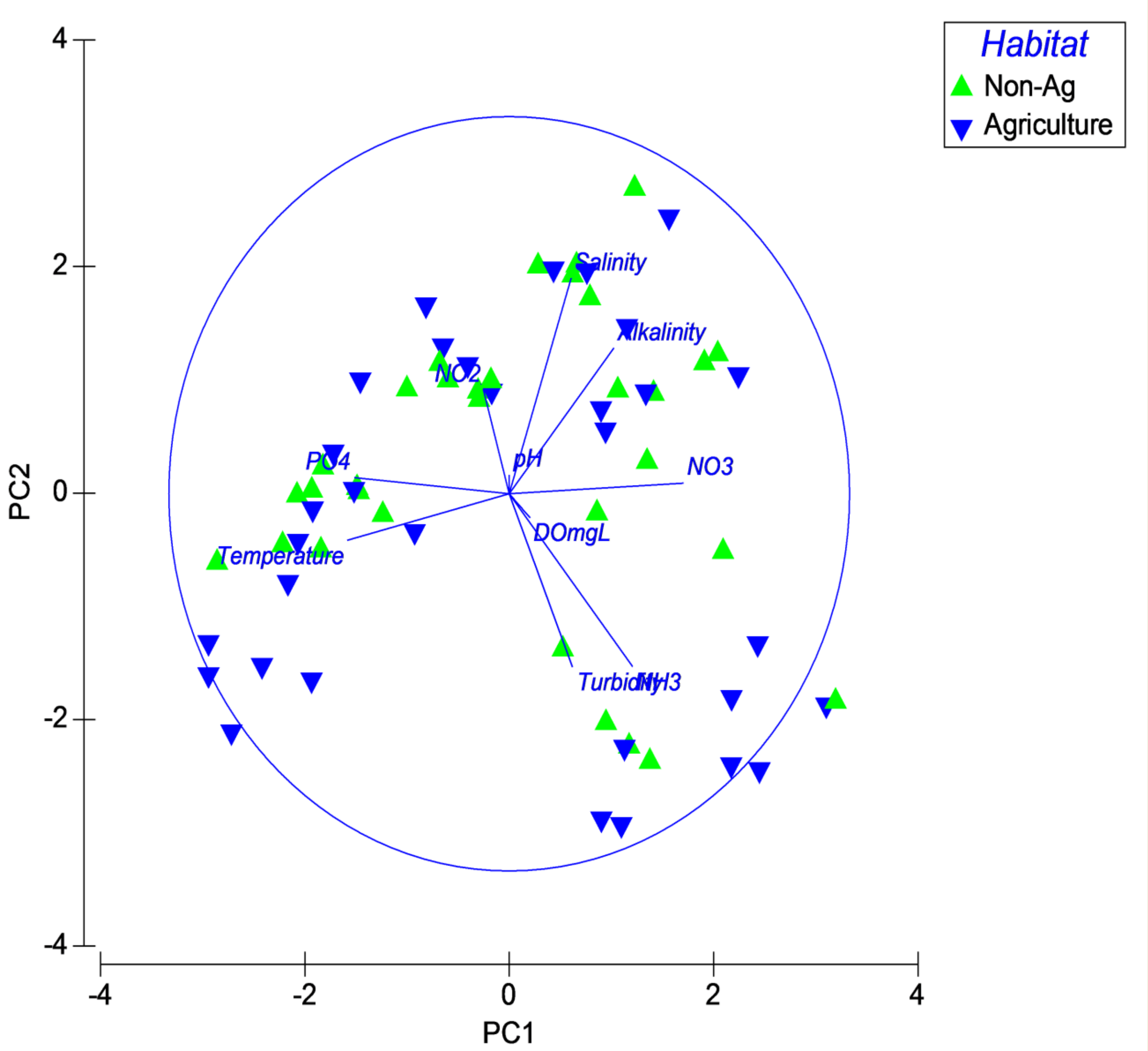


Figure 3. Principal component analysis between habitat types in 2015.

Results

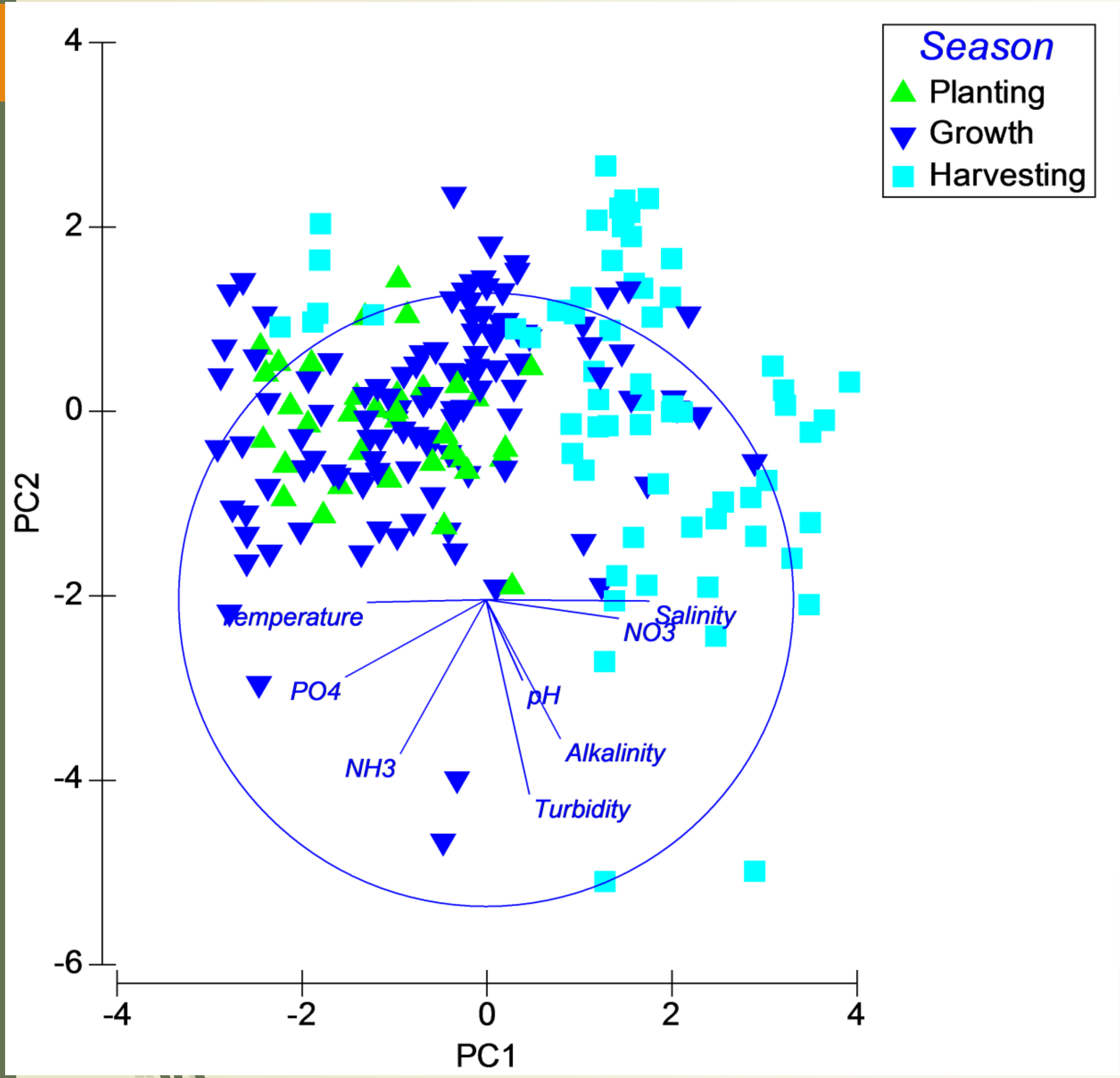


Figure 4. Principal component analysis between agricultural seasons in 2012-2014.

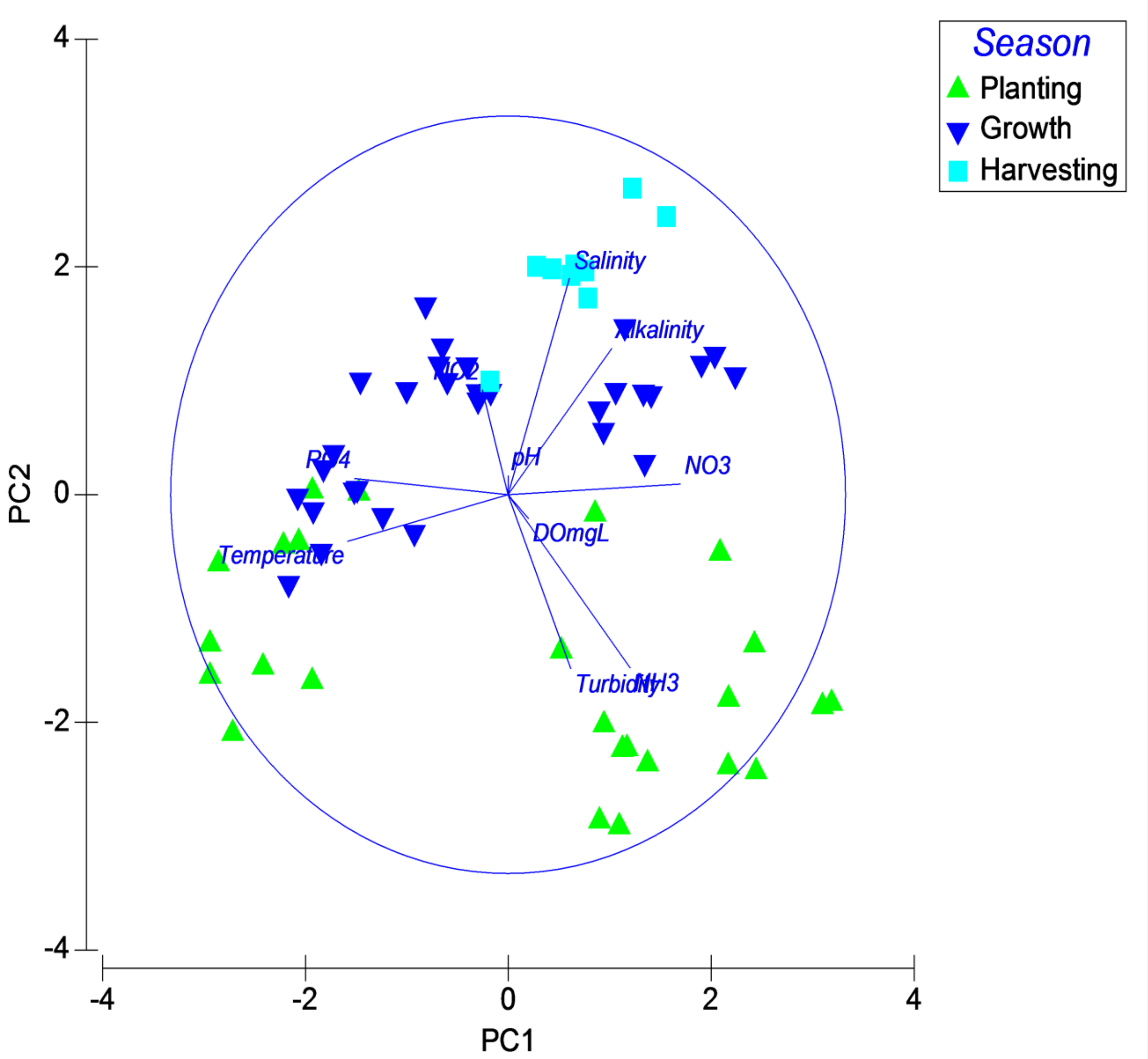
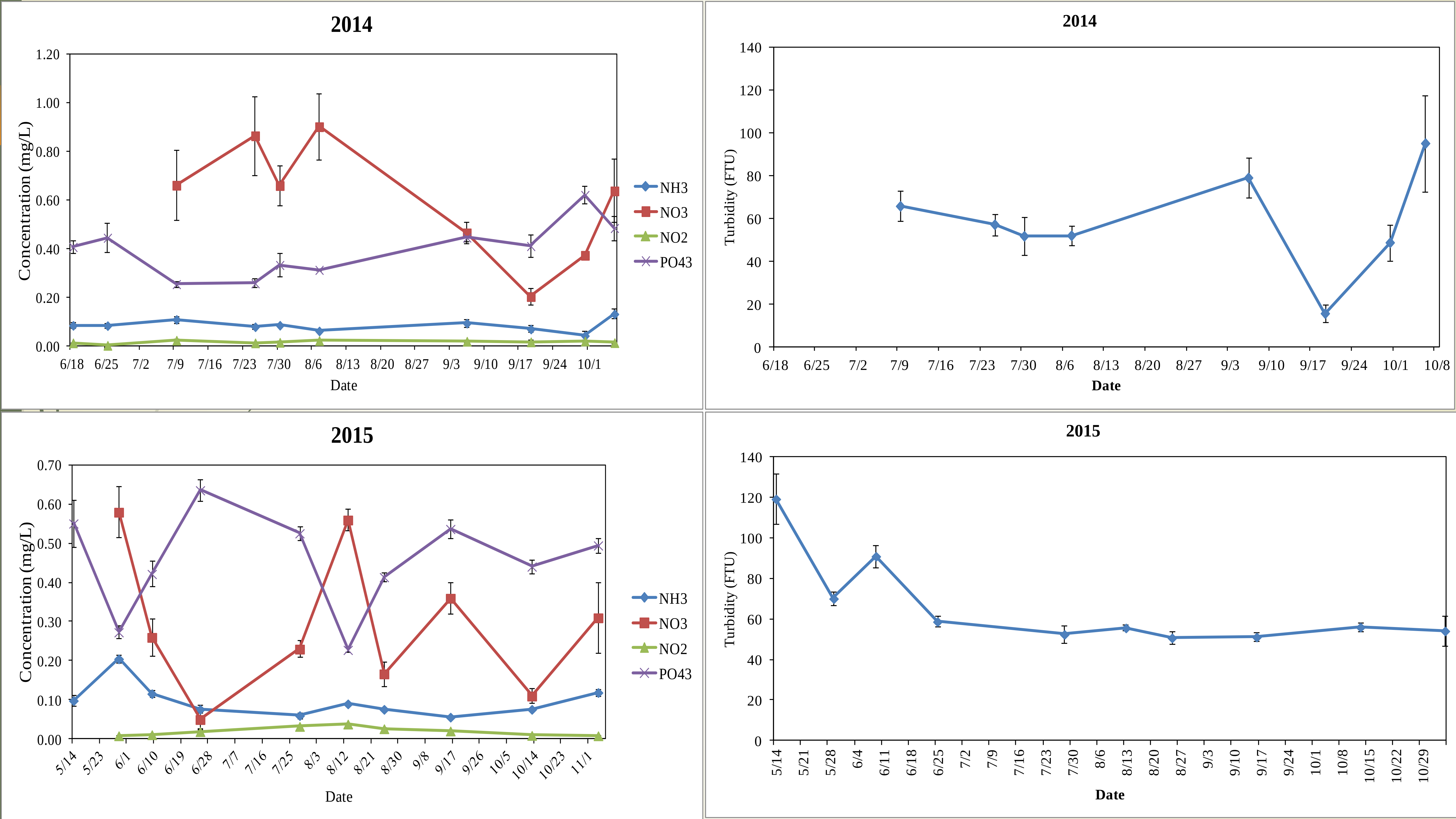


Figure 5. Principal component analysis between agricultural seasons in 2015.


2014
Concentration (mg/L)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
6/18 6/25 7/2 7/9 7/16 7/23 7/30 8/6 8/13 8/20 8/27 9/3 9/10 9/17 9/24 10/1
Date
NH3
NO3
NO2
PO43
2014
Turbidity (FTU)
140
120
100
80
60
40
20
0
6/18 6/25 7/2 7/9 7/16 7/23 7/30 8/6 8/13 8/20 8/27 9/3 9/10 9/17 9/24 10/1 10/8
Date
2015
Concentration (mg/L)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
5/14 5/23 6/1 6/10 6/19 6/28 7/7 7/16 7/25 8/3 8/12 8/21 8/30 9/8 9/17 9/26 10/5 10/14 10/23 11/1
Date
NH3
NO3
NO2
PO43
2015
Turbidity (FTU)
140
120
100
80
60
40
20
0
5/14 5/21 5/28 6/4 6/11 6/18 6/25 7/2 7/9 7/16 7/23 7/30 8/6 8/13 8/20 8/27 9/3 9/10 9/17 9/24 10/1 10/8 10/15 10/22 10/29
Date

Results Summary

- No significant differences in water quality parameters (DO, pH, Temp, Salinity, inorganic NO_3, NO_2, NH_3, PO_4, Alk, and Turbidity) between the two habitats.
- Both orthophosphate and turbidity were elevated beyond EPA-recommended values.
- There were statistically significant differences for all of the parameters between agriculture seasons.
- Because there were no differences between habitats, it was concluded that seasonal differences were likely due to basic seasonal variation and were not a function of agricultural land use practices.
- The lack of notable differences between habitats suggests that, while the watershed is generally impacted by agricultural land use practices, there appears to be no impact on the surface water chemistry.

Results Summary

- The PCA also confirmed seasonal differences for many of the water quality parameters.
- **For the study years 2012-2014,** there was no difference among the growth and planting season whereas the water quality of the samples were comparatively different during the harvesting season.
- Salinity (0.53) and NO_3 (0.46) were high among all the variables studied especially in the harvesting season.
- Temperature was high in the planting and growth season while most of the other variables seem to be low in the samples.
- There is a clear distinction among the samples with respect to the sampling years.
- **For the study year of 2015,** alkalinity, salinity, NO_2 and NO_3 were elevated in the growth season, while turbidity was elevated in the planting season.
- A clear difference can be seen between the seasons for turbidity and NH_3, which were high during the planting season (*last two PCA graphs*).

Discussion

- Water quality in Blackbird Creek is consistent throughout the watershed.
- Most of the parameters followed predictable seasonal patterns.
- Temperature and salinity increased and decreased as expected between seasons, but there were no differences in these parameters between habitats.
- Tidal direction likely influenced salinity as high saline water enters the creek from the Delaware Bay on incoming tides, whereas fresher water from upstream springs reduce salinity on outgoing tides.

Discussion - Turbidity

- Turbidity throughout the waterway was quite high, with maximum values well over 100 Formazin Turbidity Units (FTU).
- High turbidity can limit the opportunity for fish that rely on sight to find prey and often will leave the system in order to find a more suitable location to search for a food source (Kirk, 1994; DeRobertis *et al*., 2003).
- High turbidity can reduce light penetration into the water to the point that submerged aquatic vegetation (SAV) and phytoplankton cannot photosynthesize for lack of light energy (Upper Mississippi River Conservation Committee-UMRCC, 2003).
- These high values are probably a function of the nature of the tidal creek rather than effect from human use of land.
- The hydrodynamics of tidal systems are extremely complex and difficult to model because of the rheological behavior of the soft mud within which can dissociate under varying conditions (Dyer *et al*., 2004; Uncles *et al*., 2006).

Discussion – Soluble Reactive Phosphate

- Blackbird Creek had elevated levels of soluble reactive phosphate (Boyd et al., 1998), where the maximum concentration should not exceed 0.05 mg L^{-1}.
- The average concentration in this system was 0.54 mg L^{-1}.
- While there may not have been any significant differences between sites or across time, this was alarming.
- Such high values can have detrimental effects on local biota (Schindler, 1974; Schindler, 1977; Havens, 2008).
- High values could be attributable to two sources: natural erosion of the creek bed and channel sides due to fluctuating tides, or land modification by anthropogenic activity and the spraying of phosphate-laden fertilizers onto the land surface which then runoff into the waterway.

Acknowledgement

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